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APPLICATION OF GEOMETRY IN ARTS AND ARCHITECTURES

BIODESIGN INSPIRED BY THE LEAF AND FLOWER OF DANDELION (*LEONTODON TARAXACUM* L.)

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ABSTRACT: Bionics is a scientific field that studies the laws of origin and structure of "living" nature in combination with knowledge of biology and technology. By applying bionics, sustainable solutions and answers to the great challenges of the contemporary age are reached faster. Today, as always throughout history, nature is an inexhaustible source of inspiration. With the progress of civilization and the development of modern technologies, the importance of bionics is growing rapidly and becomes necessary in the humanization of today's way of life. This work is inspired by the leaf and flower of the dandelion (*Leontodon taraxacum* L.), a fascinating plant of exceptional vitality and cosmopolitan distribution. The paper focuses on the analysis of the natural shape of dandelions, using a bionic pattern and parametric modeling. It has been shown that Blender software is suitable for parametric modeling, generating of bionic parameter and sustainable solutions. Beside this SketchUp and Lumion software were used. According to this, decorative garden element inspired by leaves, leaves venation and main nerve of dandelion is shining art installation made of wrought iron, bronze color. Since morphology of dandelion flower is heading shape and seeds are with pappus, construction of geodesic dome is suggested. The focus is in fibres of pappus designed as illuminated elements which collect energy during sunny days and release the light during night period.

Keywords: Biodesign, *Leontodon taraxacum* L., Blender software, Art installation, Landscape architectural design

1. INTRODUCTION

Our entire planet, all its ecosystems, flora and fauna, are closely connected and dependent on each other. In many ways, the survival and existence of a species often depend on the survival of many other living things. Plants are of great importance for man and all other living beings. The evolution of plants is as complex as the evolution of other form of lives. Photosynthesis, which is unique to plants, is one of the most important biological processes necessary for life on Earth. "All the power of this world can be found in plants. He who knows their secret properties is omnipotent." – says an Indian proverb, portraying all plants as magical. Each miraculously grows from inorganic matter - water, carbonic acid, nitrogen, and minerals - using sunlight as the only energy. Plant bodies are storehouses of solar energy and the basis for the survival of both animal and human species [11]. Dandelion (*Leontodon taraxacum* L.) (Fig. 1) is an extremely widespread and resistant plant species with extraordinary medicinal properties that we very unfairly call "weeds". The first thing you notice about dandelions is certainly the yellow, sun-shaped head inflorescence. Still, the leaf of this plant is no less interesting, lanceolate and serrate shape, making it quite decorative.

This paper is focused on researching the scientific field of bionics/biodesign and its connection with landscape architecture through the design process of parametric modeling. Biomimetics, bionics, or biomimicry is a relatively young but very modern scientific discipline that studies models from nature, translating them into solutions to current problems while ensuring their sustainability [3]. The term bionics is a combination of two areas: biology and technology. Biology is the science of life, while technology encompasses the widely applicable development field of constructive machines, devices, tools and processes [15]. These two areas, fundamentally different, in this case ideally complement each other [4]. Biomimicry (biomimetics) as a scientific discipline aims to observe and imitate efficient mechanisms of the living world that it implements in various domains of design. Nature is the best teacher. The application of biomimicry leads to faster solutions and answers to the great challenges of the modern age.

Figure1: Dandelion (*Leontodon taraxacum* L.) on Kosančićev venac, Belgrade

2. GEOMETRIC PATTERNS IN NATURE

Geometric patterns are widely distributed in nature according to certain laws. Such natural patterns are repeated in different contexts. Most natural shapes contain basic geometric principles that suggest the presence of structural order and harmony. Natural structures and shapes represent the perfect creation of nature that evolved 3.8 billion years ago [12]. Geometric rules observed in many natural forms can be characterized as "natural patterns" [10].

3. COMPUTER TECHNOLOGY IN DESIGN - PARAMETRIC MODELING

Modern technologies and their constant improvement have enabled the translation of natural patterns into digital form, thus their better analysis and upgrade. The rapid development of appropriate software for 3D modeling greatly simplifies and speeds up the modeling process. By applying parametric modeling and digital design, complex geometric shapes that could not be created in any previously known way of modeling are now possible. Each complex model or shape can be constructed and modified using simple geometric models and different parameters within the adequate software [16]. Thanks to these features, parametric models are easy and flexible to operate.

Generative design based on parametric models uses algorithmic patterns that rely on geometric relations. Thanks to these models and with the help of modern computer software, it is possible to simulate the transformations of characteristics and analyze their variations and possible outcomes [13]. In this way, it is possible to test large-scale structures and their reactions to various materials. It is very important to find the appropriate design configuration before building these structures. Some of the software used for animation are 3Ds Max, Softimage, Maya, Cinema 4D, Blender, Rhinoceros and others with various tools that allow the transformation of the form in the appropriate period. These tools can be models derived from parametric information specified by the designer. Thanks to the introduction of parametric modeling, with the help of animation software, it is possible to generate and manipulate many structures and explore complex geometric shapes and natural patterns [5].

3.1 Form of the flower as inspiration

Flowers have always been a universal symbol of beauty, love, peace, and bliss that we primarily associate with good and positive human emotions. The shape, smell, color, and texture of flowers positively affect human perception and create a sense of harmony. This is why it is not surprising that today, in a time of accelerated technological development and growing alienation from nature, people have an increasing need to integrate with nature in urban areas. Bionics, an area of connection of nature and technology, with its principles, can contribute to that. The very essence of the growing presence of bionic forms is that through nature, as a model, it has a positive effect on modern human, primarily visually and psychologically [1].

Of particular interest is the harmonious shape of the flower, which is often used as inspiration in architectural design. Examples of modern architectural structures, whose basic shape is inspired by the morphology of the flower, are based on minimal geometric shapes that build complex structures. Possibilities for applying biomimetic principles in architectural design are based on geometric principles, providing an opportunity to develop various generic models based on parameters originating from nature and whose configuration is adapted to the requirements of spatial structures [2].

4. FLOWER OF PLANT SPECIES *LEONTODON TARAXACUM* L. - INSPIRATION AND RESULTS

Dandelion (*Leontodon taraxacum* L.) is a very resistant plant species, cosmopolitan in distribution and of exceptional vitality, considered a symbol of hope, unity, peace, happiness, and childhood. An interesting metaphysical association is that the dandelion is the only flower that, in its stages of development, represents three celestial bodies - the Sun, the Moon, and the stars. When it blooms, the yellow flower looks like the Sun; when it matures, its white head (rosary) is associated with the Moon, and the seed scattered in the wind translates to countless stars in the sky. Only seemingly tender and vulnerable, it is a symbol of perseverance and strength: dandelion is a "pioneer species," one of those plants that will be the first to grow roots after major natural disasters, especially fires. Due to its regenerating ability, it is believed that it collects and emits solar (cosmic) energy throughout the year.

The flowers are lingual yellow to light yellow, rarely orange-red or whitish-yellow, arranged in a glabrous inflorescence. The fruit is a single-seeded syncarp nut (achenia) with white papus. Achenia is light (gray to dark brown) or black, never brown to bright red, with many prickly nodules.

The universal custom associated with dandelion is to pick the plant in a blooming phase (white puffy ball), "make a wish," and then blow the seeds, which get scattered in the wind, allowing new plants to emerge. The inspiration for creating this spatial installation (pavilion) is precisely the adaptability, resilience, and great vitality of this plant species. The wide distribution of dandelions directly depends on their reproductive mechanism and plant material. In its overblown phase, the yellow dandelion flower is replaced by a white ball-shaped head composed of a large number of seeds (achenia) topped by a white pappus composed of a series of fluffy filaments.

According to the researches, the key to success is the shape and structure of the papule, which resembles a small parachute - an umbrella, thanks to which air currents transmit the seed. The structure of dandelion seeds and the way it is dispersed is a real example of how evolution can influence the creation of mechanisms of adaptation and successful survival and spread of a species. This plant is able to produce up to 5,000 seeds a year [7].

The aim of this paper is a symbolic presentation of an installation that stylizes one such perfect form of existence. The whole life cycle of this plant is made possible thanks to the tiny but very powerful seed, which represents the spark and impulse of life. The essence of survival is found in the seed carried by air and comes into contact with the element of the earth, activating a new life and continuing the life cycle. Although this flower is delicate and small, its name originates from another form of life, i.e., the animal world. Dandelion owes its name to its leaf shape - in French, its name is "dents de lion" - lion's teeth. In this paper, the form of a geodesic dome was used as a basis for the symbolic representation of the construction of the dandelion flower plant form (*Leontodon taraxacum* L.).

Figure 2: Similarity of dandelion flower (*Leontodon taraxacum* L.) and geodesic sphere

The characteristics of the geodesic dome, its high resistance, durability, and a high degree of functionality, as well as the spherical shape itself, can be related to the properties and appearance of dandelion (*Leontodon taraxacum* L.) in its flowering phase - white ball-shaped head composed of a large number of seeds with pappus (Fig. 2). The shape of the geodesic dome is related both to the geometry of the universe and the molecular structure itself. The shape of the geodesic dome provides excellent aerodynamic properties and enables great resistance and durability of this construction even in very inaccessible environments and climatic conditions. Precisely out of these reasons, *Buckminster Fuller* pointed out that a geodesic dome is the best way to secure human habitats on the Moon, Mars, or other celestial bodies [14]. The Blender software used for generating the geometric pattern of the leaves of the species *Leontodon taraxacum* L. gave the final result - a 3D model, a spatial installation. Blender is an easily accessible program as open source that provides an opportunity for both professionals and those interested in the world of animation and 3D modeling. With its performance, this software enables parametric modeling, pattern generation, and modeling of the obtained forms into the desired model.

4.1 Procedure for making the construction of a geodesic dome

The first step in creating the structure of the geodesic dome, in the Blender program, is to select the geometric solid of the icosahedron and transform it into the shape of a geodesic sphere by a digital process of geodesic triangulation. By switching to Edit mode, the lower half of the sphere is highlighted and deleted.

After the first step, in Edit mode, the edges command is turned on, the object is selected, and the Bevel option that defines the edges of the triangles, i.e., future constructions themselves. Next step is to the faces command and select all the surfaces of the triangles (Fig. 3), then Extrude Faces along Normals, which achieves differentiation and movement of all internal surface (triangular).

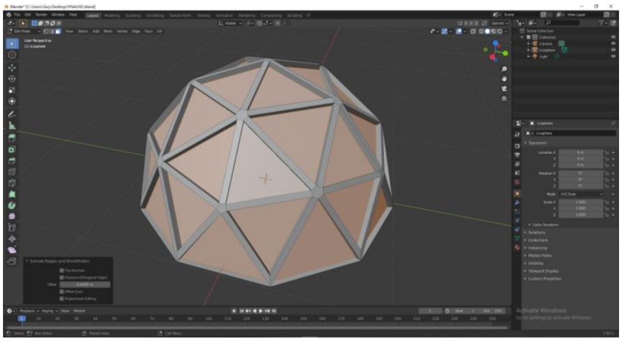

Figure 3: Phase of defining the construction of the geodesic dome - use of Bevel and Extrude options; Print Screen - Blender 2.90.1

At the end, the choice of texture remains. Using the same procedure as in the previous step all surfaces of the triangles are selected, and in the Material tab, the color is selected, Metallic is adjusted, and the entire geodesic dome takes over the selected characteristics.

To single out only the mesh construction of the geodesic dome, all surfaces of the triangles are selected and deleted (Fig.4).

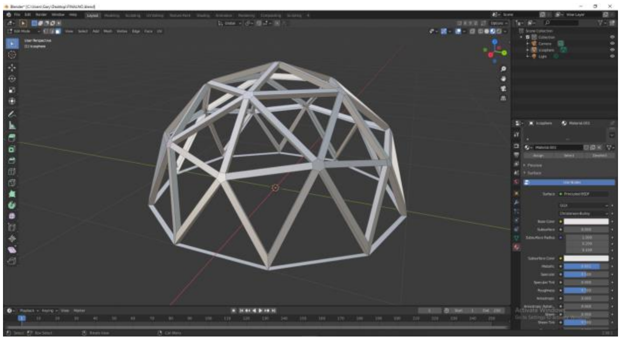

Figure 4: Final definition of the construction of the geodesic dome; Print Screen - Blender 2.90.1

4.2 Procedure for making a part of the achenia with pappus

To create the shape of a dandelion achenia with pappus, the option Mesh> Curve> Bezier is used, and to correct the selected curve, the command V> Automatic, V> Vector is used. In the Properties category - Object Properties, x, y, z coordinates are assigned, and in Object Data Properties> Depth. In this way additional curve adjustment - assigning x, y, z coordinates and Object Data Properties> Depth; in Blender software is obtained.

On the Object mode, selected command: Object> Convert to> Mesh from Curve / Mesh / Surf / Text, allows continue working in Edit mode. In this way, the initial curve with the help of Vertex is formed. Ctrl + R (Loop Cut) is used to get more Vertex.

To form as rounded top of the pappus stem where the filaments are located, the points (Vertex) are selected, and the commands S (Scale) and E (Extrude) are used alternately if necessary (Fig. 5).

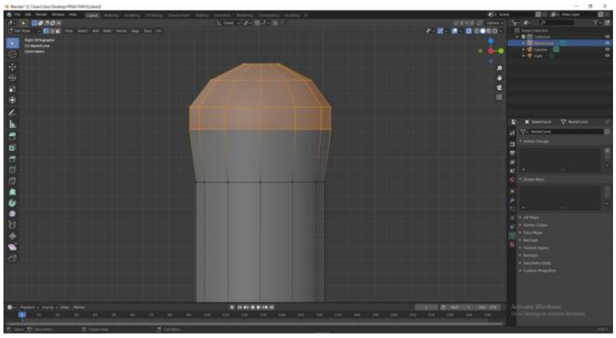

Figure 5: Forming a papule stem using the S (Scale) and E (Extrude) commands; Print Screen - Blender 2.90.1

To form papule filaments in the Object Data Properties category, a new Vertex Group is created. In the Particle Properties category, the Hair command is selected; Number, Advanced is set, and Vertex Group> Density> Group is activated. After this procedure, the pappus got its basic shape. Next, the Hair Length, Velocity, and Seed are adjusted (optional).

To adjust the thickness of the papule filaments, select Convert in the Modifier Properties tab and then run the Object> Convert to> Curve from Mesh / Text command and set Depth at the Object Data Properties tab (Fig. 6)

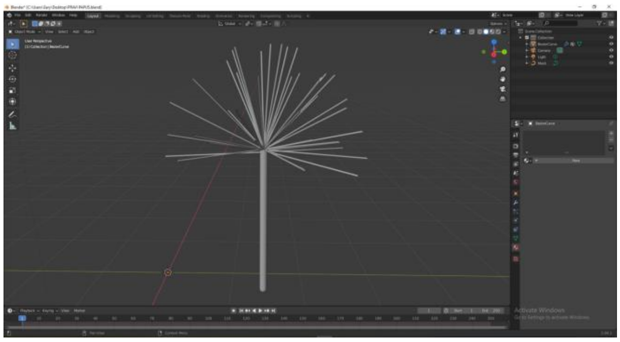

Figure 6: Final appearance of a 3D model of achenia with a pappus of the species *Leontodon taraxacum* L.; Print Screen - Blender 2.90.1

The selection of texture and material is made in the same way as described in the previous process of making a geodesic dome. To fully create a 3D model, the installation (pavilion) inspired by the dandelion flower in the overblown phase, it is necessary to add elements to the shape of the geodesic dome that represent achenes with pappus, which are characteristic for this plant species.

A 3D model of the construction of the geodesic dome and a 3D model of the element of achenia with the papules previously created in Blender was added to the SketchUp program in which they were connected. After that, to add realistic effects, the 3D model was converted to the Lumion program.

In addition to selecting the metallic white construction of the geodesic dome, the focus is on the papule filaments designed as luminous elements that collect solar energy during the day and are activated during the night to emit light (Fig. 7).

Figure 7: Final appearance of a 3D model (installation/pavilion) inspired by a flower of the species *Leontodon taraxacum* L.

5. LEAF OF PLANT SPECIES *LEONTODON TARAXACUM* L. - INSPIRATION AND RESULTS

Dandelion (*Leontodon taraxacum* L.) is an extremely widespread and resistant plant species with extraordinary healing properties that we very unfairly call "weeds." The first thing you notice about dandelions is certainly the yellow, sun-shaped head inflorescence. Still, the leaf of this plant is no less interesting, with lanceolated and serrated shape making it quite decorative (Fig. 8).

Interestingly, despite its unusual appearance and important function, the dandelion leaf is not so often a motif of design solutions, unlike the flower of this plant. Hence, the inspiration for modeling a spatial installation (an element of garden decoration) is the dandelion leaf, which, whether we notice it or not, always performs its main task: *it turns light into life.*

Dandelion is a perennial herbaceous plant with milky sap, 2-100 cm high and belongs to the *Asteracea* family. The rhizome is multiheaded. From the vertical, well-developed and deep root, a leaf rosette emerged and lay on the ground.

The leaves are obovate to narrowly lanceolate, usually deeply serrated and deeply pinnately divided, serrated.

Figure 8: Dandelion leaf

5.1 Procedure for generating a geometric leaf pattern of *Leontodon taraxacum* L. and modeling the bionic form in Blender

The first step of the procedure involves keeping the starting cube and entering the reference image into the desktop. The entered photo should be placed in the center. After selecting the cube object, Edit mode should be active > Alt + M> Merge - At Center. That is initial step of entering a sketch of the contour of a dandelion leaf (*Leontodon taraxacum* L.) and preparation for modeling in Blender software. The contour adjustment of the Vertex is the next step to obtain the desired shape. To provide the form, the E (Extrude) key should be used as needed by clicking on the selected location (Fig. 9). After selecting all Vertexes, the F (Create face) key should be used to form the area between the selected points. The E (Extrude) option is used to achieve the volume of the object.

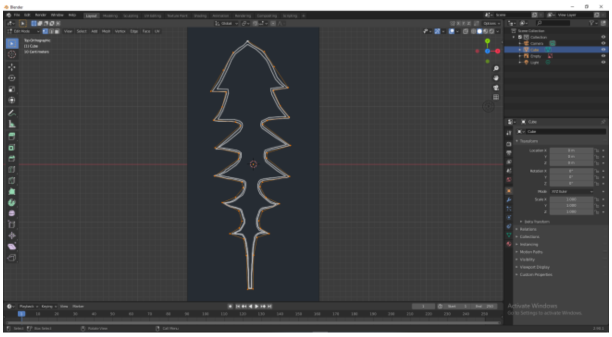

Figure 9: Vertex contour adjustment to obtain the desired shape; Print Screen - Blender 2.90.1

The second step is to select the formed object and use the Subdivide option. Solid Viewport Shading is adjusted to change the texture. At this point, the Vertex (Voronoi points) is adjusted for further work. In the next step, it is needed to start a new plug-in Cell Fracture. The parameters in this Plug-in are set: Own Participles, Small, Sharp Edges (Fig. 10). In this way, the Voronoi structure was obtained [9]. It goes into Object mode, and the whole model is selected, after which the Join option is used, which merges all the elements into one.

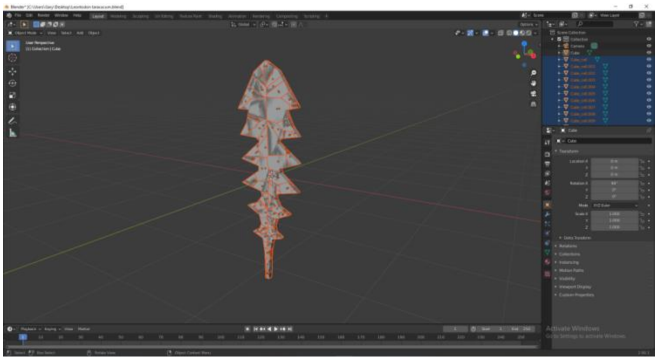

Figure 10: Final stage of application of the Cell Fracture plug-in; Print Screen - Blender 2.90.1

Using the Subdivision Surface modifier would achieve a higher degree of roundness and the appearance of the organic form (Fig. 11). The Wireframe modifier is activated to define the structure and edges. Thickness is set to 0.02.Boundary and Thickness> Even are marked to make the structure compact.

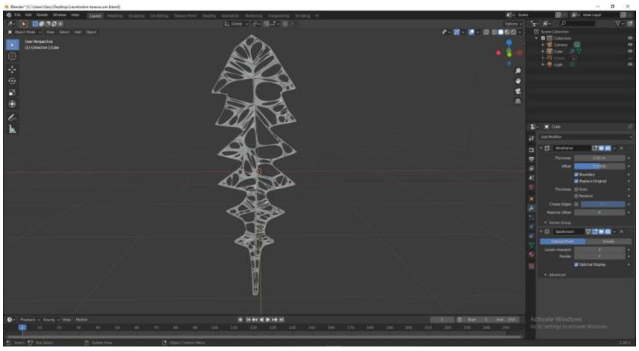

Figure 11: Appearance of leaves of *Leontodon taraxacum* L. after application of the Subdivision Surface modifier; Print Screen - Blender 2.90.1

At the end of the process, the construction material of the 3D model is selected - Material> Base Color, Metallic, Roughness is adjusted (Fig. 12 and 13).

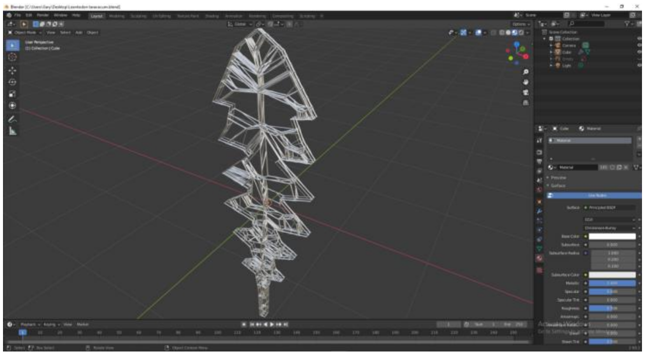

Figure 12: Appearance of the leaf structure of *Leontodon taraxacum* L. after texture selection; Print Screen - Blender 2.90.1

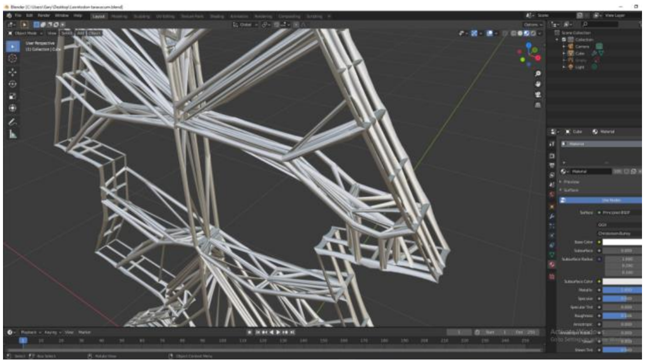

Figure 13: View of an enlarged part of the leaf structure of the species *Leontodon taraxacum* L.; Print Screen - Blender 2.90.1

The 3D model is set in Edit mode to achieve the desired structure. The 3D model must be located in the desktop center; if not, it is needed to be set.

There are many more ways to generate a leaf form pattern and here it is used several different modifiers for different purposes.

5.2 Additional programs used in digital visualization

Various software has different applications in the visualization of design ideas. In addition to the Blender software for displaying 3D models of dandelion leaves, the following programs were also used in this paper: AutoCAD, SketchUp, Lumion. The modeling process begins in AutoCAD, where a photo of a dandelion leaf is inserted, and the contour of the leaf is drawn, followed by the venetaion. The line option is used all the time to draw the shape of the leaf. After drawing a rough contour of the photographed leaf, to obtain a stylized form of the final element, in this step, an additional "adjustment" is performed, i.e., line design.

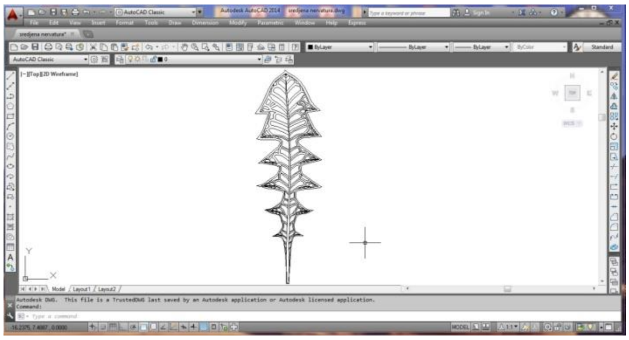

Figure 14: Display of the drawn sheet shape in AutoCAD; Print Screen - AutoCAD 2014

After drawing the shape of the leaf in AutoCAD, add the saved .dwg file to the SketchUp program. The shape of the leaf is drawn along the lines already drawn in the previous step. The entire model is then assigned the appropriate thickness (with the Push Up option) to achieve a 3D effect (Fig. 14 and Fig 15).

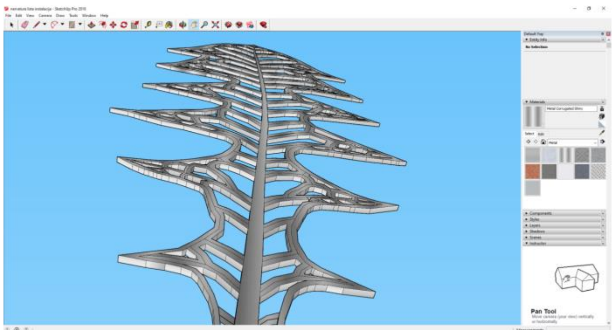

Figure 15: Display of the final 3D model in SketchUp; Print Screen - SketchUp Pro 2018

In the next step, the model texture material is selected. The desired parts of the model are selected, and in the section Materials, the desired color/texture is chosen. It is important to select the material in this program so that the material is already defined in the next software (Lumion).

After starting Lumion software, the .skp type file is imported. The model is switched from SketchUp to Lumion to display the desired 3D model more realistically. To create a leaf model of the species *Leontodon taraxacum* L., no material change was required; only the light effect was "inserted" - the option Light and Utilities.

5.3 Description and presentation of the result

The structure of the decorative garden element is inspired by a dandelion leaf, which is lanceolated and deeply, irregularly serrated. The emphasis is on the leaf venation which is reticulate, and in the case of this display, it looks transparent and lacy. The element is designed to be made of wrought iron. The copper color of the installation was chosen since it fits nicely into the natural environment (garden-park space), which is dominated by green. The installation axis, i.e., the main central nerve, should be intended for lighting and the trapezoidal glass base of this installation (Fig. 16).

Figure 16: Representation of the spatial installation of the leaf of the species *Leontodon taraxacum* L.

There are numerous positive effects when the biomimetic approach is included as a new methodology in the field of landscape architectural design [6]. These original open space design models may bring some novelty in nature-inspired urban design [8]. Creating models of organic shape modeled by those from nature and improving their morphological predispositions through generative design can result in quality functional structures that are easily integrated into space (Massena 2016) [17].

6. CONCLUSIONS

"There is nothing that would be as worth studying as nature."
Nikola Tesla

Nikola Tesla was the greatest inventor of the last millennium, and his inventions are the property of the entire human civilization. After his discoveries, the world is no longer the same! Nikola Tesla is the son of all humanity, not only Serbian and Slavic. In addition to Tesla's mechanical inventions, in the future there will be results for the humanities such as sociology, ethics, philosophy, logic, ecology, psychology, physiology, all the way to medicine itself. [18].

This paper is inspired by the leaf and flower of the dandelion (*Leontodon taraxacum* L.), a very resistant plant species, of cosmopolitan distribution and exceptional vitality, which is considered a symbol of hope, unity, peace, happiness, and childhood. The seemingly tender, fragile, and extremely resistant plant species, such as dandelion, are "designed" to perfection, proof that the essence of this life actually "lies" in small, simple things. Man adapts space to himself with his civilizational (technical) achievements. When from such a sterile environment, chained with concrete, steel and glass, through the smallest crack, this plant "erupts" (finds its way with the power of life force), then it can be said to be proof of a superior, an above-average intelligent form of life. This paper aims to represent an art installation that stylizes one such form of existence, seemingly simple but very powerful. The paper focuses on the analysis of the natural shape of dandelions, using a bionic pattern and parametric modeling recognized as biodesign.

Emphasis was placed on the use of Blender software, which enabled parametric modeling and proved to be suitable for generating bionic patterns and modeling bionic forms. In addition to the Blender software for displaying 3D models of dandelion leaves and flowers, the following softwares were also used in this paper: AutoCAD, SketchUp and Lumion. In this paper, the form of a geodesic dome was used as a basis for the symbolic representation of the construction of the plant form of the dandelion flower (*Leontodon taraxacum* L.). Fascinating is the function of the leaves and the importance they have, not only for the plant. In addition to its unusual appearance and the important function it has, the dandelion leaf is not so often a motif of design solutions, unlike the flower of this plant. Hence, the inspiration for modeling the spatial installation (element of garden decoration) and the shape of the dandelion flower and the leaf of this plant, which is noticed or not, is that they always perform their main task: turning light into life. The result of this research is a generated bionic art form that is materialized in the form of conceptual solutions for the design of spatial installations inspired by the leaves and flowers of the species *Leontodon taraxacum* L.

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GRID ON THE CUBE OF NEW SAN CATALDO CEMETERY

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ABSTRACT: The study traces on grid windows in the façade in the ossuary cu-be of New San Cataldo Cemetery in Modena (Italy), designed by Aldo Rossi (1931-1997, born in Milan) in 1971. The cemetery contains the ossuary cube which was surrounded by grid of square holes window with court-yard. The author already had reported the design process of the plan of the cemetery through the architect's diary. First, it mainly focuses the details of his diary before the competition (*I quaderni azzurri* vol.1-7). From December 1969 to February 1970, he drew cubes which showed direct connection to the cube of the Cemetery. Second, through the measurement in July 2019, the author drew the façade and section in the realized ossuary cube. After that, the author drew the geometry of grid was shown in the front and the back. In the front façades, based on the center of the window holes, Cartesian grid of 176cm and, the 88cm grid can be found. In this meaning, he kept in mind the grid on the cube before the competition of the Cemetery and it was emphasized in the realized architecture.

Keywords: Grid, Cube, Aldo Rossi, San Cataldo Cemetery in Modena, Architecture, Design.

1. INTRODUCTION

In terms of the relationship between human spatial possession and geometry, Pier Vittorio Aureli show grid plan had been politically connected to human possession of land and political meaning. Aureli detected the archeology of the grid plan in architectural and urban history, in terms of politics of the human spatial organization in his essay in 2018 titled "Appropriation, Subdivision, Abstraction: A Political History of the Urban Grid." Aureli put importance of grid schema in the land on the organization of land possession rather than on a system of distribution and circulation.(Aureli, 2018, 139) He showed the political meaning of grid in geographical plane in the earth. Also, grid façade should show geometrical intention of the architect.

Aureli was strongly influenced by the architect Aldo Rossi (1931-1997), who was born in Milan and taught in Istituto Universitario di Architettura di Venezia (IUAV) in terms of the relationship between the spatial apparatus and geometrical form. Rossi used the rigid geometrical composition in architectural design, not only in plan but also façade.

Rossi designed his masterpiece in 1971, known as New San Cataldo Cemetery in Modena, Italy (below as “Modena Cemetery”) (Fig.1)

Figure 1: Ossuary Cube of Modena Cemetery Designed by Aldo Rossi

The author already had reported the design process of the plan of the cemetery through the architect's diary. (Katagiri, JGG, 2018) According to the paper, the plan of Modena cemetery was composed of some geometrical elements such as triangle roof, conical grave, and cube ossuary, derived from the sketch of the plan that he made for another competition, inspired by a Zen Painting of Sengai-Gibon(仙厓義梵 1750-1837) so called "Circle, Triangle and Square".

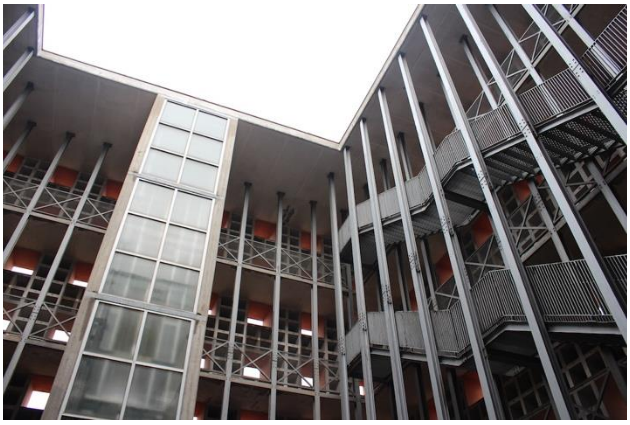

Figure 2. Inner Side of the Ossuary Cube of Modena Cemetery.

The study traces on the design process of the ossuary cube of Modena Cemetery. In terms of grid schema of façade, the author chronologically gathered the documents of the design process and detected the schema of "Grid on the Cube" before the competition. Famously, the cemetery contains the ossuary cube which surrounded by grid of square holes window with courtyard. (Fig.2)

2. DISCUSSIONS

For the first analysis, it extracts the cube drawn by Rossi from his diaries (*I quaderni azzurri* vol.1-7) before the competition until the launch of the competition of Modena Cemetery. Rossi wrote ten of his notebook**s** before sending the first design of the cemetery. (Table 1) For the second analysis, through the measurement in July 2019, the author drew the façade and section in the realized ossuary cube.

Judging from the list of his diary, he dedicated himself for the architect education in Politecnico di Milano with his communist ideology and Catholic formation. He also designed the architecture for himself, such as design for Gallaratese Housing and the competition for Plateau Beaubourg, won and realized by Renzo Piano and Richard Rogers as Pompidou Centre.

Table 1: List of *I quaderni azzurri* from (1) to (10).

No.	**Month /Year**	**Content**
(1)	June 1968	Catechetics of Logic for the Project
(2)	Nov.1968 -Dic.1969	Founding the Idea of Città Analoga(Analogous City)
(3)	Dic.1969 - Jan.1970	Project for Monte Amiata (Gallaratese Housing)
(4)	Jan.-Dic. 1970	Designing Architecture toward Socialist City
(5)	MayNov. 1970	Socialist City and Architectural Design
(6)	Feb-May 1971	Project for Plateau Beaubourg
(7)	May-June 1971	Project for the Modena Cemetery
(8)	July 1971	Project for the Modena Cemetery
(9)	Aug.-Oct. 1971	Project for the Modena Cemetery
(10)	Nov.1971-Feb.1972	Dismissal from the University and Travel in Turcky

In the end of *I quaderni azzurri* (7), below as QA07, he started to devote the com-petition of the Cemetery, writing "I'll devote myself from Next month." The announcement of the competition was in May 1971. The cube of the cemetery project was shown in QA08 and therefore the project was started from QA07.

3. DISCUSSIONS

3.1 "Cubo scavato"

On 1 December 1969, there is an image shows that the architect found the own image before the start of the competition. In QA02, he drew the drawing of the cube analogically connected to that of Modena Cemetery with square holes. (Fig.3) The square holes seems to be the windows regularly holed in the grid. The image shows that the architect found the own image before the start of the competition.

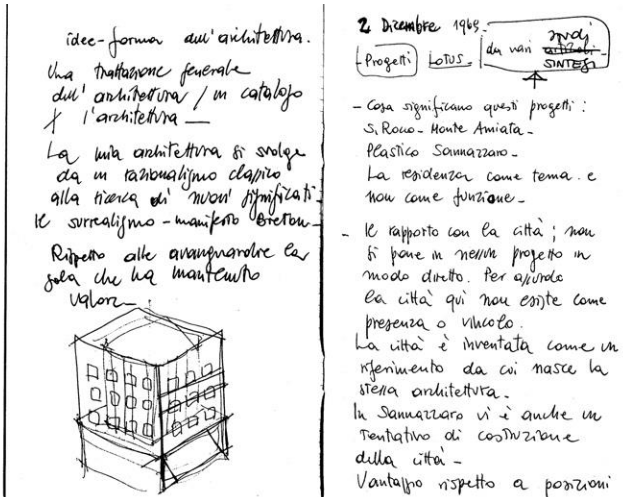

Figure 3. 26th and 27th Pages of *I quaderni azzurri* (2), written by Rossi

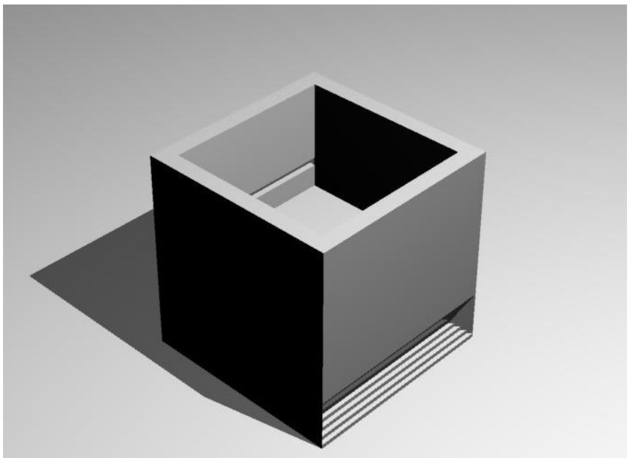
Figure 4. G.U. Polesello, A. Rossi and L. Meda, Monument in Cuneo (1962)

The cube in the diary is supposed to the cube of Monument in Cuneo (1962), collaborated with Gianugo Polesello (Gian Ugo Polesello, 1930-2007) and Luca Meda (1932-1998) The cube of the 12m was excavated as the entrance from the ground. (Fig.4)

Both cubes of the sketch on 1 December 1969 and Monument in Cuneo have the excavated entrance from the ground toward the upper floor inside. The project was represented as "excavated cube"

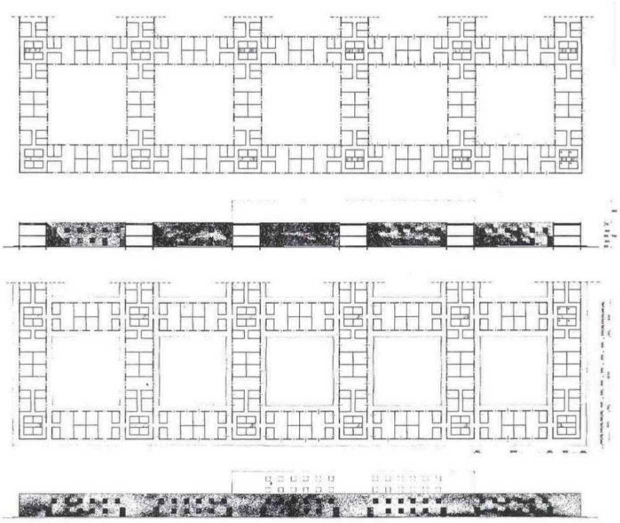
Figure 5. A. Rossi and G. Grassi, Plan and Façade of San Rocco Residential Complex (1966)


Figure 6. A. Rossi, Façade of Gallaratese Housing (1969-1973)

In addition, the cube on 1 December 1969 was added with square windows aligned regularly used in the façade of San Rocco Residential Complex (1966, Fig.5) collaborated with Giorgio Grassi, who had learnt Ludwig Hilberseimer's Project. This style of window was also associated with Gallaratese Housing (1969-1973), which had the regular-square windows rigidly aligned with grid in the façade. (Fig.6)

In QA04, the diary on 12 February 1970 is more directly connected to the cube of Modena Cemetery. (Fig.7)

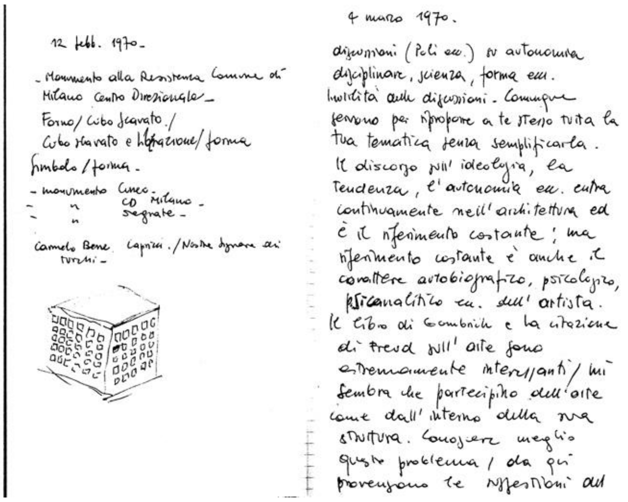

Fig.7. Second and Third Pages of *I quaderni azzurri* (4), written by Rossi

"Cubo scavato" means "Excavated cube" and then what Rossi wrote "Forno (oven or bakers' in English)" means the Tomb of Roman Baker Eurysaces, which hinted Rossi to associated the circle holes with square hole on the cube. (Fig.8)

Fig.8. Tomb of Eurysaces the Baker

Then, meaningfully, he connected this cube to the former design of him. He wrote:

"-monumento Cuneo
-monumento CD Milano
-monumento Segrate"

Needless to say, "Monument Cuneo" means "Monument in Cuneo" (Fig.4) Then, "Monumento CD Milano" means Fountain in Milan (1962), the symmetrically reduced cube surrounded by water veil. (Fig.9) The fountain for CD(Centro direzionale) in Milan was collaborated with Luca Meda, and show another varation of "excavated cube".

Also "Monument Segrate", means Segrate Fountain realized fountain in 1965. (Fig.10)

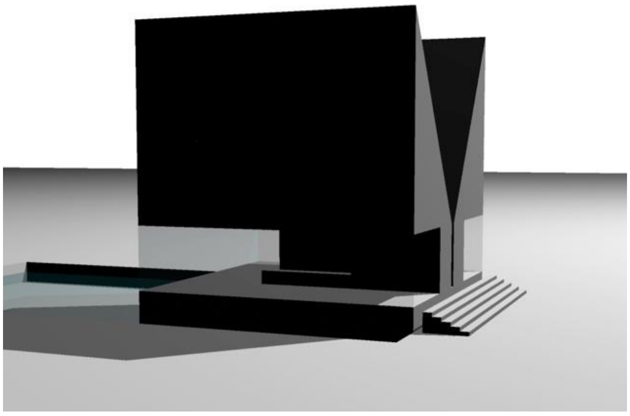

Fig.9. A. Rossi and L. Meda, Fountain in Milan (1962)

Fig.10. A. Rossi**,** Segrate Fountain (1965)

3.2 Measuring and Drawing the Grid on the Cube

From the measuring the realized cube of the ossuary by the author, on the side of courtyard, the façade grid was divided in half with the columbarium box. (Fig.11) The ossuary shelves in reinforced concrete have the square of columbarium regularly arranged around the window hole, which is 33cm on a side. The lib between the ossuary shelves is 11cm, one third of the side of the square of columbarium. Each window without sashes is 77cm square, aligned in grid shape. On 1 December 1969, in QA02, he drew the drawing of the cube analogically connected to that of Modena Cemetery with square holes. The image shows that the architect found the own image before the start of the competition. (Fig.3)

Fig.11. Columbarium of the Realized Ossuary Cube of Modena Cemetery.

In the realized ossuary excavated with square-aligned-holes, Cartesian grid can be found. Therefore, it was shown that the cube was realized in the 176cm square-grid. (Fig.12) Considering the arrangement in nine-grid shape of columbarium boxes that surrounded one window hole, the 88cm grid can be found. (Fig.13) The minimal grid of the courtyard side was half of that of the red façades, which gives some optical illusion of forest of grids.

This illusionistic effect not found in the perspective inside the realized cube but in the projection of the sectional composition of the square shelves. It is possible for us to see the 88cm grid move to the 44cm, lured by the rigidly aligned-square of columbarium.

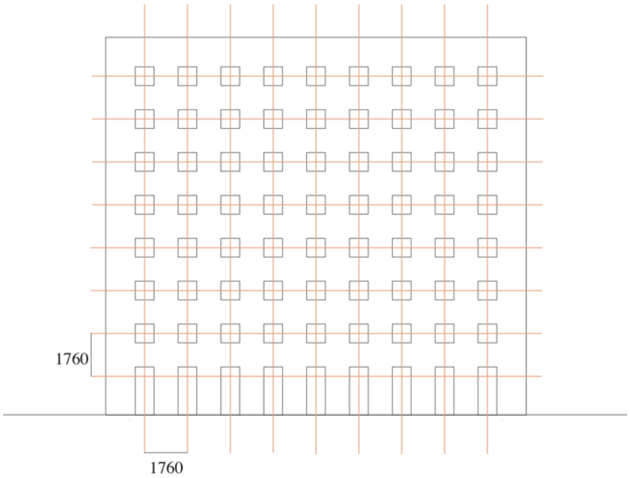

Fig.12. Façade of the Realized Ossuary Cube, measured by the author.

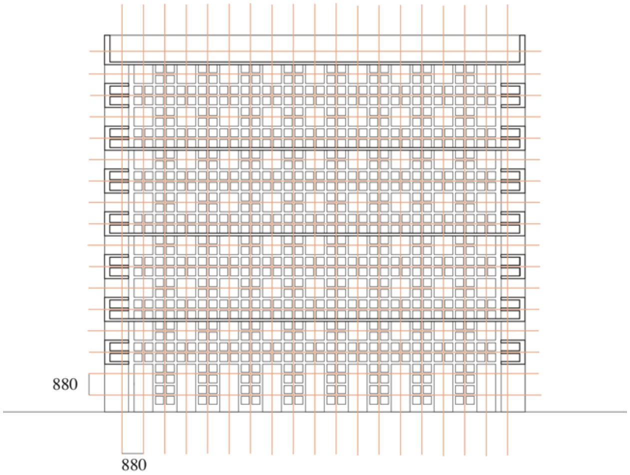

Fig.13. Section of the Realized Ossuary Cube, measured by the author.

4. CONCLUSIONS

It was shown that the cubes before the competition were developed into the ossuary cube of Modena, which remains the schema of grid on the cube.

Although the design of cemetery had changed in several times from 1971, the schema of the grid on the cube remained to be realized around the year of 1983. Beyond the former monument with the composition of the cube, he put grid-square holes in the façade in the cube of Modena Cemetery.

In the realized columbarium, he amplified the grid of inner side with the columbarium shelves. In other words, the grid on the cube in the Modena Cemetery remained in the architect’s mind and was emphasized in the realized architecture.

By the way, Moneo (1976) found the socialist ideology of Modena Cemetery. On the contrary, Eisenman (1979) discussed the religious meaning of the forms of the cemetery.

In some sense, while both Stalinist architecture in the former socialist country and the skyscraper in *art déco* style in the capitalistic country gave us the fact that architects tend to choose the window in the façade along the grid scheme, Rossi makes the synthesis of the two ideological worlds through grid in the façade.

Beyond his political complexity and contraction, Rossi kept the scheme of the grid on the cube before the start of competition and realized it. The grid on the cube was realized through the square windows aligned regularly as the façade of Gallaratese Housing allowed him to design the new geometry in the mind.

IMAGE REFERENCES

Fig.1, 2, 4, 6, 8-13 were shot or made by the author; Fig.3, 7 were cited from *I quaderni azzurri*; Fig.5 was cited from Rossi (1983).

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A STUDY ON THE EVALUATION OF STUDENTS' IMPRESSIONS OF THEIR LEARNING SPACES USING KANSEI ENGINEERING

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ABSTRACT: Students' responses to their environment have a significant impact on their developmental well-being. Consequently, it is critical for all students to experience learning environments that encourage physical and mental well-being, and young people's impressions of their experiences are significant indicators of how we can improve their well-being. This paper explores the students' impressions of their workspaces in Osaka University as a case study of higher education learning spaces using the Semantic Differential method (SD) in the framework of Kansei Engineering. The study also seeks to identify the design elements that generate a positive emotional response. A group of 77 Japanese and international students responded to a survey in both English and Japanese. The results show that: (1) students' affective impressions were described by five independent factors: Functionality and comfort, cozy and pleasant, good passive design, modern design, and outward-facing. (2) A significant correlation between the workspace dedicated to students and classroom functionality and comfort. And (3) the "connection to the outside" attribute generated all the positive emotional impressions, except for "modern design and accessibility," which did not have any correlations to the attribute. Further analysis revealed differences in the distribution of responses between Japanese and international students, as well as a difference in the semantic axes.

Keywords: Students' well-being, learning spaces, Kansei Engineering, semantic differential.

1. INTRODUCTION

Geometry as the fundamental science of forms and their order, deals with geometric figures and forms (elements) as well as proportions, angles, and transformations (relations between them)[1]. Just as geometry is crucial in reflecting the architect's ideas on the building exterior, it strongly contributes to the interior of the space and directly affects the behavior of that space [2].

In this context, researchers are still trying to figure out how the design of the built space influences behaviors and feelings within the space, therefore, helping in the design of pleasing and satisfying environments. Researchers believe that each building has a different impact on the indoor spaces and occupants. The learning space is one of the environments that requires attention because it is linked to the well-being of students as well as their learning performance [3, 4]. Since the appearance of sick building syndrome, a great concern about the impact of the classroom environment on students' performance and well-being has been noticed [5]. These studies all have made an effort to characterize the optimal learning settings to achieve more satisfaction and higher performance for the students. Some studies defined physical learning environment as the ambient environment, such as temperature, acoustics, lighting, daylight and air quality [6], while others defined it as the spatial environment, such as classroom layout, classroom furniture, visibility, and accessibility of sightline [7-9]. Hill et al. suggested in their study [10] that, taking into consideration factors, such as lighting, temperature, and space management enhanced students' satisfaction with their learning environments; conversely, adverse conditions, such as extreme temperature, inadequate lighting, and poor air quality certainly have negative impacts on student performance, retention, and attendance [5]. Lastly, Burruss in his study confirms that it is widely agreed that the architecture of the space can enhance or hinder learning and teaching [11].

Although a reasonable number of studies have investigated the impact of physical learning environments on student performance and satisfaction in primary and secondary education settings, there is relatively little literature about this impact in higher education spaces [10]. Moreover, the former studies assume that, the findings from such studies about primary and secondary education classrooms may not be applicable in higher education spaces [12, 13]. Therefore, this study is a step towards understanding how the learning spaces are perceived by the students in a university setting.

From a methodological point of view, literature review showed many approaches to study students' perceptions of their learning spaces. One of these approaches for quantifying perception is Kansei engineering. Mitsuo Nagamachi, professor and former dean of Hiroshima International University, founded Kansei Engineering. It is a Japanese methodology, which is able to find the relationship between user's emotional perception of a product, design parameters, and the final assessment of the product. Nagamachi defined Kansei Engineering as "translating technology of a consumer's feeling and image for a product into design elements" [14].

Despite the existence of other techniques that can be used to translate user needs into design characteristics, researchers believe that in these techniques, most of the attempts to collect student responses using questionnaires may represent a limitation, because such questionnaires usually used assessment scales defined by researchers or experts which may not reflect the students' perception [15, 16]. On the other hand, Kansei Engineering offers establishing a framework for working with the design elements and perceptions of users, expressed in their own words. The technique used in this study is based on the Semantic Differential method (SD) which is one of the most commonly used method in Kansei Engineering studies for assessing product perception and is thought to be the most powerful quantitative tool currently available for evaluating the affective meaning of concepts [17, 18] . Castilla et al. in their study about the assessment of university classroom, they confirm that, various studies have applied this methodology in the automotive industry, building sector, housing design, urban design acoustic and thermal environment. However, they argue that there are just a few cases of Kansei Engineering being used in classrooms to measure students' responses [19].

The aim of this research is to: (1) Analyze students' emotional responses of their workspaces using Semantic Differential method (SD) in the framework of Kansei Engineering. (2) Identify the design elements that generate a positive emotional response.

2. MATERIALS AND METHODS

This study was carried out in Osaka University, Japan, to investigate students' perception of their workspaces at the Architecture Engineering Department, which belongs to the Graduate School of Engineering located in Suita campus in Suita city in the north part of Osaka. The survey was conducted in two periods. The first period as a pilot study lasted for around two weeks, from May 24 to June 09, 2021. The second period lasted for 40 days, from June 18 to July 28, 2021. The survey was developed in an online platform to be easily accessible via smartphones and computers. The online form required that all questions included have to be answered to be able to submit the response. This step was to assure that all responses collected were valid for calculation and no data needed to be excluded.

The study followed a comprehensive structure consisting of two main phases: a) Identification of the set of emotional impressions in assessing the students' workspace. And b) Identification of the workspace design elements with the greatest impact on the emotional impressions. Followed by two more phases to further c) Identify the significance of the workspace design elements and d) analyze the differences between Japanese and International students. This was to reach the expected results of the study, shown in Table 1.

Table 1: Research structure and expected results

Phase	Objective	Method	Expected result
Phase I: Identification of the set of the emotional impressions in the assessment of the students' workspace.	Obtaining the semantic axes (affective impressions)	Factor analysis Cronbach's alpha	Identifying the elements that generate positive emotional impressions
Phase II: Identification of the workspace design elements with the greatest impact on the emotional impressions	-Obtaining groups of workspace design elements	Factor analysis Cronbach's alpha	Obtaining groups of design elements in a workspace
	-Analysis of the correlation between groups of design elements and affective impressions.	Spearman's correlation	Determining the affective impressions of students based on each group of workspace design elements
PhaseIII: Identification of significance of the design elements to the students.	A general assessment to order the significance of the design elements	Standard diviation	Ordering the elements according to their significance
PhaseIV: PhaseIV: Analyizing the differences between Japanese and international students.	Analysing semantic axes, contribution ratio, and other variances	Factor analysis Cronbach's alpha Standard diviation	Identifying any possible cultural differences between Japanese and international students

2.1 Area of the study

The department under investigation consists of 7 laboratories of different fields in architecture. A total of 10 rooms in two different buildings were dedicated as workspaces to students who belong to the department in which each laboratory has one or two rooms. The general settings of each room can be seen in

Figure 1. The selection criteria for this sample was that it was the most reachable group of students of all other departments. The rooms were the most accessible to take photos and to collect the necessary data for the study. All the rooms are dedicated to the same use for the students in all the seven laboratories, which was important to achieve accuracy in the data analysis that it does not contain variables other than the students' impressions.

2.2 Subjects

A total of 77 students who belong to the architecture department from laboratory 1 to 7, including Japanese and international students, participated in the survey, 24 females and 53 males. This difference is because the targeted sample for the study was the students that belong to the architecture department regardless of their gender. The students' grades diversified with 24% Bachelor, 61% Master's, and 14% Doctoral degrees.

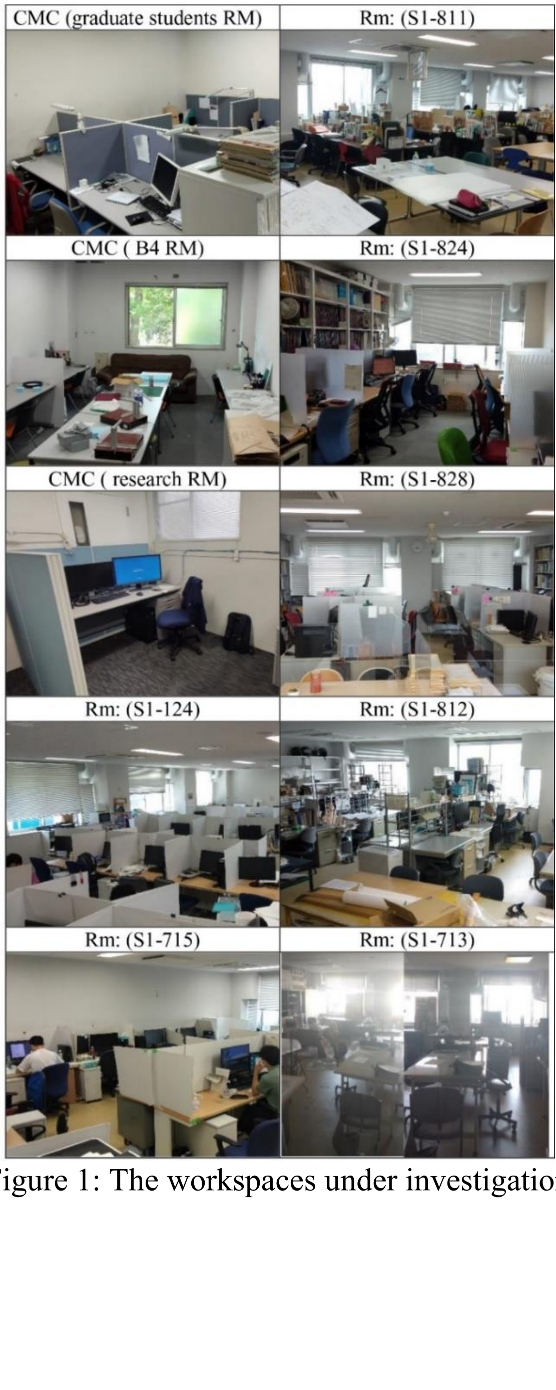

Figure 1: The workspaces under investigation

2.3 The questionnaire

The survey comprised of two blocks. The first questionnaire gathered objective demographic information on the students: sex, age range, and nationality Table 2.

Table 2: Participants' demographic information

Gender	Male	53	68.8%
	Female	24	31.2%
Age	<20	0	0%
	20-25	64	83.10%
	25-30	6	7.8%
	>30	7	9.10%
Nationality	Japanese	55	71.4%
	International	22	28.6%

The second block contained information about:

a) 24 variables that describe students' emotional responses to their classroom/workspace in English and Japanese. This research followed the procedures laid out by Castilla and Llinares [19, 20]. The primary step was to gather as many adjectives and expressions as possible that individuals use to describe the characteristics of the classroom/workspace. The authors of the previously mentioned studies gathered 160 expressions; then, they used the affinity diagram technique to decrease the number of adjectives to 26 adjectives. Only 24 were included in the questionnaire after the pilot study revealed students' confusion about two adjectives. One is "old", which was the opposite of the variable "new" and "oppressive", which was not understandable to the students. Whereas the study by Castilla included as many adjectives as possible to describe all possible perceptions of classroom, it was unnecessary to repeat this step and the collected variables were included in the questionnaire of this study as they are, after the two perplexing adjectives were eliminated. These variables were integrated in the questionnaire with the expression "*In my opinion, the classroom/workspace is…*" Furthermore, they were evaluated on a 5-point Likert scale ranging from strongly disagree to strongly agree, following other Kansei engineering research [5, 19-21].

b) 14 design variables for the classroom/workspace were chosen. These design elements were obtained from the set of variables used by Castilla [19], and a set of design elements concluded from a literature review of 35 former studies about the impact of the built environment on peoples' well-being in general and studies related to students' health, productivity, and well-being. This questionnaire is intended to measure the students' level of satisfaction about their laboratory workspace. These design elements were included in the questionnaire with the expression *"I feel…..about these design elements in my classroom/workspace"*. These variables were evaluated on a 5-point Likert scale ranging from strongly dissatisfied to strongly satisfied.

c) An additional question was added separately to study the significance of the same 14 design elements to the students in general. The expression included in this question was *"Please rate the significance of the design elements in terms of how much they impact you in any indoor space"* These variables were also evaluated on a 5-point Likert but the scale used was; not important, less important, so-so, important, and very important.

2.4 Data processing

The data were statistically analyzed using SPSS Statistics 27 according to the structure shown in Table 1.

3. RESULTS AND DISCUSSION

3.1 Phase I: Identification of the set of the emotional impressions in the assessment of the students' laboratory workspace.

3.1.1 Obtaining the semantic axes (affective impressions)

First, factor analysis was used to reduce the original set of 24 adjectives included in the questionnaire. The small coefficients with absolute value below 0.3 were suppressed to remove the clutter of not meaningful low correlations. The K.M.O (Keiser-Meyer-Olkin) measure was 0.798 > 0.7, and to test the null hypothesis that the correlation matrix is an identity matrix, Bartlett's test of sphericity was extracted and the result was significantly high. Then, a principal component factor analysis with a varimax rotation and an extraction criterion of eigenvalues greater than one yielded 6 uncorrelated factors which explained 67.75% of the variance in the original variables Table 3. Finally, each semantic axis that represent a set of variables was labeled according to the variables that most contribute to this axes.

- 1st factor: corresponds to perceiving the workspace as **Functional and comfortable**. It represents how the workspace is adequate to deliver its function. It also includes the perception of comfort and quietness. The adjectives that most support this factor are “good furniture”, “good design”, good planning”, “helps to concentrate”, well organized”, “comfortable”, “with good equipment”, “good artificial lighting”, “quiet”, and “with good temperature”.
- 2nd factor: represents the perception of **Cozy and pleasant** suggested by the students workspace. The representative adjectives for this factor are “intimate”, “pleasant”, “cheerful”, and “cozy”.
- 3rd factor: represents **Good passive design** of the workspace. The adjectives that best contribute to this factor are “good natural lighting”, “good ventilation”, “well connected to the common facilities”, and “safe”.
- 4th factor: symbolizes the aspect of **Modern design and good accessibility**. The descriptive adjectives for this factor are “easily accessible”, “new”, “well connected to the common facilities”, and “with good equipment”.
- 5th factor: stands for **Humidity** in the workspace with “damp”, “new”, “cheerful”, and “quiet” are the main adjectives contributing to this factor.
- 6th factor: includes the perception of an **outward facing** workspace with adjectives such as “spacious”, “well-lit”, “outward facing”, and “good natural lighting” most describe this axis.

Table 3: Factor analysis of emotional impressions.

Adjectives	**1**	**2**	**3**	**4**	**5**	**6**
Good furniture	.869					
Good design	.738				.318	
Good planning	.724					.390
Helps to concentrate	.721		.320			
Well organized	.715		.336			
Comfortable	.695					
Good equipment	.685			.390		
Good artificial lighting	.647			.400		
Quiet	.640		.498		-.313	
Good temperature	.456			.352		
Intimate		.750				
Pleasant		.745				
Cheerful		.674			.535	
Cozy		.570		.456		
Good natural lighting	.435		.607			.339
Good ventilation			.579			
Well connected to the common facilities			.554	.486		-.301
Safe			.491			
Easily accessible				.744		
New		.345		.397	.499	
Damp					-.733	
Spacious						.822
Well lit		.391	.412			.533
Outward facing			.374		.446	.485
Variance %	23.08	10.81	10.30	8.09	7.87	7.61
Cronbach’s Alpha	0.915	0.761	0.711	0.718	0.123	0.754

The internal reliability of the semantic spacewas measured with Cronbach’s Alpha coefficient. The total Alpha value of the six factors equaled 0.908 (greater than 0.7). The computed values of the consistency of five of the factors ranged from 0.71 to 0.92, which indicted a meritorious reliability. However, the 5th factor which represented “humidity” resulted in a low value of 0.123 in the reliability test, therefore it was excluded Table 3.

These factors were adjacent to those that resulted from the study conducted by Castilla [19] in which a total of six factorial axes summarized the semantic space in a subjective assessment of university classroom environment. The similarity lies in the fact that the axis represents functionality of the classroom was the main axis with the most contribution to the Kansei words to describe the classroom in both studies.

In addition, the axes cozy and pleasant, modern design, and outward facing were nearly representing the same adjectives on the two studies jointly. However, some differences such as the axis represents good passive design in this paper was not reflected in their study, instead there was an individual factor representing good artificial lighting. Moreover, it was noted that the functional and comfortable axis in this paper was demonstrated in two different axis in their study. These differences are believed to turn out due to aspects such as different sample size, learning environment, and culture backgrounds. These findings suggest that the methodology used in this paper along with the previous research using the same methodology [19, 20, 22] can contribute to the research applying Kansei Engineering methodology for evaluating students' perceptions of their learning spaces in different university sittings.

3.2 Phase II: Identification of the workspace design elements with the greatest impact on the emotional impressions.

3.2.1 **Obtaining groups of workspace design elements**.

The same methodology used to obtain the affective impressions was applied to identify the workspace design elements in which a factor analysis reduced a set of 14 design elements included in the questionnaire into 4 individual semantic axes (factors) which explained 69.6% of the variance in the original variables Table 4.

The K.M.O value was 0.823 > 0.7, and Bartlett's test was significantly high.

- 1st factor: correspond to **Finishes and aesthetics** which described the visual and artistic aspects of the space such as "indoor plants", "textures & materials", "colors", "décor (artwork)", and "scent (room odor)".
- 2nd factor: represents the **Personal workspace** allocated to the students. This is related to the intimate area that belongs to each student inside the room. A narrower environment with more personal students' attachment in the workspace. Elements that most contribute to this factor and represent the geometry of the space are "scale and form of the space", "furniture", "furniture distribution", and "acoustics (quiet and noisy)".

Table 4: Factor analysis of the design elements

Adjectives	1	2	3	4
Indoor plants	.787			
Textures & materials	.751			
Colors	.731			
Décor	.726			
Scent	.691			
Scale and form		.811		
Furniture	.355	.803		
Furniture distribution	.466	.688		
Acoustics		.626		
Thermal comfort			.909	
Artificial lighting			.651	.335
Air quality	.478		.527	.455
Natural lighting	.313			.745
Connection to nature	.459	.324		.580
Variance %	25.92	19.14	12.31	12.24
Cronbach's Alpha	0.855	0.806	0.666	0.693

- 3rd factor: Includes **Interior environmental conditions** of the laboratory workspace. Conditions such as "thermal comfort", "artificial lighting", and "air quality" characterizes this factor.
- 4th factor: exemplifies the workspace's **Relationship with the outside**. Elements such as "natural lighting", "connection to nature", "air quality", and "acoustics" are the elements that most this factor.

Cronbach's Alpha coefficient was used to compute the values of the consistency of the four factors which ranged from 0.67 to 0.86, with a total Alpha value of 0.874 which showed a considerable reliability.

3.2.2 **Analysis of the correlation between groups of design elements and affective impressions.**

A nonparametric Spearman's correlation was used to analyze the relationship between the affective impressions and the design elements of the students' workspaces. The overall findings of this correlation analysis suggest that the design elements of the students' workspace can noticeably generate certain affective impressions. The results in Figure 2 indicates that the feeling of a *functional and comfortable* laboratory workspace is strongly related to the personal area that belongs to each student inside the room, the *personal workspace*. It also shows a clear correlation between the *interior environmental conditions* and the impression that the space has a *good passive design.* The *connection to the outside* factor also supports the same impression. Moreover, the perception of an *outward facing* space was mainly linked to the factor that represents the elements contribute to the space *connection to the outside*. In addition, the *finishes and aesthetics* of the workspace along with the *interior environmental conditions* obviously tributed to the sensation of a *modern design*. Lastly, an impression of a cozy and pleasant workspace was generated evenly by all the design factors.

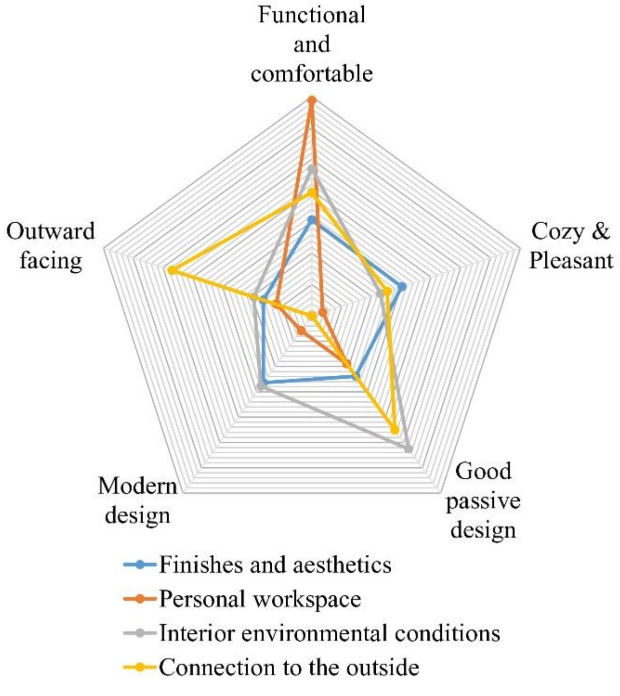

Figure 2: Correlation analysis between groups of design elements and affective impressions.

3.3 Phase III: Identificatio of significance of the design elements to the students.

The results of this assessment Figure 3 showed a relevant significance for all the factors, however students considered the interior environmental conditions factor consisting of thermal comfort, artificial lighting, and air quality as the most important elements of the indoor space. This factor significantly generates the sensation of a space with a *good passive design.*

The second most important elements were the natural lighting and connection to nature with a factor *relationship with the outside* representing these elements. The third in importance was the *personal space* with elements such as acoustics, furniture, and scale and form are important in the indoor space. And the least significant elements were the elements that explain the *finishes and aesthetics* of the space.

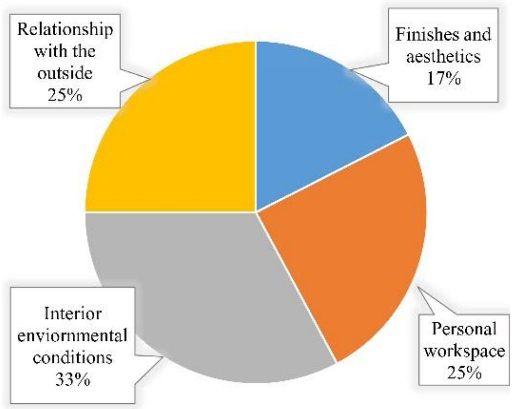

Figure 3: Level of significance of the categorized design elements

These significance results when compared to the students' satisfaction of the same design elements Figure 4, it revealed a gap between significance and satisfaction of elements such as thermal comfort, air quality, connection to nature, and indoor plants. This fact explains a lack of these elements inside the space which means that while such elements were considerably important to the students, the workspace design didn't adequately provide these elements. Other elements had a minor gap between significance and satisfaction.

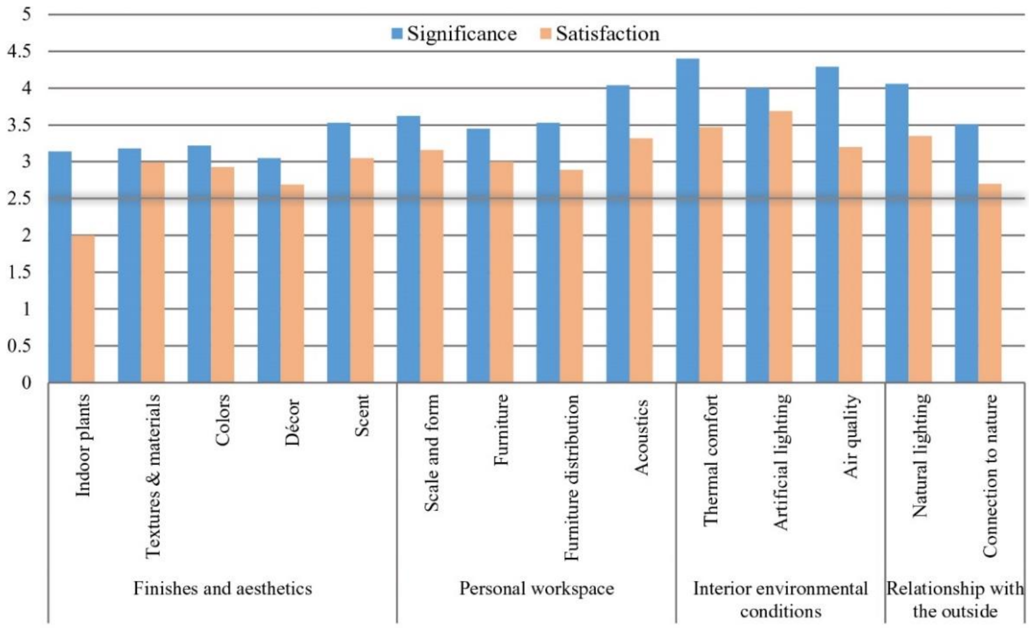

Figure 4: Significance and satisfaction of the design elements

For example, while the significance of artificial lighting was high, the satisfaction level was also high. This means that an adequate artificial lighting system was provided in most of the workspaces. In addition, elements such as colors, textures and materials, and décor had a satisfaction evaluation close to the significance. This can be due to the low importance of these elements to the students, so they were expected to feel satisfied about the current condition. This additional general assessment revealed the level of significance of the design elements of the indoor space according to the direct choice of the students themselves. The findings lead to the conclusion that efforts to enhance the learning spaces according to students' perception should be directed mainly to improving the interior environmental conditions of the space. They also suggest that design decisions related to learning spaces in a university sitting should consider connecting the learning spaces with the outside more than taking into account the materials or the textures to be given to the space.

3.4 PhaseIV: Analyizing the differences between Japanese and international students.

With a further analysis to study the differences between the Japanese and International students participated in the experiment, the results of the factor analysis show a variance in the number of the factorial axes between Japanese and international students, the order of adjectives among the factors Table 5, and in their contribution ratio Figure 5

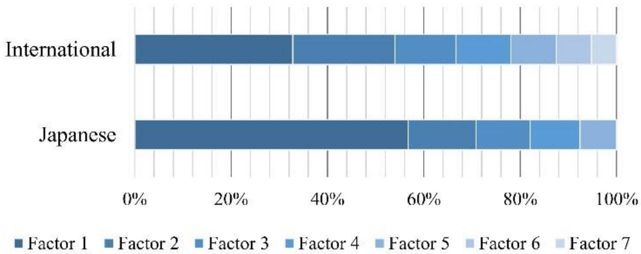

Figure 5: contribution ratio of factors among Japanese and international students

The results in Table 5 show that both Japanese and International participants preferred a *functional and comfortable* workspace. Additionally, it should be noted that Japanese students tended to like *pleasant* and cheerful sensations of the workspace, while international students prioritized the sensation of a *good passive design* with adjectives such as good natural lighting and good ventilation have a more significant impact to the International students.

Table 5: Factorial axes of Japanese and International students

Japanese students: Label	Japanese students: Adjectives	International students: Adjectives	International students: Label
Functional and comfortable	With good furniture With good equipment With good design Helping me to concentrate With good planning With good artificial lighting Comfortable Quiet Well organized With good temperature	With good planning Comfortable With good furniture With good design Well organized Helping me to concentrate Quiet	Functional and comfortable
Pleasant	Pleasant Intimate Cheerful New	With good natural lighting With good ventilation Intimate Well lit	Good passive design
Good passive design	Safe Well connected to the common facilities With good ventilation With good natural lighting	With good artificial lighting With good equipment Well connected to the common facilities	Good artificial lighting
		Cheerful New Pleasant	Pleasant
		Cozy Safe With good temperature	Cozy
Outward facing	Spacious Well lit Outward facing	Outward facing Spacious	Outward facing
Good accessibility	Easily accessible Cozy	Easily accessible	Good accessibility

Figure 6 illustrates other variances between Japanese and international students where in the assessment of both the emotional impressions and the design elements, Japanese students tended to choose strongly disagree or very dissatisfied (-2 on a 5-point Likert scale) while international students opted for strongly agree and very satisfied (2 on the scale). This may be attributed to the possibility that Japanese students have high expectations related to the standards of the learning spaces that they use, unlike the international students which seemed to be more satisfied with the current situation of their workspaces. These results could be due to cultural and contextual differences between Japan and other countries.

The outcomes of this paper identify well with existing literature on the importance of the indoor environmental conditions and how they affect the students [23-25]. Such researches reported that the indoor environmental conditions can strongly affect students' satisfaction consequently their performance.

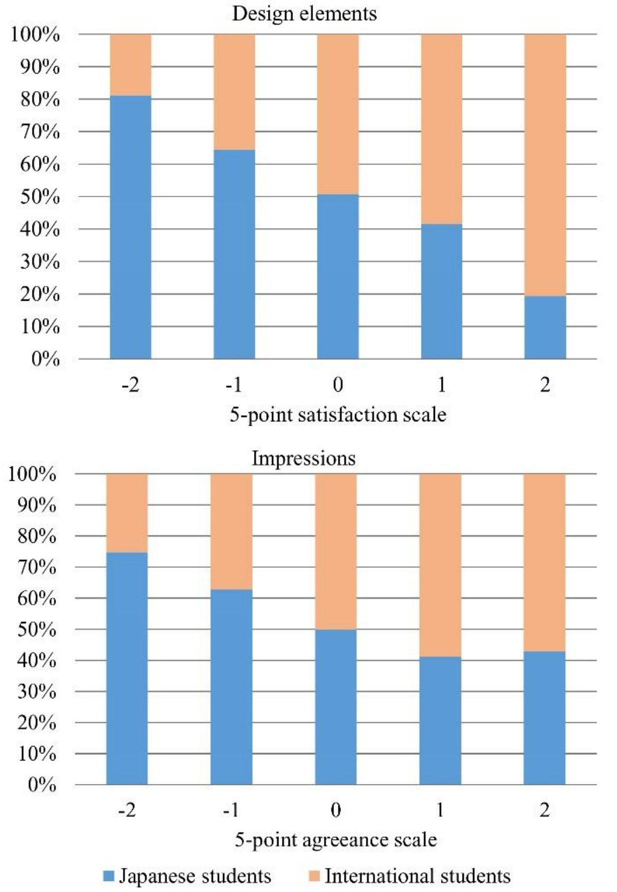

Figure 6: Evaluation of design elements and emotional impressions according to Japanese and International students.

Furthermore a vast body of research focuses on the environmental temperature of buildings [5, 26], ventilation and air quality of the classroom [15, 27], natural lighting [28, 29] to address the attributes that most affect the students in their learning environment. Studies additionally stress the importance of connecting the learning spaces with the outside [30] and identifying the significance of a view of nature in the classroom [31]. Therefore, the findings of this paper understand the outcomes of such research. Overall, it can be understandable that improving certain attributes of the learning spaces could generate positive emotional impressions, consequently increase students' satisfaction. In this regard, higher education institutions should explore students' evaluation to investigate the design of learning environments. It should be mentioned that other factors such as the student's personality or his/her mood at the time of participating in the survey may affect their perception therefore affect the results of this study as suggested by some studies [32]. It is also recommended to do more investigation in identifying student's individual requirements to be able to develop an understanding of how to design higher education learning spaces.

4. CONCLUSIONS

The primary goal of this paper was to evaluate the students' perception of their university workspace as a higher education learning space. Moreover, to identify the design elements that generate a positive emotional response. This research also sheds light upon the elements of the space that are most preferred by students when they are evaluating a physical learning environment. The findings summarized the students' impressions of their workspaces in six factors with functional and comfortable space is the main factor to explain most of the variables. The design elements were also concluded in four individual factors with finishes and aesthetics is main factor contributing to the variance.

It turned out that taking into account aspects of the physical learning environment makes sense only when assessing the influences on student satisfaction.

Furthermore, the results showed an evidence that the geometry of the architecture in the background represented by the scale and form of the space can affect the impression evaluation. Kansei Engineering methodology applied in this study, showed potentials as a user-oriented evaluation methodology in assessing students' perceptions. However, it should be noted that the findings of this study cannot be applied in another context as is, instead, it is recommended to apply the same methodology on a different context and participants to evaluate the possible similarities and contrast in the outcomes.

This research did furthermore, highlight that there may be differences in preferences for factors in the learning environment, for Japanese and international students. These variances may be down to the aspects of the cultural and contextual differences between both.

Those who are responsible for the development and renovation of higher education institutions may find this research beneficial in improving student facilities. Furthermore, the methodology used in this research may grab the attention of designers or architects seeking to involve users in their architecture study or design.

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APPLIED GRAPHICS AND GEOMETRY FOR IMAGE PROCESSING (1)

BINOCULARS' ILLUSION – LINEAR PERSPECTIVE PERCEPTION IN BINOCULARS ON GROUND

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ABSTRACT: This study aims to prove that the binoculars' illusion occurs in general observers and investigate the possible cause(s). One of the possible causes that we hypothesize is the shift of the vanishing point. To interpret a 3D scene, e.g., the spatial direction of lines, from 2D images, we tend to rely on a vanishing point as cue. When perceiving two parallel lines on a floor, the intersection of those lines must be located on a horizon. However, when the scene is viewed through a pair of binoculars, the intersection point could be shifted upward. Two interpretations are possible to explain this shift; the lines are no more parallel, or the floor is slanted uphill. In this study, we conduct an experiment on linear perspective perception with the binoculars' illusion. The experiment result confirmed that the effect of binoculars' illusion occurs for most participants. From the experiment results, it can be implied that when looking through a pair of binoculars, the perceived perspective of parallel lines on the floor appears to be reversed.

Keywords: Perception, Linear perspective, Slant perception, Illusion

1. INTRODUCTION

When looking at two parallel lines on a floor, the lines appear closer or converge into the distance. This linear perspective effect is a clue for human to perceive the depth of scenes. When one looks at the two parallel lines with a pair of binoculars, this appearance tends to be reversed as shown in Figure 1. Eltenton [1] first reported this perception effect. Tsuinashi [2] also mentioned that this effect occurs when looking at a rectangle on the floor with binoculars. The theory behind this illusion is not yet confirmed. We call this illusion "Binoculars' illusion."

This study aims to prove that the illusion occurs in general observers and discuss the possible cause(s) for such perception.

2. BACKGROUND

2.1 Linear Perspective and Perceived Angles

The image of the external world on the retina is flat or 2-D, but it is still possible to reproduce the 3-D information with remarkable precision even if perceived with a single eye. The visual system relies on depth cues to reconstruct 3-D information from the 2-D image projected on the retina. Depth cues include both physiological and psychological cues. The physiological depth cues are accommodation, convergence, binocular parallax, and monocular movement parallax. Convergence and binocular parallax are the only binocular depth cues, all others are monocular. The psychological depth cues are retinal image size, linear perspective, texture gradient, overlapping, aerial perspective, and shades and shadows.

As an example of linear perspective cues, the parallel lines, when projected on the retina, would converge at a vanishing point on the retina, located on the crossing point of the extended parallel line passing through an eye and the frontoparallel plane (projected plane as in 3D CG). Figure 2 illustrates the vanishing point of the parallel lines indicated in black bold lines on the projected image on the yellow plane.

The projected image (yellow plane) shown in Figure 2 can be reproduced by any stimuli like blue and green lines, as shown in the figure. For

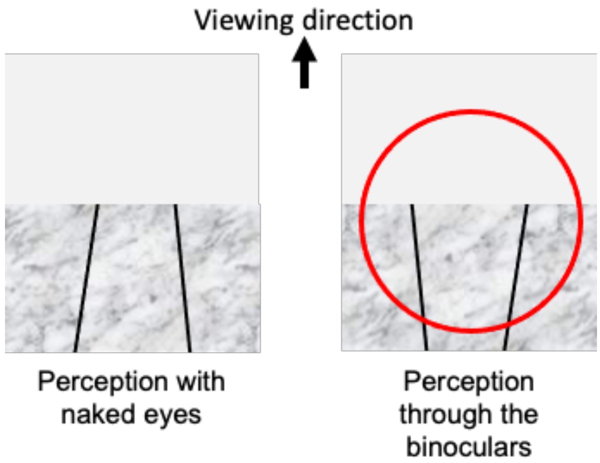


Figure 1: The example of Binoculars' illusion. Left: The perception of parallel lines that is placed on the ground surface with naked eye(s). Right: The perception of the same stimulus through a pair of binoculars.

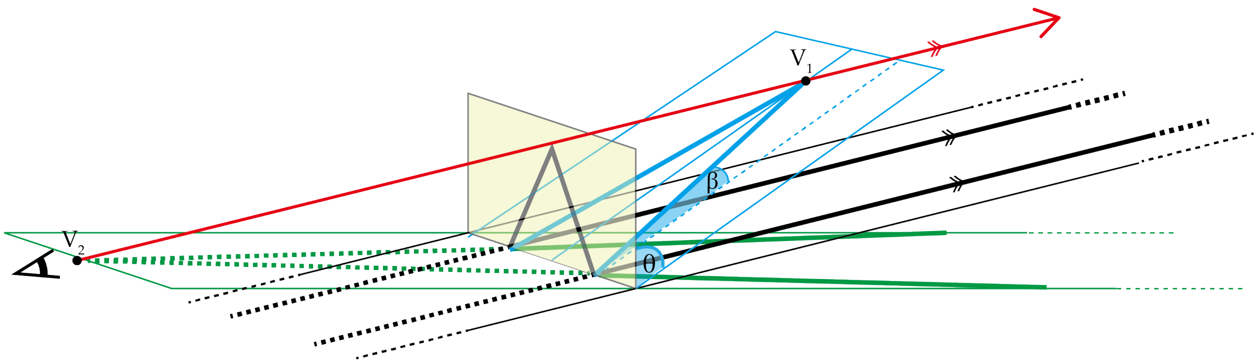
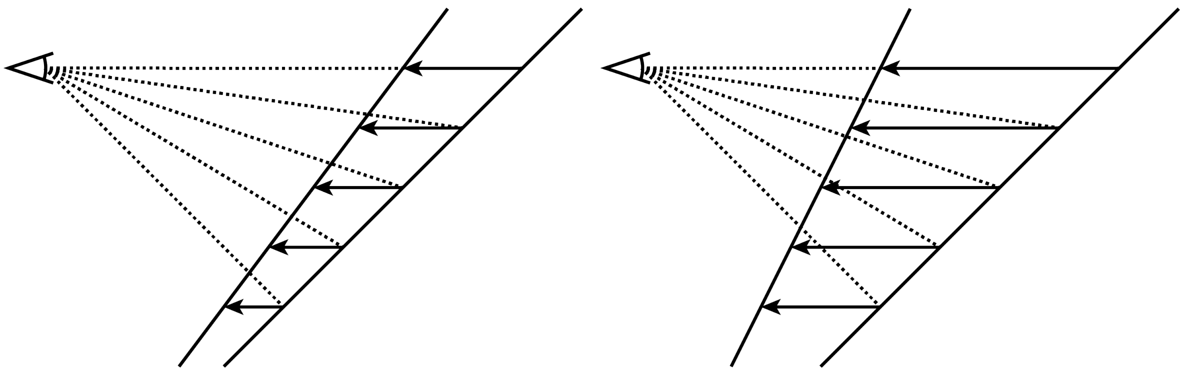


Figure 2: Illustration for multiple interpretation of one projected retinal image (yellow). One can interpret the stimulus as being parallel line placed on the ground (black lines), or being converge and slanted upward (blue lines), or being diverged and slanted downward (green lines).

example, the stimulus could be interpreted as being parallel lines placed on the ground (black lines), being converged on a slanted ground (blue lines, with V_1 as crossing point), or being diverged (green lines, with V_2 as crossing point) on a slanted ground. Suppose the distances to the parallel lines from the eye are equal, two lines drawn from the crossing point to the projected plane (frontoparallel plane-yellow plane) would form an isosceles triangle with the same bottom. We define the angle between the projected plane and a plane of the isosceles triangle as *optical slant angle,* θ, while the half of its apex angle as *perspective angle*, β.

To determine depth with linear perspective cue, the visual system would rely on perspective angle and the bottom width information existing in the 2D image projected on the retina [3, 4]. In principle, changes in interpretation of optical slant angle would result in changes in perspective angle and vice versa. In this work, we explore the perception of binoculars' illusion by examining perceived optical slant angle and perspective angle of two lines of the perceived isosceles triangle.



(a) (b)

Figure 3: Depth compression

2.2 Distance perception vs. optical slant perception

Egocentric distance, i.e., perceived distance from an observer to an object, would be shortened by using binoculars. Over centuries, distance perception in human visual perception has been extensively investigated. Many studies reported that human would compress egocentric distance (as much as 0.7 in [5] [6]). This depth compression may cause underestimate in optical slant [7] [8] [9]. Figure 3 illustrate the mechanism of optical slant underestimation. Li and Durgin [10] conducted an experiment to find out perceived optical slant by manipulating a range of physical slants and found that the data fit perfectly to the logarithmic function of viewing distance proposed by Bridgeman and Hoover [11]. They further investigated the cause of slant underestimation by focusing on depth compression theory and intrinsic bias hypothesis theory [12].

2.3 Measurement of slant perception

To measure perceived optical slant, many methods were employed. A particular method that has been used is *haptic measurement*. Haptic measure [9] [11] refers to adjusting an unseen palm board to match the orientation of the observing surface. A palm board is a flat plate that can be rotated by hand about a horizontal axis. The palm board is placed near waist level and the arm is extended down to meet it. The task of adjusting a palm board is refer to as "visually guided action". Another method used in the early studies is *verbal estimate*. However, many studies found that verbal estimate or other type of conscious report induce a phenomenal underestimation of optical slant (virtual and manmade hills) by 5-25 degree [9, 10, 13-16]. These verbal estimates of slant are accompanied with *haptic matching*, where the people would hold their unseen hand and / or forearm parallel to the slope. The free hand orientation is measured with an autocollimator, i.e., an angle measurement device, that would be attached to the hand. The slant overestimation in verbal estimate is said to be because of proprioception calibration [17] which cause bias in verbal estimates of visually perceived optical slant and proprioceptively perceived hand orientation. Shaffer [18] also confirmed that proprioceptive calibration exists in pedal estimate as well as haptic.

3. HYPOTHESIS

This study aims to prove the existence of binoculars' illusion.

We hypothesize that the cause for such perception effect is the shift of the vanishing point. When perceiving two parallel lines placing on a ground, the vanishing point of those lines must be located on a horizon. On the other hand, when the scene is viewed through a pair of binoculars, the projected image on the frontoparallel plane is enlarged. Consequently, the vanishing point could be shifted upward. The shift of vanishing point may lead to either or a combination of the

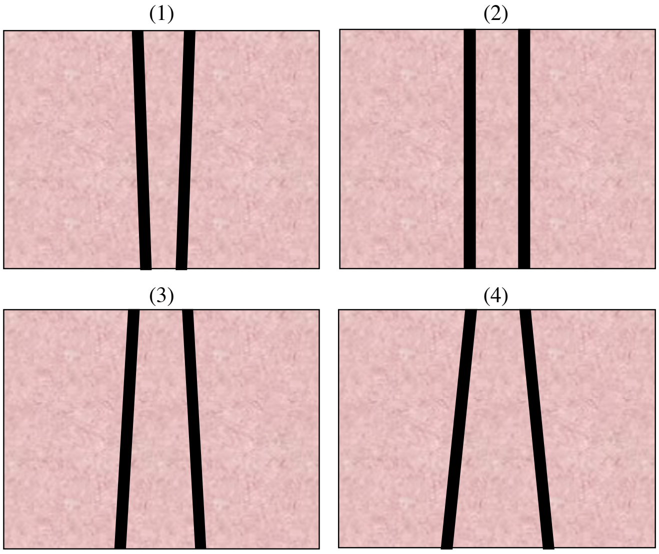


Figure 4: Stimuli used in the experiment.

Figure 5: Photos from the experiment. Left: the participant was using an angle adjuster to report the perspective angle. Right: the participant was using slant pad to report the optical slant angle.

Table 1: Four viewing conditions.

	Binoculars	
	With	**Without**
Use one eye	1	2
Use two eyes	3	4

following interpretations.

1. The lines are not parallel (perspective angle has been changed)
2. The ground is slanted (optical slant angle has been changed)

4. EXPERIMENT

In this study, we conducted an experiment on linear perspective perception to examine the binoculars illusion.

4.1 Participants

Twenty-three students (16 males, 7 females, mean age = 24.5 years, SD = 4.76 years) participated in the experiment. Research was performed with the approval of and in accordance with Shibaura Institute of Technology Institutional Review Board. Informed consent was obtained from all participants.

The participants were unfamiliar with the aims of the experiment and received no feedback about their performance. All participants had normal vision or wore contact lenses. Stereoacuity was tested using four random-dot stereograms and all participants could report all images correctly.

4.2 Stimulus

We performed a preliminary experiment to test the perspective angle when changing actual angles between the two lines and decided additional three angles of stimuli for this study. Figure 4 shows stimuli used in the main experiment. Lines are drawn on a plate with texture in light pink to make the plane noticeable. We used the 1/f natural-noise texture which is considered the least helpful in slant discrimination [19]. The lines are diverged lines (1), parallel lines (2), converged lines (3), more converged lines (4). Every stimulus is horizontally placed on the floor. The slant of the stimuli is never changed throughout the experiment.

4.3 Apparatus

The subject could only see the experimental setup through the binoculars or a paper cylinder, because the experiment area was covered by curtain with a hole in the middle only to fit the binoculars or the paper cylinders. The binoculars or the paper cylinders are placed on a tripod, which fixes the viewing height and viewing distance. A photo from the experiment is shown in Figure 5.

The tripod is placed 3m away from the center point of the stimulus. The tripod is set to 1m height from the floor. The size of the stimulus is

91cm x 60.5cm. For the binoculars used in the experiment, we used Olympus 8x21 RCII, with 8x as the strength of magnification and the size of the objective lens is 21mm.

The answering tools in our experiment were developed so that the observer could replicate what they perceived. For perspective angle measurement, we create *an angle adjuster* using two digital angle finders. The angle adjuster can be placed on the participant's lap while viewing the stimulus. For slant measurement, we create *a slant pad* by referring to palm board [9]. A digital angle finder is also attached to the slant pad. The slant pad is fixed to the table, around 70 cm from the floor. Unlike the traditional haptic measurement method, the participant is allowed to look at the stimulus, the angle adjuster and the slant pad and adjust both optical slant and perspective angles as many times as they desire until they are satisfied with the replication. After the participant feels satisfied with the replication, they report the numbers shown on digital angle finders attached to the angle adjuster and the slant pad. The angle adjuster and slant pad are shown in Figure 5, left and right accordingly.

4.4 Design

Participants were assigned to four viewing conditions in order. In the first two conditions, participants look at the stimulus through a pair of binoculars, monocularly and binocularly. In the second two conditions, the participants look at the stimulus through paper cylinders, using one eye or two eyes. Four viewing conditions are indicated by numbers, as in Table 1.

We record perspective and optical slant angles of four stimuli in one of viewing conditions. The order of stimulus shown in one viewing condition is fully randomized.

4.5 Procedure

The participant viewed the stimulus monocularly or binocularly, with or without binoculars. In the monocular condition, the participant used his/her dominant eye. They were instructed to look through the binoculars or paper cylinders, which are positioned on a tripod. Since the experiment area was covered with the curtain, the participant only saw the stimulus through a limited field of view. For each stimulus, the participant was asked to estimate the perspective and the optical slant angles of the stimulus. The participant first looked at the stimulus, then adjusted the digital angle finders until both of the angle adjuster and slant pad replicate their answer. The participant could adjust the angles while or after observing the stimulus. The participant was allowed to repeat the procedure until he/she was satisfied with the result. The participant recorded their responses by copying the numbers shown on the digital angle finders to an answer sheet. The optical slant angle, θ, and the perspective angle, β, were calculated from the recorded numbers for analysis.

The participant was not given any feedback regarding their performances. After finishishing recording, the participant was instructed to sit on a chair until the experimenter finishes changing the stimulus. The participant's location was always behind the curtain, which always covered the view of the experiment area. The experimenter stayed with the participant the whole time.

5. RESULTS AND DISCUSSION

Because θ and β are related, we need to analyze these two values together. By inspecting each participant's θ and β values, we notice that there are some outliers. Before proceeding to the data analysis, we calculated the Ma-halanobis distance for each point (θ, β), in each viewing condition, in each stimulus, and then calculate the average Mahalanobis distance for each participant. The participant that shows the highest average of Mahalanobis distances is considered as outlier. We eliminated one partic-ipant in the following analysis.

Firstly, we compare the values θ and β under different viewing conditions (VC) for each stimulus separately. The comparisons are shown in scatterplots in the left column of Figure 6. We illustrate four plots, indicating four different viewing conditions, in each graph corresponding to a stimulus.

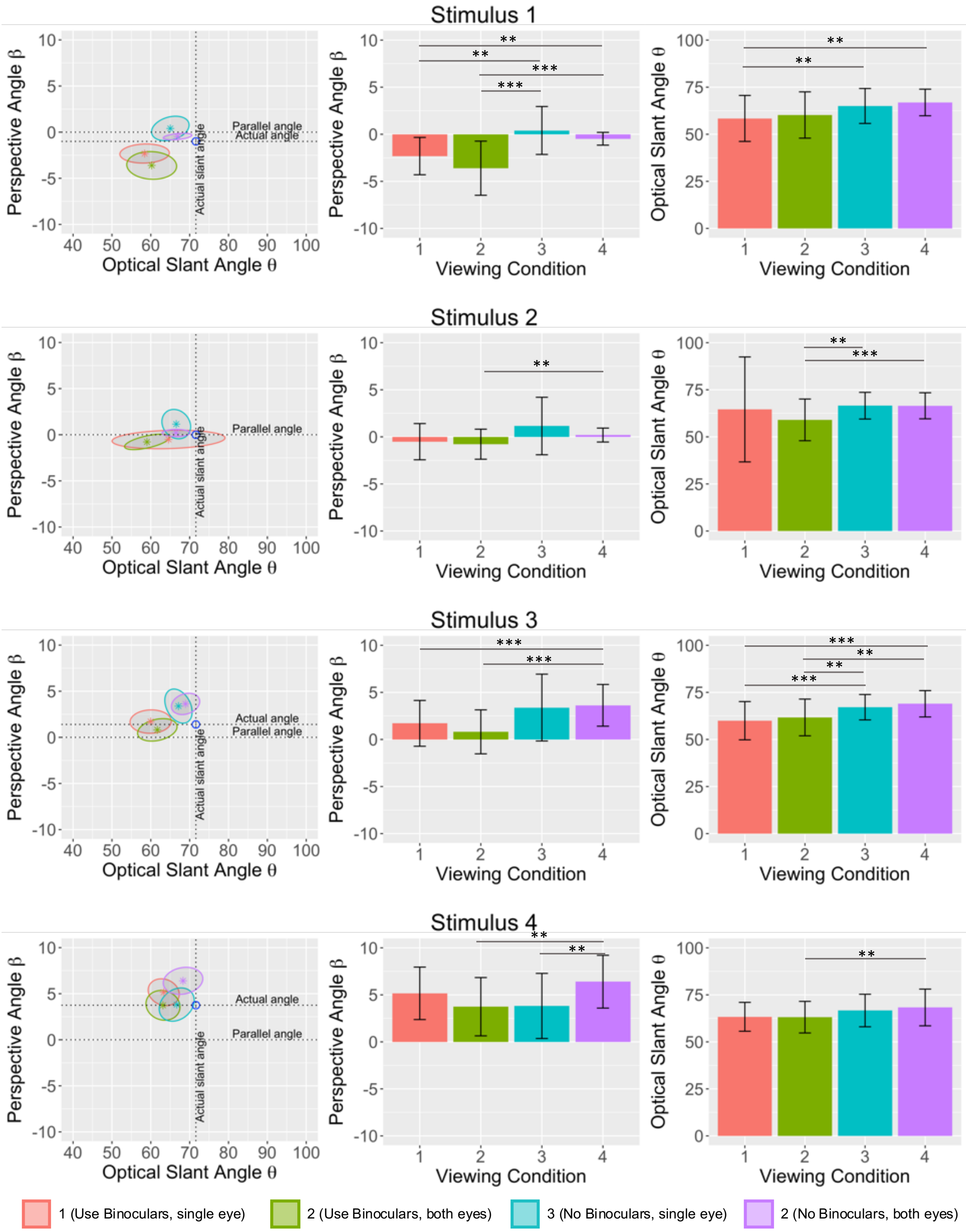


Figure 6:Scatterplot of β and θ (left column). The bar chart of average β and θ for all possible viewing condition (VC) pairs, each shown with significant effect (middle and right column), **p<0.05, ***p<0.01

The plot is drawn with a confidence ellipse and the average value indicated using $*$ symbol. A dotted vertical line shows the actual slant angle, i.e., the ground truth value for θ. We also place two horizontal lines for the parallel angle ($\beta = 0$) and actual stimulus angle, i.e., the ground truth value for β.

From the figure, some plots seem to locate separately from each other and some seem to overlap. For further comparison, we performed a one-way repeated measures ANOVA on θ and β between every pair of viewing conditions, for each stimulus. Then, we perform post-hoc analysis to find the pair with significant differences.

From one-way repeated measures ANOVA result, β was significantly affected by viewing condition in Stimulus 1 [F(1.944,40.83) =16.93, p < 0.0001 , η^2 =0.446], in Stimulus 2 [F(1.492,31.34) =4.395, p = 0.03 , η^2=0.173], in Stimulus 3 [F(2.02,42.42) =6.48, p = 0.03, η^2= 0.236], and in Stimulus 4 [F(3,63) =6.728, p <-0.0001 ,η^2 = 0.243]. Meanwhile, θ was significantly affected by viewing condition in Stimulus 1 [F(2.603,48.36) =6.69, p = 0.001, η^2 = 0.24], Stimulus 3 [F(2.04,42.87) =12.141, p < 0.0001 , η^2 =0.366], and Stimulus 4 [F(2.668,56.03) =5.291, p = 0.004 , η^2=0.201] only.

For stimulus 1, the plots (in scatterplot shown in the left column of Figure 6) tend to shift to lower left when viewed with binoculars, either monocularly or binocularly, indicating more diverged perception of lines(β), and the stimulus is perceived to slant toward the frontoparallel plane more than viewing with naked eye(s) (θ). The pairwise comparison also shows β is decreased when viewed using binoculars monocularly, VC1 (M=-0.23, SD=1.98) vs. VC3 (M=0.4, SD=2.55), p=0.007, and binocularly, VC2 (M=-3.6, SD=2.87) vs. VC4 (M=-0.4, SD=0.68), p<0.001. Difference in optical slant angle perception is observed when viewed monocularly ,VC1 (M=58.40, SD=12.02) vs. VC3 (M=65.03, SD=9.27), p=0.016.

For the scatterplot of stimulus 2 (parallel lines), the perspective angles are always below the parallel angle ($\beta = 0$) when viewed using the binoculars. Pairwise comparison shows the significant difference when viewed using both eyes, VC2 (M=-0.78, SD=1.6) vs. VC4 (M=0.19, SD=0.74), p=0.03. This confirms the perceptual effect of binoculars' illusion. More interestingly, we found that the slant angles are shifted toward the frontoparallel plane too, when viewed through binoculars, using both eyes, VC2 (M=59.02, SD=11.07) vs. VC4 (M=66.50, SD=6.92), p<0.001.

In the case for converged lines (stimulus 3) and more converged lines (stimulus 4), when viewed without using binoculars, the perspective angles are always above ground truth angles Meanwhile, when viewed using binoculars, the perspective angles shift to below or at ground truth. Statistical difference can be observed for both eyes in both stimulus 3, VC2 (M=0.81, SD=2.33) vs. VC4 (M=3.62, SD=2.21), p<0.001 and stimulus 4, VC2 (M=3.73, SD=3.1) vs. VC4 (M=6.4, SD=2.8), p=0.004. Meanwhile, the slant angles are also shifted toward the frontoparallel plane, indicating the perception of slanted ground when viewed monocularly, VC1 (M=59.96, SD=10.16) vs. VC3 (M=67.13, SD=6.74), p=0.001, and binocularly, VC2 (M=61.68, SD=9.74) vs. VC4 (M=68.94, SD=6.99), p=0.016, for stimulus 3. We also observe the same tendency when viewed binocularly in stimulus 4, VC2 (M=63.13, SD=8.4) vs. VC4 (M=68.3, SD=9.76), p=0.05.

From these above statistical analysis results, it can be concluded that binoculars illusion does exist. The illusion perception could be regarded as the misinterpretation of a scene. That is, the lines are not parallel (decreased in β) and the ground is slanted (decreased in θ). This combination of misinterpretation could be caused by distance forshortening. The distance forshortening may lead to shift of vanishing point, which occurs because the scene is magnified on the frontoparallel plane when viewed through a pair of binoculars.

6. CONCLUSION

In this study, we proved the occurrence of binoculars' illusion in general observers. By conducting the experiment to measure perspective angles and optical slant angle, we were able to explore possible causes for such perception. The experiment result confirmed the effect of binoculars' illusion. From the experiment results, it can be implied that when looking through a pair of binoculars, the perceived perspective of parallel lines on the floor appears to be reversed. We also found another interesting effect of the illusion. It also causes a slant perception of the stimulus on the ground. The stimulus appears to look slanted when viewed through the binoculars compared with the situation viewed with the naked eye(s) with a limited field of view. These findings suggest causes for binoculars' illusion, which could be useful when designing an environment that limit the field of view such as the virtual reality scene.

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ANALYSIS OF NOSTALGIC ILLUSTRATIONS BASED ON PHOTO-GRAPHIC TECHNIQUES

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ABSTRACT: Nowadays, many illustrations are published mainly on Social Network Service (SNS), and we can see various illustrations every day. Among them, we have seen nostalgic illustrations. People and landscapes are consistently chosen as motifs, and everyone can feel nostalgia in almost the same way. Illustrations are still images, and like photographs, they have composition, three-dimensionality, and color. Therefore, we think that illustrations that make us feel nostalgic might have something in common with other images. The purpose of this research is to clarify the components of illustrations that make people feel nostalgic. This research collected 420 nostalgic illustrations of people and landscapes and investigated five items . We investigated five items based on the basic techniques of camera photography. (1) Camera angle: we classify into three heights: high angle, eye level, and low angle. (2) Balance: we classify by symmetry or asymmetry of illustrations. (3) Position of the main subject: we analyse the four intersections of the tripartite method and the five positions of the center in illustrations. (4) Expression of depth: we classify the five items of overlapping perspective, texture perspective, linear perspective, Large and small perspective, aerial perspective, and combinations of these expressions. (5) Induction by the line of composition: we classify into four S-shape compositions, radial composition, oblique composition, and none. The results of these analyses revealed the graphic characteristics of illustrations that evoke nostalgia.

Keywords: Nostalgic illustrations, Photography techniques, Image analysis, Component of illustration.

1. INTRODUCTION

With the advancement of network services, there are more and more opportunities for artists to freely present their works.

In Japan, social networking services such as Pixiv[2] and Pinterst[3] are being used to publish and share illustration works. One of the most popular genres of illustration in recent years is that of nostalgia. In Japan, it is sometimes described as “Emoi”. In Japan, nostalgia is often seen as nostalgia or melancholy, but it is also seen in a positive light, as something that moves you. Nostalgia is an experience and emotion that is felt worldwide, including by the Japanese [1].

In Japanese illustration, nostalgia is popular, but it is unclear why people feel nostalgia.

Although emotional research on nostalgia has been conducted, few studies have focused on illustration or animation. Research on nostalgic illustrations will lead to the development of methods to support their production, which in turn will lead to the expansion of nostalgic content.

In this study, we collected nostalgia-inducing illustrations and investigated their composition and depth expression based on basic photographic techniques. As a result, we discovered the characteristics of illustrations that evoke nostalgia.

Chapter 2 describes previous research on nostalgia, Chapter 3 describes the collection of illustrations and the analysis method, Chapter 4 presents the analysis results, and Chapter 5 presents the conclusion.

2. ABOUT NOSTALGIA

The concept of nostalgia was coined by Johannes Hofer (1668), a Swiss medical student, and was treated as a nostalgia disease [6]. However, the current concept of nostalgia is closer to the nostalgia defined by Holbrook et al. In Horiuchi's study, the definition of nostalgia was summarized as "the overall positive emotional experience that occurs when one thinks about the past" [5].

The emotion of nostalgia includes feelings of nostalgia, sadness, love, and longing. According to Horiuchi's research [5], nostalgia is classified into two categories: personal nostalgia and historical nostalgia. Personal nostalgia is that which extracts only the pleasant aspects of one's past. Historical nostalgia is caused by emotional involvement with historical stories and historical figures from the good old days before we were born.

Both of these elements are included in nostalgic images, which suggests that nostalgia is a positive emotion and is popular because it is favorable.

3. INVESTIGATION OF ILLUSTRATIONS THAT FEEL NOSTALGIA

The purpose of this research is to investigate illustrations that feel nostalgia and to clarify the characteristics of composition and depth. We collected 420 illustration images by searching for the words "nostalgic" and "natsukashii" in Japanese using Google image search and the Pinterest.

Each image was analyzed in terms of five items based on camera shooting techniques.

1) Camera angle: The images were classified into three heights: high angle, eye level, and low angle. Figure 1 shows an example.

Figure 1: Example of Camera Angle.

2) Balance: This is divided into symmetry and asymmetry. Figure 2 shows an example.

3) Position of the main subject: This is the five positions of the four intersections and the center by the tripartite method. Figure 3 shows an example. If the main subject is considered to be multiple, each area is recorded. If the main subject is a distant object, such as a landscape, or an extremely large object, the center position is selected. The positions of each intersection point of the tripartite method are from 1 to 4.

Figure 2: Example of Symmetry.

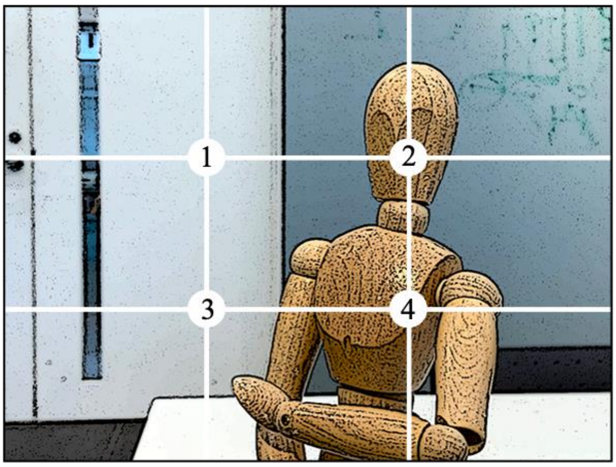


Figure 3: Example of Balance.

4) Expression of depth: For the expression of depth, combinations of the following five items were recorded: overlap of objects, texture perspective, linear perspective, large and small perspective, and aerial perspective. Figure 4 shows an example. The overlapping of objects is the overlapping of multiple objects, making the one in front seem closer and the one behind seem farther. The gradient of texture is an expression in which the narrower the interval between textures, the farther the object seems, and the wider the interval between textures, the closer the object seems. Line perspective is a method for express-

ing perspective by using oblique lines that converge to a vanishing point. Large-small perspective is a technique that uses objects of the same size and makes them seem closer when drawn large and farther when drawn small. For example, an illustration of many telegraph poles standing along a road falls into this category. Aerial perspective is an expression in which the more hazy the image appears, the more distant it appears due to the nature of the atmosphere. This expression is also used in the perspective of near, middle, and distant views.

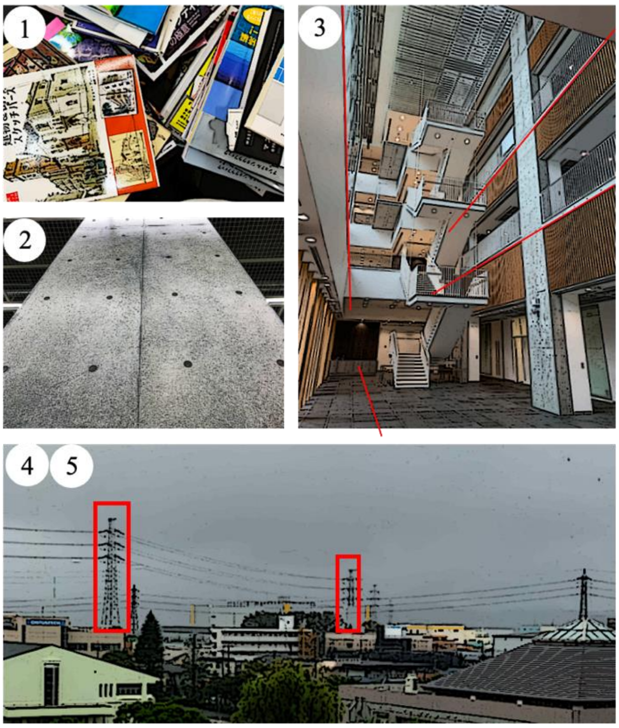
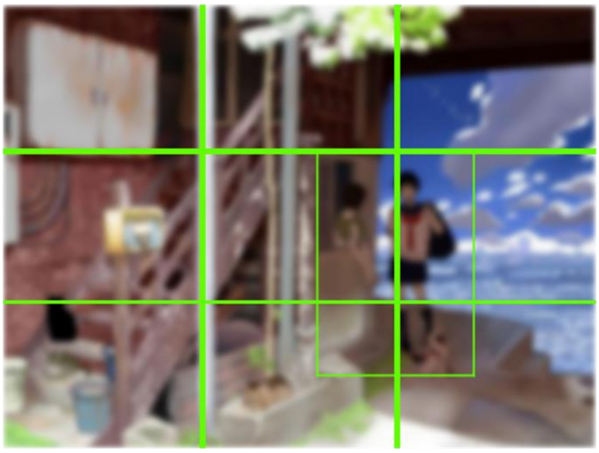


Figure 4: Expression of depth. (1. overlapping perspective, 2. texture perspective, 3. linear perspective, 4. Large and small perspective, 5. aerial perspective)

5) Induction by compositional lines: Induction by lines consists of four items: S-shaped composition, radial composition, diagonal composition, and none. Figure 5 shows an example. The S-shape composition makes use of the S-shaped curves to create an image of flow and movement, and to express depth. It is often seen in photographs of roads, rivers, and other subjects. Radial composition is a technique that emphasizes radial lines to emphasize depth and power, and to guide the eye toward the vanishing point. Oblique line composition is a composition in which oblique lines are placed across the picture plane, and is a technique for adding movement and expressing depth to a picture.

These five items were used to analyze the collected illustrations.

As shown in Figure 5, the analysis procedure consists of drawing a grid of the tripartite method on the illustration to be analyzed, surrounding the main motif with a square frame to identify the location of the main motif. Then, the camera angle and balance were checked, and the depth expression was investigated and recorded.



1. Create the grid of the tripartite method.
2. Surround the main motif with a rectangular frame.
3. Investigate the camera angle.
4. Investigate the balance.
5. Investigate the depth expression.

Figure 5: Analysis Procedure

4. RESULTS AND DISCUSSION

4.1 Result of illustration composition analysis

The results of the compositional analysis are described below.

Camera angle: As shown in Table 1, the camera heights were 226/420 eye level, 130/420 low level, and 64/420 high level. 53.8% of the images were composed at eye level.

Table 1: Results of Camera Angles.

Camera Angle	
Eye level	226
Low angle	130
High angle	64

Balance: Symmetry composition was 39/420 or 9.3%. Table 2 shows the results.

Table 2: Result of Compositional Balance.

Balance	
Symmetry	39
Asymmetry	381

Position of the main subject: Table 3 shows the results of the intersection of the center and tripartite methods. We were able to extract 254 center positions. Position 1, 2, 3, and 4 were 42, 52, 74, and 100, respectively.

Table 3: Result of Position of the Main Subject.

Position of the main subject	
Center	254
Position 1	42
Position 2	52
Position 3	74
Position 4	100

Expression of depth: The overlap of the objects was 330, the gradient of the skin was 173, the perspective was 206, the large and small perspective was 114, and the air perspective was 170. The results are shown in Table 4.

Table 4: Result of Expression of Depth.

Expression of depth	
D1: Overlapping perspective	330
D2: Texture perspective	173
D3: Linear perspective	206
D4: Large and small perspective	114
D5: Aerial perspective	170

Induction by the line of composition: 13 for S-shape composition, 96 for radial composition, 56 for inclined line composition, and 255 for none. The results are shown in Table 5.

Table 5: Result of Induction by the line of composition.

Induction by the line of composition	
S-shape compositions	13
Radial composition	96
Oblique composition	56
None	255

4.2 Discussion

The details of the analysis are described below.

As for the camera angle and balance, we had to choose one of them, and clear characteristics appeared. Figure 6 shows the results of the camera angle. 53.8% of the 420 illustrations used the eye-level composition.

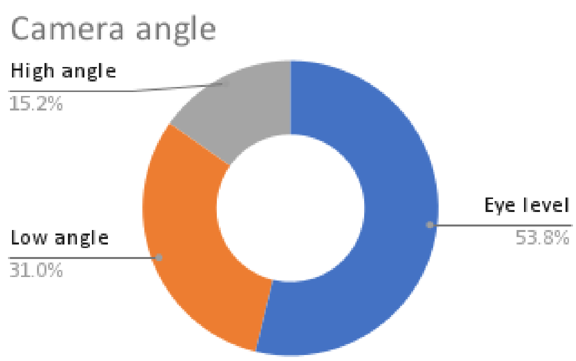


Figure 6: Percentage of results for camera angle

Figure 7 shows the result of balance. It can be seen that 90.7% of the total images are asymmetrical. Therefore, it is rare for nostalgic illustrations to adopt a symmetrical composition.

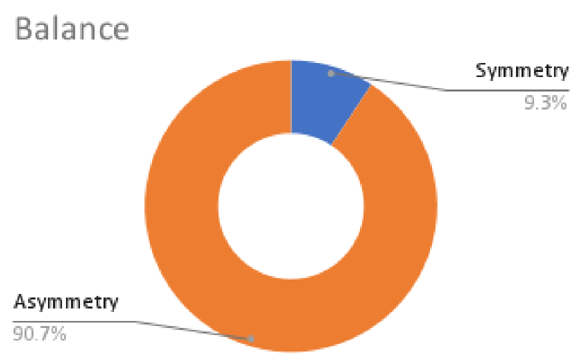


Figure 7: Percentage of results for Balance

Figure 8 shows a graph of the positions of the main motifs. There were 254 images in which the motif was placed in the center position. Many of these images had a large motif or a person in the center.

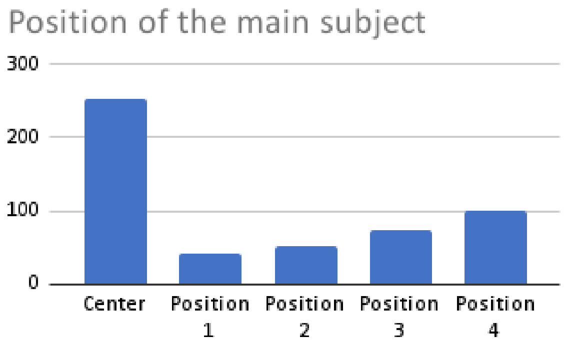


Figure 8: Result for Position of Main Subject

The other positions have multiple motifs in one image, and all combinations are shown in Table 6.

Table 6: Combination of Main Subject

Combination of Main Subject			
No	**Combination**	(M)	**%**
1	Center	232	55.2
2	Position 1,3	19	4.5
3	Position 1	6	1.4
4	Position 2,3	28	6.7
5	Position 2	9	2.1
6	Position 3	35	8.3
7	Position 4	45	10.7
8	Position 1,2,4	2	0.5
9	Position 3,4	8	1.9
10	Position 1,2	5	1.2
11	Position 1,4	6	1.4
12	Center, Position 4	6	1.4
13	Position 1,2,3	1	0.2
14	Center, Position 1	2	0.5
15	Center, Position 1,3	1	0.2
16	Center, Position 3	6	1.4
17	Center, Position 2	3	0.7
18	Position 2,3,4	1	0.2
19	Center, Position 2,4	2	0.5
20	Position 2,3	1	0.2
21	Center, Position 3,4	2	0.5

The most common combination was the motif in the center position, and the next most common combination was motif position 4 (35 images, 10.7% of the total).

As shown in Table 4, the most commonly used expression for depth was the Overlapping perspective of D1. Table 7 shows the combinations of expression for depth, 30 in total. The most frequently used combination was D1 and D3, which accounted for 10.3% of the total.

The percentages of the other combinations are shown in Table 7.

Table 6: Combination of Liner Perspective

No	**Liner Perspective**	**(M)**	**(%)**
1	D 2, 5	9	2.1
2	D 3	27	6.4
3	D 1, 4	12	2.9
4	D 5	9	2.1
5	D 3, 4, 5	3	0.7
6	D 4, 5	9	2.1
7	D 2, 4, 5	3	0.7
8	D 3, 5	5	1.2
9	D 1, 5	36	8.6
10	D 2, 3	9	2.1
11	D 1	49	11.7
12	D 3, 4	2	0.5
13	D 2	4	1
14	D 1, 2	19	4.5
15	D 4	4	1
16	D 1, 3	43	10.2
17	D 2, 3, 5	4	1
18	D 1, 4, 5	10	2.4
19	D 1, 2, 3, 4, 5	14	3.3
20	D 1, 2, 3, 4	14	3.3
21	D 1, 2, 4	11	2.6
22	D 1, 2, 4, 5	9	2.1
23	D 1, 2, 5	29	6.9
24	D 1, 2, 3	37	8.8
25	D 1, 3, 4	18	4.3
26	D 1, 3, 5	17	4
27	D 1, 2, 3, 5	9	2.1
28	D 1, 3, 4, 5	3	0.7
29	D 2, 3, 4, 5	1	0.2
30	D 2, 4	1	0.2

Induction by the line of composition was not used in 60.6% of the cases, as shown in Figure 9. The most common item used was Radial composition, which was used by 23% of the total.

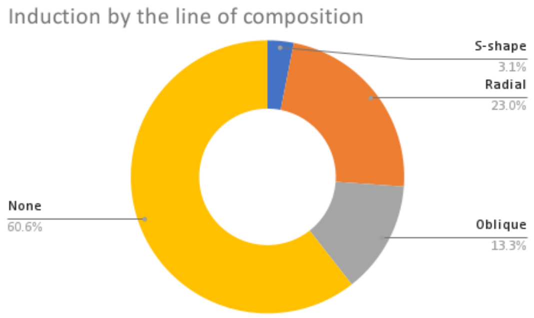


Figure 9: Induction by the Line of Composition

The characteristics of each item were found. Finally, the combination of these items is shown in Figure 10. As shown in Fig. 10, the combinations were varied, and there were 280 combinations of the items analyzed in the illustrations, with a maximum of 11 illustrations having the same combination. Even the most common combination accounted for 1.7% of the total, so it can be considered to be almost uneven. The analysis items for the 11 illustrations with the largest number were camera angle: eye level, balance: asymmetry, positions of the main motifs: center, expression for depth: D1, D3, and Induction by the line of composition: none.

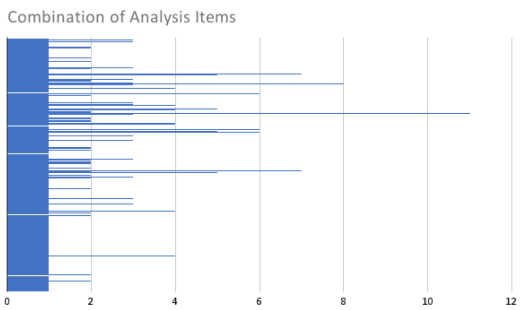


Figure 10: Combination of Analysis Items

5. CONCLUSIONS

In this research, we collected 420 nostalgic illustrations and analyzed them using five items based on photography techniques. As a result, it was found that the illustrations with a sense of nostalgia had certain characteristics in each composition analysis item. This may provide an indicator for creators to be conscious of composition when drawing.

However, there is room for reconsideration of the analysis items because the combinations of the composition of the analysis items were different. In the future, it will be necessary to analyze not only the composition but also the color scheme and the types of motifs. It is also necessary to compare it with illustrations that do not have nostalgia tags.

ACKNOWLEDGMENTS

We would like to thank Hinata Kinugasa for collecting the nostalgic illustrations.

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RESEARCH OF GEOMETRICAL PATTERN ON RECTANGULAR PARALLELEPIPED SURFACE

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ABSTRACT: This research is exploring a method of drawing straight-line patterns on cubic or rectangular parallelepiped surfaces. The purpose of this research is to create a type of pattern using straight-line that cover all six sides of a rectangular parallelepiped surface, and to produce basic reference for designing products and architecture.
Using a cube as the basic solid, how to construct a straight-line pattern on its six surfaces is explored in this research. 3 major method is used to create pattern on rectangular parallelepiped surfaces. There are 13 types of patterns created and classified in this study. 5 patterns are created by using straight-line that run on surface of rectangular solid in different angle. 2 patterns are created by using dots. 6 patterns are created by using section line. These patterns can possibly work as structure without sides of rectangular parallelepiped surface.
As a result, all methods are different from each other but can find similarity in between those different method. These similarities suggest that no matter how methods are, impressions of these patterns can be similar. This mean that cubical surface patterns in this study can be summarize. It’s possible to summarize 2 or 3 patterns into one pattern. To accomplish this optimization, more cubic patterns should explore. This geometric pattern on the solid is the initial part of this research. And analyzing structural characteristics will be the second phase.

Keywords: Geometry Pattern, 3D pattern, Additive Manufacturing.

1. BACKGROUND

This research is exploring a method of drawing straight-line pattern on cubic or rectangular parallelepiped surfaces.

There are references on straight-line patterns on 2D surfaces. For example, Penrose tiling has relation between architecture and art [1].

And there’s a references of 3D tilling patterns explored by Cecil Balmond [2] in architectural design.

Surpentine Pavilion 2002 which designed by Japanese architect Toyo Ito was used square based pattern wrapped onto rectangular parallelepiped surfaces [3]. This is not only design pattern but also work as a structure.

However, most of them are not on all six surfaces, but on four of five surfaces, excluding the surface that touches the ground or roof.

The purpose of this research is to create a type of pattern using straight-lines that cover all six sides of a rectangular parallelepiped surface, and to produce basic reference for designing products and architecture.

2. CREATION OF 3D PATTERNS

Using a cube as the basic solid, how to construct a straight-line pattern on its six surfaces is explored in this research. 3 major method is used to create pattern on rectangular parallelepiped surfaces. There are 13 types of patterns created and classified in this study. 5 patterns are created by using straight-line that run on surface of rectangular solid in different angle. 2 patterns are created by using dots. 6 patterns are created by using section line. These patterns can possibly work as structure without sides of rectangular parallelepiped surface. Patterns in this research is for cube surfaces.

2.1 Straight line pattern 1

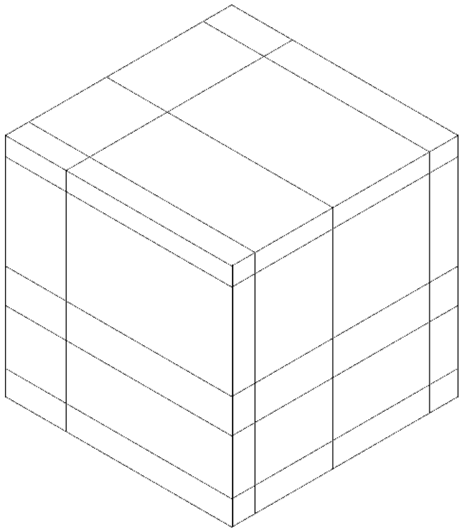

Figure1: Orthogonal line pattern 1

This pattern is most simple way to create. Using orthogonal straight line that run parallel to the sides of cube.

2.2 Straight line pattern 2

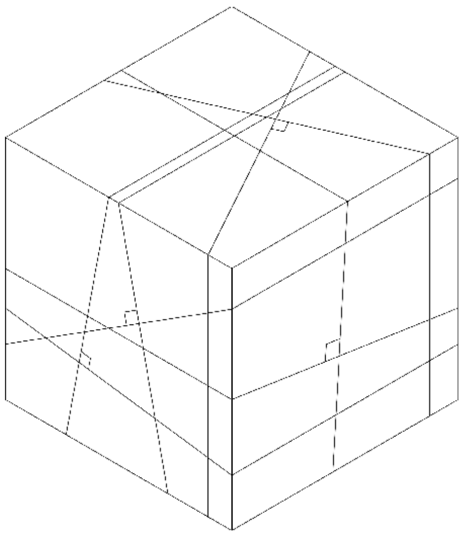

Figure2: Orthogonal Pattern 2

This pattern Using almost same method as 2.1. This method adding rotation around the nodal point. Then diagonal line was created and more moving impression can be add to the design.

2.3 Straight line pattern 3

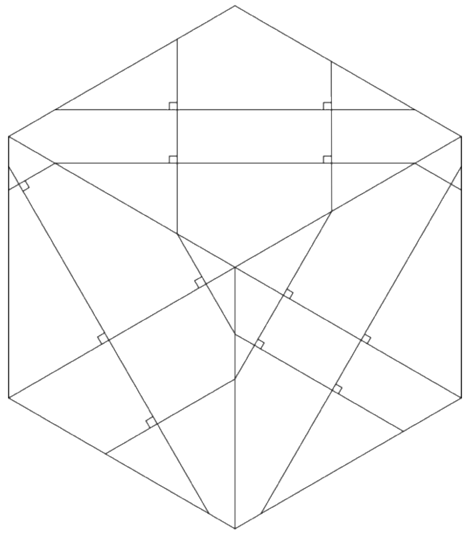

Figure3: Orthogonal Pattern 3

This pattern is made by line with 45 degree inclination defined by [y=ax(a=1)]. This pattern's all intersections are orthogonal.

2.4 Straight line pattern 4

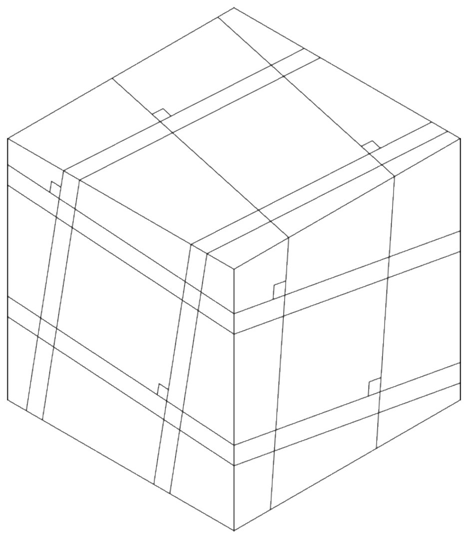

Figure4: Orthogonal Pattern 4

This pattern is development pattern from Orthogonal line pattern 3. This pattern's straight line defined by [y=ax]. Inclination of Pattern 3 is 45 degree but of this pattern is optional. And same specific remain as pattern3, all intersection are orthogonal.

2.5 Straight line pattern 5

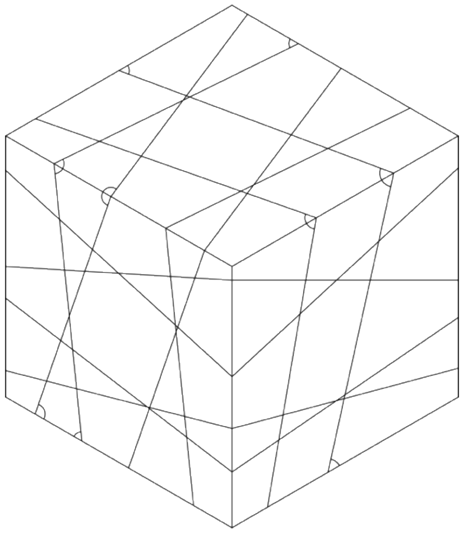

Figure5: Orthogonal Pattern 5

This pattern using line symmetry. Straight line goes to sides of cube, then the line flipped around the sides. Angles between Straight line and sides is same as those of adjacent surface.

2.6 Pattern by dot 1

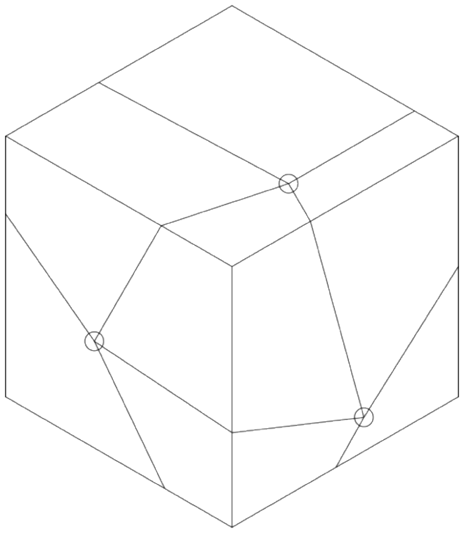

Figure6: Pattern by dot 1

This pattern is made by networking dot with using straight line. Figure.6 shows example of this pattern.

2.7 Pattern by dot 2

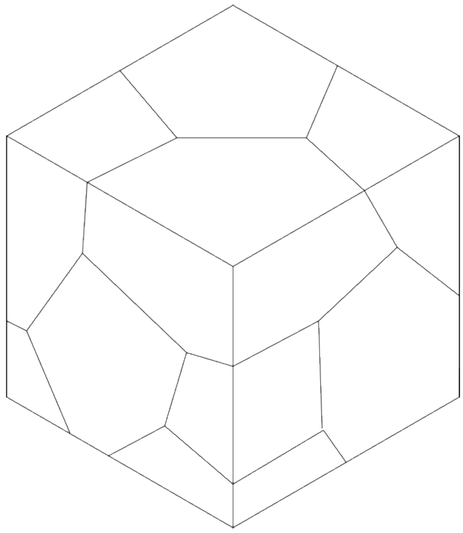

Figure7: Pattern by dot 2

This pattern is so common known as 3 dimensional Voronoi. Basically, Voronoi is 2 dimensional pattern but this is apply to the surface of cube.

2.8 Section line pattern 1

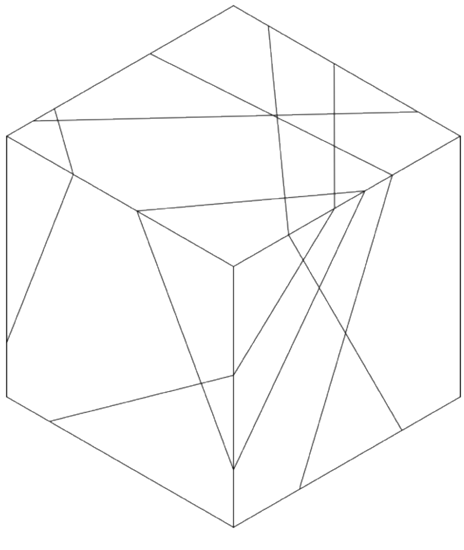

Figure8: Section line pattern 1

This pattern is composed by section line. When cutting a cube with plane surface, triangle, square, pentagon, hexagon will appear. This pattern is using all type of section line to create patterns.

2.9 Section line pattern 2

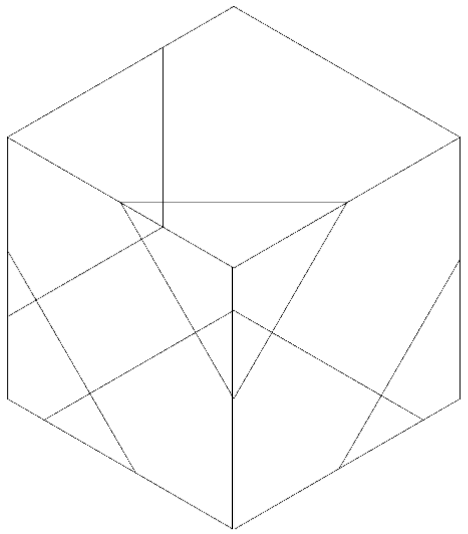

Figure9: Section line patter 2

This pattern is using only triangle shaped section line. This diagonal line act as brace so this will be very rigid structure.

2.10 Section line pattern3

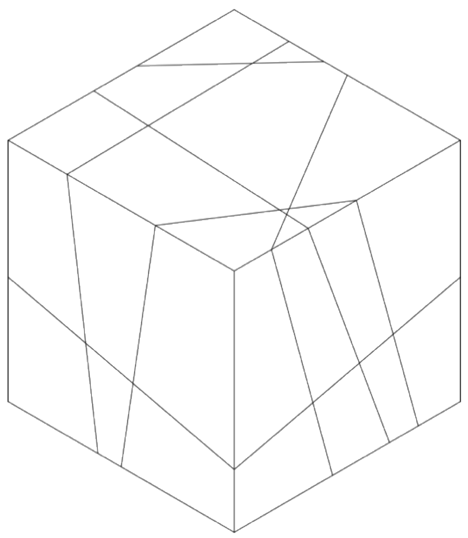

Figure10: Section line pattern 3

This pattern's section line is square only.

2.11 Section line pattern 4

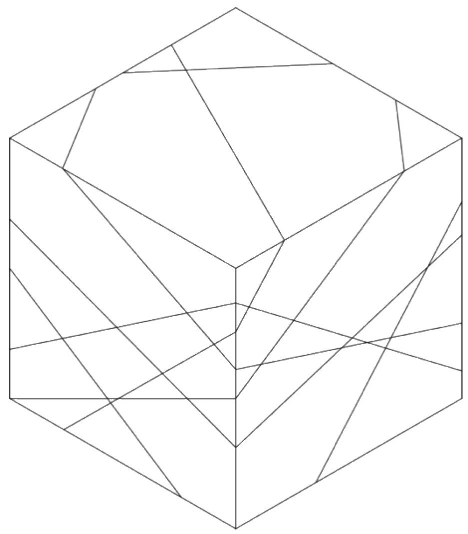

Figure11: Section line pattern 4

This pattern's section line is only pentagon shape.

2.12 Section line pattern5

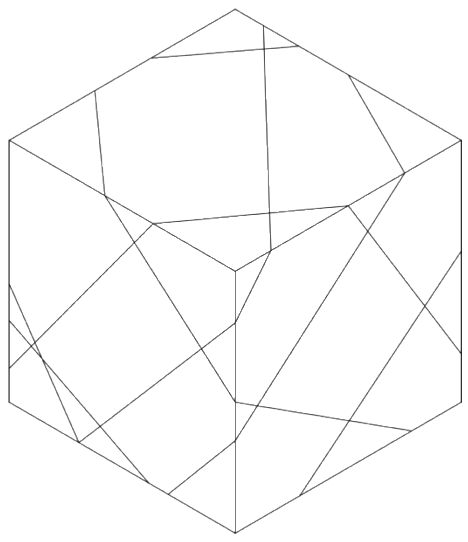

Figure12: Section line pattern 5

This section line shape is hexagon. And this pattern only using hexagon.

2.13 Section line pattern 6

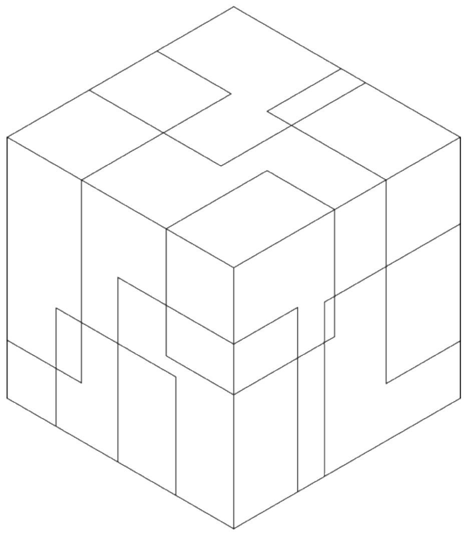

Figure13: Section line pattern 6

This pattern is using a concept of Boolean Operations. Cube and rectangular parallelepiped surface is use as two solid. The edge made by [A not B] operation.

3. DISCUSSION

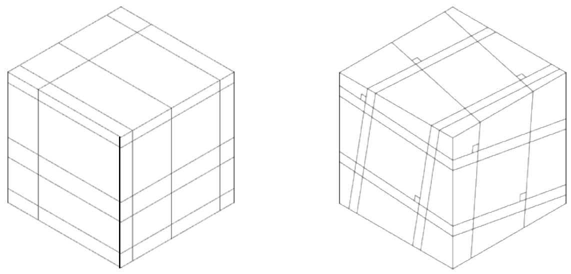

Figure14: Group A

As a result, all methods are different from each other but can find similarity in between those different method.

There are two groups A and B. Group A is containing 3 methods(Orthogonal Pattern1,2,4) and this group is basically using orthogonal straight lines. This is easy to guess because similar methods are used for creating these patterns. Figure14 illustrates the similarity of those patterns. Figure14 is consist of Straight line pattern1, Straight line pattern 4. The impression is similar because the all intersections are orthogonal.

On the other hand, Group B is containing different method using straight line and section line(Orthogonal Pattern3, Section Pattern1,2,4,5). These similarities are diagonal lines. Figure15 illustrate these similarities. And the other patterns are hard to classified into specific group.

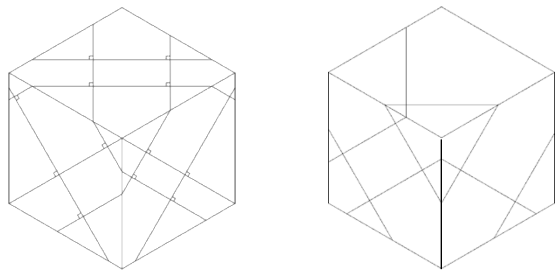

Figure 15: Group B

These two groups suggest that no matter how methods are, impressions of these patterns can be similar. This mean that cubical surface patterns can be optimized. It’s possible to summarize 2 or 3 patterns into one pattern. To accomplish this optimization, more cubic patterns should be explored.

The range of applications of these designs created is wide. The development of additive manufacturing has greatly advanced the production methods of design, and these patterns are expected to be applied to product design, architectural design, and mobile space. In this article, Straight lines are major method to create pattern. Exploring more pattern using curve is another possibility since additive manufacturing has a high degree of flexibility in modeling. This geometric pattern on the solid is the initial part of this research. And analyzing structural characteristics will be the second phase.

4. CONCLUSIONS

In this research, 13 patterns are created from different methods. There’re similarities in these patterns that can combine two or three different pattern into one.

And more patterns should be explored. After those exploration of patterns, summarization of those pattern is necessary so that making effective design pattern to apply multiple design products.

Also structural function of those design should explore in a 2nd phase.

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TRIPLY AMBIGUOUS OBJECTS

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ABSTRACT: This paper presents a systematic method for designing triply ambiguous objects, the objects that give three different appearances for three special viewpoints in such a way that it is difficult to understand that they come from the same objects. The objects are mainly 2D pictures but they are decorated by 3D additional items and are placed in 3D environment. As a result, a viewer does not recognize that they are 2D and thus optical illusion occurs. The method is based on mathematical properties of pictures of rectangular polyhedrons and psychological properties of the human vision system such as the preference for rectangularity and high sensitivity to the direction of gravity. A possibility of a six-interpretation ambiguous object is also discussed.

Keywords: Ambiguous object, rectangularity preference, impossible object, optical illusion, height-reversal property.

1. INTRODUCTION

Pictures having two or more interpretations are called ambiguous pictures and they are studied in vision research for understanding our visual intelligence [1, 3, 7, 12]. Each time, they evoke one interpretation in our minds; it is rare that two interpretations occur simultaneously. For some pictures, the interpretation changes to the other when we change the way of looking at them, such as turning the picture upside down. An example is a crater illusion, in which the perceived depth is reversed when we rotate the picture [11]. For other pictures the interpretation changes occasionally although we do not change the way of looking at them. Examples include the Necker cube [1, 6], in which the perceived depth is reversed, the Mack book [12], in which an open standing book changes to a face-down book, and the Rubin's base [1], in which the figure and ground are reversed. The Schröder's staircase [12] has both properties in the sense that the perceived depth is reversed even if we look at it stationary, but the reversal becomes more apparent if we rotate the picture.

Ambiguity is observed also for 3D objects. Fukuda's multiple silhouette sculptures give quite different silhouettes when we see them in two mutually perpendicular directions. For example, see “Encole”, which has the pianist and violinist silhouettes [13].

Another class of 3D ambiguous objects is height reversal objects [15]. A picture of a 3D object projected obliquely onto a horizontal plane evokes the perception of the height reversed object when it is seen from the opposite side with the same oblique angle. This geometric property can be used to create a 3D object whose height is partly reversed in a mirror; for example, the height of a garage roof is reversed. The same property can also be used to design objects part of which disappear in a mirror [16].

Still another class of 3D ambiguous objects is ambiguous cylinders [14, 17]. The section of a cylinder generates quite different appearances when it is seen from two prespecified viewpoints. The two appearances can be perceived simultaneously if we place a mirror behind the cylinder. For example, a round roof changes to a corrugated roof in the mirror and a circle changes to a square in the mirror. When we see them, we feel something impossible is occurring, and hence they can be regarded as a kind of impossible objects.

In general, ambiguous solids can be made for two desired shapes, but not for three. This is because the two appearances decide the 3D object uniquely by binocular stereo, i.e., by the triangulation principle. There are few examples of success in creating ambiguous solids with three interpretations; a solid with three silhouettes “W”, “H” and “O” by Ohgami and Sugihara [8] and a solid with three silhouettes “1”, “2” and “3” by Hopkins [2]. However, their objects can be created only for special combinations of three silhouettes, which require heuristic search instead of systematic.

In this paper we propose a systematic method for designing a class of triply ambiguous objects. When we put such an object on a desk and place two mirrors behind it in different vertical orientations, we perceive quite different three objects from one viewpoint, the direct view and the two mirror reflections. This method consists of two processes, one for drawing 2D pictures with a certain rule and the other for inserting additional 3D decorations to specify the direction of the gravity. It is guaranteed that the resulting object creates the impressions of the mutually different three 3D objects. This is a systematic method, instead of heuristic, for creating ambiguous solids with three interpretations. One example of the objects made using this method won the first prize at the Best Illusion of the Year Contest 2018 [18].

We review mathematical properties of pictures of rectangular objects (Section 2), and construct a method for designing ambiguous solids with three interpretations (Section 3). We also touch upon psychological natures of our vision systems suggested by those new ambiguous objects (Section 4), and also extend the method to create six-interpretation ambiguity (Section 5).

2. PICTURES OF RECTANGULAR POLYHEDRONS

A 3D object bounded by planar faces is called a *polyhedron*. We say a polyhedron is *rectangular* if all adjacent faces are connected by right angles, i.e., by 90 degrees. Cubes and bricks are simple examples of rectangular polyhedrons. For each rectangular polyhedron all the faces are classified into three groups so that faces belonging to the same group are parallel, and those belonging to different groups are perpendicular. Similarly, all the edges are classified into three groups so that edges belonging to the same group are parallel, and those belonging to different groups are perpendicular

Suppose that, as shown in Figure 1, we place a rectangular polyhedron on a horizontal desk surface in such a way that one group of faces are horizontal, and that we see this object from above in a slanted direction. Let $\boldsymbol{v}$ be the unit vector parallel to the view direction. Assume that $\boldsymbol{v}$ is not parallel to any face of the object. Let θ be the angle formed between $\boldsymbol{v}$ and the line of intersection of the vertical plane containing $\boldsymbol{v}$ and a horizontal plane. The angle θ is called the *pitch angle*. Let D be a picture of a rectangular polyhedron obtained by projecting it onto the plane along $\boldsymbol{v}$ orthographically.

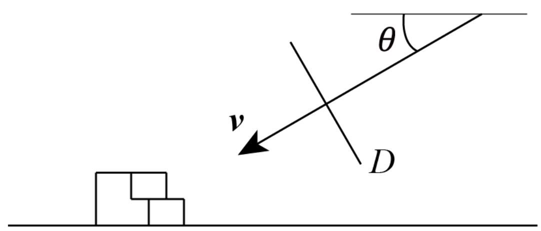


Figure 1. Rectangular object and its picture.

In this paper we use the term “vertical” in two meanings. The first meaning is being vertical in 3D space. In that case we just say *vertical*. The second meaning is being vertical in our retinal plane when we see a picture. In that case we use the term “retinally vertical.” For example, when a picture is viewed in such a way that a line in the picture is projected on the retina vertically, then we say that the line is *retinally vertical.*

In what follows, we present the picture D of a rectangular polyhedron in such a way that one group of parallel edges are retinally vertical. This convention corresponds to the situation that the viewer stands vertically when he or she sees the objects placed stably on a horizontal surface. Figure 2(a) shows an example of such a picture. The other edges in the picture are classified into two groups, one consists of mutually parallel edges running from left upper to right lower, and the other consists of those running from right upper to left lower.

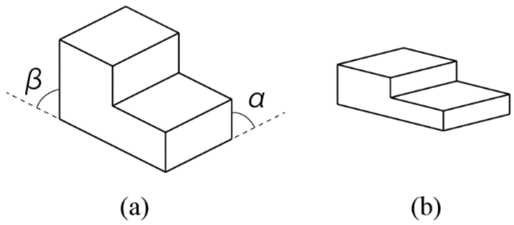


Figure 2. Picture of a rectangular object and that of its vertically scaled variant.

As shown in Figure 2(a), let α and β be the acute angles between the retinally vertical edge and the other two groups of edges. They satisfy

$$0 < \alpha < \frac{\pi}{2},\ 0 < \beta < \frac{\pi}{2}. \tag{1}$$

It is known [4, 8] that any picture of a rectangular polyhedron should satisfy

$$\alpha + \beta > \frac{\pi}{2}. \tag{2}$$

As shown in Figure 1, the picture *D* is the orthographic projection of a rectangular polyhedron. So, if we want to reproduce the same appearance as the object, we have to see the picture in the direction perpendicular to the picture plane.

Suppose that we place the picture *D* on the horizontal plane, and see it in the same view direction $\boldsymbol{v}$. Then, the picture appears to be compressed in the retinally vertical direction, as shown in Figure 2(b). From this picture we perceive an object that is different from the original one. However, this object is also a rectangular polyhedron, because the picture consists of three groups of mutually parallel edges, and their directions satisfy the inequalities (1) and (2). In general, a picture of a rectangular polyhedron continues to represent a rectangular polyhedron even if the picture is compressed in the retinally vertical direction. This property is a basis of our method for designing triply ambiguous objects, as will be shown in the next section.

3. DESIGN METHOD

A triply ambiguous object we are proposing in this paper is basically a picture of a rectangular polyhedron augmented by certain 3D decorations. The basic idea is the following.

Let *D* be a picture of a rectangular polyhedron *R*, and assume that we really perceive *R* when we see *D* in the view direction perpendicular to the picture plane. Suppose that we rotate the picture *D* so that one group of parallel edges becomes retinally vertical. Then, we perceive an object that is obtained by rotating the object *R* in the 3D space. As shown in Figure 3, there are three ways of seeing the picture *D* according to the choice of a group of retinally vertical edges, but what we perceive is the same object *R* in different postures. Therefore, the picture *D* itself cannot be an ambiguous object. However, we can construct a triply ambiguous object by adding several tricks to picture *D*.

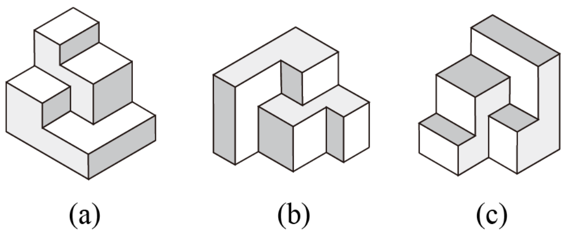


Figure 3. Three orientations of a picture of a rectangular polyhedron.

The first trick is to see the picture in a slanted direction instead of an orthogonal direction. For this purpose, we place the picture *D* on a horizontal plane, and see it in a slanted direction with the pitch angle θ other than 90 degrees as shown in Figure 4. As we have seen in Figure 2, seeing the object in a slanted direction results in compression of the picture in the retinally vertical direction, and consequently the perceived object will be also compressed. Hence, we can expect that the object is not the same when it is seen from three view directions.

Figure 5 shows the three appearances of the picture in Figure 3 when we see it with the pitch angle θ =30 degrees in the directions where each one of the three groups of lines is retinally vertical. The panels (a), (b) and (c) in Figure 5 correspond to the panels (a), (b) and (c), respectively, in Figure 3 in the sense that the retinally vertical groups of lines are the same. We can see that it is more difficult to recognize that the three appearances in Figure 5 come from the same picture. Actually, they cannot be the orthograhic projection of the same object, because the pictures are compressed in different directions.

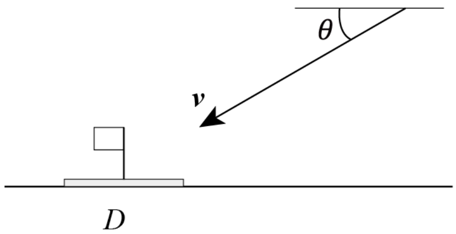


Figure 4. Seeing picture *D* in a slanted direction.

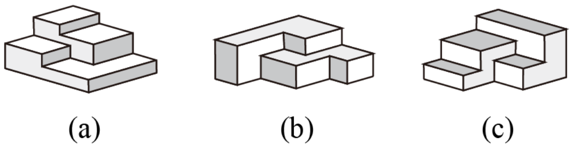


Figure 5. Three views of the picture in Figure 3(a) placed on a horizontal plane and seen in pitch angle θ.

The second trick is to add 3D objects that suggest the direction of the gravity. Human vision system is sensitive to the direction of the gravity in interpreting the 3D shapes [5]. A typical way to suggest the direction of the gravity is to put a vertical pin, such as a miniature pole with a flag as illustrated in Figure 4, at a convex corner of a rectangular polyhedron represented in the picture. Because the picture is horizontally oriented and the pin is vertical, the pin appears to be vertical whichever direction we see the picture from, which strengthens the impression that the three views correspond to different objects.

Another example of inserting a real 3D object is to add a thick plate on the back of the picture. When we see it from three directions, we perceive that the object is placed on the thick plate whose shape fits the bottom of the object. This plate also suggests the direction of the gravity.

Figure 6 shows an example of a triply ambiguous object made using the tricks described above. The object is a horizontally oriented picture of a rectangular polyhedron placed on a thick plate decorated with vertical poles and flags. Behind this object two plane mirrors are placed vertically, and hence the three views of the object can be seen simultaneously. It is not trivial to recognize that the three appearances come from the same object. A general view of this object is presented in Figure 7.

Note that a 3D object and its mirror image in general have mutually opposite orientations. However, we are familiar with the mirror-symmetric pair of appearances. So, the use of the mirror itself does not affect much for us to judge whether or not the two appearances come from the same object. Therefore, the triple ambiguity is not because of the use of the mirrors.

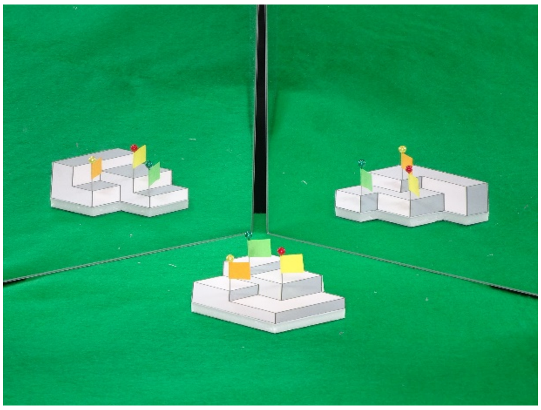


Figure 6. Triply ambiguous object.

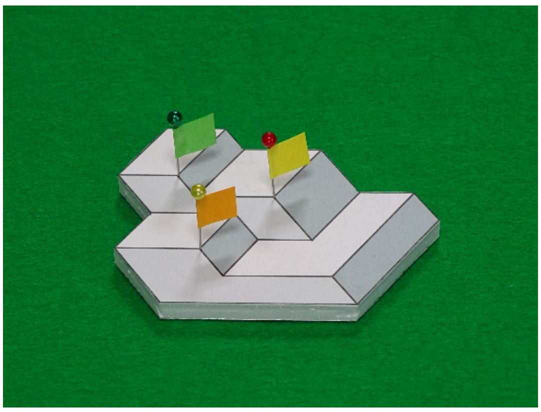


Figure 7. General view of the object in Figure 6.

Figure 8 shows another sample. Panel (a) shows an object together with two mirror images, and panel (b) shows a slanted view of this picture with 3D decorations. This object is also an orthographically projected picture of a rectangular polyhedron, and it is decorated by three flags and a thick supporting plate.

Still another example is shown in Figure 9, where the original polyhedron is not exactly rectangular; it contains a few of faces with other orientations. Panel (a) is an object and its two mirror images, and panel (b) is a general view of the picture with 3D decoration. We can see that the triply ambiguous object can be created even if the original polyhedron is deviated from an exactly rectangular polyhedron.

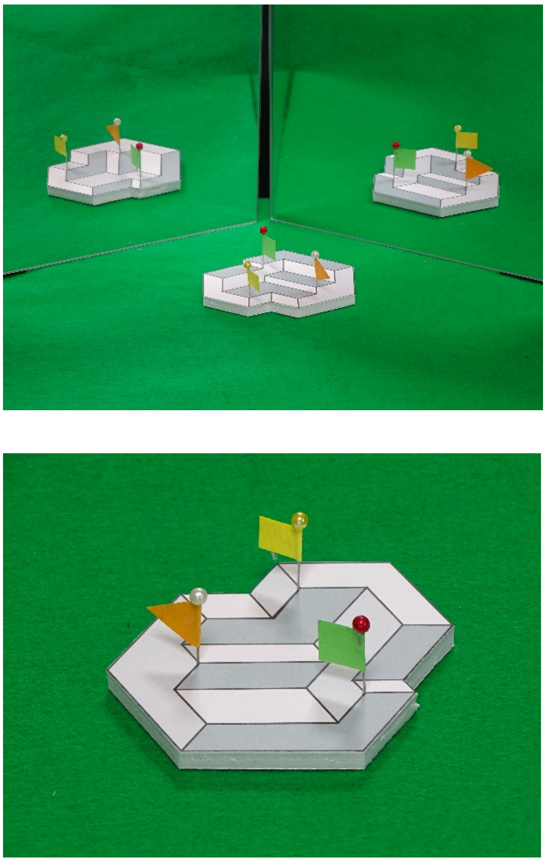


Figure 8. Another example.

It should be noted that the example pictures presented above do not contain an occlusion, where part of a surface is hidden behind another surface. This is also important to make the triply ambiguous object natural, because the occlusion gives a strong cue for the viewer to recognize the correspondence between the original picture and its rotated version. An example of a rectangular polyhedron with occlusion is shown in Figure 10(a). This polyhedron consists of three blocks, two on the other, and the top surface of the lower block is partly hidden by the upper blocks, and thus occlusion occurs.

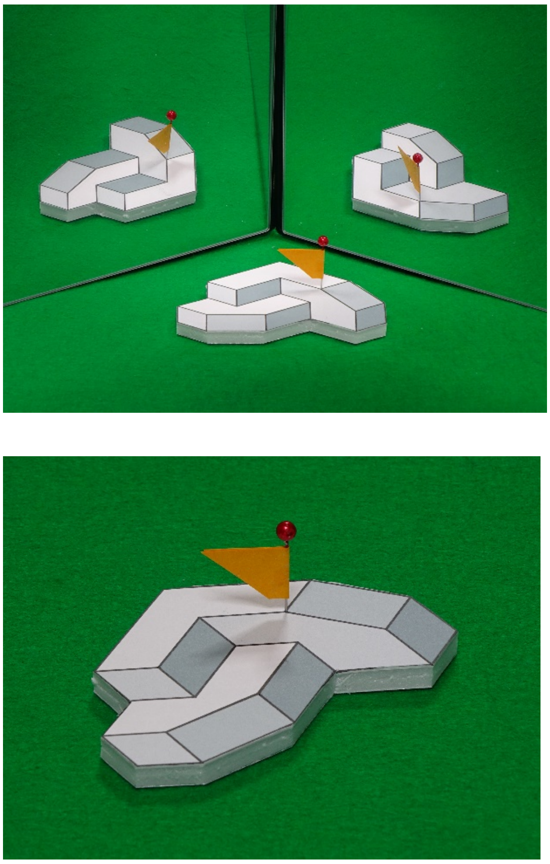


Figure 9. Triply ambiguous object created from a picture of a non-rectangular polyhedron.

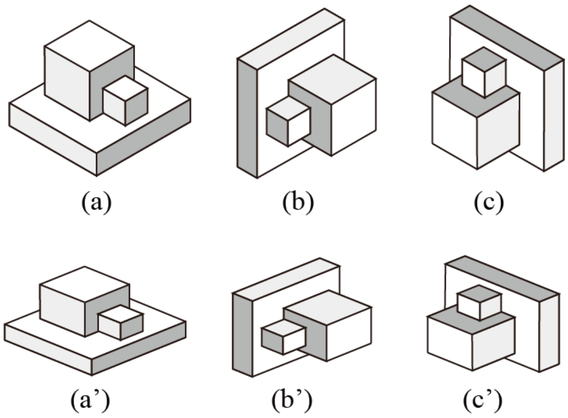


Figure 10. Picture with occlusion, and its rotated versions.

The rotated versions of this picture are shown in panels (b) and (c), and vertically compressed versions of (a), (b), and (c) are shown in (a'), (b') and (c'). We may see that it is easier to recognize that they are rotated version of the picture in Figure 10(a). This might be because in the rotated picture, the occlusion implies the horizontal protruding structure from a vertical wall, and thus it conveys the information about the original direction of the gravity. Therefore, occlusion should be avoided for the picture to create triply ambiguous object.

4. DISCUSSIONS

The triply ambiguous objects proposed in this paper are based on a fact that pictures of rectangular polyhedrons have three groups of parallel lines. When we see a picture in such a way that lines belonging to one group are retinally vertical, we perceive a rectangular polyhedron whose vertical lines represent the direction of gravity. We place the picture itself on a horizontal plane, add 3D items such as vertical poles, and see it in slanted directions. Placing two vertical mirrors in the way parallel to the remaining two groups of lines, respectively, we can see the three views at the same time. The three perceived polyhedrons appear to be quite different, and it is hard to recognize that they come from the same picture. This is the basic idea of the proposed triply ambiguous objects.

The tricks are simple, but still we usually perceive three different 3D shapes from a single object, as shown by examples in Figures 6, 8 and 9. This might be because of the following reasons.

First, we see the picture in slanted directions and consequently the picture is compressed in different directions in our retinae, so that, if we regard the three views as orthographic projections, they correspond to mathematically different 3D objects.

Second, these figures are photographs printed on the paper instead of real objects. When we see the object directly, we usually perceive the true shape, i.e., a horizontal picture with vertical poles, due to binocular stereo. A photograph, on the other hand, is taken by a camera, which has a single lens center instead of two eyes, and consequently does not contain depth information explicitly.

Third, our brains prefer rectangles to other angles when interpreting pictures [9, 10]. So, a picture of a rectangular polyhedron easily evokes the impression of 3D structure instead of the impression of a picture.

Fourth, the object is not a pure 2D picture; it includes 3D additional objects. They strengthen the impression of the 3D structure.

Fifth, we see the object in a 3D environment, that is, we put it on a horizontal plane, place vertical mirrors behind it, and see it and the mirror images in a slant direction. This gives us the sense of gravity direction. This environment is different from the environment that we see only a picture facing toward us.

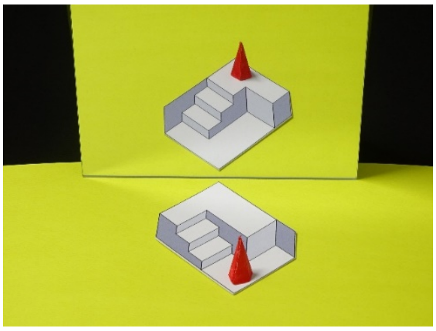
All of these factors together create the impression of the 3D structure and hence create the visual effect of the triple ambiguity.

One remarkable point of this observation is that we perceive three different objects even after we know the true shape of the object. In logical part of our brains, we understand that the object is a horizontally placed picture with additional 3D decorations, but in intuitive part of the brains, we perceive three different objects automatically, ignoring the knowledge about the true shape of the object. This fact implies that the interpretation of the retinal image as a 3D shape of the object is something automatic rather than logical reasoning.

5. TOWARDS SIX-INTERPRETATION AMBIGUITY

A horizontally oriented 2D picture can be a source of another ambiguity. If a picture is the projection of a 3D structure seen in a certain slanted direction, the same picture coincides with the projection of the height-reversed structure seen in the direction from the opposite side with the same pitch angle. This is called the "height reversal property" [15]. Therefore, if we place a vertical mirror facing toward the viewer, we perceive a height reversed pair of 3D structure. An example is shown in Figure 11, where the horizontal picture is placed together with a vertical mirror behind it. We perceive the height reversed 3D structure in the mirror.

Note that the picture is a little different from these in Figures 6 and 8, in the sense that the represented 3D structure includes thin plates; the right vertical wall and the bottom horizontal plate in the direct view, and the left vertical wall and the bottom horizontal plate in the mirror image. They are necessary to give a natural impression of a different 3D object in the mirror. In other words, the pictures in Figures 6 and 8 have non-convex outermost boundaries, while the picture in Figure 11 has a convex outermost boundary. If the outermost boundary of a picture is not convex, the height reversed version in the mirror contains vacant space below the floor or behind walls, which might weaken the optical illusion.



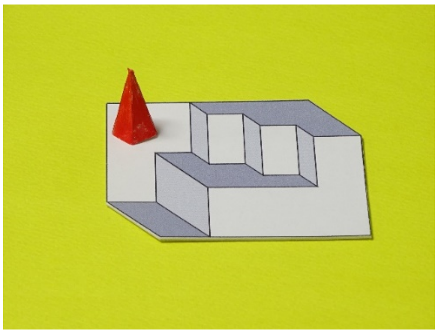


Figure 11. Height reversal object "Staircase".

Combining this height reversal ambiguity with the triple ambiguity proposed in this paper, we get six different interpretations from a single object. All of these interpretations can be perceived at the same time if we use five mirrors in the following way.

For simplicity, let us assume that the three groups of parallel lines form 120-degree angles, i.e., the angles α and β in Figure 2 are 60 degrees. (Note that the apparent angles are different from 120 degrees because we see the picture in a slanted direction.)

Assume that we place the picture on a horizontal plane, and view it in the direction $\boldsymbol{v}_0$ as shown in Figure 12, which represents the situation seen from above. Note that $\boldsymbol{v}_0$ is not horizontal but is directed downward though this fact cannot be represented in Figure 12. Then, the other five view directions are as shown by the directions $\boldsymbol{v}_1$, $\boldsymbol{v}_2$, …, $\boldsymbol{v}_5$ all facing downward by the same pitch angle as $\boldsymbol{v}_0$. The directions $\boldsymbol{v}_2$ and $\boldsymbol{v}_4$ correspond to the other two directions for the triple ambiguity, $\boldsymbol{v}_3$ corresponds to the height reversal direction, and $\boldsymbol{v}_1$ and $\boldsymbol{v}_5$ correspond to the height reversal directions with respect to $\boldsymbol{v}_2$ and $\boldsymbol{v}_4$, respectively. If we place five vertical mirrors M_1, …, M_5 as shown in Figure 12, the groups of parallel lines associated with the view directions $\boldsymbol{v}_1$, …, $\boldsymbol{v}_5$ become retinally vertical in the mirror images with respect to the view direction $\boldsymbol{v}_0$. By this way, we can see all the six different views of the object, and thus enjoy the six interpretations.

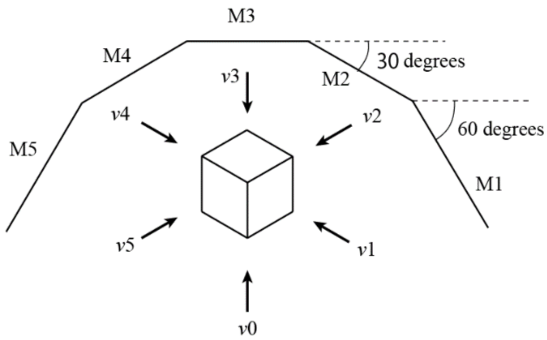
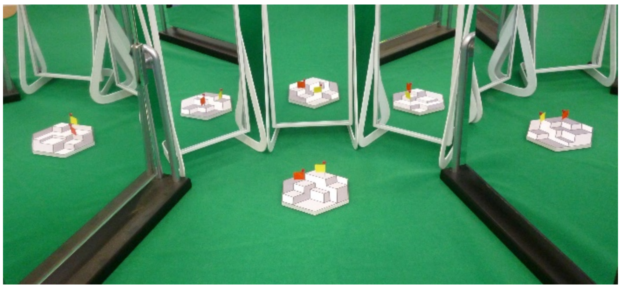


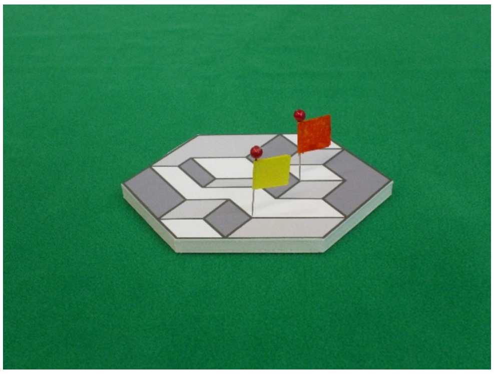
Figure 12. Arrangement of mirrors for perceiving six interpretations simultaneously.

Note that the mirror angles represented in Figure 12 are applied when we see the object and the mirror images from the viewpoint at infinity. In actual situation, we place our viewpoint in a finite distance, and hence the mirror angles should be adjusted according to the distance.

Figure 13 shows an example of the six-interpretation ambiguous object. Panel (a) shows the object and its five mirror images, and panel (b) shows a general view of the object. The object consists of a horizontally oriented picture of a rectangular solid, vertically standing two flags, and a thick supporting plate on the back of the picture. We can see that the direct view and the five mirror images create mutually different appearances and thus a six-interpretation ambiguous object is realized. Note that the outermost boundary of the picture of the object is convex.



(a)



(b)

Figure 13. Object having six interpretations: (a) object and its five mirror images; (b) object seen from a general view direction.

In Figure 13, the six appearances of the object are represented by five mirrors, as shown in the left of Figure 14. We can represent those six appearances using only two mirrors, as shown in the right. The idea is to use, in addition to the simple reflections, multiply reflected images. We place two vertical mirrors so that they form the angle of 60 degrees, and put the object inside this angle. Then, we have one direct view of the object, two simply reflected images, two twice reflected images, and one triply reflected image. The triply reflected image consists of the left and right images meeting at the center, and so we need to adjust two mirrors precisely at 60 degrees.

Figure 15 shows an example of the display of another object using two mirrors. Note that the twice reflected images (corresponding to c and e) are different from the corresponding images created by five mirrors, because even number of reflections gives an orientation opposite to that created by an odd number of reflections. However, the difference of the orientations does not affect much when we perceive the ambiguity of the shapes; no matter whether the orientations are opposite or not, we perceive quite different shapes.

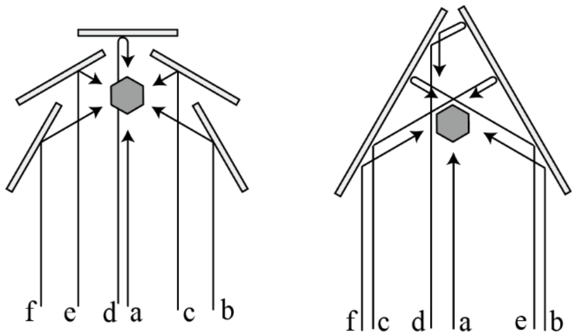


Figure 14. Display of the six appearances using five mirrors (left) and two mirrors (right).

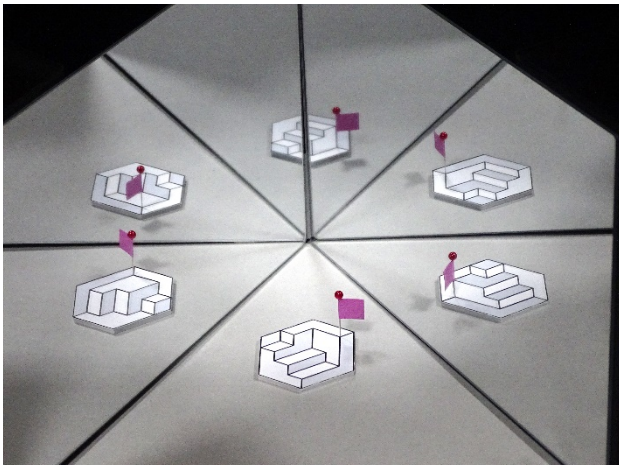


Figure 15. Six appearances represented by two mirrors.

6. CONCLUSIONS

We have proposed a systematic method for creating triply ambiguous objects. The method is based on the properties of pictures of rectangular polyhedrons, i.e., (1) they have three groups of parallel lines, (2) they evoke three different 3D structure corresponding to the three different directions of gravity represented by the three groups of parallel lines, (3) they represent 3D structures compressed in the vertical direction when they are seen obliquely, and (4) additional real 3D decollations can strengthen the impression of the gravity direction. These properties together with the human preference for rectangularity create the impression of three different 3D objects although it is a single 2D picture. We also discussed possibility of ambiguous objects with six interpretations.

Most of known ambiguity created by 2D pictures are two-interpretation ambiguity such as the depth reversal and the figure ground reversal. These kinds of ambiguity can be perceived when the pictures are seen in normal posture, i.e., they face right toward the view. Oblique view, on the other hand, is used when we see anamorphosed pictures. In both cases, we concern the relative relation between the pictures and the view directions, while we do not care about how the pictures are placed in the 3D space.

The triple ambiguity presented in this paper depends on how the pictures are placed in the 3D space and how we see them with respect to the direction of gravity.

In this sense this paper presents a new aspect of ambiguity caused by 2D pictures in 3D environment. To study its psychological implications is one of research topics in future.

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COMPUTER AIDED DESIGN AND DRAFTING

IMPROVEMENT OF THE CAMERA OF "DONBURI DE PLANETARIUM" WITH 3D-CAD

Kazuhiro YAMASHIMA[1], Yuki AKIZUKI[2] and Hidekazu TSUJIAI[2]

[1]Tsukuba Gakuin University,Japan [2]University of Toyama, Japan

ABSTRACT: Dr.Tsujiai invented the Donburi de Planetarium to project a picture in a bowl onto a planetarium. The camera of the Donburi de Planetarium has been improved. To improve it, Autodesk Fusion 360 was used to design the camera. Autodesk Fusion 360 was used in the product development process, from designing to development and production. In the designing process, photographic equipment was placed at the center. The use of 3D-CAD makes it important to create and process a model of product shape and other attribute data within a computer, as the world's product design methods are going through the digital process. The advantage of using the Autodesk Fusion 360 is that it may be repeated in a similar way to draw a 3D. Thus, even with the same kind of work, users can work with a high level of concentration, and users can make good pictures with the same quality. It is considered that there is a ability to take into consideration the efficiency of the work so that the work can be carried out accurately and speedily at all times. However, no small ambiguity can be drawn to the precise drawings that are consistent with the intent of the content. On the Internet web browser to hold meetings before entering the drawing, this function ensures that the content conveyed from the content of the order is properly understood. It is possible to proceed with the work of planned drawings. In order to do so, it is necessary to prioritize the work content and consider the allocation of work up to the date. Users have the ability to accurately understand what skills they possess and to carry out their work while managing planned content. An alternative to a bowl was also designed. The redesigned points are as follows: I. The form is redesigned to be semicircular, and a stand to support the half circle is designed; II. The new design allows the photographic equipment (THETA) to be placed at the center; III. And a hemisphere is made instead of a bowl. The results were output in STL file format to allow a 3D printer to manufacture the new design. Machines for photography shall be installed inside the equipment. Design the base that supports the half-circle shape.

Keywords: 3D-CAD, Planetarium, Autodesk Fusion 360, THETA.

1. INSTALLATION

Planetarium is a facility and facility for displaying light emitted from a projector on a curved screen located inside a dome-shaped ceiling. The motion of stars and stars can be reproduced. "Donburi de Planetarium" is a project in which children draw pictures on styrene foam roofs, take pictures using a fish-eye lens, and make full circle images and project them to planetarium.

The Donburi de Planetarium was developed by Tsujiai [1] to show the images in the acorn-shaped device to planetarium. The camera of the Donburi de Planetarium has been improved. To improve it, Autodesk Fusion 360 was used to design the camera. The base supporting the central camera portion of this system was designed and improved. It is reported.

The camera of the Donburi de Planetarium has been improved. To improve it, Autodesk Fusion 360 was used to design the camera. Autodesk Fusion 360 was used in the product development process, from designing to development and production.

The results were output in STL file format to allow a 3D printer to manufacture the new design.

2. “DONBURI DE PLANETARIUM "

Planetarium reproduces the image by displaying the light emitted from the projector on a curved screen located inside the dome-shaped ceiling. The "Donburi de Planetarium" is imaged by drawing pictures in the acorn of Happo Styrol, which is displayed on a screen of planetarium. Fig.1 is where Tsujiai is working, and FIG. 2 is showing the image taken in FIG. 1 with a planetarium.

Fig. 1: Tsujiai is working on “Donburi de Planetarium”(by Dr. Kondo)


Fig.2: Pictures drawn by children.

Conventionally, from the photographing of FIG.3, FIG. 4 is removed and reflected on the planetarium of FIG.5.


Fig. 3 Shooting place

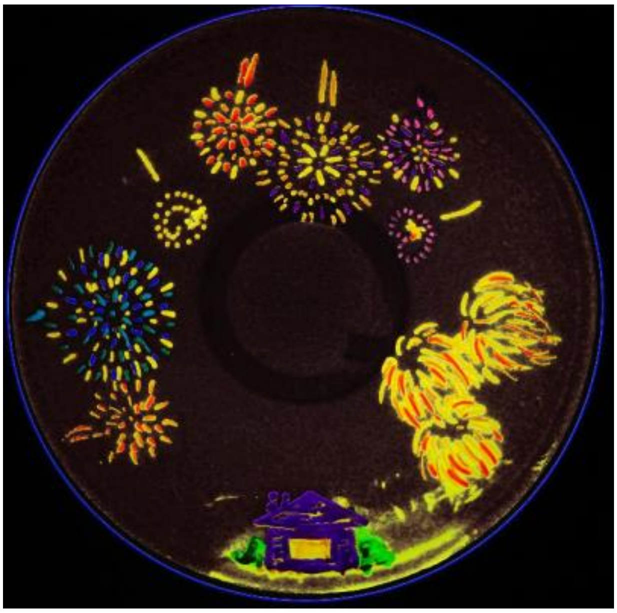
Fig 4: Picture

It was photographed with THETA V as shown in Fig. 5. Recently, multiple projectors are available for display. Projectors can also project to domes other than stars [1]. For this reason, the image of the PC can also be projected. Planetarium of the Toyama City Science Museum [2] has been holding a screening of the Zensho Content Content since FY2016 and holding concerts . However, it is difficult to create a full circumferential image projected on planetarium in the plane of a personal computer by imagining a curved surface.

"Donburi de Planetarium" was designed to easily create a full circumferential image by taking a picture of the inside of an acorn on a hemispheric canvas and projecting it on a planetarium dome using a fish-eye lens.

This approach has been reported in Fig. 4, including the results of workshops for children.

"Donburi de Planetarium" is a project in which children draw pictures on styrene foam roofs, take pictures using a fish-eye lens, and make full-circle images and project them to planetarium.

THETA is a camera designed to capture sky photography. 360 degrees of image can be generated from two fish-eye lenses.

However, “Donburi de Planetarium” uses a single fish-eye lens to take pictures of the inside of the sputum.

Taking advantage of this role, we aim to take pictures of a mold with an image of a swing and a half-circle top and a painting with a transparent film shape.

Fig 5: THETA V (RICOH)

Table 1:RICOH THETA

Exterior/ external dimensions	45.2 mm (W) x 130.6 mm (H) x 22.9 mm (D)
Weight	Approx. 121 g
Object distance	Approx. 10cm - ∞ (from front of lens)

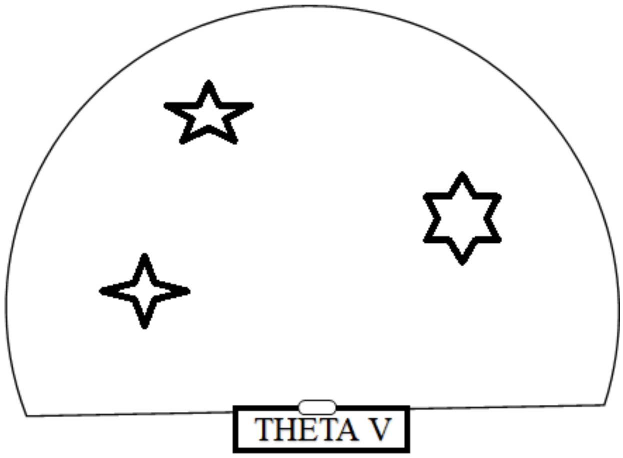

Fig 6: "Donburi de Planetarium"

3. PLAN

We are working on the following plans to complete this project.

In 2021, Changing the shooting part of the fish-eye lens of Donburi de Planetarium to a 360-degree camera causes instability in the camera part. To prevent this, a 360-degree camera table is constructed as a prototype 3D model. The 3D model is constructed on a prototype 3D printer and the convenience of the workshop is investigated.

In 2022, Numerical simulation is performed on a 360-degree camera table manufactured on the basis of the optical characteristics of Donburi de Planetarium. The load on the 3D model created on the PC is analyzed. The model that has cleared the data analysis is then re-constructed with a 3D printer as a table for a 360-degree camera.

In 2023, Investigate the optical properties of Donburi de Planetarium and the convenience of the workshop, reconsider the platform for the 360-degree camera, and re-manufacture it with a 3D printer.

4. DESIGN

4.1 3D-CAD

The camera of the Donburi de Planetarium has been improved.

To improve it, Autodesk Fusion 360 was used to design the camera. Autodesk Fusion 360 was used in the product development process, from designing to development and production. In the designing process, photographic equipment was placed at the center. The use of 3D-CAD makes it important to create and process a model of product shape and other attribute data within a computer, as the world's product design methods are going through the digital process.

The advantage of using the Autodesk Fusion 360 is that it may be repeated in a similar way to draw a 3D. Thus, even with the same kind of work, users can work with a high level of concentration, and users can make good pictures with the same quality. It is considered that there is a ability to take into consideration the efficiency of the work so that the work can be carried out accurately and speedily at all times. However, no small ambiguity can be drawn to the precise drawings that are consistent with the intent of the content. On the Internet web browser to hold meetings before entering the drawing, this function ensures that the content conveyed from the content of the order is properly understood. It is possible to proceed with the work of planned drawings. In order to do so, it is necessary to prioritize the work content and consider the allocation of work up to the date. Users have the ability to accurately understand what skills they possess and to carry out their work while managing planned content. An alternative to a bowl was also designed.

The References section contains a numbered list at the end of the article, ordered alphabetically by first author, and referenced by numbers in brackets.

4.2 Improvement of the base part

The foundation portion was designed with the image shown in FIG. 6. Machines for photography shall be installed inside the equipment. Design the base that supports the half-circle shape. The camera can be installed at Fig 6.

We tried to create a hollow inside using THETA product data so that the fish eye lens was centered.

First, Fusion 360 has a large number of product data, but THETA was not linked as a product to Fusion 360 and could not be used.

However, the image data was imported into fusion 360 and the image was then used for 3D modeling.

From Insert, select the campus to include pictures of THETA.

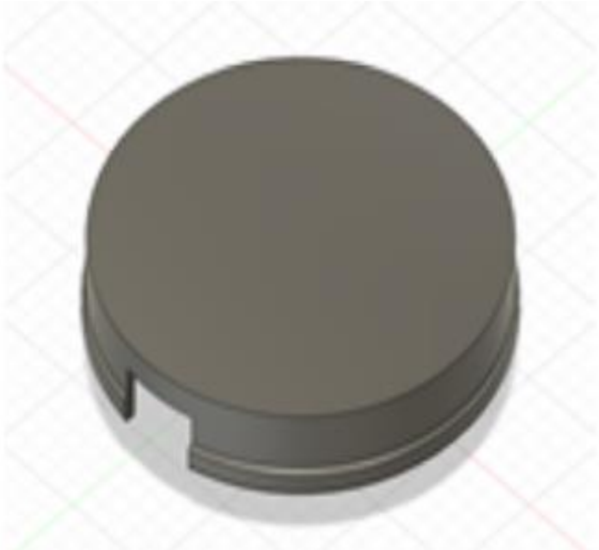

Fig.6: Design the base

4.3 Hemisphere improvement

The portion of the hemisphere has improved the central portion of the acorn shown in Fig 7. Fig 8 shows.

Stop writing on the inside of the crowd, and apply seals so that it can be used many times. The finished shape is shown in Fig 8 and Fig 9.

This section summarizes the improved parts of the Donburi de Planetarium.

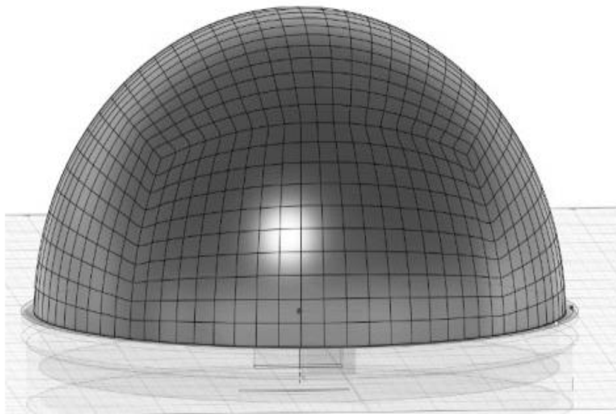

Fig.7: Finished shape

Fig.8 Completed shape(inside)

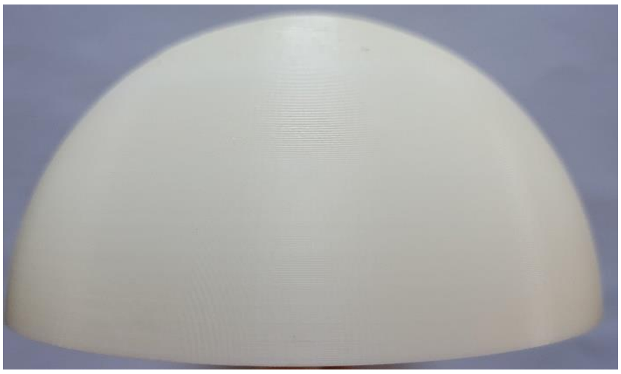

Fig.9 Completed shape(outside)

4.4 Drawing drawn by 3D-CAD

Finally, we got the drawing out of Autodesk Fusion 360 (Fig10).

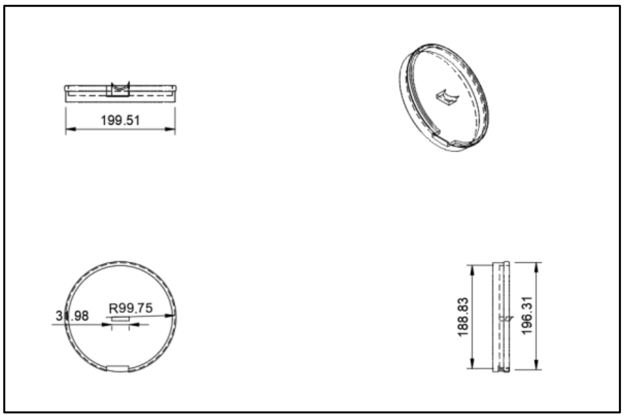

Fig.10: Drawing drawn by 3D-CAD

4.5 Drawing drawn by 3D-CAD

Drawings were created using fusion 360. Based on the design data of the 3D-CAD, the 3D printer constructs a three-dimensional model by stacking one sliced two-dimensional layer at a time. In this case, a thin layer of resin dissolved by heat was piled up.

5. POINTS TO REALIZE -PROJECTION DOME

Research on planetarium must also be advanced a little.

The shape of the projection dome can be broadly divided into horizontal and tilt forms. The horizontal equation is like a bowl-shaped dome that actually looks up in the sky, and is closer and more intuitive to the fact that it actually looks at the starry sky in the field. On the other hand, the inclination method is such that the dome is inclined by about 5-30 degrees and the seat is arranged in a stepwise fashion with the seat facing in one direction.

This design was done for the horizontal method.

6. CONSIDERATION

Dr.Tsujiai invented the Donburi de Planetarium to project a picture in a bowl onto a planetarium.

The form is redesigned to be semicircular, and a stand to support the half circle is designed. The new design allows the photographic equipment (THETA) to be placed at the center. And a hemisphere is made instead of a bowl.

Autodesk Fusion 360 was used in the product development process, from designing to development and production.

The use of 3D-CAD makes it important to create and process a model of product shape and other attribute data within a computer, as the world's product design methods are going through the digital process. The advantage of using the Autodesk Fusion 360 is that it may be repeated in a similar way to draw a 3D. Thus, even with the same kind of work, users can work with a high level of concentration, and users can make good pictures with the same quality. It is considered that there is a ability to take into consideration the efficiency of the work so that the work can be carried out accurately and speedily at all times. However, no small ambiguity can be drawn to the precise drawings that are consistent with the intent of the content. On the Internet web browser to hold meetings before entering the drawing, this function ensures that the content con-veyed from the content of the order is properly understood. It is possible to proceed with the work of planned drawings. In order to do so, it is necessary to prioritize the work content and consider the allocation of work up to the date. Users have the ability to accurately understand what skills they possess and to carry out their work while managing planned content.

In this study, we tried to create a hollow inside using the product data of THETA so that the fish eye lens could be centered.

First, Fusion 360 has a large number of product data, but THETA was not linked as a product to Fusion 360 and could not be used.

However, the image data was imported into fusion 360 and the image was then used for 3D modeling. From Insert, select the campus to include pictures of THETA.

7. CONCLUSION

The functionality of the Projection dome requires the design to be redesigned. Autodesk Funsion worked well in designing the projection space. The results were output in STL file format to allow a 3D printer to manufacture the new design. Machines for pho-tography shall be installed inside the equipment. Design the base that supports the half-circle shape.

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CREATING 3D MODELS FROM THE SEM IMAGES OF FINE PROTRUSIONS FORMED BY SPUTTER-ETCHING OF STAINLESS STEEL

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[1] Meisei University, Japan [2] Hiroshima Kokusai Gakuin University, Japan

ABSTRACT: Argon ion sputter-etching of stainless steels forms cone-, column-, and grain-shaped protrusions with bottom sizes ranging from 200nm to 50μm. The gripping ability, or coefficient of static friction, between the fine protrusions and soft and slippery sheet can be measured by experiment. However, to conduct a large number of experiments is time- and cost-consuming, whereas fundamental principles to predict the optimum gripping combinations between these protrusions and soft bodies have not been established. Thus, the implement of analysis and simulation of gripping behaviors of the fine protrusion are necessary. This paper presents an approach for creating 3D models of fine protrusions from their scanning electron microscope (SEM) images, which is an essential part of the analysis and simulation. A large-scale 3D models of protrusion can be created effectively. The models will be used in finite element method (FEM) and moving particle semi-implicit method (MPS) to calculate the deformation of soft bodies and the gripping forces without slipping. The results of this research will be applied to the development of a software to find the optimum protrusion shapes and sizes depending on the properties and shapes of soft and slippery bodies.

Keywords: Sputter-etching, fine protrusion, SEM image, coordinate recognition, 3D model.

1. INTRODUCTION

Fine protrusions of various shapes, sizes and distributions can be formed on the surface of metals and alloys by sputter-etching using argon or xenon plasma [1-3]. According to our research, cone-shaped protrusions in micrometer size formed on stainless steels have excellent mechanical properties [4-7]. The experimental results revealed that fine protrusions provide high gripping ability for holding soft and slippery bodies, and the gripping ability depends not only on shapes, sizes and distribution of fine protrusions, but also on the properties of the soft materials. Because it is very difficult to find the optimum protrusion shapes to grip soft bodies only by experimental methods, a simulation and development of a software are necessary according to the processes shown in Figure 1, which illustrates outline of our project including fabrication of protrusions, gripping tests, recognition of 3D coordinates of protrusion vertexes, creation of the 3D models, calculation of stresses and strains, and development of a software to select the optimum protrusion shapes.

In order to calculate the stresses and strains through FEM or MPS [8, 9], 3D models of fine protrusions are needed. However, it is time consuming to create a lot of different fine protrusions with 3D- CG or CAD software. In the present research, we propose an approach for creating 3D models of fine protrusions from their scanning electron microscope (SEM) images, which is an essential part of the project. The approach consists of the following steps. (1) Fabricate fine protrusions on surface of a specimen of stainless steel by sputter-etching using argon plasma, and take images of the fine protrusions in different directions with a SEM. (2) Forward the images into a CG software to calculate 3D coordinates of fine protrusion vertexes. (3) Forward the 3D coordinates into an original softwa-

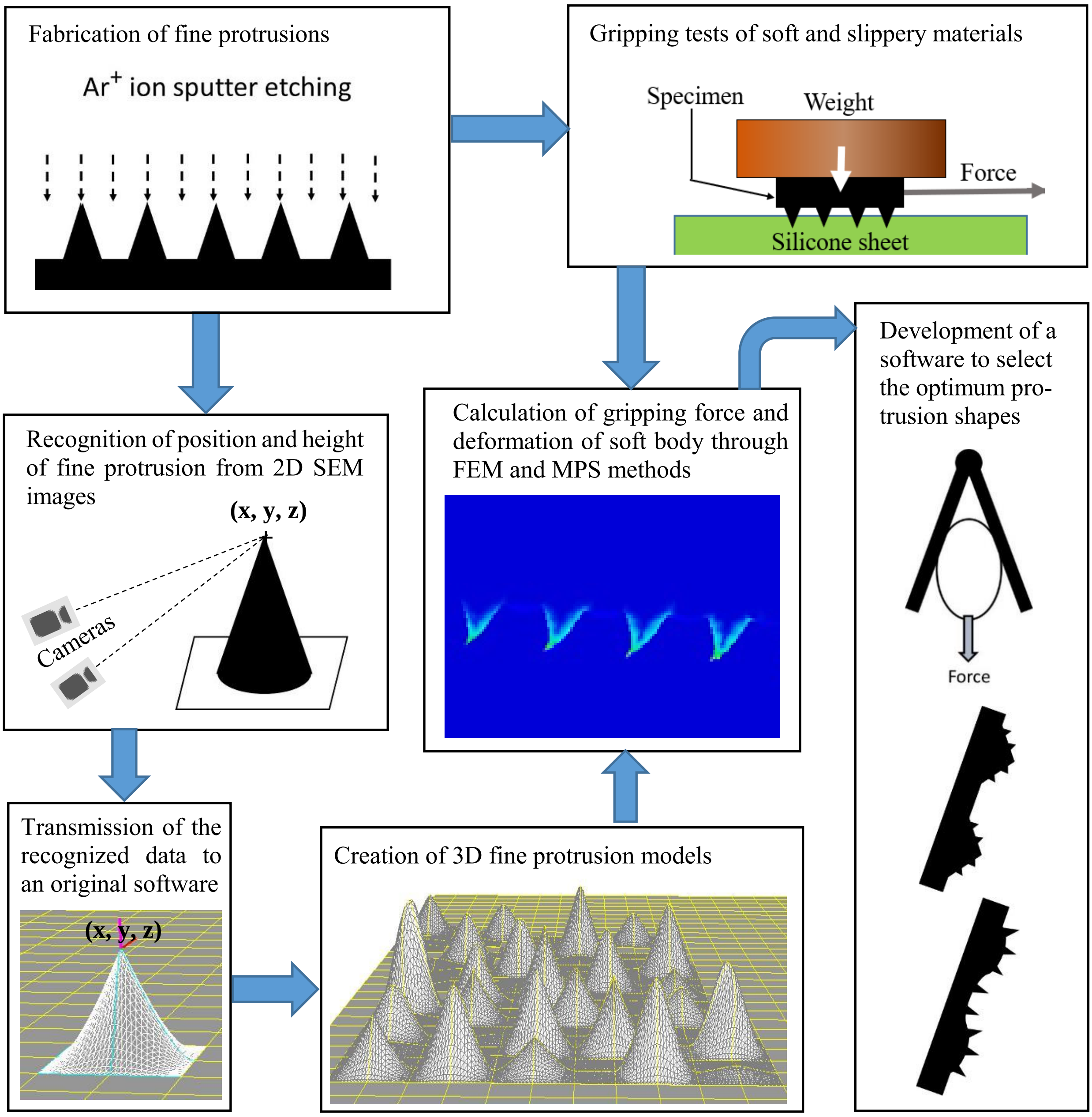


Figure 1: Flow of present research to develop a software to select the optimum protrusion shapes for gripping soft bodies.

re developed by the authors to create 3D models of the fine protrusions.

2. PREPARATION OF A PROTRUSION SPECIMEN AND SEM IMAGES

Only one experiment that was carried on AISI type 420 (JIS: SUS420J2) martensitic stainless steel was introduced here. The chemical composition (mass %) of the steel is C: 0.35, Si: 0.50, Mn: 0.41, P: 0.027, S: 0.02, Ni: 0.34, Cr: 12.21, Fe: Bal. An as-received steel square (20mm×20 mm) bar was cut to a specimens of 5 mm thickness, and the specimen surface was polished with emery papers up to #1600 and ultrasonically cleaned in ethyl-alcohol. The specimens were placed on a type 304 stainless steel disk with 100 mm diameter and 3 mm thickness set on the copper cathode electrode of a radio-frequency magnetron sputtering apparatus (Sanvac Co.: SP300 (M)). After vacuum pressure fell below 6×10^{-3}Pa, argon gas (purity: 99.999%) was introduced and maintained at a pressure of 0.67Pa. The sputter-etching of the specimens was carried out at a sputter power of 250 W for 7.2ks.

The specimen was fixed on a 45° angle block which was set on the table of a SEM (S-4700, Hitachi Co.) as shown in Figure 2. Fine protrusions on the specimen surface can be photographed at different rotation angles of the table. Figure 3 shows an example of SEM images of cone-shaped protrusions. The vertex angle of sharp cone-shaped protrusions is about 40°, and the maximum base diameter is about 10μm.

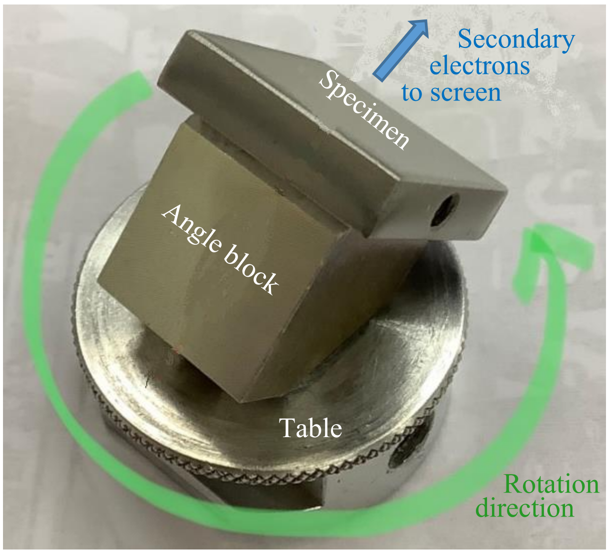


Figure 2: Installation of the specimen in SEM.

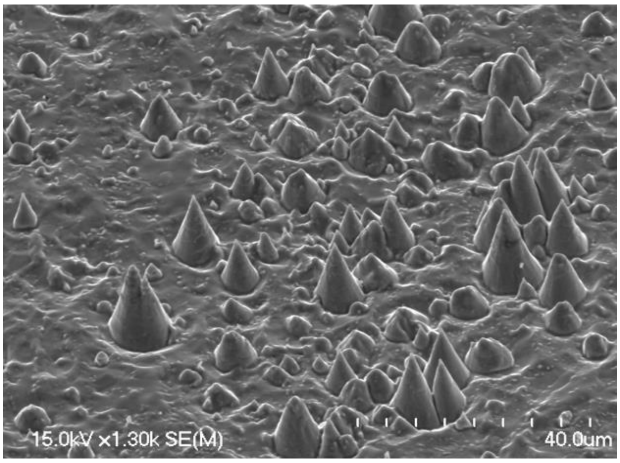


Figure 3: A SEM image of protrusions (tilting angle: 45°, acceleration voltage:15.0kV).

3. CALCULATION OF 3D COORDINATES OF FEATURE POINTS FROM IMAGES

A fundamental issue here is how human beings and animals view various shapes and size of objects and establish their 3D images. The key is the stereo viewing function of their eyes. A similar function can be achieved with two cameras taking more than two 2D images of an object. Figure 4 shows the principle of constructing a 3D object from its 2D images. The distance between two cameras e_1 and e_2 is d, the origin of coordinate system (x, y, z) is located at the middle point of line segment e_1e_2, point s is on the line e_1e_2, and line ps is perpendicular to the line e_1e_2. The coordinates of arbitrary 3D point $p(x_p, y_p, z_p)$ can be calculated from angles of observation α_1, α_2 and θ according to the following equations.

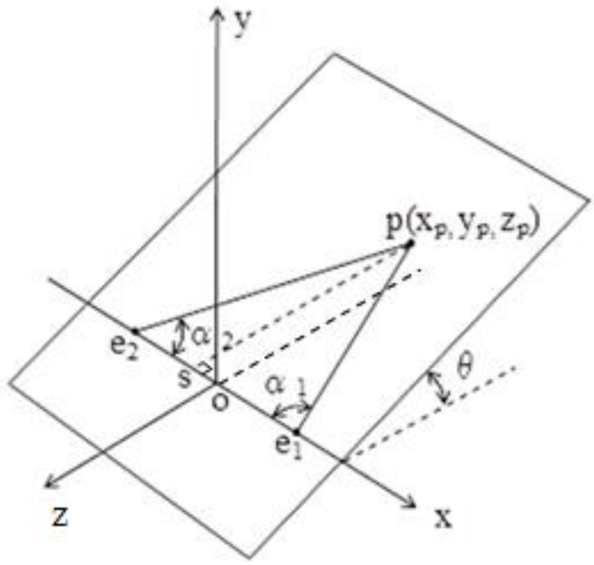


Figure 4: Principle of constructing a 3D object from 2D images.

Since

$$d = \overline{e_1 e_2} = \overline{e_1 s} + \overline{s e_2} = \overline{ps} / \tan \alpha_1 + \overline{ps} / \tan \alpha_2 \tag{1}$$

so that

$$\overline{ps} = \frac{d \tan \alpha_1 \tan \alpha_2}{\tan \alpha_1 + \tan \alpha_2} \tag{2}$$

because

$$\overline{os} = \overline{e_1 s} - \overline{e_1 o} = \overline{e_1 s} - d/2 \tag{3}$$

$$\overline{os} = \overline{oe_2} - \overline{se_2} = d/2 - \overline{se_2} \quad (4)$$

From Equations (3) and (4), we have

$$\overline{os} = (\overline{e_1 s} - \overline{se_2})/2 \quad (5)$$

Then the coordinates x_p, y_p, z_p are obtained as follows:

$$\begin{aligned} x_p &= -\overline{os} \\ &= -(\overline{e_1 s} - \overline{se_2})/2 \\ &= -(\overline{ps}/\tan\alpha_1 - \overline{ps}/\tan\alpha_2)/2 \\ &= \frac{d(\tan\alpha_1 - \tan\alpha_2)}{2(\tan\alpha_1 + \tan\alpha_2)} \end{aligned} \quad (6)$$

$$\begin{aligned} y_p &= \overline{ps}\sin\theta \\ &= \frac{d\tan\alpha_1\tan\alpha_2\sin\theta}{\tan\alpha_1 + \tan\alpha_2} \end{aligned} \quad (7)$$

$$\begin{aligned} z_p &= \overline{ps}\cos\theta \\ &= \frac{d\tan\alpha_1\tan\alpha_2\cos\theta}{\tan\alpha_1 + \tan\alpha_2} \end{aligned} \quad (8)$$

Note that the cameras are different from human eyes, and both the photo taking directions and focal distances vary. The locations of cameras should be determined from images of the object before calculation of coordinates of points on the object.

A CG software (3DM-Modeler, 3D MEDiA) based on the above principle was used in this research. In general, for constructing a 3D object, two or more images are needed, and interval of two photographing angles is between 5° and 15°. In the case of fine protrusions, the preliminary examination showed that two images were enough, and the best interval of two photographing angles was 5°. Two SEM images taken at 5°different rotation angles as shown in Figure 5 were input into the software. One was specified as a base image, another was linked to the base image to obtain the heights of the protrusions. Almost all correspondence points of the two images were extracted as shown in Figure 6. If a feature point (vertex of a fine protrusion) was not extracted (e.g. point P), it was added to the two images by mouse. Line segments for example AB can also be inserted to the two images for increasing the calculation precision. The calculated results were output in CSV format of Excel including coordinates of vertexes of the fine protrusions.

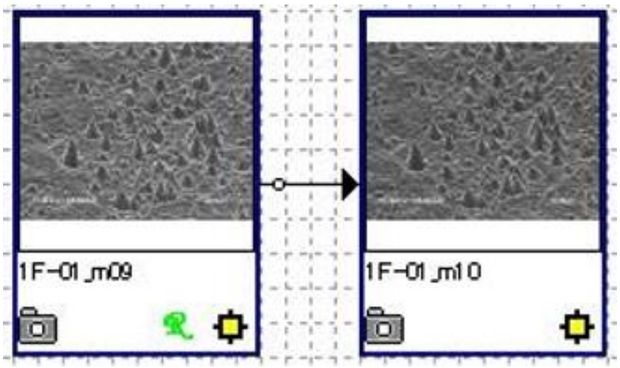


Figure 5: A couple of the images with 5° different rotation angle.

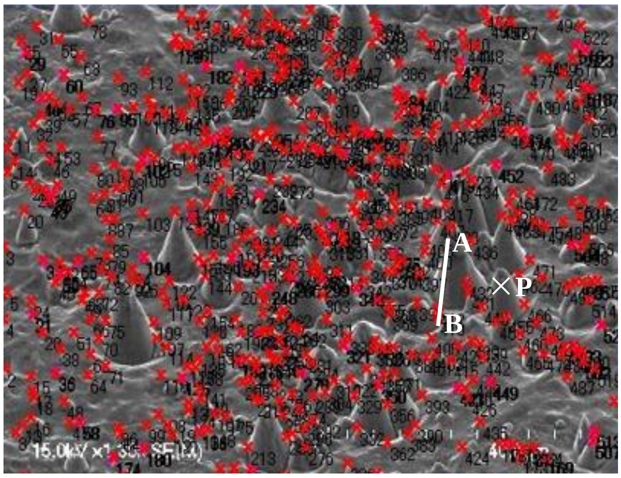
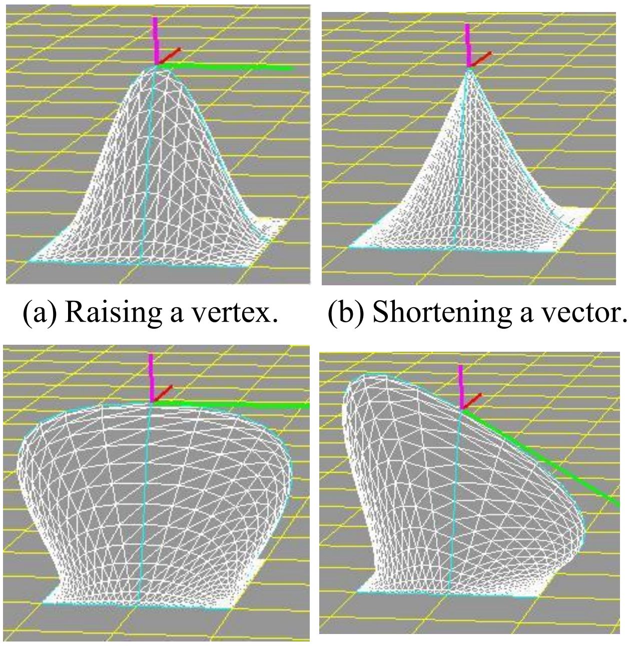


Figure 6: Output of the 3D feature points.

4. CREATION OF 3D MODELS OF THE FINE PROTRUSIONS

The authors have developed a software for modeling fine protrusions [10], in a form of bicubic surface patch derived from horizontal squares, which are mathematically described by the Hermite equation [11]. As shown in Figure 7, each vertex can be raised to a height to create four patches around it to create a protrusion, and tangent vectors can be shortened/extended/rotated to change the shapes of the protrusion. A cone-shaped protrusion can be created by shortening the tangent vector as shown in Figure 7(b).



(a) Raising a vertex. (b) Shortening a vector.

(c) Extending a vector. (d) Rotating a vector.

Figure 7: Variations of patches through changing the tangent vector length and direction.

In this research, in order to create 3D models of the fine protrusions automatically, the following programs were added to the software: (1) Extract coordinates of 3D feature points from the Excel CSV file. (2) Adjust the direction and scale of fine protrusions. Figure 8 shows an example of the created 3D model of protrusions. Almost of all the large cone-shaped protrusions were created. Although small protrusions were not represented well, they are not functioning and can be disregarded. The maximum number of modeled fine protrusions is about 10^6, which is enough for the FEM or MPS analysis and simulation. To create a protrusion is very fast by using the proposed method. The 3D models of fine protrusions will be useful to develop a gripping software to find the optimum protrusion shapes and sizes depending on the properties and shapes of soft and slippery bodies.

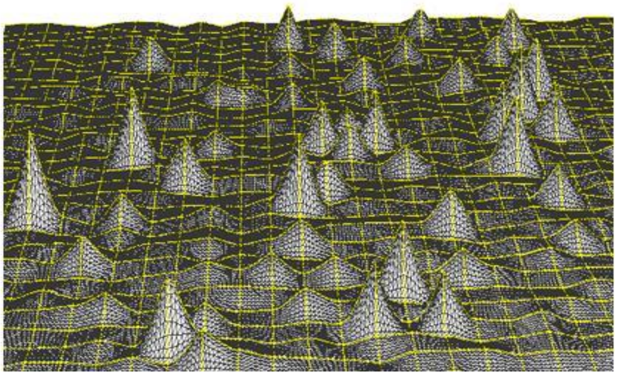


Figure 8: The created 3D model of protrusions.

5. CONCLUSIONS

3D coordinates of vertexes of fine protrusions can be recognized from their SEM images by using CG software 3DM-Modeler. Two images are enough, and the best interval of two photographing angles is 5°. Inserting line segments to the 2D images can increase the recognition precision. 3D models of fine protrusions can be created effectively by the modeling software developed by the authors. The 3D models will be used in FEM or MPS analysis to calculate stresses and strains at different gripping forces. The results will be applied to the development of a gripping software.

ACKNOWLEDGMENTS

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MICRO-/NANO-TEXTURE SURFACE DECORATION OF METALS VIA LASER PRINTING AND PRECISE IMPRINTING

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ABSTRACT: The optical performance of metals and alloys was limited to their metallic shining and brilliance of their polished surfaces. These original surface conditions were easy to be damaged and aged during their long-term usage of products. The surface and interface decoration was an engineering tool to control and sustain their surface conditions and properties without essential change of these metals and alloys. Two-step surface decoration method was proposed to imprint the micro-/nano-textures onto the metallic products. This consists of the femtosecond laser printing process for micro-/nanotextures onto the mother dies and the computer-numerical-controlled imprinting process for duplication of textures onto the metallic product surfaces. This paper was concerning with the geometric data transformation from CAD data of micro-/nano-textures to their imprinted metallic products. In the first process, seven micro-patterns with designed geometric textures were cut into the thick DLC (Diamond-Like Carbon) coating as a mother die by using the femtosecond laser machining. Each micropattern consisted of the assembly of line segments and laser-induced nanogrooves. In the second process, CNC (Computer Numerical Control) stamping system was utilized to imprint the micro-/nano-textures on the DLC-die to the metallic sheets. AA1060 aluminum plate was employed as a specimen for imprinting to describe the two-step surface decoration methods. SEM (Scanning Electron Microscopy) with varying the resolution was utilized to compare the micro-/nano-textures on the mother die with their replicas imprinted onto the aluminum sheet.

Keywords: Geometric data-transformation, Surface decoration, Micro-/nano-texturing, Femtosecond laser printing, DLC-coating dies, Precise imprinting, Aluminum alloy plate

1. INTRODUCTION

The smooth and metallic-shining surfaces have been preferred to an artificial product even without significant surface profile modification and decoration [1]. On the other hand, a natural life has huge diversity even on the surface profile and condition in geometry [2]. The shark skin has a tremendous alignment of tiny convex dimples to reduce the surface friction [3]. The gecko's foot surface has a wonderful microtexture to increase the adhesive force to any material surfaces [4]. This relationship between the modified surface geometry and the surface function stimulated the biomimetic design to change the flat or smooth surfaces to the tailored ones for functionalization of device, part and tool surfaces [5].

This biomimetic design encounters the difficulty when the targeting plants, insects or animals are absent in the world. In addition, the surface function of artificially designed products is always inferior to the original one of natural lives. Instead of the traditional biomimetic approaches, a new methodology is necessary to build up and control the micro-/nano-textures in topology and geometry as tailored in CAD (Computer Aided Design) and to investigate the role of surface geometry on the surface property, the surface condition, and other physical and chemical performance on the surface and interface.

The ultrashort-pulse laser processing has grown up as an effective tool to build up the tailored microtextures on the artificial product surfaces [6]. As had been reported in [6-8], the picosecond laser machining was effective to form the alignment of micro-textured dimples onto the cylinder liners and the inlet of dies to improve the fuel efficiency and to reduce the friction coefficient, respectively. As had been studied in [9-12], the hydrophilic surface of metals is easily modified to be super-hydrophobic by micro-/nano texturing the surfaces via the femtosecond laser processing.

The color grating by microtexturing and the surface-plasmonic brilliance by nanotexturing are an attractive optical decoration on the surfaces and interfaces of artificial products for their applications to arts, informatics and medicals. Typical applications to surface decorated metals are illustrated in Figure 1 [13-15].

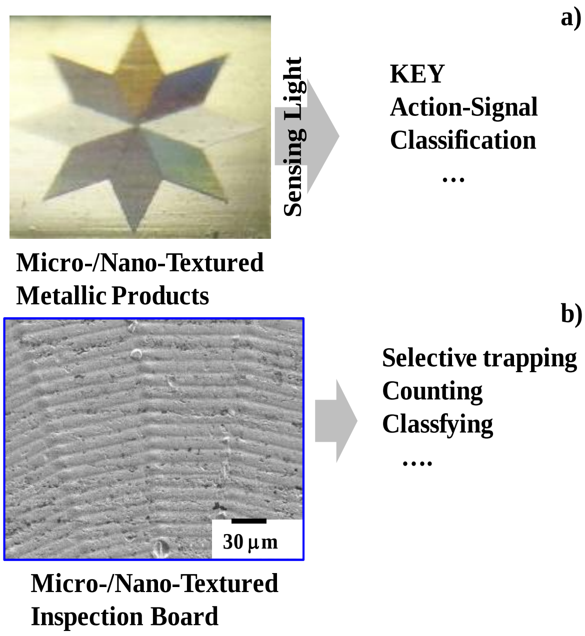

Figure 1: Two types of the micro-/nano-textured surface design on the artificial products. a) Metallic surface with specified jewelry brilliance as an optical key, and b) soft metallic surface to detect each living cell by difference of colors for biomedical handling of cells.

The tailored color-texture by topological design is selectively imprinted onto the metallic part and device surfaces as an emblem of products, an accent to products and a key for coding, as depicted in Figure 1a. Each micro-textured segment has its own nanotextured alignment; the tailored geometric angulation is represented by an assembly of segments. A typical nano-textured segment of metallic plates is depicted in Figure 1b.

Nanotextures are imprinted onto the terrace between two microgrooves. By using this micro-/nano-textured surface, a multi-scaled assembly of living cells is classified by trapping each sized cell group at different positions on this plate. In particular, whether the targeting cell is trapped into the designed nano-groove, can be detected by the color change. In order to put this micro-/nano-manufacturing into practice, two key-processes are necessary; one is a laser printing to cut the tailored micro-/nano-textures into a mother die, and another is a CNC (Computer Numerical Control) imprinting of mother die and mold to the metal and alloy product surfaces.

In the present study, these two fundamental processes are first explained by using a thick DLC (Diamond-Like Carbon) coating as a die material. The femtosecond laser machining system is employed to cut the micro-/nano-textures into this DLC film. This die is fixed into the cassette die-set to imprint the mother texture onto the pure aluminum plate. The original textures on the mother die and the imprinted replicas are compared by SEM (Scanning Electron Microscopy) and three dimensional profilometer. A geometric data-transformation from CAD to metallic products is supported by this two-step printing procedure.

2. EXPERIMENTAL PROCEDURE

A micro-/nano-texture is first designed to shape each microtexture as a constituent segment of nano-grooves. This pattern is cut into the DLC coating die as a mother platform by using the femtosecond laser machining. CNC (Computer Numerical Control)-stamping is employed to actually imprint the micro-/nano-textures onto the metallic sheets and plates.

2.1 Femtosecond laser processing system

A femtosecond laser system was used to print the tailored spatial textures directly onto the DLC coating surface, as shown in Figure 2. The wavelength (λ) of the laser was 515 nm, with the pulse width of 200 fs and the pulse repetition rate of 400 kHz. The maximum average power was 40 W, and the maximum pulse energy was 50 μJ. The working area was 300 mm x 300 mm. In practical operation, a working plate of size 280 mm x 150 mm is placed on the work-table in Figure 2b. The irradiation power of a single pulse is estimated to be 0.25 GW. This high power irradiation in the 200 fs interval drives a well-defined ablation into the targeting materials.

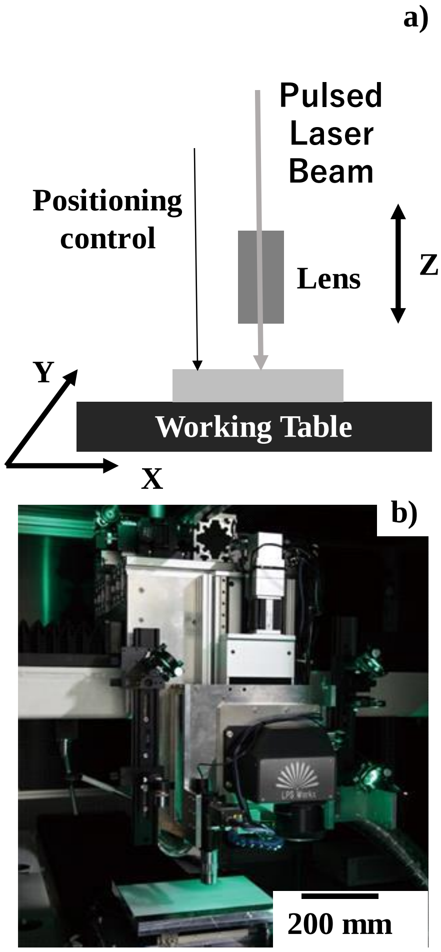

Figure 2: Femtosecond laser micro-/nano-texturing system. a) Illustration on the experimental setup, and b) setup in the present study.

The femtosecond laser machining takes place after the CAM (Computer Aided Manufacturing) data. In this experiment, each microtexture is represented by the assembly of line segments. Nanotexture is cut into each microtexture by the LIPSS (Laser Induced Periodic Surface Structuring) effects. In this LIPSS, each nano-groove is formed by the nonlinear optical interaction between the controlled incidental laser beam and the traveling beam on the surface. Depending on the laser irradiation parameters and the surface condition, the nano-groove depth (d) is uniquely determined; in this case, d ~ 400 nm. On the other hand, the LIPSS-period (Λ) or the nano-groove width is also determined by the laser processing conditions. In this case, Λ ~ 300 nm.

Although the power and fluence necessary for laser ablation is dependent on the die material, almost all the die materials can be targeted for femtosecond laser printing. In the following experiments, a thick amorphous carbon coating film with the thickness of 20 μm is employed as a die material. Its mirror-shining smooth surface with $R_z < 0.01$ μm and its high hardness with 22 GPa is preferable for stamping die in the imprinting process.

2.2 Micro-/nano-texture design

In the present micro-/nano-texture design, each microtexture is represented by an assembly of line segments. A circular unit is employed as an example to explain this micro-/nano-texturing process. This circular unit is approximated by a regular polygon with 30 edges. These 30 segments are edited to five groups. One group consists of six nanotextured segments with varying the nano-groove orientation from 0° to 180° by every 30°. This operation forms a group of segments with regular distribution of nano-grooves. This group is duplicated by 5 times to build up the regular-polygonal microtexture by 30 segments.

Since every geometry in each microtexture is constructed by line segments, the CAD-data are automatically transformed to the CAM data to drive and control the femtosecond laser printing. During the LIPSS process, the nano-grooves are formed on the convex or concave terraces between microtextures and on the microtexture edges.

2.3 Fine imprinting by CNC-stamping

The laser printed DLC coating punch was fixed into the upper die set. Both the upper and lower dies sets were respectively fixed to the upper and lower bolsters of CNC (Computer Numerical Control; ZEN90; Hoden-Seimitsu, Co., Ltd., Kanagawa, Tokyo) – stamper, as shown in Figure 3a. In the following experiments, the upper bolster was incrementally lowered to imprint the micro-/nano-textures onto the aluminum work after the starting position in contact of the DLC coating punch to the work surface, as illustrated in Figure 3b. The stroke velocity was constant by 0.05 mm/s. The upsetting was performed until the total stroke became 150 μm by the applied load of 3 kN.

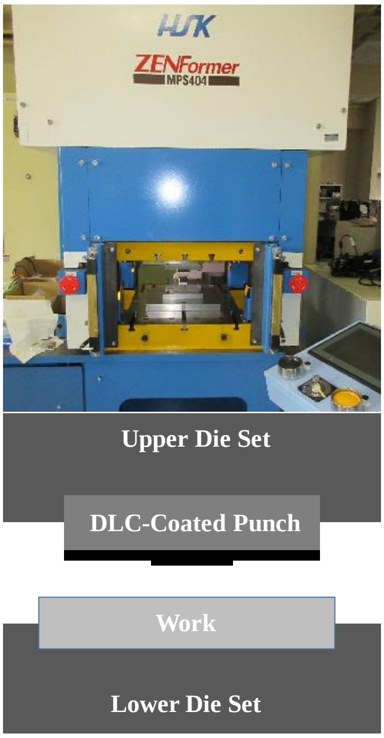

Figure 3: Imprinting process with the use of CNC-stamper. a) Overview of CNC-stamper where four motors are independently working to compensate of the eccentric loads, and b) a schematic image on the imprinting process.

2.4 Die and work materials

A SKD11 substrate with 100 mm x 100 mm was DLC-coated by MF (Medium Frequency) – CVD (Chemical Vapor Deposition method) as reported in [15-17]. The DLC-coating die in Figure 4a was cut from this mother plate and finished to a die shape. The DLC coating thickness was 20 μm. A pure AA1060 aluminum plate was utilized as a standard work material to describe the imprinting process.

3. EXPERIMENTAL RESULTS

Micro-/nano-texturing onto DLC coating dies via the femtosecond laser machining was performed to describe the geometric accuracy of laser printing. This textured DLC punch was fixed into the die set in Figure 3 and utilized for imprinting experiments to coin the micro-/nano-textures onto the AA1060 aluminum plate.

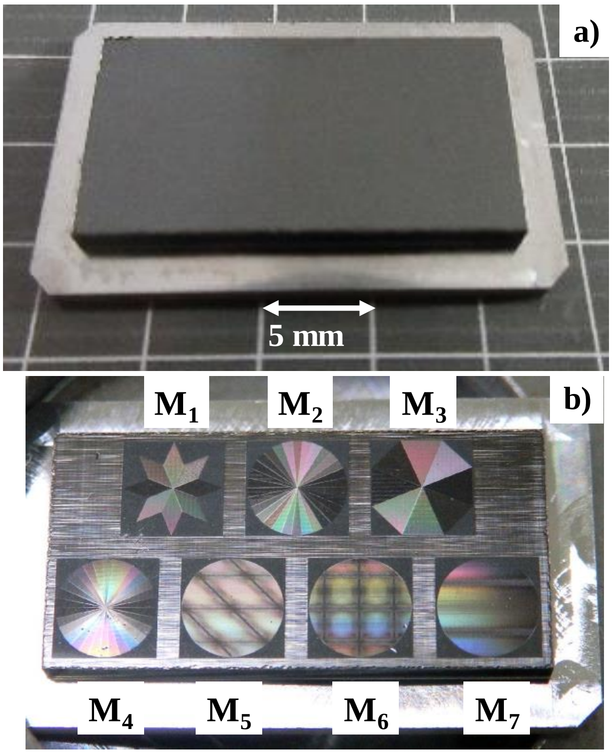

Figure 4: Femtosecond laser printing onto the DLC coating die. a) DLC-coated SKD11 punch with DLC coating thickness of 20 μm, and b) laser printed DLC coating punch with seven microtextures (M_1 … M_7).

3.1 Micro-/nano-texturing of DLC dies

The DLC-coated SKD11 punch with the size of 10 mm x 20 mm x 4 mm was prepared for femtosecond laser printing, as depicted in Figure 4a. Since the DLC coating thickness was 20 μm, every microtexture with the maximum depth of 4 μm was laser-printed only into the amorphous carbon layer.

Figure 4b depicts seven microtextures from a star-shaped texture M_1 to a circular texture M_7. Each microtexture consists of polygonal segments including the nano-grooves with their tailored orientations. Each segment is distinguished by its own color-grating and its surface plasmonic brilliance. In the laser machining operation, the whole DLC surface was ground down to 7 μm except seven square areas with the size of 4 mm x 4mm. Each microtexture was formed onto each square area to build up an alignment of seven micro-textures on the DLC coating punch.

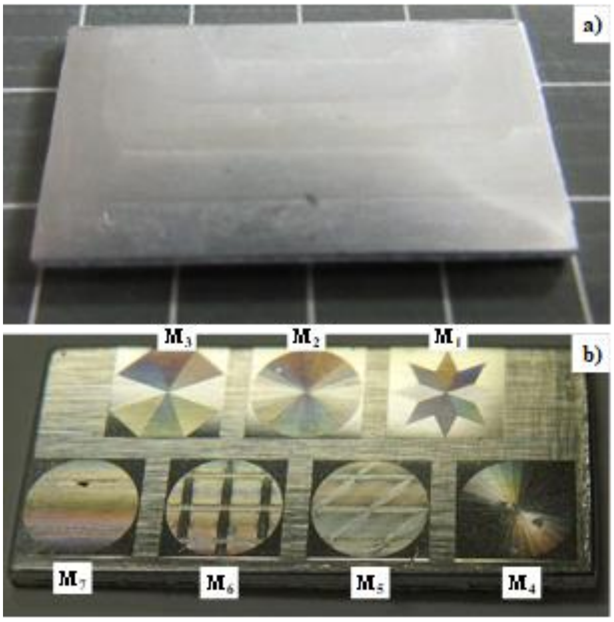

Figure 5: Imprinting of seven microtextures and nanotextures onto the AA1060 aluminum alloy sheet with the thickness of 1mm. a) AA1060 aluminum alloy plate work with the size of 10 mm x 20 mm, and b) seven micro-/nano-textured replicas imprinted onto the pure aluminum sheet.

3.2 Fine imprinting to pure aluminum plate

The laser printed DLC coating die was employed for fine stamping to imprint these micro-textures onto the AA1060 aluminum alloy plate. This aluminum alloy plate with the thickness of 1 mm and an as-rolled surface roughness, was utilized as a work for imprinting as depicted in Figure 5a.

Figure 5b shows seven micro-texture replicas which are imprinted by coining the micro-textured DLC punch in Figure 4b. Seven replicas in Figure 5b correspond to seven microtextures in Figure 4b in a mirror image between two. In parallel with the geometric imprinting from the microtextures on the DLC punch to the aluminum alloy plate, the color-grating properties are also duplicated on this aluminum work.

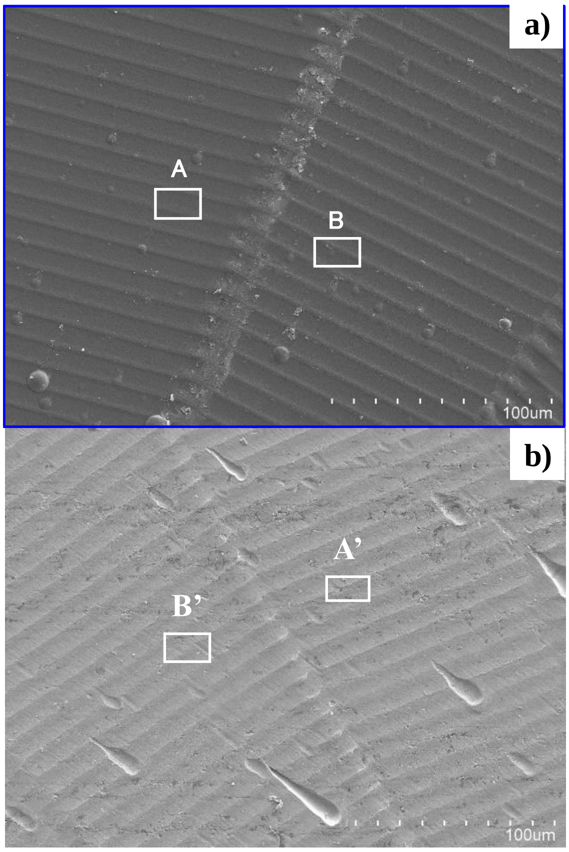

Figure 6: Comparison of SEM images between the micro-textured DLC punch surface and the imprinted replica on the pure aluminum plate. a) SEM image on the two segments of M_1 microtextures, and b) SEM image on the replica.

SEM was first utilized to make comparison on the microtexture geometry between the original DLC microtextures and the imprinted replica on the aluminum work plate. Two segments from M_1 microtexture in Figures 4b and 5b were employed for SEM analysis. Figure 6a depicts two neighboring segments of A and B across the intersectional edge on the DLC die. Each segment consists of an alternative alignment of microgrooves and convex terraces. On the other hand, two segments of A' and B' on the imprinted aluminum plate is made of the alignment of micro-peaks and concave terraces. This mirror-image inversion between Figures 6a and 6b reveals that the microtextures on the DLC die are accurately imprinted onto the aluminum alloy plate.

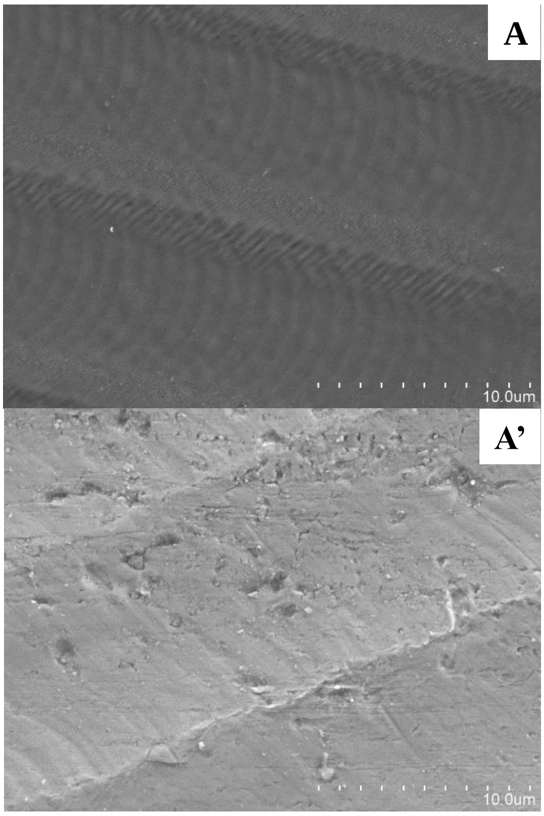

Figure 7: Comparison of high resolution SEM images between the nano-textured DLC punch surface and the imprinted replica on the pure aluminum plate. a) Nanotextures in the region-A in Figure 6a, and b) nanotexture replica in the region-A' in Figure 6b.

High resolution SEM was utilized to investigate the accuracy in imprinting of nanotextures from the DLC punch to the aluminum plate. As depicted in Figure 7a, the nano-circles and nano-line segments with the period of 300 nm are formed on the convex terraces and the intersectional edges respectively by LIPSS. On the imprinted replicas in Figure 7b, these nano-circles and nano-line segments are vaguely formed even on the concave terraces and the peak edges, respectively

As compared in Figure 7, the accuracy in imprinting the nanotextures, depends on the local plastic flow of work materials as well as the loading sequence in CNC stamping.

4. DICUSSION

Since the DLC film thickness coated by MF-CVD reaches to 20 μm, each microtexture and nanotexture is cut into the maximum depth of 4 μm in this DLC film to form steep edges and edge corners. In addition to its higher hardness of this DLC coatings than 20 GPa, its surface smoothness is preferable to a die and punch material to imprint micro- and nano-textures with sufficient accuracy in geometry. Furthermore, the amorphous carbon structure such as GC (Glassy Carbon) and DLC are suitable to fast-rate, homogeneous ablation by the short-pulse laser machining.

Different from the diamond coating, various kinds of substrate materials can be employed as a die material for this thick DLC coating. The curved surfaces and inner surfaces of parts and members can be also coated by DLC via MF-CVD process [15]. This suggests that the rolling process with the micro-/nano-textured DLC-coated rolls enables to make large-area imprinting onto the metallic sheet, and that the extrusion and drawing processes are also useful to imprint the micro-/nano-textures onto the external surfaces of bars and wires and onto the inner surfaces of pipes, respectively.

Let us consider what determines the dimensional accuracy of CNC-imprinting process. As demonstrated in Figures 6b and 7b, the experimental setup in Figure 3 for stamping is properly adequate to drive the plastic flow of work materials into to the micro-meter and nano-meter scaled die cavities. Well-defined correlation between the original micro-/nano-textures on the DLC die and their replicas on the work plate, proves that micro-meter scaled imprinting homogeneously takes place to duplicate the original textures but that nano-meter scaled imprinting process becomes heterogeneous by the difference of microscopic plastic flow of work materials in local. This suggests that the flow stress of work materials has influence on this local plastic flow and the dimensional accuracy in imprinting. Softer and harder metallic materials are employed to investigate this flow stress effect on this CNC-imprinting behavior in [15].

In this experiments, the stroke speed in CNC-stamping was constant by 0.05 mm/s, where the local plastic flow is rather difficult to be controlled. When using the CNC-stamping system for imprinting, various loading sequence programs are available to control this plastic flow. Among them, the incremental imprinting with loading and unloading steps was suitable to make micro-punching into the aluminum sheet [18]. This also suggests that the accuracy in imprinting the micro-/nano-textures must be improved by the programed loading sequence in CNC-stamping.

5. CONCLUSIONS

Two step printing procedure is proposed to transform the tailored geometric model with micro-/nano-textures to its reprint on the artificial product surfaces. The femtosecond laser printing provides a way to fabricate the mother stamp with the tailored textures. The CNC-imprinting process enables to duplicate the mother textures onto the metallic plates and sheets. The accuracy in imprinting the micro- and nano-textures onto metallic products is strongly dependent on the flow stress of work materials as well as the programmed loading sequence in CNC-stamping. In particular, the incremental loading sequence must be well programmed to improve the accuracy in imprinting the nano-textures.

The data transformation from the geometric model to the micro-/nano-textured product surfaces, grows to be essential to make physical and chemical surface decoration of artificial products. Different from the biomimetic design, the theoretically tailored models in topology as well as the emotionally designed patterns in geometry are directly imprinted onto any product surfaces via this two-step printing procedure. In similar manner to meta-materials with accommodation of the tailored properties to materials, this surface decoration has a potential to yield a meta-product with the tailored surface functions onto any metallic and polymer products.

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VERTICALITY ASSURANCE FOR CONSTRUCTING BORED PILES USING LASER SCANNER

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ABSTRACT: This research study investigates the use of laser scanner for checking the verticality of steel casing which governs the verticality of pile shaft. Traditionally, the site workers checked the steel case verticality before driving the steel casing underground. The verticality is examined manually using inclinometers. However, the quality of manual checking is not assured for preventing the driven steel case being inclined. As such, a laser scanner is used for determining the casing verticality based on the collected point cloud data and M-estimator SAmple Consensus (MSAC) algorithm. The results proved that the quality of case verticality can be assured cost-effectively such that the related abortive work can be avoided.

Keywords: Laser scanner, Verticality check, Steel case driving, Point cloud, Piling construction.

1. INTRODUCTION

Bored pile is one of the typical deep foundations for transferring loadings from structures to layers of soil or rock. The deep piling is commonly adopted in urban area high-rise building designs because of its excellent load-bearing capacity, minimal disturbance caused to the neighborhood, and low working space and headroom requirement [1]. Stringent regulations for ensuring pile's quality, which includes the pile verticality, is set, so as to ensure the piles sufficiently support such high loadings. Verticality check is a commonly used quality assurance and quality control measure.

The requirements of bored pile's verticality are specified in codes of practice. Table 1 states the acceptable tolerances. The results indicate that a tolerance of 2% is acceptable.

Table 1 Verticality standard of bored piles

Region	Acceptable deviation of verticality (%)
United Kingdom [4]	1.33%
Australian [5]	1.00%
Europe [6]	2.00%
United States [7]	1.50% (founded in soil layer) 2.00% (founded in rock layer)
Hong Kong [8]	1.33%
China [9]	1.00%

Pile's verticality is difficult to be guaranteed by the Contractors. Beckhaus and Heinzelmann (2015) indicated that bored piles always encountered minor deviations during installation, testing, and evaluation [2]. In practice, minor deviation within 2% discrepancy is accepted [3]. To ensure the casing inclination is within acceptable range, the verticality must be assessed after extending steel casing and concreting.

In practice, Koden test is conducted after extending the steel casing, and Sonic coring test is conducted after concreting. Both tests are quality control measures [2]. These tests check the quality of constructed piles. If the pile verticality is not within the acceptable limits, remedial actions would be very difficult to be implemented and the pile loading capacity may have to be downgraded. Structural safety is questionable if piles are excessively inclined because the loading is not distributed and balanced according to the loading plans, leading to overloading of piles locally.

When installing steel casing, verticality must be checked for assuring pile quality. The site workers examine the verticality by directly placing and adhering a handheld inclinometer [10] to the steel casing based on worker's personal experience. The results of manual inspection are not reliable after factoring in human errors, worker safety, and potential bias.

As such, we are motivated to explore other method for detecting the inclination of the steel casing objectively when driving and extending the casing. We are proposing to use a terrestrial laser scanner to determine the steel casing verticality based on calculating the captured point cloud data of the steel casing using MSAC algorithm.

2. LITERATURE REVIEW

2.1 Terrestrial laser scanning technologies in construction industry

In past decades, research endeavors explored the construction applications adopting terrestrial laser scanner. Li et al. (2020) developed an approach for assessing the flatness quality of concrete stair and exterior wall panel using terrestrial laser scanner [11]. Kim et al. (2014) established a coordinate transformation algorithm to automate dimensional quality checks for precast concrete panels using terrestrial laser scanner [12].

Li and Kim (2021) presented a mirror-aided registration-free method for inspecting geometrical quality of planar-type prefabricated elements using terrestrial laser scanner [13]. Kim et al. (2021) inspected the rebar work using terrestrial laser scanner. They identified the rebar diameters based on machine learning techniques [14]. Zhou et al. (2021) automatically detected the bolt holes based on terrestrial laser scanning data [15]. They improved the boundary detecting technique based on RANSAC (random sample consensus) algorithm.

In summary, the related studies indicate that the construction applications of terrestrial laser scanner are centered on the inspection works for checking the work quality.

To the best of our knowledge, there is no related research focusing on assuring the verticality of steel casing when part of the casing is still above ground. As such, the research aim is to determine the steel case verticality when driving the steel casing for assuring the pile quality. The research objectives are (i) to produce the steel casing verticality data using terrestrial laser scanning; (ii) to identify the steel casing verticality using circle fitting algorithm; and (iii) to validate the verticality measurement in practical settings.

3. RESEARCH METHODOLOGY

The proposed methodology consists of three stages: (Stage 1) data collection; (Stage 2) data pre-processing; and (Stage 3) data deduction.

3.1 Stage 1: Data collection

Point cloud data is collected using terrestrial laser scanner (model: FARO Focus^{S} Plus 350). An 8-meter steel casing is selected as a sample dataset to illustrate the method application. After installing and adjusting the verticality of the steel casing which is attached to the casing oscillator, the laser scanner will acquire the data.

3.2 Stage 2: Data pre-processing

Point cloud data was pre-processed using a software platform, named as FARO Scene, to eliminate the background noise. The point cloud data associated with the steel casing was extracted. Most of the background noise is removed. The point cloud is further processed using the software platform, named as MATLAB, to remove outliers.

3.3 Stage 3: Data deduction

Geometric cylinder model will be generated based on the given point cloud data. This research estimates the cylinder geometry using the half-cylinder point cloud data. M-estimator SAmple Consensus algorithm (MSAC) is adopted for fitting the half-cylinder. The location of the central point is at the origin of circular face, which is at the top of cylinder. The location of another central point is at the origin of circular face, which is at the bottom of cylinder. Given the two coordinates, the verticality of the steel case, which is the difference between the two coordinates, can be derived.

3.4 Site experiment

To illustrate the method application in practice, a site experiment was conducted in Hong Kong. As shown in Figure 1, an 8 meters steel casing with nominal diameter 1.5 meters was fixed onto the casing oscillator. Any crack or internal curve of steel casing surface were not detected.

The terrestrial laser scanner model was setup on site close to the steel casing. The field of view should be set such that the full steel casing was captured. The terrestrial laser scanner model is FARO^S Plus S350 as mentioned. The 3D point accuracy is 2mm@10m and 3.5mm@25m [16]. The scanning resolution is ¼ with quality 4×. The scanning time is 3.52 minutes (Figures 2, 3).

Figure 1 Experimental setup

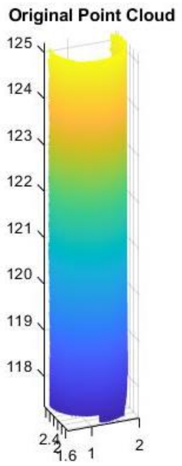

Figure 2 Half cylinder point cloud data

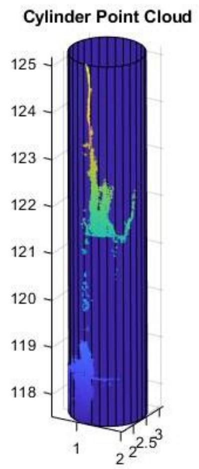

Figure 3 Fitted cylinder

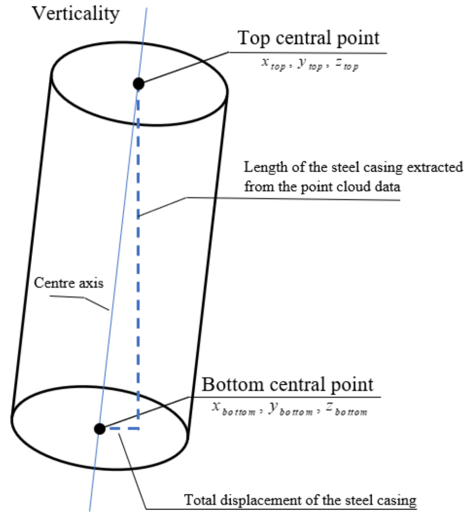

Figure 4 Point extraction

4. RESULTS AND DISCUSSIONS

The point cloud data was fitted with a cylinder geometry model using MSAC algorithm. The difference (i.e., distance) of the points between the fitted cylinder model and actual point cloud model was determined. This above fitting process was repeated 1,000 times by fitting the cylinder models of particular sizes, positions, and orientations. The cylinder geometry model with the least fitting error was chosen as the best fit. Based on the best fit model, the coordinates (x, y, z) of the bottom and top central points were derived as (1.2528, 2.3145, 117.496) and (1.2433, 2.3429, 125.1485) respectively. The difference of the central points was (0.0076, 0.0275, 7.3989) as shown in Figure 4. Then, Eq.

(1) was used to calculate the verticality [22]. The verticality was calculated as 1:259.7248. The feasibility of determining the case verticality based on the point cloud data produced by laser scanner is proofed.

$$\text{Verticality} = \frac{z_{\text{top}} - z_{\text{bottom}}}{\sqrt{(x_{\text{top}} - x_{\text{bottom}})^2 + (y_{\text{top}} - y_{\text{bottom}})^2}} \quad (1)$$

where $z_{\text{top}} - z_{\text{bottom}}$ = Difference of z coordinates, $x_{\text{top}} - x_{\text{bottom}}$ = Difference of x coordinates, $y_{\text{top}} - y_{\text{bottom}}$ = Difference of y coordinates.

The proposed method is a reliable and cost-effective solution for assuring the pile quality in context of shaft verticality when fixing, installing, and advancing the steel casing using a laser scanner.

The manual check cannot identify the big difference of verticality if the inclination is not obvious and small. However, a very small variation (e.g., 1 degree) when advancing the casings for pile shaft (e.g., 100m) from above ground down to the rock layer may potentially cause huge deviation of the pile shaft verticality. The abortive work related to one excessively inclined steel casing is costly (e.g., HKD $1 million) and timely (e.g., 10 days).

In contrast, this proposed laser scanner approach introduced an innovative quality assurance process to assure the steel casing verticality. The price of a laser scanner is HKD $0.8 million. An extra 15-minute is required for setting up, scanning the casing, and analysing point cloud data. Notably, the scanner will be able to be redeployed (in other projects). Time-cost trade-off analysis for monitoring of the pile verticality indicated that the proposed method outperforms the traditional approach by reducing the chance of related abortive work time-efficiently and cost-effectively.

5. CONCLUSIONS

This research study proposed a novel method for assuring the verticality of steel casing when fixing, installing, and advancing the steel casing using laser scanner. The verticality of steel casing is determined based on the scanned point cloud data and MSAC algorithm. A bored pile construction site at Sheung Wan was selected as a case study for method illustration. Over 0.5 million point cloud data was extracted to determine the verticality of the steel casing, leading to the formation of the pile shaft. The total invested time and cost were 15 minutes and HKD $0.8 million. The result confirms that the proposed methods can eliminate human errors and bias by objectively checking the case verticality. Although the Contractors require to pay extra time and costs for applying the proposed method, the risk of abortive work due to excessively inclined steel casing and non-conforming pile shaft can be potentially reduced. The proposed cutting-edge approach, which augments the existing piling tests for quality control in practice, provided a novel yet time-efficient and cost-effective solution for quality assurance in piling construction.

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MIXED REALITY AND VISUALIZATION

SPATIAL COMPOSITION OF TRADITIONAL STREETSCAPES - ANALYSIS OF SIMPLIFIED STREETS MODEL IN VR

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ABSTRACT: Countries from all over the world are preserving or rebuilding traditional buildings, especially in traditional shopping streets. We need to consider not only the development of commercial and tourist value but also the preservation of original historical styles. In this study, we made some simplified models of the streets in the "Important Architectural Complex Preservation Areas" which designated by the Japanese Agency for Cultural Affairs, changed the depth, height, and location of the architectural styles, and conducted experiments in VR to summarize the important factors that affecting the sense of history and the integrity of traditional shopping streets.

Keywords: historical streets, VR, landscaping

1. INTRODUCTION

Streets are like the venation of an area, inheriting the local history and residents' lifestyle. The streets in every region have their own unique characteristics. Some unparalleled historical streets have been reconstructed through streetscapes. However, although some streets retain some historical buildings, there is no unified streetscape. Our research aims to analyze the most critical elements of street preparation by VR, focuse on the streets whose landscape is not unified, and explore how to endow the streets with more distinctive characteristics with as few changes as possible.

In Japan, the "preservation area of important buildings" which was designated by the Agency for Cultural Affairs has selected some specific areas and promulgated some protection regulations to protect and repair the traditional buildings. For we obtain three types example, the regulations on protecting traditional buildings in Kawagoe City stipulated the size, height, structure, design, doors and windows, billboards, and etc.

2. STREETS COMPOSITION OF JAPAN

In the initial phase of the research, we took some photos and videos from cities, including Inariyama, Chikuma City, Nagano prefecture, Takehara City, Hiroshima prefecture, Ichiban Street, Kawagoe, Saitama prefecture, and other places in the "preservation area of important buildings" by an action camera and a 360-degree panoramic camera. We obtained the real VR images of the local traditional streets, as shown in Figure 1. The advantage of VR images is that we can still look around 360 degrees in the later stage of the study even though we are not there, which is more conducive for us to experience the overall sense of the street.

With the changes of times, the buildings in the historical streets are also gradually updated. From the ancient buildings in the Edo Period to the western-style buildings in the Meiji period to today's modern buildings, it is difficult for many

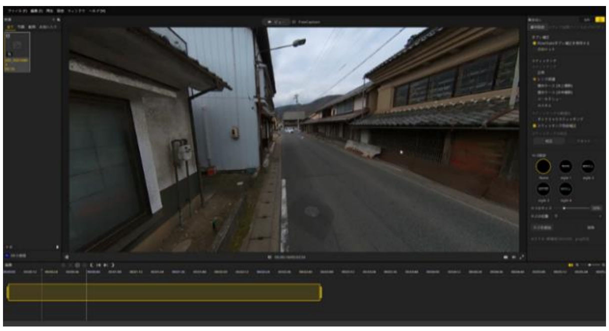


Figure1: 360-degree Video

Figure2-1: Takehara Street

Figure2-2: Ichiban Street

Figure2-3: Inariyama Street

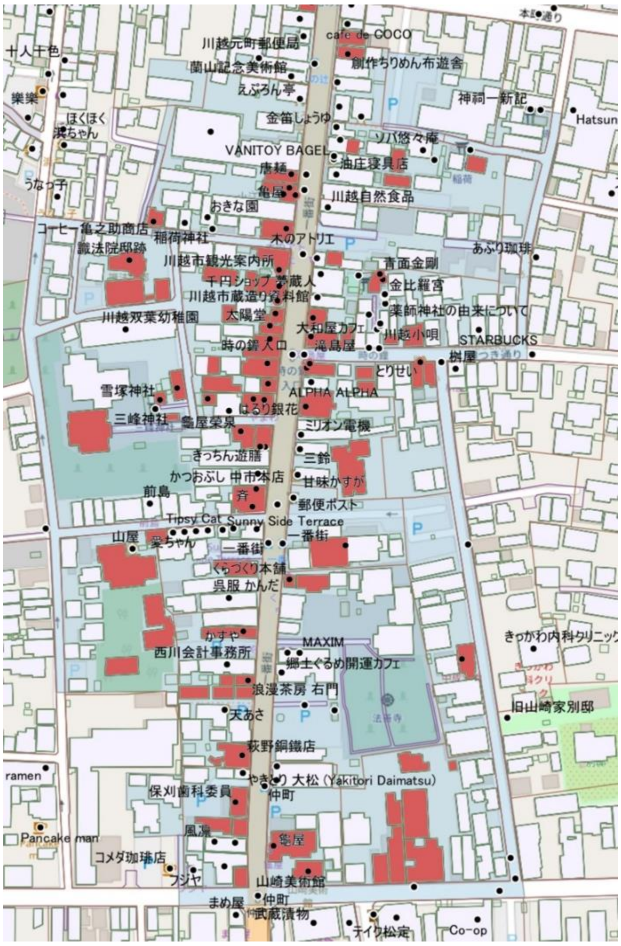


Figure 3 Map of Kawagoe Ichiban Street

buildings to be unified in the streetscape. Therefore, according to the proportion of traditional structural buildings, it can be roughly divided into three different types. Figure 2-1 shows a street that has been completely rebuilt, with all forms, colors, roofs, and etc. It has a complete historical atmosphere, representative streets such as Narai-juku, Shiojiri, Nagano Prefecture, and Takehara, Hiroshima Prefecture. The street in Figure 2-2 contains some traditional buildings, but it also contains some reconstructed buildings. Such as Ichiban Street, Kawagoe, Saitama prefecture and Sawara, Katori District, Chiba Prefecture. The street in Figure 2-3 is complete without streetscape repair, so no historical features can be seen from it. Such places as Makabe, Ibaraki Prefecture and Inariyama, Chikuma City, Nagano prefecture.

Figure 4-1: Traditional Buildings

Figure 4-2: Newly Constructed Buildings

Figure 4-3: Modern Buildings

Buildings in Ichiban street, (hereafter, street in Kawagoe), are not completely traditional, even if the reconstructed buildings are as unified as possible in terms of eaves, window colors, and etc. Figure 3 is the map of the street in Kawagoe. The red mark is the location of the main street buildings. According to the statistics of the structural form of the building, we have reached the results in Table 1. In Kawagoe, there are historical buildings constructed by wood, built in the first half of the 19th century or earlier; there are also modern buildings with a Western form built in the latter half of the 19th century.

After a general summary of the above types, we obtain three types. figure 4-1 shows some preserved Kurazukuri traditional townhouses. These buildings are less than 11 meters and have

Table 1: Types of buildings in Ichiban Street

architectural style	quantity
Kurazukuri construction store	22%
Makabe construction store	10%
Western-style store	2%
Japanese-style house	16%
Western-style house	1%
Modern Western-Style Architecture	3%
Others	31%
Infrastructure	19%

lower eaves. The walls on the second floor are more retracted than those on the first floor. The roofs of these buildings are hirairi and their outer walls are black. This building in figure 4-2 is newly constructed one, but the eaves with new materials are considered to express the historical form. Figure 4-3 shows some new designs without a sense of history. It is easy to see that when the proportion of both traditional and reconstructed buildings is high, the street has developed a unique traditional style.

3. OBJECTIVE

We believe that a plan such as the street in Kawagoe is a way to create the historical unity of the street by increasing the proportion of traditional architectural structures.

In this study, we focus on Kawagoe, where historical and modern elements are mixed, and Inariyama, where only a few historical elements remain, and analyze their streetscapes and represent their image in VR. a simple model of the streetscape is created based on the map of the selected area. And some changes and experimented are made through VR. Based on the results of the analysis, we will create an optimal maintenance plan.

Through VR, we will analyze the most important factors in the development of the city, focus on the unplanned streets, and explore the way to improve the city's characteristics by making as small changes as possible when choosing the maintenance plan. The residents will be able to recognize the city more intuitively after the reconstruction.

4. GENERATING THE FORMS OF-STREETS

This chapter focuses on Inariyama, where three types of buildings (tumairi, hirairi, and modern) are mixed, and a proportion of hirairi is small. We carried on the simulations by varying the ratio of building types, placing buildings on vacant lots, and adding materials.

4.1 Building's Type Simulation

In the first experiment, we set up 20 buildings on both sides of the streets, randomly arranged

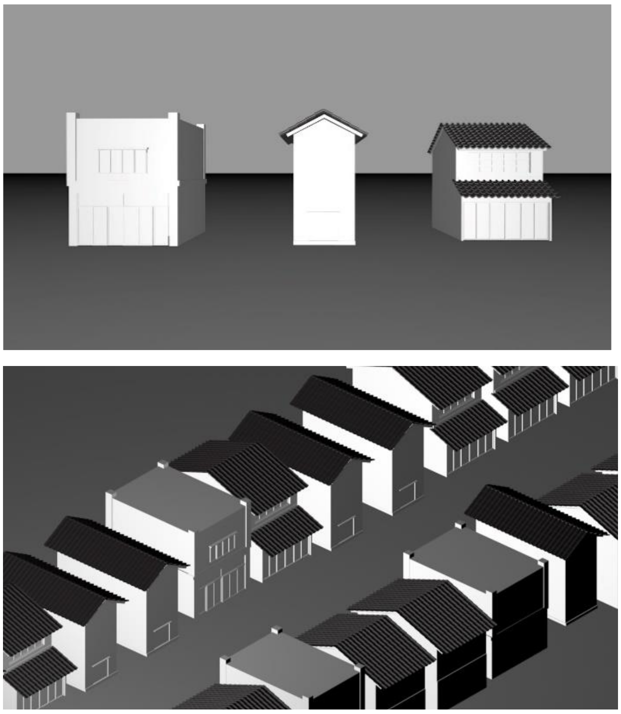


Figure 5: Types of Models and Building's Type Simulation

the location of the buildings, selected six examples from several random streets, and counted the number of three building types respectively. Then, the experiment evaluated the sense of the history of the simulated streets from the perspective of VR. The perspective of VR simulation is shown in Figure 6. We set the evaluation to five levels, namely very high, high, medium, low, and very low. The sample consisted of five architectural students.

As can be seen from Table 2, only from the perspective of architectural form, the more hirairi buildings there are, the higher the evaluation of the sense of the history of the street. Relatively speaking, the more modern buildings there are, the lower the evaluation of the sense of history. And the more tumairi will also reduce the evaluation of the sense of history.

4.2 Building's Depth Simulation

As shown in Figure 7, in the second experiment, we only retained hirairi buildings but set three types in the deep of the buildings, namely as deep, mid, and shallow, which are all tiled.

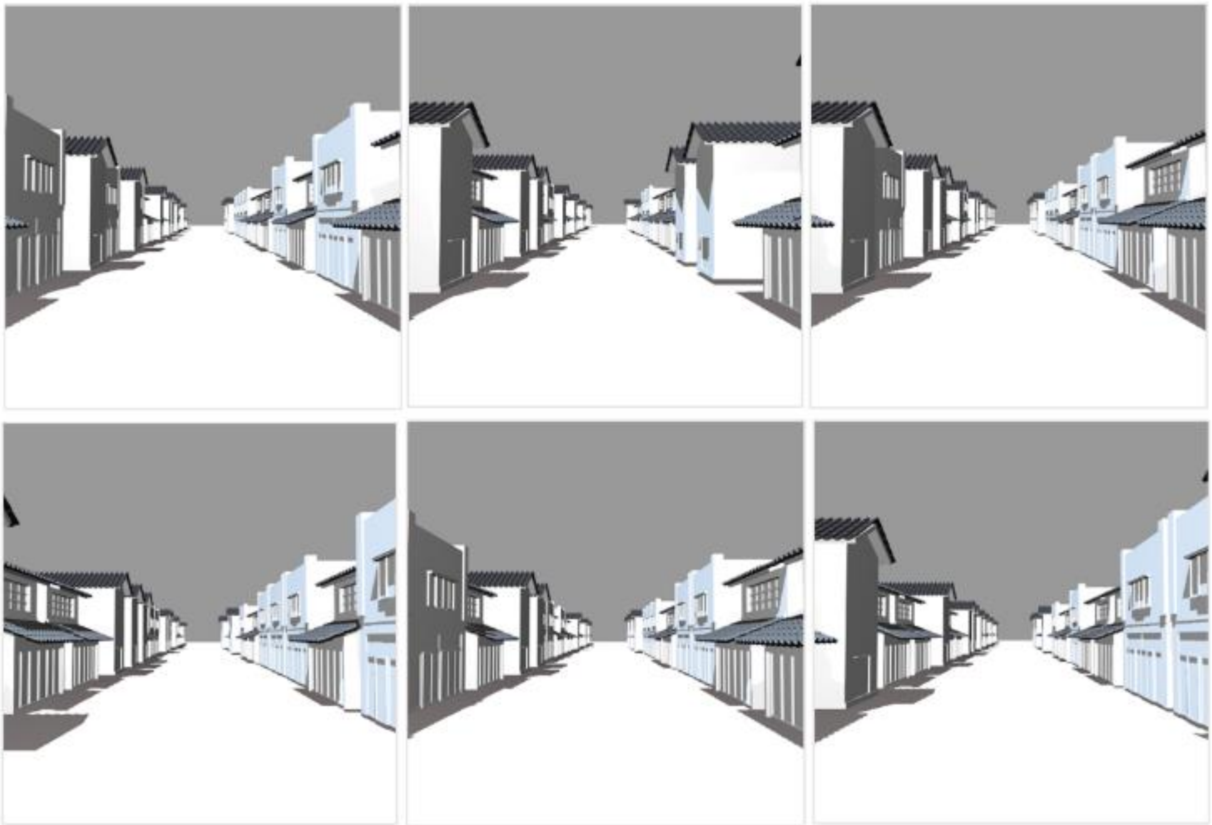


Figure 6: Buildings Type Simulation

Table 2: Building's Type Simulation

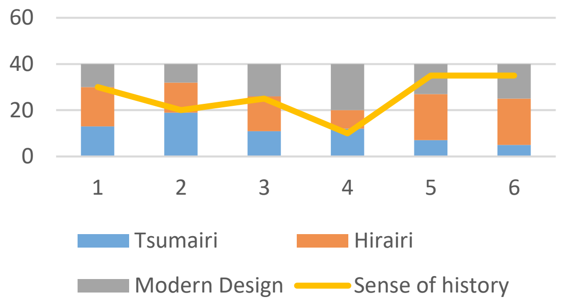
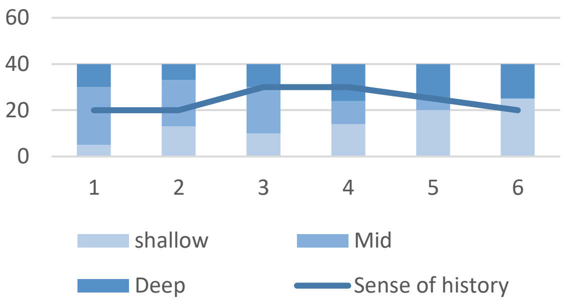


Table3: Building's Depth Simulation



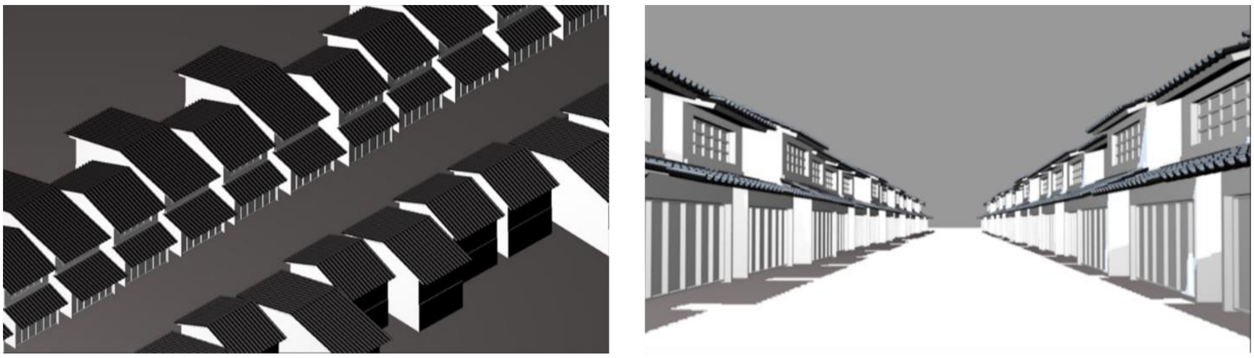
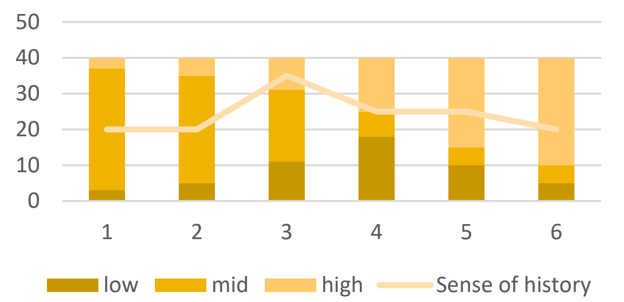


Figure 7: Building’s Depth Simulation

Table 4: Building's Height Simulation

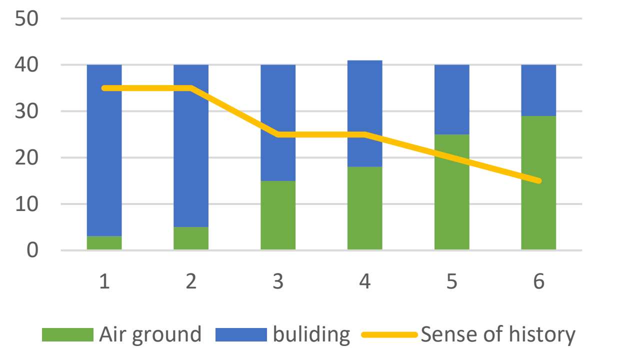


The changes of depth mainly affected the roof slope and had no obvious impact on the sense of history from the perspective of VR. However, it can be seen from Table 3 that the deeper the type, the more natural the overall feeling, so it is more conforms to the feeling of naturally formed historical streets.

4.3 Buildings Height Simulation

The third experiment also set three heights dimensions for the height of the buildings on the premise of retaining only hirairi buildings. Like the conclusion of Building's Depth Simulation,

Table 5: Air-ground Simulation



the higher the average proportion of building height, the more natural the overall feeling of the street. However, since most traditional townhouses only have two floors, it can be seen from Table 4 that the higher the proportion of medium and high buildings, the higher the evaluation of the sense of history. Therefore, in the streetscape, appropriately increasing the height difference between buildings can make the whole street look more harmonious, but a too low or too high proportion of buildings will destroy the integrity.

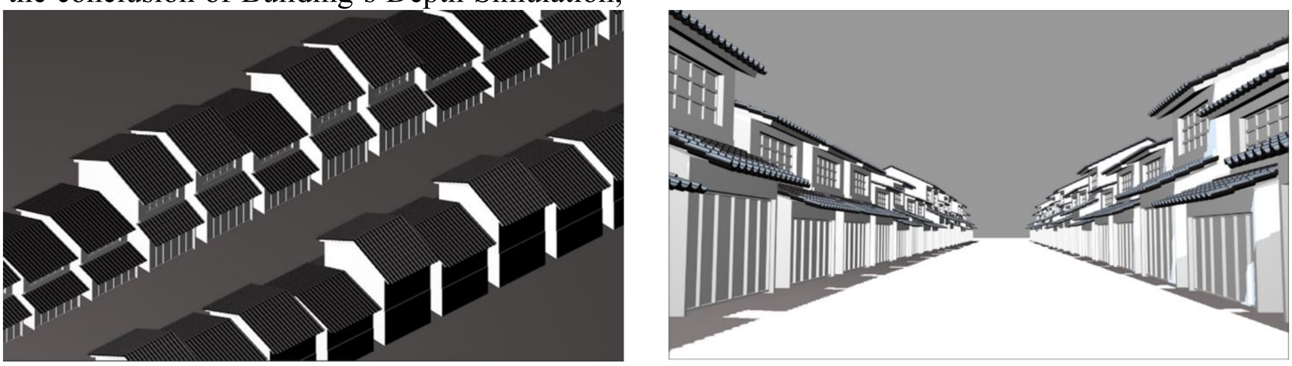


Figure 8: Building's height simulation

Figure 9: Air ground simulation

4.4 Air-ground Simulation

After streetscapes, the main functions of the historical blocks are not only to restore the historical characteristics but also to meet the living needs of local residents. Nowadays, many families have cars, but the setting of parking spaces is not considered in the traditional streets. So, in our streetscapes, small parking spaces have to be set in those blocks. Therefore, in the fourth experiment, we interspersed open spaces in the building complex to indicate the location of the parking lot. The scene in the VR simulation is shown in Figure 9. We randomly arranged the proportion of open space from less to more according to the number. It can be seen from Table 5 that when the proportion of open space exceeds half, it will have a great impact on the sense of the history of the street. Therefore, when setting up parking spaces, we need to consider keeping a certain density between buildings.

4.5 Building's Material Simulation

We already know that the modern buildings in the traditional streets will destroy the integrity of the sense of history. But under the condition of maintaining the unity of height and depth, we can convert the materials of the modern buildings, use the colors and eaves similar to the traditional buildings, as shown in Figure 10, adding wood grain to the modern buildings and replacing the canopy with tiles will reduce the impact on the sense of the history of the streets.

5. CONCLUSIONS

By simplifying the model, we simulated the traditional streets from the aspects of building type, depth, height, open space and material, and evaluated the sense of history through a VR experiment.

We drew the following conclusions: in the process of traditional street planning and reconstruction, we need to consider preserving the historical characteristics, but on this basis, we can plan the integrity of the street through as few changes as possible.

In terms of building types, try to keep the proportion of hirairi buildings as much as possible and reduce the proportion of modern buildings.

Figure 10: Building's Material Simulation

In terms of building depth and height, the staggered eaves slope and building height can improve the interest of the street, but a too high deviation will affect the integrity of the street. In order to meet the needs of residents, appropriate increasing the open spaces will not affect the integrity of the street. In the overall streetscapes, we can consider changing the materials of modern buildings to form a unity.

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[7] Insta360 Studio
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SEARCHING FOR HUMAN VARIABLES IN THE DISCUSSION ABOUT THE DEVELOPMENT OF VIRTUALLY ENHANCED SPACES

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ABSTRACT: When trying to observe the possible future developments of different forms of communication and socialization, today traditionally linked to physical environments, it often seems inevitable that one day they may change through the increasing integration of technological solutions capable of superimposing alternative virtual universes to our physical world. Virtual spaces, once generated through rigid rules and representations derived from drastic geometric reductions of reality, are becoming more and more advanced, obeying increasingly more dynamic systems, and sometimes giving the appearance of being able to imitate life itself. Can this guess match the reality? In one of our studies in progress, we talked about how technology is encroaching on «dystopian» aspects and that, in a more or less evident way, this happens in many aspects of reality including that of the generation of geometric shapes. In particular, the latest trends on which the modelling principles develop towards a procedural logic that has its core purpose in solving functional problems, first of all, and also in reaching out to the market logic, developing styles suitable to attracts attention from specific target audiences. The current discussion wants to bring the topic back to the human being and to nature seen as: «Man is the measure of all things» phrase expressed by Protagora, generally interpreted as the non-existence of an objective truth, that is, the existence of a truth not the same for everyone. The ease of translating into algorithms of the generative processes of geometric shapes often leads to the creation of results detached from this kind of logics and which in the past, since the Renaissance age, are based on modulus and on the proportional relationships among the parts and of each part with the whole, moving from «measurability» to «commensurability». The aim is to use in a modern language the same codes and principles on which nature is based and communicates, starting for example from the growth laws of living organisms (Fibonacci series, golden section, etc.), from the principle of similitude and from the law of least effort.

Keywords: nature, algorithm, parametric, virtual worlds.

1. INTRODUCTION

Technological progress has led to the development of realities that until recently were told only in science fiction books. Today these realities are entering more and more predominantly into people's lives and professions. Since there is a generation process, it is imperative to critically ask oneself about the nature of these places in relation to the human variable in a triple relationship: temporal, spatial, functional, and commensurability. Then to the temporal aspect of perception of elapsed time, in the spatial aspect of the creation of spaces as well as of the contexts involved. All in relation to the modalities of generation and relationship between the parties, passing from questions of measurability to questions of commensurability. Path already traveled in the past in different eras in search of the laws of growth of living systems and the discovery of the laws that govern nature.

2. THE FORESEEABLE FUTURE ABOUT THE IMPLEMENTATION OF VR ENVIRONMENT IN EVERYDAY LIFE

The recent events of our contemporaneity have freed the imagination of many scholars and professionals towards the development of technological applications capable of enriching remote communications between people, through the use of real virtual spaces. Many communities had to apply strict limitations to various natural social behaviors, generating challenging dilemmas over the alternative processes to implement as substitutes to the traditional experiences.

The general distrust in the physical contact between individuals, in particular, has led to the rediscovery of themes dear to the science fiction imagination, the dualism of a physical reality capable of integrating itself with virtual reality. Virtual reality has quickly become an influential topic of discussion, transforming itself from an abstract field of research to a concrete and actual solution for the future development of multiple productive and educational activities.

Figure 1: Congolese designer Anifa Mvuemba started to plan new ways of organizing collections presentation via virtual events even before COVID-19 breakout. In this solutions, the new dresses are digitalized and shown via the performance of invisible 3D models. Many events were held last year following similar directions[1].

These virtual spaces are by definition an immaterial construct that does not require a physical production phase, and because of this, they can be perceived as easily manipulable entities. Contrary to this assumption, however, many experiments have highlighted singular characteristics in the bond that these spaces can establish with the people who navigate them. The ever-increasing number of ongoing studies is in fact giving rise to the generation of a complex aggregation of knowledge about the unique properties that the use of virtual spaces can manifest in certain contexts. But this information is not only useful in relation to the modeling and design of virtual environments, as it can also become a starting point for a critical analysis of the real/physical places in which we conduct our lives. Although with considerable differences, the reasoning of picturing virtual spaces as an alternative to real environments for the continuation of human activities is an act that implies some kind of equal standing between the two concepts, and due to this it would be possible to operate with surprising effectiveness, a transfer of knowledge between the two experiences.

In particular, the development of numerous architectural traditions has often paid particular attention to the natural environment as a primary reference source for the resolution of numerous compositional, symbolic, and functional aspects of the design. Can this ability to read and transform information be useful to consider also in relation to these apparently artificial technological solutions, and by their very definition «virtual realities»? And on the contrary, can virtual environments support a renewed ability to optimally bring the formulation of real spaces closer to human life?

The use of virtual spaces, especially if conveyed by integral VR headsets, has shown in several studies that it can exert a significant influence on the time perception of the users engaged in navigating within the simulation [2]. This phenomenon described as temporal compression has verified how, within this type of experience, a consistent base of users evaluated the time spent inside the virtual environment generally longer than what had elapsed in real life, in some cases even recording how the perceived time interval was 28.5% higher than the real one [3]. The temporal and spatial dimensions are the foundation of the information that human beings can acquire from the use of a place, and while it can be considered a known fact that the perception of time is sometimes subjective, it can become remarkable to know that the use of these technologies can somehow alter it in an homogeneous way among different individuals. Many suggest that a partial explanation to these phenomena lies in the way in which these immersive technologies can replace the image of the real world with a virtual one, thus deceiving the sense of sight of a person while leaving other bodily perceptions unchanged. This discrepancy between what is felt and what is seen therefore can sometimes generate contradictory perceptions [4].

Is it possible that in a future where these technologies will be exploited more frequently, the fact of dealing with these kinds of issues will become a common necessity?

For example, in a distance learning context, it may be inconvenient for the participants of a lesson to perceive the time spent as greater than what it is in reality, as it would end up generating negative results on their attention and fatigue levels. These phenomena of distorted perception are not always present in every simulation [5], and this could suggest that maybe they are the result of the interaction of certain elements about the composition, or the use, of a virtual space instead of a simple direct causal relationship concerning the mere use of these technologies.

Within this discussion it might be interesting to pay more attention on the natural environment, and to the possible implications that it could have even within the treatment of virtual environments. Starting from the assumption that virtual environments, as previously mentioned, are freed from the limitations of the physical realization of what they contain, their compositional design does not place any «physical» limit. While the shape of a real architectural object will have to be closely related to its practical realization, a virtual environment places fewer constraints, leaving more possibilities to design spaces for «as they could be» and not «as they should be». A simple consequence of this could be for example, the freedom to imagine a virtual classroom as something even radically different from a traditional room.

In this sense it might perhaps be possible to intertwine these issues with the work that numerous researchers and professionals have produced, concerning the positive effects that can be produced on the occupants of a building thanks to greater visual contact with the movement of natural elements [6]. In particular, a research carried out by the University of Oregon [7] has conducted an in-depth study on how it is possible to reduce the stress levels of people employed in different types of activities inside closed environments, thanks to the controlled exposure of «natural movements», such as: the variation in shading caused by the movement of the sun during the day, the random variation of background elements moved by the wind, or the direct perception of atmospheric elements such as rain. The research finds that in contemporary times many people spend extended periods engaged in indoor activities, often in places with limited relationships with the external environment. These situations are not inherently bad, but as is further pointed out in a subsequent article by the same authors in the Washington Post, most of the buildings we live in have become so efficient at protecting occupants from the elements that they also eliminate some key requirements for our well-being, that is nature and change [8]. The reference goes to previous studies, which have shown how the human mind greatly benefits from the presence of sensory stimuli that vary over time [9], a fact directly linked to the natural environment in which humanity has developed. Buildings in which the environment is excessively «static» and artificial, develop feelings of discomfort and alienation in the occupants, while the introduction of a greater natural dynamism, for example through direct projection on the floor, or on the work surfaces, with variable patterns of light and shadow throughout the day, makes it possible to improve their mental state.

Figure 2: Soul Garden House by the studio Spacefiction Studio. Example of architectural spaces designed to bring natural element inside the habitable space [10].

The parallelism between excessively hermetic architectural environments, and a virtual simulation capable of «separating» a person from the physical environment may not be overly daring. Perhaps the perceptual distortions, and the widespread discomfort, which can sometimes be developed during the use of a virtual reality experience, could be mitigated by the inclusion within the spatial composition of appropriate elements that mimic certain natural characteristics.

In this sense, there are now many solutions to generate extremely faithful representations of different biological and meteorological entities, through applications specifically designed for the production of environments that can be used through virtual realities. Through this interpretation, the design of real and virtual environments can begin to be considered less and less disconnected and pursuing the goal of generating environments suitable for human use, a direct exchange between the two experiences could become possible.

Figure 3: The digital representation of natural elements is becoming increasingly accessible. In this example, a simple virtual meeting space was integrated with a natural environment. This basic template could also be updated with different features.

The way through this can happen in our opinion is still largely to be discovered, and it can undoubtedly become a very stimulating scenario to explore for deepening the link between people and the places where they live [11].

Fantasizing how the study of the composition of architectural space approaches the generation of virtual environments, it is easy for the mind to drift to visualize vast and complex scenarios, sometimes even utopian, as can be, for example, spectacular reconstructions of the ancient world [12], or the on the contrary, audacious visions of certain science fiction scenarios [13]. The power of these images is no small thing, as they are often able to resonate deeply with the people involved in their vision. In particular, the reproductions of contexts derived from the so-called «ancient world» are receiving ever greater interest as articulated and complex study tools, and following this spirit, numerous publications on the subject are finding in the last year extremely fertile ground to develop a dialogue on these issues. This may be the case, for example, of the collection «Classical Antiquity in Video Games: Playing with the Ancient World» [14], which is proposed as an entry point into this multifaceted and multifaceted world. In our opinion, these publications also have the interesting merit of recognizing how the use of architectural environments developed through the revival of compositional codes drawn from classical culture is actually welcomed with great interest by the vast public [15].

Scenarios created in such a way as to re-propose and bring to life architectural practices of the past, such as the Greek or Roman culture, are definitely still able to resonate positively with the sensitivity of people born and raised in our contemporaneity. In this sense, the flexibility of the design of virtual environments could provide the possibilities for a rediscovery of the codes linked to the architectures of the past, as a solution to the generation of environments in which the reproduction of natural components, and their interaction with architectural volumes, can humanize more the simulations carried out.

This could also create the conditions for studying in detail the relationship between space and occupants, according to unusual patterns that are difficult to reproduce in the physical world, also thanks to the implementation of modular elementary environments, capable of being able to grow in complexity in response to contact with users. This could happen both through processes, so to speak very straightforward, such as the growth of the dimensions of the scene based on the number of occupants, but also through more sophisticated behaviors, such as the adaptation of virtual atmospheric conditions with respect to the real conditions belonging to the connection places. of each person, or the alteration of the chromatic composition of a scene based on certain visual impairments of the users.

3. A NEW VIRTUAL 1492

The virtual spaces that current technologies are able to create have taken on different names over time such as 'cyberspace', 'mirror world', 'other plane' or 'metaverse', etc. From before they were mentioned only in novels and science fiction books, now different characters outside that environment are using those same words to give a name to something that is assuming a real form even though they are virtual environments.

For example, Novak in 1991 spoke of cyberspace in theoretical terms, meaning a type of virtual reality uncoupled from logical and rational aspects, without necessarily there being causal links between cause and effect and where rules of Euclidean geometry or perspective and physical laws are not necessarily must obey the same ones present in the physical world [16]. Or much more recently, Zuckerberg has reintroduced a new word 'metaverse' to describe a shared online space in which augmented physical and virtual reality can coexist. A universe in which to meet, watch movies, play, socialize and work, eliminating distances and being able to manage the virtual environment at will. All against the background of an environment based on advertising and on the sale of digital objects, avatars and personifications in the same way as Second Life did years before [17].

In old science fiction books it was often told of worlds directed towards dystopian futures, in which over time technology and technique would first be placed side by side as an aid to the condition of human impatience and as a form of suppression of pain and the intrinsic fatigue of being beings living and then replacing man and the environment itself as on the one hand substantially static from the evolutionary point of view with respect to technological progress, on the other hand difficult to control as a biological system.

Gunther Anders already warned some time ago about how technology has made man antiquated affirming how man has been chained in a binary production-consumption logic. His imaginative attitude has also become antiquated, unable to grasp the effects of the gestures that he himself performs [18].

The transition to an increasingly technologized system beyond the intrinsic advantages of society as it is structured when viewed from a more natural and biological perspective, certainly involves losses in terms of complexity, diversity and relationship between biological entities compared to biological entity and machine.

Part of these relationships underlie the way we are made, the numbers that compose us such as: Golden Section, Pi Greco or Fibonacci and the physical laws to which we are subject have defined us and made us become what we are in millions of years. Detaching ourselves from these conditions, although it may be a sort of liberation from limitations imposed by nature itself, could also be seen as an impoverishment of the human experience.

Figure 4: Representation in both images of an interior space with a similar futuristic architectural style.
Above: digital representation of the 'metaverse' being introduced by Zuckerberg: virtual spaces based on moving the physical interaction of people into generally empty and aseptic environments (creation of need), on which to set up advertising systems as well as the sale of personifications and virtual objects. (satisfaction of the need)
Below: a possible example of a digital representation of a virtual space in which attention is focused on the diversity and complexity of the environment by integrating architecture and nature. No earning system, and on the contrary sharing and integration of heterogeneous spaces and search for the link between man and nature. (freedom to experiment and know) [19].

From this we can see a return to the understanding of the complexity of nature and the integration of technology with a higher level of conscience, no longer trivially in economic terms or in terms of quantity of products sold but of further enrichment of the human condition.

Since therefore the first principle on which the markets mainly focus is that of solving functional problems or attracting people for commercial purposes or precisely "doing business". No one is really interested, if not a facade, in anything other than 'measurable', losing that form of incommensurable beauty characterized by some past eras. Although pessimistic, the scenario that is emerging is the mirror of the structure with which society has historically organized and developed, a scenario in the image and likeness of the result of the present 'progress'. Similarly, it is as if we were in a new 1492 discovering a new world but in virtual metaverses and the 'conquest' of new spaces, traveling on the thread of Orwell's 1984 background. On the basis of these premises, the value of those places can no longer reside in the places themselves and in the quality of these, but in the people who decide to emigrate there. The value will be in the time avatars spend in metaverses watching advertisements, selling items, or any other form of entertainment. Hence the need to take up the concept expressed by Protagora who stated "Man is the measure of all things" and therefore taking into account the different nature and needs of each person.

The need arises to return to old models such as the classical or Renaissance ones, also taking up stylistic rules that are increasingly rarely used, but with a different awareness that knows how to integrate the present context through the new possibilities given by parametric modeling by developing algorithms in close connection with the numbers of nature that make us up.
The need arises to rediscover the human variable increasingly obscured by shadows detached from the very nature of man.

4. BACK TO THE TRADITION

In the field of representation, it has passed from the predilection for the design of «static» project based on orthogonal projections and axonometric views, useful especially to know the real dimensions of the artifacts, to the use of models, virtual and augmented reality, and therefore of perspective views and animations that simulate human vision. For the benefit of the users, it is possible to choose appropriate camera points to do not create marginal aberrations and other interference in perception.

Another fundamental aim is the creation of real and virtual spaces, that show the will to use clear proportional rules for the sizing «on a human scale», using the module as a minimum fundamental element to ensure commensurability, therefore the correspondence and harmony of all the parts between them and the parts with the whole.

Since the Renaissance the use of the module and the remarkable relationships for the proportioning of the spaces has aroused a certain fascination because tied to the concept of beauty. Proportions create an analogy with the natural world and are a guarantee of beauty and perfection. On the use of proportions, the repertoire of treatises is very wide, especially Leon Battista Alberti [20-21], with the study of the modules on the facades of his architectures, and Albrecht Durer [22] that illustrates the human body in all its parts perfectly proportioned with modules and sub-modules, as if it were an architectural organism. It has also been seen that there are remarkable relationships that are analogous to those ones of musical harmony, and that if used, in architecture as in music, they are therefore pleasing to sight and hearing.

Throughout history we frequently find the use of the golden ratio, in relation to the series of Fibonacci, present in the pattern of accretion of numerous living organisms, which also dictates the rules for the creation of the scheme of *Modulor* [23] during the modern movement, one of the highest examples of «humanization» in the design of architectural spaces.

Even the choice of simple shapes in the design can be a useful choice to create harmony, there are in fact some archetypal figures, the square, the circle and the triangle [24] used in architecture and design, basic for the study of the structure, of forms and form. But we talk about «measure» also in the meaning of «measure of the form», for this reason it is important to also know the neurosciences to understand the mechanisms that act in the brain regarding vision.

About the analogy with the natural world, D'Arcy Wentworth Thompson [25] studies the dynamics of the accretion of living organisms, their structure and form, relating them to the laws of mathematics and physics. He argues that the stability of living organisms is explained by the intimate relationship between forms and their equilibrium, (as the minimum potential energy of the system, guaranteed by the balance of forces).

The generation of architectural environments, real and virtual, should follow that of natural elements, whose form is always an answer to a functional problem, and turn out to be the most convenient from the point of view of energy, aimed at resource economy and minimum energy expenditure.

5. CONCLUSIONS

As far as we can progress technologically towards alternative worlds or increasingly complex and advanced virtual spaces, it is necessary to ask ourselves some questions related to how the human component integrates into these environments and what possible solutions can be used to overcome the problems of both temporal and spatial nature. The solution is in the past by bringing to light in a modern key styles, elements, and rules of the past, as well as in the nature and rules that govern it. By researching and integrating these elements within virtual environments, a different value can be given to a space that nowadays is created solely for functional and profit-seeking issues.

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3DIMENSIONAL ZOETROPE IN VIRTUAL 6 DOF ENVIRONMENT AS AN ART INSTALLATION AS WELL AS OBSERVING TOOL FOR WHAT ENHANCES PLAYERS' PSYCHOLOGICAL ENGAGEMENT

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ABSTRACT: This paper presents a 3D zoetrope Art Installation in a VR environment which brings players the unique experience of physically digging into virtual landscape inside their own animated loop. The work also aims to explore the potential of serving as a self-help tool, utilizing several interdisciplinary methods to increase the impact of media art with looping structure. One of the main goals of the work is "to provide the player with an introspective experience by evoking the link between the cyclic structure of the game and the player's personal condition." Therefore, it is important to obtain excellent player engagement in this game-style media artwork, since VR games are a tool that covers player's field of view completely with an artificial world space by using HMD. It is characterized by its ability to eliminate noise, which is already an advantage over traditional video games. In this study, we will consider adding some unique elements unique to VR in order to further increase viewer engagement in this game.

Keywords: VR Game, Zoetrope, Art Installation in VR, Self-helping tool, Experimental Animation.

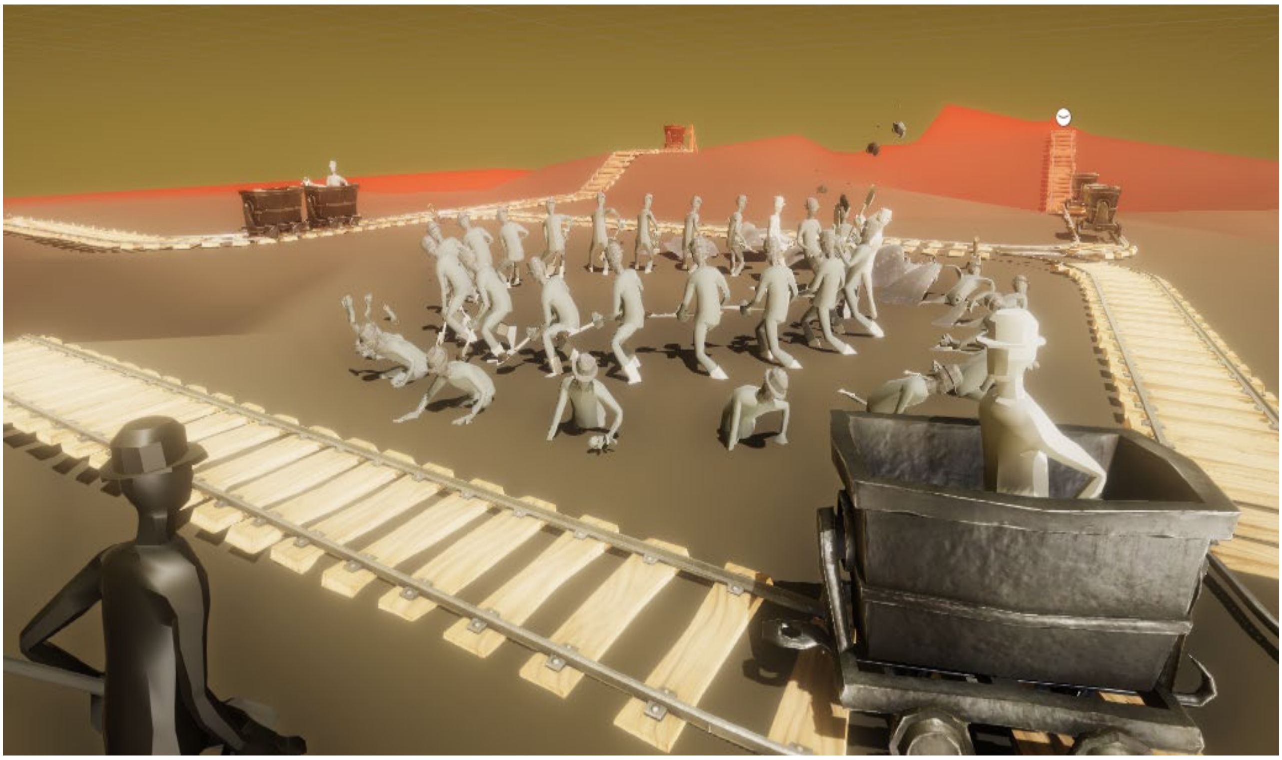

Figure 1: The 1st level of *Digging Down*

1. INTRODUCTION

As mentioned at the beginning, one of the major purposes of this work is to provide players with an introspective experience by evoking the relevance of her/his personal condition. Therefore, obtaining a good player engagement is of great importance.

In order to achieve this objective, what we thought as an effective game structure is that player keep digging a hole in various scenarios through several different environments (mining grounds, construction sites, dungeon, fairy tale scenes, dollhouses in the corner of the children's room, etc.), and execution of the action provides players a sense of progress while they move through the designed level of the game.

The key element of the piece is a sequence of 20 men who keep on digging into the ground. The hole they dig is continuously covered with the dirt which they have just dug out from the hole. It is a representation of an unproductive labor, the condition of being caught up in an unwanted loop in one's life, and the feeling of ending up as part of something that offers no easy way out.

The Zoetrope, an effective Victorian optical “toy” which was invented by British mathematician George Horner in early19th century, gives audience with no background knowledge of motion pictures an understanding of how replacement animation works.

The two VR-specific elements presented below may help increase viewer engagement. The first is "physically provided objects (3D printed Key Props)" and the second is "to exhaust the player's physical strength".

Figure 2: Physically Printed 3D Zoetrope

2. CONCEPT OF THE WORK

The work is provided in the form of approximately 5 minutes of VR game for the audience (player).

The aim here is to achieve two things at the same time: (1) High engagement for the players, and (2) A sense of irony that raises questions, "Why do I stay inside this loop which takes my energy?" Because of the eccentricity and irrelevance of the scenes (and sometimes outrageous environment), evoking questions that may followed by a dry laugh is a part of the design. The core of this game (the Zoetrope) is made up of cyclic structures that endlessly repeat the same action of digging holes in various landscapes.

While the definition of “cyclic” is to return to the same place repeatedly, in reality, the situation often gradually gets worse due to endless repetition of unfavorable acts within the cycle, literally as in the term “Negative Loop”. This game suggests with an ironic tone that, in our daily lives, even if the surrounding scenery changes, we may not adapt to the situation but continue the same behavior, putting ourselves in a disadvantageous situation.

To explain how this theme was chosen as the core of this project, we must mention another project that one of our authors (Murakami) was involved with in 2015 in California, which was basically a self-help study that consisted of members who were both ex-tobacco addicts and ongoing addicts in mental health community. [1]

It is usually known that the only individual who can break their own negative loop is oneself, and we also know that people often tend to stay where they are. Therefore, the concept of this game is based on the premise that we recognize the difficulty of breaking our own negative loop.

3. OUR APPROACH

Designing an interactive VR journey that players will find satisfying and engaging requires several considerations.

3.1 Level Design

Various scenes are provided in order to encourage the audience to go on digging. In all environments (except the final level in which players would turn into one of the 20 digging men), the player's body sinks into a hole shortly after they arrive to the new scene from the level above. During the production process, this hole is called the Rabbit Hole. Once inside, players move their controllers in a digging motion to hit the hot spots that are placed inside the lower part of the hole. The animated wall around them provides the illusion that their bodies are sliding through to another level below.

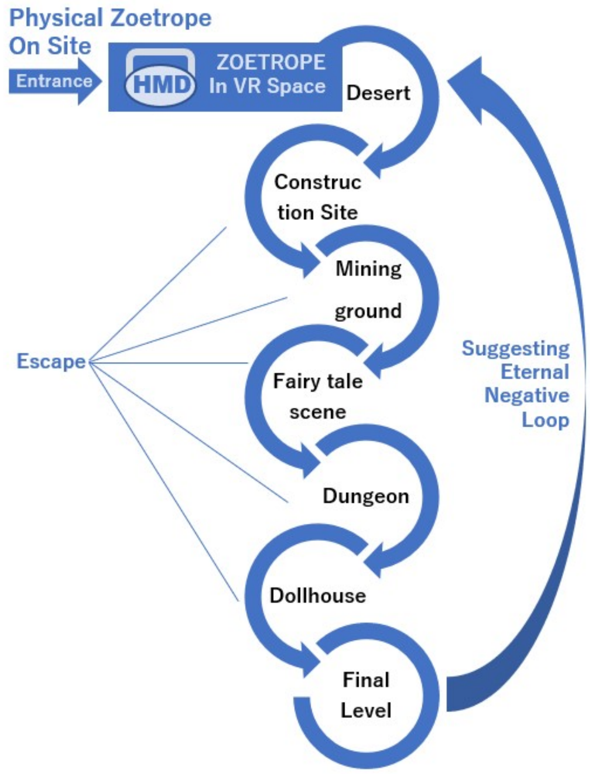

Figure 3: Game Structure

3.2 Physical Key Object on Site

At the onsite exhibition, players can see or touch a 3D printed zoetrope that looks exactly the same as the virtual one which is used as the trigger of their VR journey. This physical object can be used as a bridge between the real world and VR space [2] [3]. The 3D zoetrope (the main object in our VR space), consists of two circular layers (the outer circumference and the inner circumference), which share the same center. There are total of 40 skinny male figures (20 on each circumference). Each one of them is posed as a part of the animated frame-by-frame sequential action of endless digging. Each circumference represents (1) unproductive labor, and (2) rejection of opportunities.

3.3 Sand Animation

Cinematic lighting is applied for the purpose of establishing desirable atmosphere. In the entrance level of this project, it is controlled through traditional sand animation movie sequences that loop on transparent planes and domed ceilings (which are handled by C# script). Players would enter a 360-degree sandstorm playing inside an environment that changes endlessly between a blue and a dark sky, representing the emotional ups and downs of human experience. The rabbit hole challenge is also sand animation.

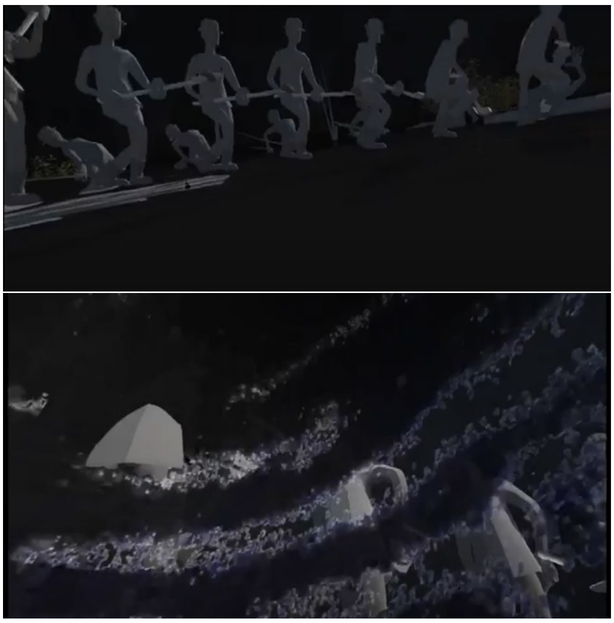

Figure 4: Traditional Sand Animation Texture

3.4 VR Implementation

We are currently implementing our VR interactive story using the Unity game engine and Oculus Rift. Although Oculus Quest 2 allows for stand-alone use, we did not employ that function in the current version.

1) The zoetrope, which consists of life-sized

male figures that appear when the world is activated, rises from the ground and begins to rotate, and when it reaches a speed that functions as an animation at 8 fps, the doll starts to move as an animation in front of the viewer. This is the imitation of the optical illusion of a flashlight and turntable in the real world. In this setup, it is implemented by C# script and automatically switches at certain point of spinning motion of the object.

2) We are also implementing two types of viewpoints ("racoon" and "hawk") in order to provide more multifaceted vantage points.
3) Although multiple viewpoints are provided, the player sees the sequence of the negative loop everywhere through every aspect in all kinds of scale.
4) The looping traditional sand animation sequences with alpha channel are handled by C# script.
5) The player has to dig up or dig down with a virtual shovel quite hard in order to progress to the next step rather than simply clicking a button on a 2D screen. Despite the substantial amount of body movement required, the game is designed so that most players will not be able to get out of the looping sequence of the zoetrope.

3.5 Body Movement

Another approach is the adoption of body movement. The player newly arrived at inside the VR space is required to spin the small 3D zoetrope by moving their hand in such a way that evokes tighter psychological engagement to with the story inside VR space. *"Embodied Cognition (EC) theory states that systems for sensing, acting and thinking are intrinsically interdependent and that human cognition is made of modality-specific representations."* This concept is based on the evolutionary principle of relationships between people and the environment. It is ideal for improving the design of VR systems based on physical interactions. An example of this theory can be seen in general human behavior, such as getting used to driving a new car and grasping the width of the car when you park the car. [4] There are also a few studies that report positive effects on cognitive functions in healthy older adults by "exergaming": "*the activity of playing video games that involve physical exertion and are thought of as a form of exercise*",[5] The exergaming example in these studies is Dance Dance Revolution (DDR).

4. 5 Evoking Empathy

Body movements were applied to other expectations based on hypotheses rather than developed theories in addition to the initial function of increasing player cognition and concentration. What we are looking for is a correlation between the amount of physical exhaustion in a VR space and the quality of the player's experience in that VR space. In other words, the point here is whether physical exhaustion can connect the player psychologically to the game space and as a result, create more empathy with the events involved in the game space.

There are a few key triggers in this VR art installation just like any other game. These triggers that players encounter along to his/her journey are supposed to require interaction. Each action in this journey is designed to require players to move their bodies instead of clicking on the targets. Furthermore, the collision detection for completing the action command is strictly set so that players need to move their bodies quite a lot.

This idea that "mild body exhaustion does good to the player" was inspired by a neuroscience study that showed positive correlation between physical training of hand movement and the recovery of brain activity.

Another inspiration is *The Theory of Cognitive Dissonance* (Festinger,1957), which proposed that *"People strive to make sense of contradictory ideas and lead lives that are, at least in their own minds, consistent and meaningful."* [6]. Our suggestion here is that "the harder a player works or invests, the more emotionally they becomes attached to the subject."

Figure 5: Motor learning using turntable tasks. [7]

Figure 6: 3D Zoetrope, the first key trigger.

If this idea is supported by further experimentation, the potential of efficient storytelling in VR should increase. For example, having an interactive relationship between players and game characters that causes players to burn more calories as they play can have an impact on the story arc and player navigation. It also might open up more possibilities in the area of self-help therapy.

4. FEED BACK

On March 2021, *Digging Down* was exhibited in as a work in progress at a small art space in Tokyo. The players at the exhibition could only play the opening and the main ending of the game in which players would fall to a deep level and become trapped inside a loop, ultimately turning into one of the 40 digging figures. We received some comments from players during these 2 days of exhibition. [8]

5. DISCUSSION

- Data on the correlation between engagement and the amount of body movement is needed. The evaluation methods also need to be determined (VR-EEG, etc).
- Consider an environment to properly experiment with and examine the effectiveness of a VR self-help tool. Where and in what community is the test appropriate?
- Consider an implementation example of physical objects (controller shape and key game element synchronization, etc.) in a VR project. How in-game objects function should depend on the content and its structure. For example, it might be beneficial to include physical copies of VR digital objects in the real world (such as diary, pencil, or amulet) as a reminder of the self-helping tool and user progress.
- Seek opinions from experts in the field as to whether there are any overlooked elements that make the tool effective as a VR self-help tool.
- Finding a good balance between aesthetics and comfortable user experience. Anything that could potentially over-intensify the experience should not be included.

6. CONCLUSIONS

We expect that our study can contribute to the development of players' psychological engagement in a variety of immersive media contents. For future work, we plan to conduct a pilot study to investigate how factors such as the provision of on-site physical objects, demanding physical activities, and VR media contribute to the player's psychological involvement in the story and artwork.

ACKNOWLEDGMENTS

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COMMENTS FROM PLAYERS

"Love the interaction, love the part that I have to spin 3D zoetrope." "Thrilled seeing the life-sized 3D zoetrope showing up from the ground as the result of spinning action." "Hard to notice that that one view was provided as raccoon. Everything happens too quick." "That's it? When it'll get done?" "I was Feeling very uncomfortable wearing HMD on top of mask, glasses, and Ninja mask." (the player quit right after wearing HDM) "Feeing less VR sick than I imagined. Please tell me why." "Feeling sick, I can't play this one." "Cool story structure that implies endless circular repetition among one player to another" "I enjoyed the uniquely intensified atmosphere. Scary". "Gaming experience is a lot more dynamic than seeing it on the 2D screen. Surrounded by figures are creepy as hell." "Pose detection system would be nice for this game." "I want to see the other ending." "I like the sand animation loop" "Low accuracy. Finish your work and I will be back"

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2. Satoshi Cho …

A METHOD FOR CONFIRMATION OF INTER-VEHICULAR DISTANCEIMPRESSIONS USING CAMERA MOVEMENT IN VR SPACE

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Abstract: When driving a vehicle, it is difficult to accurately estimate the impression one's driving gives to others. For example, when passing a bicyclist, the driver may think that he has passed the bicyclist safely, but the bicyclist may feel that they are in danger. Also, when following a vehicle ahead, the driver of the vehicle ahead may think that the distance between the vehicles is close, even though the driver of the vehicle behind thinks that the distance is appropriate. In this way, there are cases in which an action that the subject of driving thinks is appropriate is not considered appropriate from the viewpoint of others.

In order to solve this problem, we thought it was important to understand how our own actions are seen from the perspective of others. To solve this problem, we developed a method that allows the user to confirm his or her own driving behavior from another person's viewpoint using a virtual traffic space created as software. This is because we thought that confirming one's own driving behavior from another person's point of view, which is impossible in reality, would be useful for understanding the appropriateness of one's own driving behavior. In order to improve the sense of immersion, we used a head-mounted display (HMD) for the experience.

In this study, we propose the following flow of experience, which is based on the scene of driving while following a vehicle ahead(Figure 1). Experience 1: The experiencer controls the following vehicle and drives it at a normal distance (Figure 2, Figure 3). The software records the driving data at this time. Experience 2: The experiencer moves to the driver's seat of the vehicle ahead and checks the distance from the vehicle behind through the rear-view mirror(Figure 4). At this time, the software plays back the driving data recorded in Experience 1. Experience 3: The experiencer manipulates the position of the vehicle behind from the viewpoint of the vehicle ahead and places it in a position that they thinks is appropriate(Figure 5). At this time, the software records the distance between the vehicles. Experience 4: From the viewpoint of the vehicle behind, the experiencer checks the distance to the vehicle ahead. At this time, the software replays the distance recorded in Experience 3.

As a preliminary experiment, we conducted the following tests. The subjects were four university students who possessed a driver's license. The subjects experienced Experiences 1 and 2, and immediately after each experience, they rated the distance on a scale of 1 to 10(Figure 6). The results are shown in Figure 7. It was found that the distance perceived by the following vehicle in Experience 1 was different from the distance perceived by the preceding vehicle in Experience 2. In the future, we would like to conduct an experiment to confirm experiencers can reflect understanding of this difference in their own driving behavior by having them experience Experiences 1 through 4 in succession.

Keywords: VR, Inter-Vehicular Distance, HMD

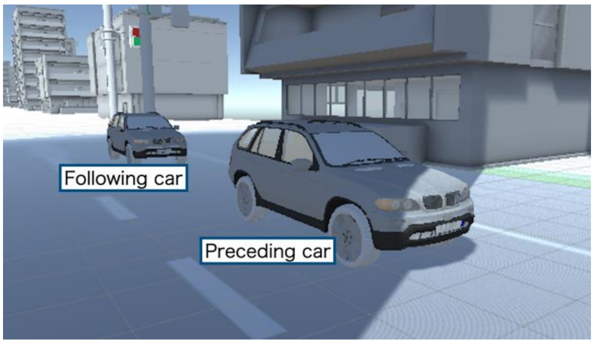

Figure 1 Virtual transportation space

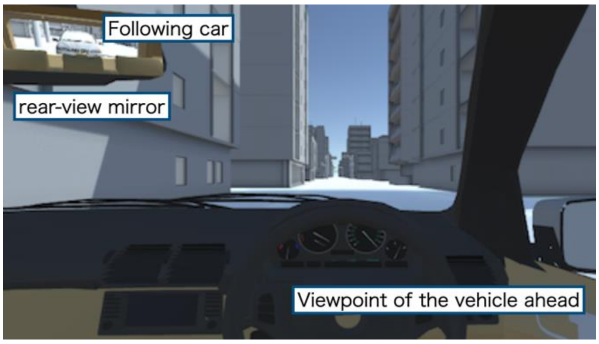

Figure 2 Viewpoint of the vehicle being followed

Figure 2 Controller operation in Experiment 1

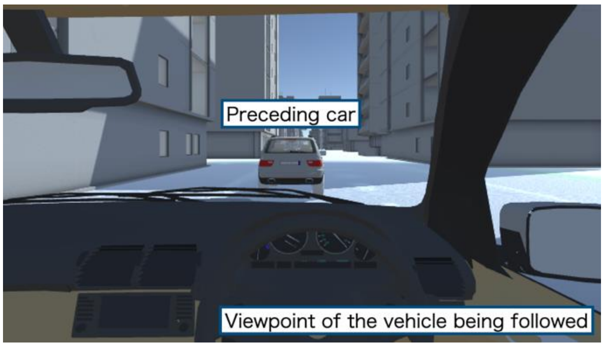

Figure 1 Viewpoint of the vehicle ahead

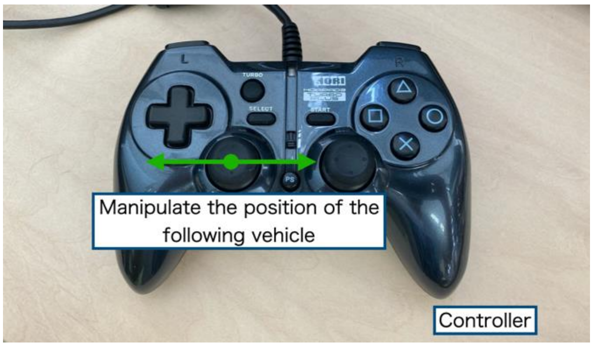

Figure 5 Controller operation in Experiment 3

Figure 6 Equipment of the subject

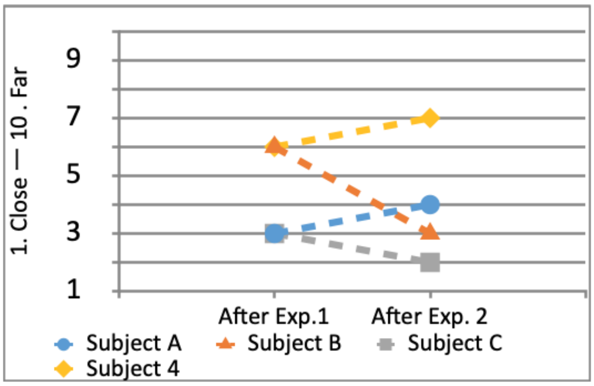

Figure 7 Change in subject's evaluation

APPLIED GRAPHICS AND GEOMETRY IN BUILDING ENGINEERING

ANALYSIS OF DEVELOPMENT OF OPEN BIM-BASED AUTOMATED RULE CHECKING SYSTEM IN KBIM PROJECT

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ABSTRACT: OpenBIM is one of the approaches to BIM which improves the availability, workability, operation, and feasibility of digital data in the AEC (Architectural, Engineering and Construction) sectors. The main objective of openBIM is to enhance the data exchange and interoperability among the users involved in the BIM modeling. The data exchange in openBIM is mostly accomplished through IFC (Industry Foundation Class), which is a neutral and open standard data exchange format. IFC facilitated the design rule checking process. Rule checking is a crucial and complex stage in which the architectural design is compared with the government-specified permit rules and legislation. These permit rules should be translated from human language to computer language for achieving automation which is a difficult task and mostly miss interpretation occurs. Moreover, there are some data losses and miss mapping of model elements when using IFC. Various approaches have been determined in many countries to prevent data loss in IFC and accurately convert the normative language into computer language and automate these processes.
Korean government has funded a R&D, KBIM (Korea BIM) project to automate the architectural design process. The KBIM project aims to magnify the productivity of architectural design by 30% of the current condition. Numerous articles have been published about the enhancement of automated rule checking and an enormous amount of literature is available for exploring the automated rule checking development in Korea.
In this article, the authors intend to give an insight into the development of ARC (**automated rule checking)** by the KBIM Project in Korea through literature analysis. Automation for reducing the IFC data loss and improving the rule interpretation has been explored. Various article related to automated rule checking are reviewed and the framework and different application technologies mentioned in these articles have been given a sequence and layout. This framework shows the rule compliance checking system developed in Korea and provide detailed information about various stages of rule checking system. It was noticed that many intellectual KBIM applications have been developed through which a rule compliance system is built. This study will help understand the flow of e-submission and rule checking system in Korea which will be effective in adopting openBIM rule checking in the construction industry.

Keywords: OpenBIM, automated rule checking, IFC, KBIM, architectural design.

1. INTRODUCTION

Automation is one of the important factors in the current periods of construction industries. With the rise of automation technologies various industries have attained technical advances to enhance their work and business process. Construction industry is also striving to enhance its quality, productivity, collaboration, and innovation. Construction industries are using Building information modelling (BIM) as technology to facilitate the process of information and data exchange and communication during the project life by interchanging, integrating, and reusing of BIM data throughout the building lifecycle [1].

Utilization of BIM technology in quantitative ways has been increasing rapidly in the AEC industries. Architectural design information is managed, and its compliance is checked throughout the life cycle in AECO (Architecture, Engineering, Construction and Operation) domain which effect various aspects justified by codes and standards [2].

Automated compliance checking is also referred as automate rule checking which is a process of verifying the design according to the building laws and legislations. Figure 1 shows a typical process of automated compliance checking.

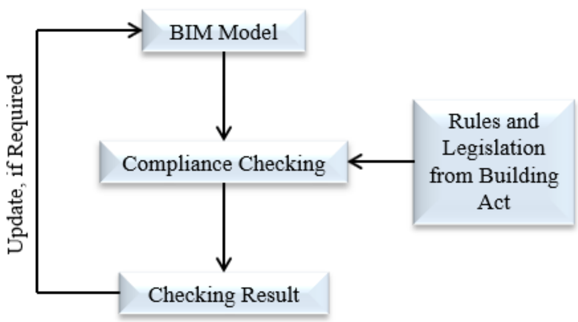

Figure 1: Typical building rule compliance System

Regulation checks can reduce the design error, duration, and incompetent use of human resources. Researchers from various countries are working on developing and adopting the automated rule checking process. The construction sectors are mostly focused on developing automated rule checking process based on openBIM [3]. Most of the developed countries are becoming aware of the BIM importance and working on reviewing different BIM application but still BIM processes are lacking some unified standards, which leads to ineffective use of BIM technology. Many countries have started use of BIM in stepwise manner and developed BIM related laws and policies. Since 2015, Singapore has mandated that BIM modelling will be required for proposed buildings having area greater than 5000m^2 [4] and Korea made the use of BIM mandatory in all public sector projects since 2024 and full BIM implementation from 2030 [5]. Even after such policies, the e-submission and rule checking process are still based on 2D drawings, and the BIM model is used for reference only and there are still needs of developing a process for rule checking using 3D model. For achieving this goal, Korean government had funded a R&D project for creating automated rule checking system based on openBIM.

The main objectives of this article are to give insight into the Korean automated rule compliance system by exploring the various application technology which are utilized by both the users and authoring personal for quality and rule checking of architectural design in compliance process and to present layout for the use of all the KBIM application technology. For reviewing the rule checking system, the application and process developed since the beginning of KBIM will be explored.

The article is divided into the following sections. Section 1 provides the basic introduction to the automatic code checking, section 2 gives overview of the current code checking systems around the world, section 3 provides detailed discussion on Korean automatic rule checking system, in section 4 and 5 smart work technology and AI (artificial intelligence) utilization is briefly analyzed correspondingly, and in section 6, the author summarizes the article and give conclusions at the end.

2. EXISTING AUTOMATIC RULE CHECKING SYSTEM AROUND THE WORLD

2.1.ARC prior to openBIM

Research on the idea of automated rule checking is active for more than half a century, where the first successful implementation of automated rule checking systems such as SICAD, SASE and SPEX occur which perform compliance check based on the specification of the AISC (American institute of steel construction) and serve its purpose well in 1980s. [6]. These systems were based on the earliest possible normative provision representation in the decision table formulation by Fenves [7]. These processes were the cases of pre-openBIM era in which the automated rule checking system were mostly associated with the information exchange ability [8]. During this period, only few researchers worked on normative approach representation [9].

2.2.ARC based on openBIM

In 1994, the idea of IFC came into being [10] by which the process of building information exchange has been improved. Later, the IFC is presented as openBIM approach with which the opportunities for rule compliance checking are opened [11]. Based on openBIM approach, the development of the automated rule checking started around the globe. Singapore and Australia were the first countries who started the development of automated rule checking and e-submission systems [12-13]. Beside these countries many other countries have worked on developing automated rule checking systems. ARC systems in various countries are discussed in the following sub sections.

2.2.1. Singapore

In September 2000, Singapore was the earliest country to officially implement CORENET (Construction and Real Estate Network) which is object-based and automated rule compliance system-based system [14]. It consists of e-submission, e-PlanCheck and e-info. E-PlanCheck is compliance system based on FORNAX which is developed by novaCITYNETS and beside other features it can be used for compliance checking [15]. E-submission system is internet-based platform where 2D plans and other related documents of a project are submitted for its review based on the guidelines of the Singapore government. E-info a repository where various rules, laws and regulations are published by different regulatory agencies in Singapore [16].

2.2.2. Norway

Byggsok, a public system in Norway for providing building and zoning services, it consists of two separate systems for e-submission of building application and zoning proposal and an information system [17]. The Byggsok system is based on IFC because of its supporting organization, standard Norway and Norwegian buildingsmart, and building and construction industry.

2.2.3. Australia

In 2006, Australian research organizations have initiated DesignCheck Project. The project was processed in two stages. In the first stage, application technology for compliance checking around the word is analyzed to check which technology fits best with the Australian standards. In the second stage, DesignCheck system was developed [18]. DesignCheck has a rule schema for initial and final detailed design phases as well as for specification, so it has the benefit of facilitating the checking ability for compliance at various stages during the design process. It is therefore mostly used by architects and designer and not by building control certifies. Moreover, the design check still generates reports in text form and does not have the functionality of 3D models [19].

2.2.4. United States

The SMARTcodes project in the USA introduced semantic representation as part of its work on codifying the International Code Council (ICC) code. Using an ontology and web-based interface, users select written rules and the SMARTcodes builder identifies key phrases and their logical role. It, then, formalizes the phrase using terms from a dictionary of properties. The SMARTcodes are modeled based an approach called RASE (Requirement, Applicability, Selection, Exception). A building code rules is composed of: Requirement (the conditions that must be satisfied by one or more features in the building); Applicability (which aspect of the building the requirements apply to); Selection (instantiation of the rule to a specified cases among applicable elements); Exception (where the check is not required/applicable) [20].

2.3.Summary

The review of rule checking systems shows that many countries are making effort in developing their ARC system and adopting to the policy of BIM. Scholars have performed various research related to technology for ARC and theoretically solved different issues during the checking system such as issue of data quality assurance, regulatory information extraction etc. However, to implement BIM in actual building administration system, a systematic framework and supporting application technology are required. Various application technologies and framework of ARC system developed in KBIM project are discussed in the subsequent sections.

3. AUTOMATED RULE CHECKING SYSTEM IN KOREA

In 2013, Korean government lunched a project related to the automation of architectural design in which one of the automation aspects was automated rule checking system. Since then, various researcher and development sectors have performed research and innovations to develop a framework and application technology for proposed ARC system. The framework for e-submission and legality assessment system is show in Figure 2.

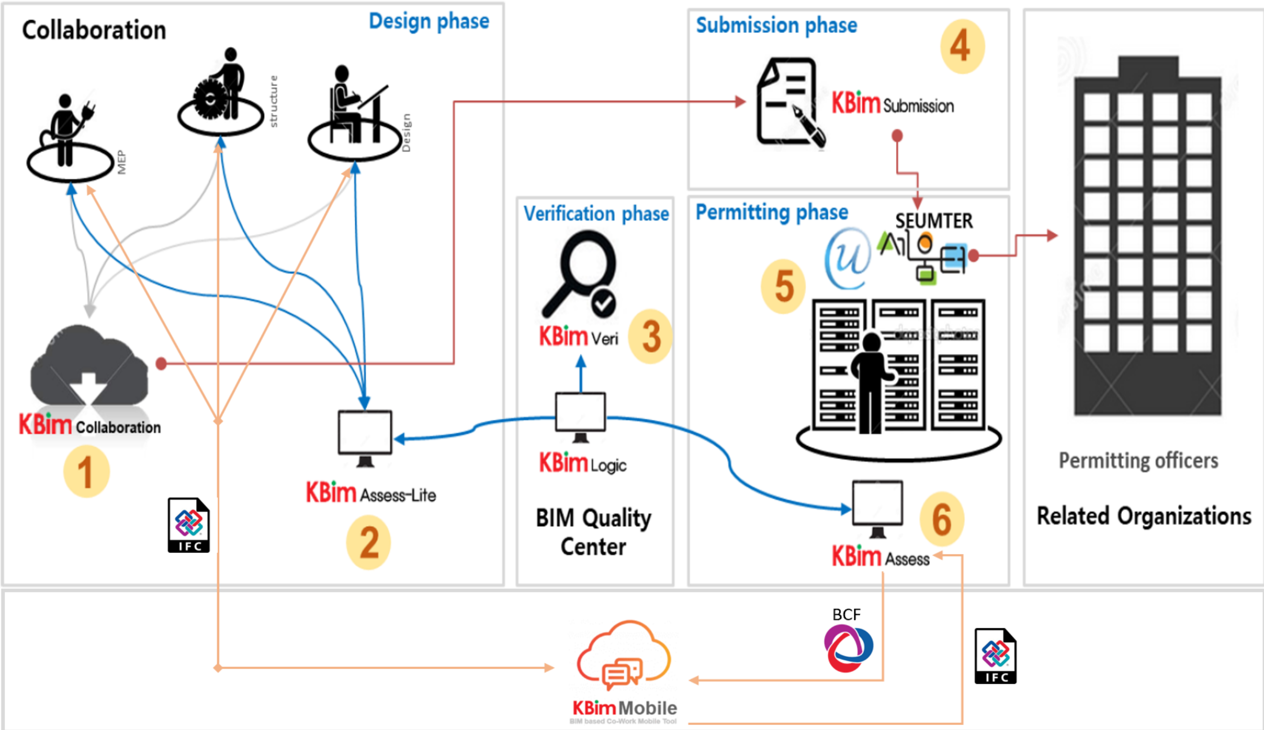

Figure 2: OpenBIM based e-submission and legality review system [21].

3.1.Design Phase

In the design phase, BIM model of the proposed building or structure is created by a group of users such as MEP (Mechanical, Electrical, and Plumbing) engineers, architects, designer etc. all the users communicate through the KBIM Collaboration software and create an integrated BIM model. To precheck the compliance of the BIM model with rules and legislations, KBIM Assess-Lite is used by all the user to check their corresponding rules. The users also use KBIM D-Generator to create 2D drawings of the architectural design which can be submitted with the model during submission phase. As this ARC system is based on open BIM so the BIM model is converted into IFC data exchange format before it is forward to the BIM Quality Center. The functionality and development of the KBIM application which are used in design phase are discussed in the subsequent section.

3.1.1. KBIM Collaboration

KBIM Collaboration is openBIM based platform for data storage and exchange among different stakeholders. The main features of this application are to collaboration of design activities and management of work history, BIM model creation history, Request for Information (RFIs), and history of any type of issues faced during design. This application also interacts with the submission phase to provide any required details about the design [22]. With the help of KBIM Collaboration, project stakeholders can easily work on various BIM application which are based on openBIM and support IFC (Industry Foundation Class) and BCF (BIM Collaboration Format) [23].

3.1.2. KBIM Assess-Lite

KBIM Assess-lite is an open access version of KBIM Asses which is used by user group (Stakeholders) in the design phase for automatic self-checking of architectural design compliance. It works as rule-based quality checking technology for IFC-based BIM model [24]. It helps the user in the design phase to check the quality of their model before submission for approval by authorities. The result is displayed in 3D graphics with text description of the corresponding building clauses from the Building Act. The result and its review report can be published in Excel or .pdf file. Figure 3 shows the self-checking process using KBIM Assess-Lite.

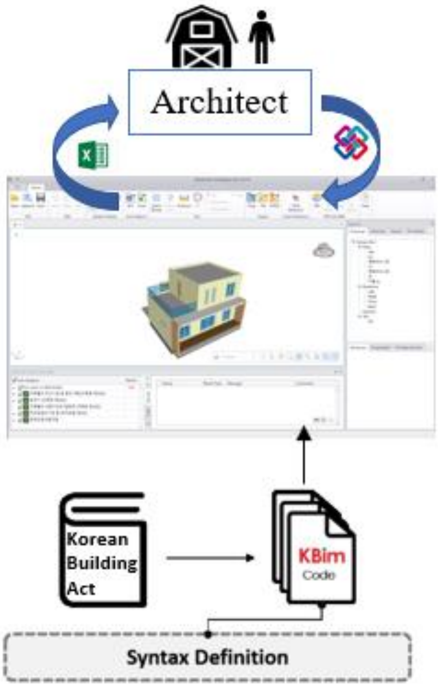

Figure 3: Self-checking process in KBIM Assess-Lite

3.1.3. KBIM D-Generator

The KBIM D-Generator application is used for automatically generating the building permit submission documents such as 2D drawings which includes plans, sections, and elevations. The drawings are generated directly from IFC BIM model. The 2D drawings are connected to the 3D model and can be viewed together. Different information can be accessed in 3D model from the 2D drawings and vice versa. Figure 4 shows the automatic 2D drawings creation form IFC file by KBIM D-Generator.

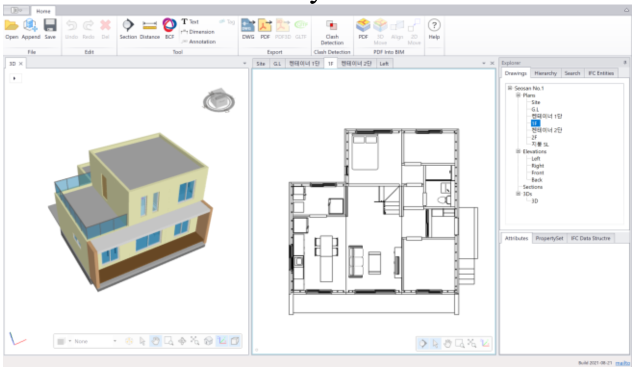

Figure 4: Automatic 2D drawings generation from IFC file

3.2. Verification Phase

As BIM models are created manually, there is highly chances of error or elements which are in non-compliance with the guidelines. Moreover, the IFC model should also provide attributes, naming and other necessary information for performing automated rule checking. Inaccurate data will result in inaccurate check. So, prior to submitting IFC model to the authoring personals for building permitting, the quality of BIM model is verified in the BIM Quality Center via KBIM Veri.

3.2.1. KBIM Veri

KBIM Veri is the main technology for checking the quality of IFC based BIM Model. The IFC file is submitted to the quality center by the user where the KBIM Veri pre-check the model against the modelling guidelines to determine whether all the necessary information is included in the IFC file. If the model passes the prechecking then a verification certificate will be provided from the quality center otherwise a report is generated which contain various errors in the model. The report can be used as a reference by the user to update the BIM model and resubmit it to the quality center until prechecking process is passed [25].

3.2.2. KBIM Logic and KBIM Code

The KBIM Logic application is a management system based on logic rules which digitalize the national building regulations and rules of Korean government from natural language to computer executable rules set (KBIM code) [26]. It consists of Meta Database based on logic rules, authoring tools corresponding to KBIM code, and system and KBIM code data bases and, detailed management tools. The logic rules based meta database classify the regulatory specific elements and attributes, sentences relations. Using the logic rule-based process, the KBIM code authoring tools approach the meta database for the creation and management of KBIM code.

KBIM code is transitional script language for Korean building rules sentences which can be reused and implemented as per Korean Building Act. The KBIM code is managed by KBIM logic, and it is used in KBIM Assess and KBIM Assess-Lite for compliance checking.

3.3.Submission Phase

The BIM model which passes the prechecking process in the quality center must be submitted for obtaining permit. The submission process can be carried out using KBIM submission application which extract the required data form the IFC-based BIM model. The data extracted is then used for obtaining building permit in the permitting stage.

3.3.1. KBIM Submission

To directly extract the data from BIM model upload to the application, KBIM submission interface with SEUMTER for extracting the necessary data for building permitting process. This data extraction helps in increasing the overall efficiency and decrease the administrative work. The KBIM submission facilitate the management of permitting information such as building agreement, documents, permitting documents and building model. The process from design to submission is easily managed via KBIM submission using IFC model. The KBIM submission and SEUMTER contain the same building data files that is why it act as information management application for building permit. The KBIM submission can also connect with KBIM Collaboration to get the required data and due to highly automated features of this application it can be used to manage data from design stage to submission stage. The extracted data from this application can be exported to XML file and can be submitted to SEUMTER [27]. Figure 5 shows the working flow for e-submission using KBIM Submission.

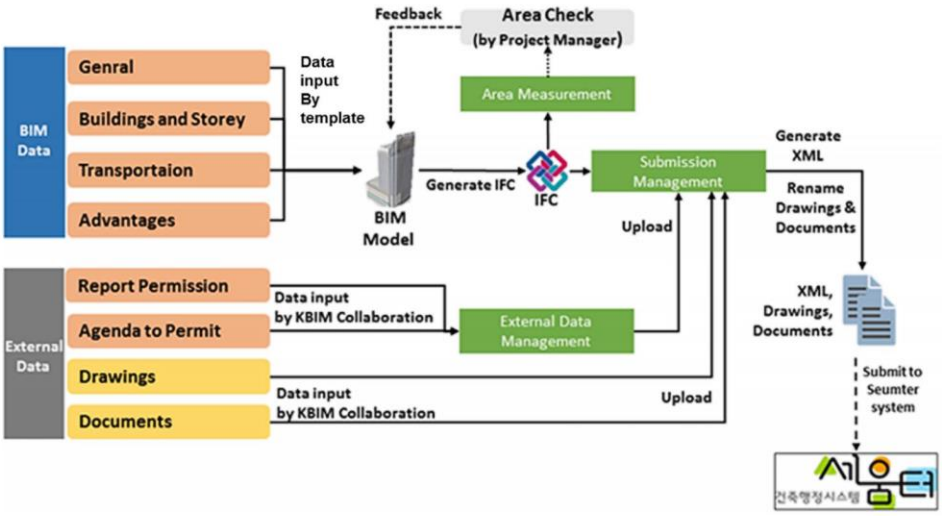

Figure 5: KBIM e-Submission working system [27]

3.4.Permitting Phase

This is the last stage of Korean automated compliance system; In this phase the authoring personals check the submitted IFC files against the laws and legislations of the Korean Building Act. If the any change is required after the checking, then report is sent back to the users for update. The authoring personal in this phase is SEUMTER (Korean Building Permission System). KBIM Assess is used for the final compliance check of the IFC model. KBIM Assess has the same functionality as KBIM Assess-Lite, but the difference is that the prior one is available for SEUMTER personals only and its performance depends on the SEUMTER system. It only checks model from SEUMTER and get the result back to the SEUMTER system while KBIM Assess-Lite is public access application and work as standalone software. In KBIM Assess only those IFC files are checked which are provided by SEUMTER. The permitting phase is shown in figure 6.

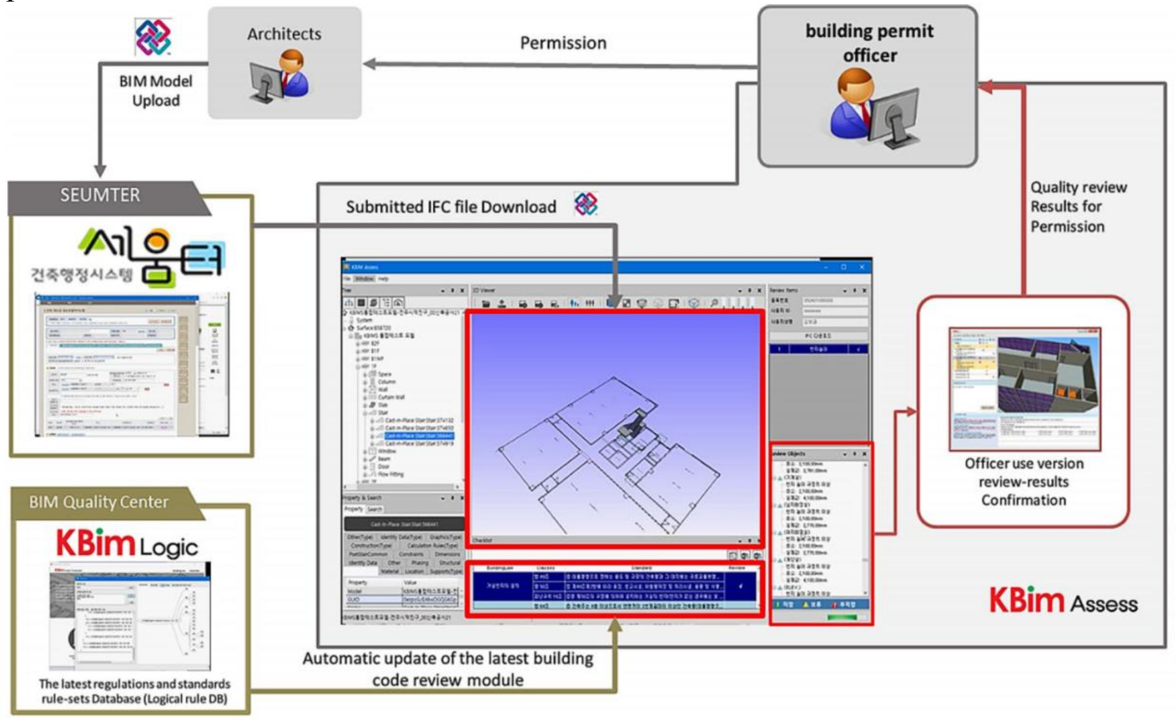

Figure 6: Use of KBIM Assess in permitting stage [28]

3.5.Construction Stage

Once a project passed the design evaluation process and then the final BIM Model is used for the realization of the project. During construction of the project, an evaluation and management tool is required which can confirm the construction quality with respect to the BIM model. Therefore, in KBIM project site supervision application technology KBIM CS Assist is currently in the development stage which will improve the construction quality and help in reducing any errors in construction.

3.5.1. KBIM CS Assist

KBIM CS Assist is site supervision and construction administration application based on openBIM. It facilitates the site quality control procedures by the comparison of real time 3D view with onsite construction. It is developed for both Mobile and PC. When a construction error occurs, a picture of the error is taken, and it is mapped with relevant element in the 3D Model using the BIM viewer functionality of KBIM CS Asses Mobile version. All the mapped photos are stored in the field photo collection and then an NCR (Non-Conformance report) can be generated by selecting those pictures. The location information of the error is generated automatically as per the mapped BIM model. The report can then be extracted into .pdf file.

Figure 7 provides the workflow for KBIM CS Assess lite.

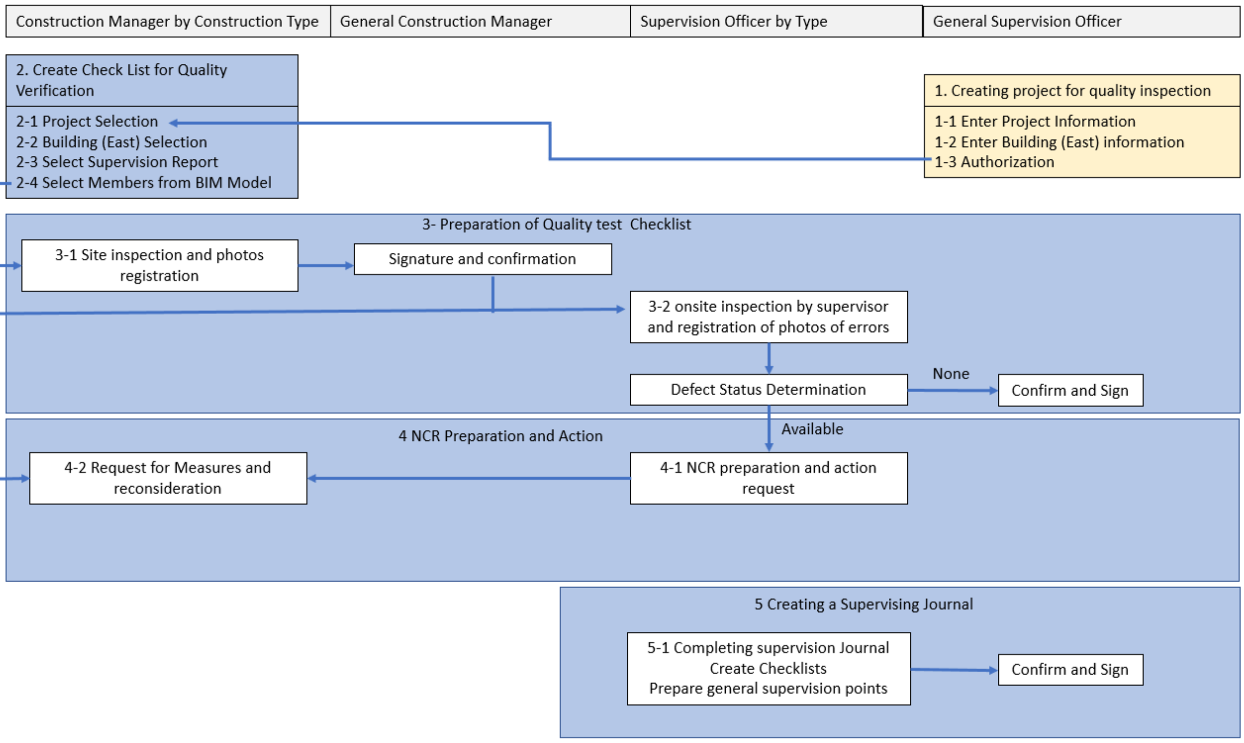

Figure 7: Workflow for KBIM CS Asses (Mobile Part, PC Part).

4. SMART WORK TECHNOLOGY FOR BUILDING RULE COMPLIANCE CHECKING

The Application technology developed for the compliance checking are mostly on pc platform and which sometimes causes the problem of accessibility to some users. So, there was a need for smart work technology for building rule compliance system which is easily accessible and have similar functionality as that of other application technology. KBIM Mobile is developed during the KBIM project which perform the function of smart work technology.

4.1.1. KBIM Mobile

KBIM Mobile is an application technology for mobile users which perform various compliance checking related task such as BIM model review, BIM model error sharing, project collaboration and communication platform. It is based on openBIM and use IFC file for performing its various functionality. It is also used as a messenger application in which different stockholders can communicate with each other and discuss any issues or confusion about the IFC model. The IFC model can be viewed in synchronization by different users in the KBIM Mobile which gives better understanding of IFC model. Moreover, KBIM Mobile can be used as a data exchange pathway with KBIM Assess.

5. MACHINE LEARNING UTILIZATION IN KOREAN ARC SYSTEM:

During performing the automated rule checking, researcher from various countries noticed that there is inconsistency between the BIM elements and their corresponding IFC entity. Many researchers tackle some of this problem by using formulation of rules sets based on topology and semantics of BIM element [29]. However, not all the issues can be solved by these methods. So, machine learning has been utilized to solve such issue during compliance process.

5.1. Use of Machine Learning in KBIM Assess-Lite API

Inconsistency in IFC entity mapping is noticed in Korean compliance system when some of the BIM element does not align with the standards and rules during KBIM Assess and KBIM Assess-Lite checking. To solve this issue a deep learning approach has been developed in which MVCNN (Multi-View Convolutional Neural Network) and PointNet were trained and utilized for classifying various infrastructure elements [30].

A Machine learning-based BIM object auto-recognition programs is developed for BIM-based legal and design quality reviews and IFC classification consistency verification. MVCNN and SVM (Support Vector Machine) algorithms were used which will be incorporated in the KBIM Assess-lite to improve the code compliance checking system as shown in figure 8.

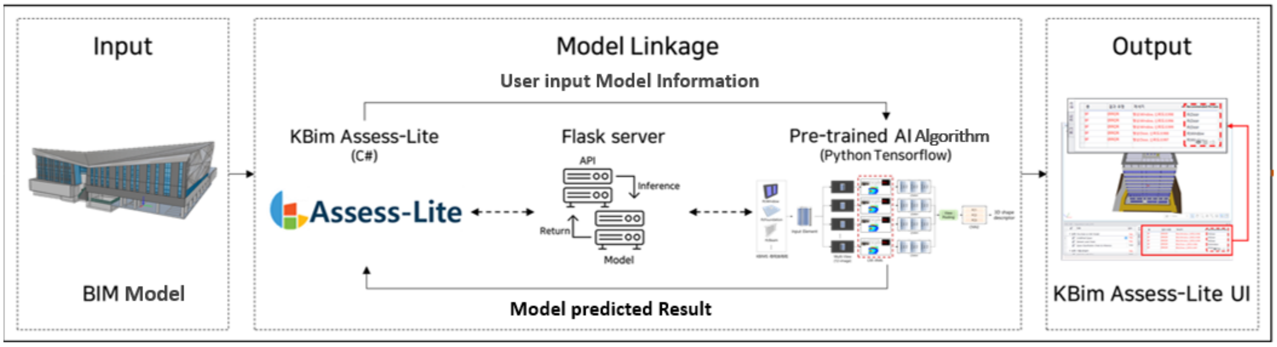

Figure 8: AI algorithms incorporation in KBIM Assess-Lite API

6. CONCLUSION

This article presents a comprehensive analysis of the automated rule checking system in Korea. The compliance system framework and different application technologies are discussed in this article. Compared to other countries, Korean rule checking system has many application technologies which are used at different stages in the compliance system to ensure best quality control of the BIM model. Also, in Korean compliance system, the BIM model is checked more than which facilitate the rule checking system and leads towards the better architectural design.

This article concludes that using the application technology and automated rule checking system, the errors in the design can be reduced by high ratio and the time for checking the quality can be reduced. Improving the quality and reducing the time will reduce the total cost of the compliance checking system. Moreover, the data extraction can now be carried out in less time with higher accuracy.

The Korean compliance checking system also provide extra functionality for construction quality control using mobile and PC platforms. In addition, machine learning algorithms have been utilized to improve the compliance checking result and to tackle the issues of element miss mapping. From all the above conclusion, Korean building rule compliance system is more advanced and automated than other countries systems and once it is implemented it can improve the AEC sectors in many aspects.

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HOW DOES GAZE BEHAVIOR OF HAZARD RECOGNITION IN AN IVR ENVIRONMENT RELATE TO SITUATIONAL AWARENESS? AN EXPERIMENTAL STUDY USING EYE-TRACKING TECHNOLOGY

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ABSTRACT: A construction site is a complex place with many unpredictable hazards. Previous studies have shown that many accidents were caused by individuals' low situational awareness (SA) thus fail to recognize the hazards. To alleviate relevant accidents, understanding the relationship between hazard recognition and individual SA is important. Eye-tracking technology uses eye-movement data to objectively capture one's cognitive response to the environment. Against this background, this study aimed to develop an Immersive Virtual Reality (IVR) hazard identification environment to investigate how gaze behavior is related to different levels of SA by analyzing the data of gaze traveling, fixation duration, and scan strategy. The results indicated that gaze traveling, and fixation duration are strongly related to Level 1 and Level 2 SA. The first stable gaze traveling behavior may be on behalf of Level 1, and fluctuated gaze traveling behavior may be affected by the complexity of the environment, resulting in the longer time of Level 2. Shorter fixation duration may indicate relatively obvious hazards that may be identified without experience, which to some extent represent shorter Level 1 and Level 2 processes. Scan strategy affects the total time of hazard recognition, inevitably affecting Level 1 and Level 2 due to the process of time. Insights into the relationship between gaze behavior and SA provide a solid basis for a deeper understanding of individual safety behaviors.

Keywords: Situation awareness; Gaze behavior; Hazard recognition; Eye-tracking technology; Safety.

1. INTRODUCTION

The construction site is a dynamic and complicated environment with unpredictable hazards and thus has been recognized as one of the most hazardous working conditions globally [1]. Even though eliminating potential hazards at construction sites is important, it is also critical to enhance the ability of construction personnel to recognize unforeseen hazards at the dynamically changing and unstructured construction environment [2]. Previous study have reported that lots of construction accidents are associated with poor hazard recognition by construction workers and providing appropriate training to enhance hazard identification ability would be essential to prevent construction accidents [3].

One of the systematic approaches to investigating hazard identification ability is a situational awareness (SA) model proposed by Endsley [4]. SA is generally defined as the up-to-the-minute awareness required to move about and operate equipment to maintain a system by involving psychological, perceptual, and cognitive processes [5]. In a safety science domain, the concept of SA has been widely used to investigate three cognitive processes of SA – perceiving the environment (Level 1), identifying potential risks in the environment (Level 2), and predicting the consequence of hazards for decision making (Level 3) [6]. Previous research efforts have applied Endsley's SA model to investigate safety behaviors in various domains such as construction [7], traffic [8], and aviation [9].

In the construction domain, Choi et al. [10] investigated the SA construction equipment operators to understand the factors that would affect their SA.

Despite the utility of the SA model to understand one's ability for hazard identification, the current methods of measuring SA have been criticized. One of the well-established methods of measuring SA is SAGAT [11]. Although it provides a comprehensive measure of SA, it still uses recall and questionnaires [11]. Recently, to tackle the limitation of subjective survey-based methods, objective measures of capturing one's cognitive response to the environment, such as brain signals [12] or eye movement, are gaining attention [13, 14]. Eye-tracking has shown its potential to understand hazard search behavior, as gaze movements and fixation obtained from an eye-tracker are associated with hazard identification [3]. However, it could not directly used to measure SA, as previous studies focused on perception only relevant to Level 1 SA.

This paper examines the possibility of using eye-tracking technology to measure different processes of SA, aiming to understand the hazard recognition ability of construction workers. And we investigated the hypothesis that gaze behavior shows significant differences between perception (Level 1) and comprehension (Level 2) when recognizing any potential hazards. To validate this hypothesis, we conducted an experiment in which participants were asked to identify any potential hazards in a virtually simulated construction environment and collected their eye-tracking data using HTC VIVE Pro EYE. Based on our results, we discuss the potential of measuring eye-tracking data to objectively understand one's different SA levels, and the implication of VR-based eye-tracking for construction safety studies and training.

2. LITERATURE REVIEW

2.1 Hazard recognition and SA

The construction industry suffers from a high rate of fatality globally [15, 16]. Research indicates that these poor safety performances of individuals are related to low levels of hazard recognition and project management [17]. For example, Perlman et al. [18] has elucidated that worker were unable to identify more than more than half the hazards at the construction site. When workers are exposed to a dynamic and dangerous construction environment, they need to first perceive the properties and states of objects within the environment, then comprehend whether the objects surrounding them are hazardous based on the perceived information and their experience and memory. Finally, they should make proper decisions to mitigate or avoid the hazards from further development. When individuals fail in any of the above cognitive procedures, it suggests that they are unable to identify hazards, demonstrates that the safety management programs are unsuccessful, and suggests that these individuals are more likely to encounter dangerous situations and suffer catastrophic injuries [13, 19].

Successful hazard recognition can be considered if there is sufficient perception, comprehension, and projection of the elements in the environment corresponding to the three levels of the SA model [20, 21]. According to Endsley's model, SA is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and a projection of their status in the near future [4]. Therefore, SA problems refer to situations wherein workers are unable to perceive and identify hazards that may result in unsafe behaviors and lead to accidents [9, 22]. In addition, these high levels of high-risk perception skills and cognitive ability represent good SA when encountering a variety of hazards [7]. Moreover, SA has been proven to successfully reflect crane workers' perception of safety risks during actual lifting operations [7]. Thus, it is important to always hold a good state of SA regardless of the construction environment.

2.2 SA and eye-tracking technology

Traditional safety training methods play a limited role in deeply exploring why construction workers cannot successfully identify hazards from a cognitive aspect [23]. While SAGAT is a reliable way to measure SA, previous studies have suggested that direct measurement of human cognitive activities is not easy, as they are mostly implicit [24]. Technology such as virtual reality (VR) [25], augmented reality (AR) [26], electroencephalogram (EEG) [12], and eye-tracking [13, 14], have been utilized to better understand the cognitive process and physiological behaviors of individuals during hazard perception tasks. Studies [27] have found that eye movement is a powerful predictor of user attention allocation, and it is often used as a non-invasive and indirect measure of cognitive activity [27]. Accordingly, eye-tracking is a highly informative method of observation when a high visual workload in a construction environment is indispensable [28]. It provides real-time eye movements data of individuals when they are searching for hazards in the construction site [29] or an immersive VR environment [12]. Eye-tracking is widely applied in studies on hazard recognition, which is tightly associated with SA [8]. For example, for Level 1, Zeuwts et al. [30] used eye-tracking to explore the time of initial hazard recognition. Habibnezhad et al. [31] found that workers with a higher SA recognized hazards more quickly and had shorter fixation times than did people with a lower SA (Level 2). Likewise, experienced workers can better balance their time between gazing at hazardous places and searching other scenes (Level 3) [32]. However, even though some researchers have adopted eye-tracking technology to measure construction SA [3], there is few research about using of eye-tracking data for hierarchical analysis of SA.

2.3 The importance of understanding each level of SA

A lack of or weak SA is a common reason showed in accident reports [33]. It is helpful to understand the cause of cognitive failures in hazard recognition by applying this SA model to the cognitive process of individuals. However, the proportion of errors varies at each level of SA. Jones and Endsley [9] classified 143 aviation accidents according to the model of SA and tracked the causes of the accidents according to each level. For example, flight crew and air traffic controllers made the largest percentage of errors at Level 1 (77.4% and 72.4%, respectively). At Level 2, the flight crew made 21.1% of the errors, while controls made 17.2%, and at Level 3, they made 1.5% and 10.4%, respectively. Different people have different proportions of errors at different SA levels when dealing with the same potentially dangerous situation. Furthermore, each level of SA can represent different reasons. At Level 1, there may be failure to observe or monitor data; at Level 2, there may be a lack of or an incomplete mental model; at Level 3, there may be over-projection of current trends. However, previous studies focused more on Level 1 perception without attempting to delve into the SA model and explore the causes corresponding to each level [13, 31]. As SA plays an important role in risky conditions, it is crucial to understand that different SA levels can influence an individual's behaviors and alleviate or mitigate accident rates by promoting efficient training plans for maintaining good SA.

2.4 Gaze behavior and visual scan pattern

To some extent, the process of danger identification is a visual search task [34]. Analyzing eye-tracking data can provide relevant information on visual allocation and visual alternation. A previous study showed that gaze behavior is a pivotal factor during this search procedure [35]. This is because visual allocation (e.g., eye fixation location) indicates the focal point of a person's attention, whereas visual alternation (e.g., eye fixation duration) indicates the degree of cognitive difficulty [35]. Eye-tracking technology has been used to capture visual search patterns of construction workers during hazard identification experiments [36]. For example. Dzeng et al. [3] compared the scan patterns of experienced and novice workers, and Xu et al. [37] compared the searching strategies of successful and failed participants; both showed that experienced and successful participants have clear and similar hazard-searching patterns. Jeelani et al. [13] demonstrated a positive correlation between searching time in the workplace and the number of hazards identified. Workers who were highly centralized with more fixations and a longer fixation duration performed better than did workers who had dispersed and broad visual searching areas. In addition, McCurry et al. [38] concluded that fixation location and visual scanning are critical elements to operator SA by investigating the visual scanning behavior on relevant event cues without damaging the uninhabited aerial vehicle in such tasks. Meanwhile, Moore et al. [39] found that the percentage of time fixating on an area of interest was a good indicator for the current and future SA scores in an air traffic control task. Understanding the relationship between gaze behavior and SA is of great significance for determining effective hazard identification, as it provides useful practical insight into hazard identification strategies of construction projects.

3. METHOD

To investigate whether there is an innate relationship between gaze behavior and the level of SA, we prepared an immersive VR model with various hazards for this study. Since it was impossible to present all hazards in one IVR model, we created eight hazards that were identified to be the common hazard types at construction sites (Table 1). Among these eight hazards, four were with significant features (e.g., suspended in mid-air), and the others were associated with some safety rules (e.g., the pedestrian system should be separated from the vehicle system). Five participants were recruited from the Faculty of Civil and Environment in Hong Kong Polytechnic University and were asked to identify potential hazards based on their understanding. A head-mounted display (HMD) with eye-tracking technology was used to record the individual's gaze behavior (e.g., fixation location, fixation time, scan behavior, and scan path). The accuracy of identification and time taken were recorded for further analysis.

Table 1: Hazards present in the IVR model.

Hazard type	**Status**
Ladder	Suspended in mid-air.
Scaffolding Planks	Sparse distribution on the scaffold.
Handrail	Scaffolding has no railings.
Paint Worker	Close to the edge; no safety line.
Forklift	Random parking.
Oil Drums	Topple over; near the welder.
Pallet	Piled high; a danger of falling.
Garbage	Stacked in the working area.

3.1 Apparatus

To run the VR model smoothly, a high processing computer is needed. The computer used in this experiment had the specification of Intel(R) Core (TM) i7-10700 CPU @ 2.90GHz, RAM 32.0 GB, 64-bit operating system, NVIDIA GeForce RTX 2060 Graphic Card. An HMD (HTC VIVE Pro Eye) with a screen of Dual OLED 3.5" diagonal and a resolution of 1440 × 1600 pixels per eye (2880 × 1600 pixels combined) was connected to the desktop to display the VR model. The function of recording eye movement was offered by the HMD itself at a gaze data output frequency of 120 Hz and an accuracy of 0.5–1.1 degrees of the visual arc.

3.2 Participants

Five participants, with an average age of 26.5 years, were recruited as paid volunteers from the Department of Building and Real Estate. All participants had some VR experience with games or experiments and had normal vision (including visual correction). Their emotion was normal before the experiment, and they reported barely feeling dizzy during the VR experiment. All participants signed a consent form before the experiment and received a 50 HKD coupon as a reward.

3.3 Procedure

Each subject was invited to the laboratory to participate in the experiment. Firstly, we introduced how to wear the HMD and how it worked with the VR model. The HMD performed the eye movement calibration process before the experiment. The participants were then told to tell the experimenter as soon as they identified any potential hazards in the IVR environment. There was no time limit for the participants to identify all the hazards. They were required to report the hazards one by one, and the experimenters did not interfere in their risk-searching approach (i.e., they could follow their will to search some areas and report the hazards or search the whole area and then report the hazards). The hazard-identification process inside the VR environment with eye-tracking data was automatically recorded by the HMD. The experimenter used a cell phone to record the entire session, specifically what the participants said during the session, to help with subsequent data analysis.

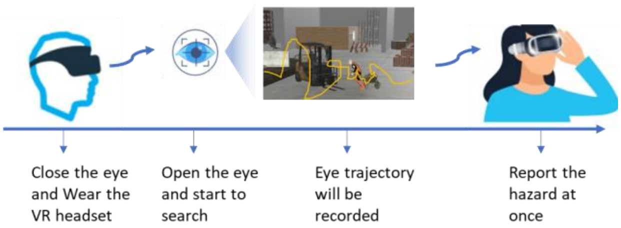

Figure 1: Experiment Procedure.

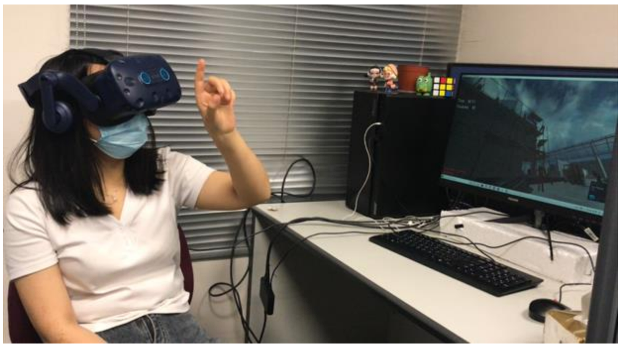

Figure 2: Photo of Participant.

3.4 Define the time of each level in situation awareness

Based on previous studies, fixation location shows an individual's interest in a specific object, and fixation duration reflects the cognitive difficulty when it comes to deeper comprehension. Rayner [40]demonstrated that viewers could extract the gist of a scene from a short exposure of 40-100 milliseconds and that the reader only needs to scan the text for 50-60 ms before reading it properly. At the same time, Seya and Watanabe [41] elucidated that the effective acquisition time of a visual search task is $\leqslant$ 50 ms. In this study, we applied a rule that a gaze time of $\geqslant$ 50 ms is required to perceive hazards. Regarding comprehension, Loschky [42] developed a Scene Perception & Event Comprehension Theory, which mentioned that front-end processes in the brain occur during single-eye fixations involving information extraction and attentional selection, and back-end processes occur across multiple fixations involving working and long-term memories to construct the event model and understand what is happening. The information displayed on the back-end is accumulated over multiple fixations ranging from milliseconds to minutes [42]. Since the front-end and back-end processes are continuous, we defined the duration of Level 2 SA to be after the end of Level 1.

We tried to build the segmented model for the levels of SA, but the subjects did not need to perform any actions when they encountered the hazards. Hence, as it was hard to determine the Level 3 (projection) of SA in this study, we differentiated the time between Level 1 and Level 2 in the first research stage (showed in Figure 1):

1. Navigation (Nav): the beginning was when they started to enter the IVR environment or when they finished reporting the hazard; the end was before the first gaze on the corresponding hazard.
2. Level 1 (L1): when the gaze time on the corresponding hazard was firstly $\geqslant$ 50 ms, this gaze time would be considered as the first gaze, and the duration would be Level 1.
3. Level 2 (L2): the beginning was the end of the first gaze; the end was the moment before the subjects started reporting the hazards.

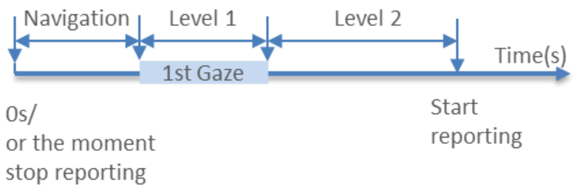

Figure 3: Segment Situational Awareness Based on Gaze Behavior solution.

4. RESULT AND DISCUSSION

4.1 Gaza traveling pattern

The eye movement data (e.g., timestamp, fixation location [x, y, z], fixation duration) were abstracted from the HMD. To visualize the gaze traveling behavior, we measured the distances between two points in a three-dimensional space coordinate system and represented them in a two-dimensional coordinate system. We selected four examples, shown as Figure 2, Figure 3, Figure 4, and Figure 5, for further analysis.

Generally, the trajectory of the navigation period fluctuated. This is consistent with the perception model that the eye gains stimulus from the environment by looking around. When it comes to hazards, it is clear from the figures that the fixation point has been in danger for some time. This reflects that the hazards obtained the attention of the participant resulting in nearly zero distance of gaze traveling distance in Level 1. During Level 2, different hazards appeared with different eye movements. Hazards of Ladder and Scaffolding Planks showed more volatility, while Forklift and Can were more stable. This might have been because the environment surrounding Ladder and Scaffolding Planks has more elements of construction, (e.g., a tall building, a wide range of scaffolding, a sweeping worker, and a paint worker), which were a part of comprehension resources. Participants need to gather more information from the surrounding to determine whether the current event of interest is dangerous. On the other hand, the areas where the Forklift truck and Oil Drum are located is relatively empty. For example, there is only a single, orderly container next to the Oil Drum. Participants only needed to judge whether the current events were dangerous and did not need to consider too many environmental factors. This reduced the cognitive difficulty, and their gaze points were relatively concentrated at Level 2. Furthermore, four figures showed multiple refocused duration during Level 2, which was consistent with the findings of Loschky [42] that the comprehension procedure accumulated over multiple fixations ranging from milliseconds to minutes.

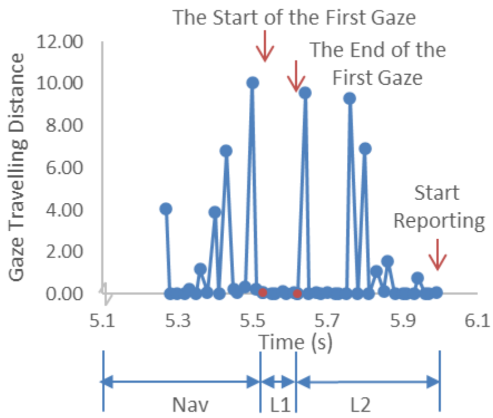

Figure 4: Examples of Gaze Traveling on Ladder.

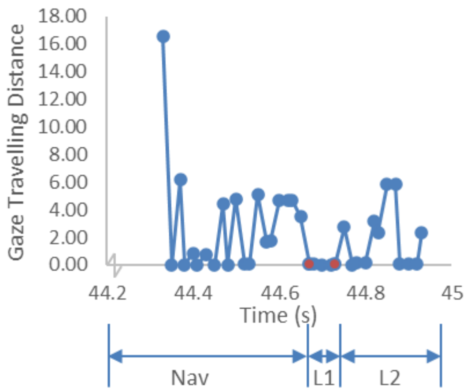

Figure 5: Examples of Gaze Travelling on Scaffolding Planks.

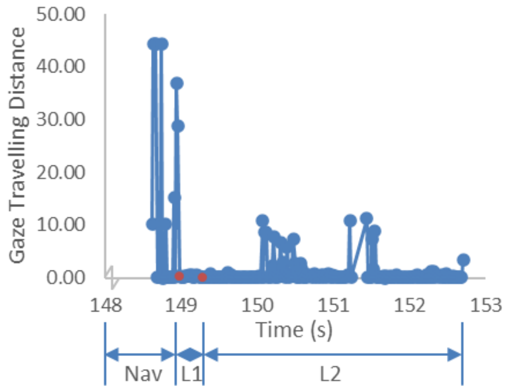

Figure 6: Examples of Gaze Travelling on Scaffolding Forklift.

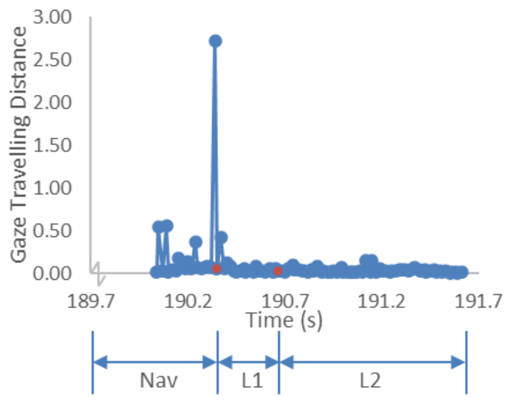

Figure 7: Examples of Gaze Travelling on Scaffolding Oil Drums.

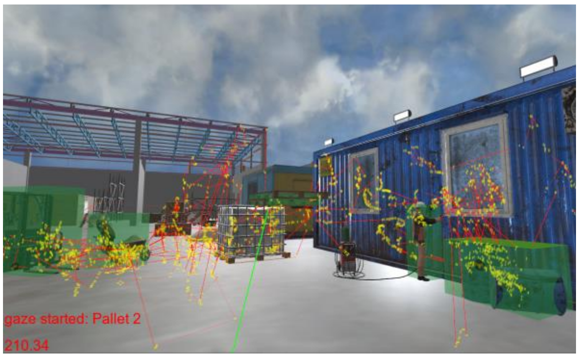

Figure 8: Examples of Gaze Trajectory.

4.2 Fixation Duration

The type of information (e.g., texts, graphics) and the type of task (e.g., reading, problem-solving) make a significant impact on the fixation duration [43]. This is seen in Table 2, where each hazard is significantly different in the average time of Navigation, Level 1, and Level 2 of SA. The shortest average perception time (Level 1) is the hazards of the Ladder with a time of 0.09 s. This should come down because falling ladders are an obvious hazard, and all five participants identified it as a danger. The comprehension procedure (Level 2) of the Ladder was significantly longer than that of the other dangers because two participants chose the "look at the whole picture" strategy. They did not report danger when they saw the ladder, resulting in a longer average time at Level 2 of the Ladder. In addition, the hazards of Garbage and Forklift had a relatively long time in Level 1 and Level 2, and their time of Level 2 was ranked first (4.66 s) and second (3.98 s), respectively (except for the Ladder). This is because these two hazards were more difficult to identify in the VR model and required participants to have some experience on the construction site. For example, garbage should not be piled anywhere but should be dumped in the garbage pool, and the pedestrian system should be separated from the vehicle system. If participants are inexperienced in this area, there is a high probability that they will not consider these two hazards as a danger. This was reflected in the cumulative number of identified people (n=2, n=3). The position and duration of gaze can indicate a person's cognitive strategies and prior knowledge or experience [44].

This implies that when the time of Level 1 is relatively short, participants need to identify some obvious or no empirical risks. When Level 2 takes a long time, it means that some prior experience is needed for comprehension.

Table 2: Hierarchical classification of situational awareness for hazard identification.

Hazard type	**Average time of SA at each stage (s)**			**Number of identified participants**
	Navigation	Level 1	Level 2	
Ladder	10.69	0.09	16.60	5
Scaffolding Planks	8.92	0.16	1.30	4
Handrail	6.45	0.18	1.33	3
Paint Worker	2.93	0.11	2.51	2
Garbage	11.42	0.23	4.66	2
Forklift	9.46	0.31	3.98	3
Pallet	18.93	0.21	2.09	5
Oil Drums	10.39	0.27	1.54	3

4.3 Scan Strategy

P1 and P5 generally adopted a search strategy of sequentially focusing on local areas, and they found the highest number of hazards in the shortest time. They performed well in time for Level 1 and Level 2 of all hazards, which contributed to their total shortest time of 56.3 s and

51.61 s, respectively (Table 3). P2, P3, and P4 took an overview of the overall situation and then returned to the local hazards, which resulted in their overall time being much longer than P1 and P5. In addition, when P2 and P3 returned to local recognition, they tended to focus more on a certain area and spent less time on other potentially dangerous areas, so their cumulative number of recognitions was also small (both were 4). After looking around the overall environment, P4 adopted a flashback search strategy of focusing on local areas, which contributed to her having a higher number of dangerous identifications; however, her overall time was the highest among all participants. Scan paths reveal certain spatial features of fixations that provide useful insights into visual observation patterns, especially about search strategies [45]. These five participants adopted a sequential scan strategy and had a higher chance to recognize more hazards. The longer total time suggested a longer comprehension time (Level 2) because the perception was just receiving the stimuli, and the scan path varied depending on the learning experience [46].

Table 3: Scan Strategy of Each Participant.

Hazard type	The Order of Identified Hazards			
	Total Time(s)	Total Identified	Ladder	Scaffolding Planks
P1	56.3	6	1st	2nd
P2	79.66	4	1st	4th
P3	101.33	4	1st	/
P4	119.88	6	3rd	5th
P5	51.61	6	1st	6th

Table 3: Scan Strategy of Each Participant (cont.).

The Order of Identified Hazards					
Handrail	Paint Worker	Garbage	Forklift	Pallet	Oil Drums
3rd	/	/	4th	6th	5th
2nd	3rd	/	/	/	/
/	/	4th	/	2nd	3rd
/	4th	6th	2nd	1st	/
2nd	/	/	3rd	4th	5th

5. LIMITATIONS AND FUTURE DIREACTION

Although all the hazards in this experiment were derived from common risk types on the construction site, it was quite difficult to distinguish some hazard data because the scene was relatively complex, and some risks were densely distributed. Therefore, the next step could be to use multiple, simple models with one risk factor, which would improve the accuracy of the data. In addition, this experiment did not investigate Level 3 SA, so we will consider adding decision-making factors to the model to fully evaluate the relationship between eye movement behavior and SA. Further, the number of participants in this experiment was relatively small, so we intend to increase the number of participants to enhance data reliability.

6. CONCLUSIONS

To conclude, SA is closely related to eye movement behavior. At Level 1 SA, the gaze traveling distance is almost 0, and the gaze point of the eyes stays at the corresponding dangerous place for some time to get enough stimulation. At Level 2, the eyes either scan again or stay where they were at the previous level, depending on the complexity of the environment. The main purpose of this comprehension stage is to obtain enough information and time to carry out information integration in the brain. When the perception process at Level 1 is completed in a short time, it is easier to identify the current hazard. In contrast, when the time at Level 2 is longer, it reflects that the danger is difficult to understand or that the participants lack relevant experience about this kind of hazard. Furthermore, the scan path also has a potential impact on the time of Level 1 and Level 2. The strategy of sequential identification of local dangers is more conducive to rapid identification of hazards, leaving more time for deciding how to deal with dangers. Based on the useful information obtained from this study, we can better understand hazard identification behavior and develop corresponding risk coping strategies. In the future, we will combine the knowledge of psychology, neurology, etc., and use various advanced equipment, such as EEG, fMIRS, etc., to conduct more in-depth and systematic research on SA.

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A STUDY ON THE CHARACTERISTIC OF URBAN BLOCK RESIDENTIAL DISTRICT

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Abstract: In modern cities, collective housing can be said to be a general form of urban residence. However, with the development of socio-economic, more and more people flock into the cities, and collective housing have been forced to large-scale, high-rise and high-density. Urban residence is a network extending to various areas of life within the city, not just housing. In order to realize such a network and maintain the continuity and diversity of urban space, it has been proposed to develop a “urban block residential district” that whole or most part of the urban areas surrounded by streets as residential district.

In China, the mainstream of collective housing is a closed “gated community” that limits access to the premises to residents only. Figure 1 shows the layout of “Vanke Xishan Garden”, a gated community type collective housing built in Beijing in 2003. On the other hand, in the collective housing of Japan, the automatic locks that only restrict occupants to buildings have become common, but restrictions on access site have not been widespread. Nevertheless, although the number is not large, examples of closed “urban block residential district” have emerged in recent years.

Compared with such closed block type residential district, there are open block type residential district without restrictions on access the site. As an example, Figure 2 shows the layout of the “Hillside Terrace” built in Tokyo from 1969 to 1998. (1) to (3) in Figure 2 show the blocks in the city, and (4) to (5) in Figure 2 show the range of the“Hillside Terrace”. Unlike the Gated community, the “Hillside Terrace” is used as residence, offices, stores, and an exhibition hall in the premises. In addition, the residential district extends to the surrounding blocks located on the opposite side of the main street. That is to say, this “urban block residential district” belongs to a part of the urban block and conveniently interact with other functional spaces in the block.

The figure 3 is a model diagram. The left figure is a closed block type “gated community” and the right figure is an open block type “urban block residential district”. The open block type has the characteristic of high integration with the city.

The purpose of this study is to explore the transformation of “gated community” by verifying the composition of the “urban block residential district”, and to analyze the urban block residential district graphically and attempt to categorize the models. In the case of small-scale collective housing in the existing residential areas of Japan, investigated the cases published in the architectural journals by literature materials and field research, and define housing complexes with “open block type” characteristics as “urban block residential district” and examine the actual situation and characteristics.

Keywords: Urban block residential district, Graphic analysis, Collective housing

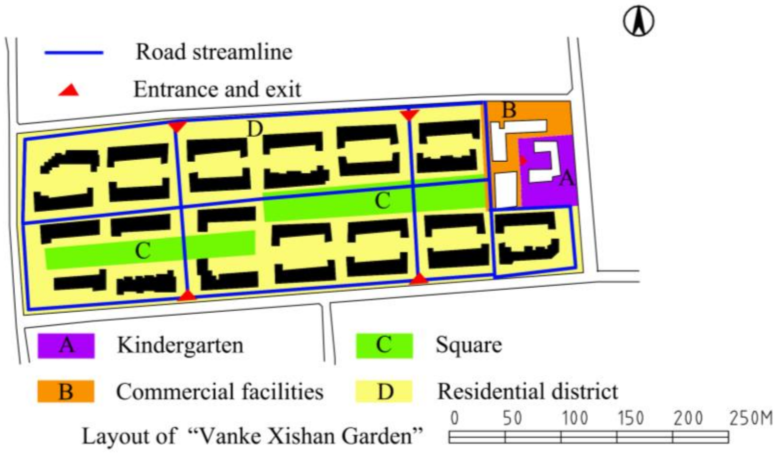

Figure 1: Example of gated community type collective housing.

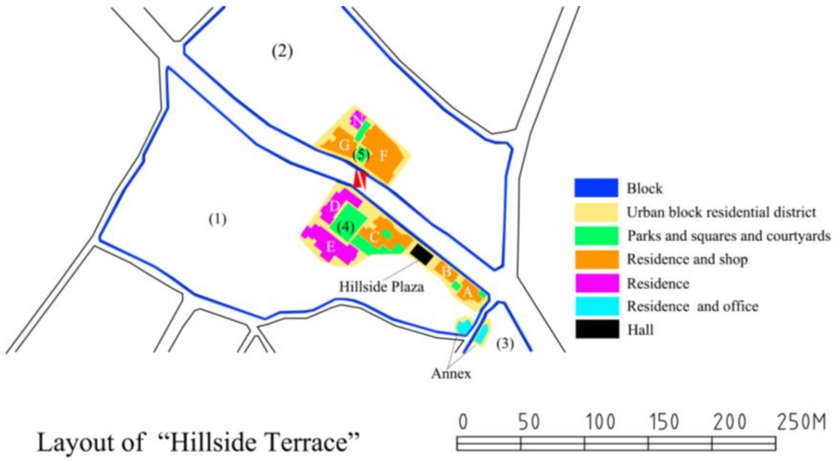

Figure 2: Example of urban block residential district type collective housing.

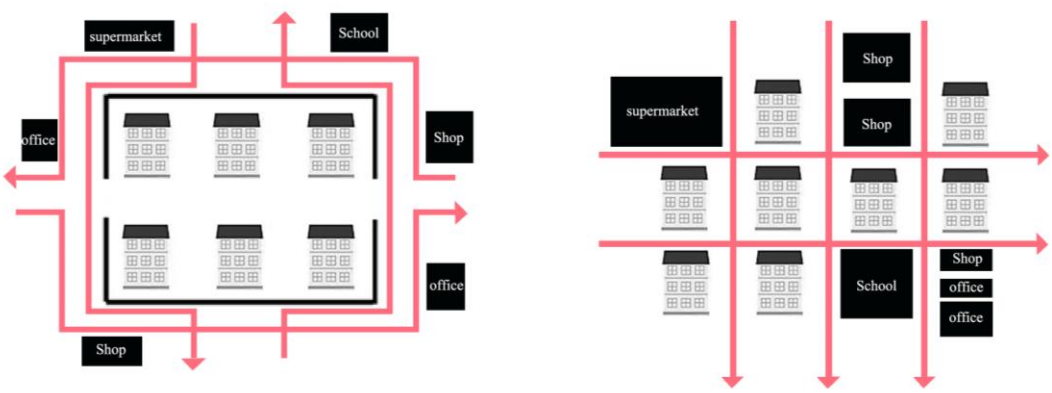

Figure 3: Model diagram of gated community and urban block residential district

APPLIED GRAPHICS AND GEOMETRY FOR IMAGE PROCESSING (2)

DIFFERENCES IN PERCEPTION OF HYBRID IMAGES BY PROJECTION

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ABSTRACT: Hybrid images are images created by combining two images, a high-frequency image that is easy to recognize from a close distance and a low-frequency image that is easy to recognize from a far distance, so that different images can be seen depending on the viewing distance.On the basis of these previous studies, this study investigates whether there is a difference in the way hybrid images are perceived depending on the medium in which they are drawn. In fact, we investigated the difference between the perception of the hybrid image when it is viewed and the hybrid image created when it is projected using a projector. The investigation was conducted twice, each time with a black and white hybrid image and with an EPSON-EV100 projector.The first investigation was a projection mapping of the hybrid image, which was carried out in December 2019. This one investigated whether it is possible to distinguish between high and low frequency images by projecting hybrid images with a projector. When the hybrid image was projected on the wall of a shopping center, many people said that it was difficult to distinguish between the high and low frequency images. The following were speculated as the causes: the light level in the exhibition space was difficult to adjust, making it difficult to recognise the pictures themselves; it was difficult to view the images while moving around; and the structure made it difficult to recognise the high and low frequency images from each other.Based on these results, we conducted a second survey. Unlike the previous study, we adjusted the amount of light in the exhibition space and the size of the projected images to design a viewing space with a shorter viewing distance. In particular, when creating the hybrid image, we tried three different ways of creating a composite of the high and low frequency images: overlapping the characteristic parts of both, reducing the surface where the motifs overlap, and completely overlapping the motifs. As the location of the experiment was a university classroom, the hybrid images were displayed in a narrower space from the projection surface, so the images were zoomed to become larger and larger, which was more recognisable than in a shopping mall. In particular, of the three hybrid images, the one created using the "method of overlapping the characteristic parts of both" resulted in the easiest discrimination between the high and low frequency images. The same result was obtained when these images were printed on paper and viewed.These studies show that it is possible to discriminate between high and low frequency images by projecting and viewing hybrid images. It was also found that the same hybrid image did not differ significantly in recognizability depending on whether it was printed on paper or projected, but that the contrast of the hybrid image when projected on a projector had a significant effect on how it was perceived, depending on the intensity of the colours.

Keywords: Hybrid images, Projection mapping, Image processing.

1. INTRODUCTION

A hybrid image is a composite image consisting of a high-frequency image seen from a close distance and a low-frequency image seen from a far distance, so that different pictures are seen mainly at different distances. There are some previous researches on hybrid images such as Aude Oliva[1] and Yasushi Yamaguchi[2] in Japan on the principle of hybrid image visibility and the method of image creation[3].

In this research, we will present how hybrid images are perceived when projected using projection mapping, based on a projection mapping event at a large commercial facility in December 2019, which was conducted in collaboration with Mitsui Fudosan Co., Ltd, and a projection experiment conducted in a classroom at the University of Toyama in December 2020. The presentation will show how the images are perceived and how the images were produced in practice.

2. PROJECTION EXPERIMENTS

2.1 Environment of the projection

The next step was to decide on a location for the projection mapping in Mitsui Outlet Park Hokuriku Oyabe. The Mitsui Outlet Park side proposed locations that would not interfere with the tenants' business, that would not conceal the security and fire prevention equipment, and that would allow the equipment to be installed safely without disturbing the customers. It was decided to project the device on the wall near the emergency stairs on the first floor (Fig. 1).

Furthermore, a preliminary experiment was carried out in the laboratory of the University of Toyama, Faculty of Art and Design, Takaoka Campus. The purpose of this preliminary experiment was to check the visibility of the hybrid image projected by the projector and to see at what distance the visibility of the image changes. In the laboratory, the high-frequency images were discernible at a distance of about 1.2 m from the projection surface, while the low-frequency images were discernible at about 2.4 m. Based on this result and considering the size of the image and the distance to be projected in the field, it was decided that the ratio of the distance from the projection surface where the high frequency image could be recognised to the distance where the low frequency image could be recognised should be 1:2.

The angle, the amount of light and the size of the hybrid image were fine-tuned so that the high-frequency image could be seen at a maximum distance of 7 m and the low-frequency image at 14 m. The viewing position was set across the escalator entrance.

The angle, light intensity and size of the hybrid image were fine-tuned. To make it possible to distinguish between the low and high frequency images at close range, a zooming image was also projected so that the hybrid image became progressively larger. The image was zoomed in for 4 seconds before changing from the minimum image to the maximum image and remained in that state for 4 seconds. From there, the image continues to expand for 7 seconds, so that it takes 15 seconds to project a single hybrid image at its maximum size.

Figure 1:Hybrid image seen from 14 m
(projected on the wall in the top centre of the picture)

2.2 Projected images and production instructions

The hybrid image "Tiger & Sheep" (Fig. 2) combines a high frequency image of a tiger with a low frequency image of a sheep (Fig. 3). These images were created using the image editing software Adobe Photoshop.

The production procedure is as follows.

Firstly, the original images of high and low frequency images were made monochrome in grayscale in order to create a sense of colour unity.

Then I blurred the low-frequency image with the blur tool, and applied a high-pass filter to the high-frequency image to make the lines in the image stand out. High-pass filter is a feature of Photoshop which detects edges in an image and enhances them by increasing contrast.

By adjusting and layering these filters, I created a hybrid image to be projected during the experiment."The technique used to create Tigers & Sheep was also used to create Owl & Red Panda (Fig. 4), a hybrid image that combines a high frequency image of an owl with a low frequency image of a red panda (Fig. 5). These two hybrid images were created on the assumption that by overlapping the eyes of the animals in the high and low frequency images, it would be possible to switch between the perceptions of the images while maintaining eye contact.

These images were downloaded from " Unsplash [4]".

Figure 2:" Tiger & Sheep "

Figure 3:Images of tigers and sheep from "Tigers & Sheep".

Figure 4:"Owl & Red Panda"

Figure 5:The owl and the red panda from "Owl & Red Panda"

In addition, there are two hybrid images which were produced using different techniques from the above ones.

Camellia & Castle" (Fig. 6) was created using a high frequency image of a camellia flower and a low frequency image of a castle. The image was completely black when it was processed in grayscale, so I used the clipping mask function of Adobe Illustrator to cut off the perimeter of the petals of the camellia photo before processing.

In "Train & Cat" (Fig. 7), I processed the photo of the train to make it look like a line drawing in order to highlight the lines in the high-frequency image of the train. The original image was filtered with the edge glow filter, one of the Adobe Photoshop representational techniques, and then the tones were inverted to remove the white areas.

Next, the low-frequency image of the cat was processed in grayscale and blurred. The blur is weaker than in 'Camellia & Castle' because I wanted to keep the cat's fur visible.

"Camellia & Castle" and "Train & Cat" were created with the idea that the difference in the outlines of the motifs in the high and low frequency images would make them easier to distinguish, but the extracted lines were so thin that it was difficult to distinguish between the printed image on paper and the projected image.

The high-frequency and low-frequency images in Figures 6 and 7 were downloaded from " PAKUTASO[5]".

Figure 6:"Camellia & Castle"

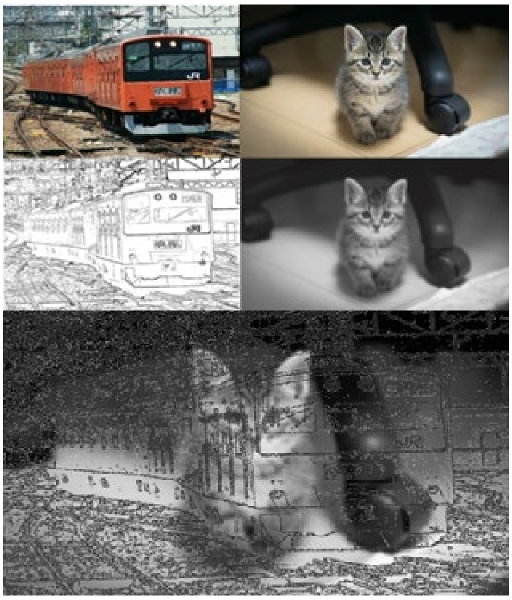

Figure 7:"Train & Cat"

2.3 Projected images and production instructions

The table 1 below shows the viewers in the vicinity of the projection site on 6 December 2019, the first day of the projection of the hybrid image.

Table 1: The audience

How to watch	Number of people (people)
A quick glance	17
Walk and see	9
Stop and watch	9
Stare until the end	2

In fact, many of the viewers commented that it was difficult to understand. Although it is possible to recognize high-frequency images, it can be assumed that it is difficult to recognize low-frequency images, which are difficult to determine the viewing position for each individual.

In addition, it was difficult to adjust the light level due to the fact that this was a commercial facility, unlike a university classroom. Another factor could be that the hybrid image was projected in a lighter colour than expected.

3. RE-EXPERIMENT

3.1 Reconstruction of the projection environment

Based on the speculation from the 2019 experiment that there might be a difference in perception depending on the shade of the colour, we created a new hybrid image and conducted the projection experiment again.

Because of the outbreak of the new coronavirus, it was difficult to project the images in the same place as before, so the experiment was conducted in a university classroom. As in the previous experiment, the projector used was an EPSON EV-100. The brightness of the projected light was 2,000lm and the brightness of the room at the time of projection was 7.2lx.

There were 6 subjects in the re-experiment, 3 of whom wore glasses (Fig. 8). These 6 subjects were given a questionnaire about the most easily identifiable hybrid image.

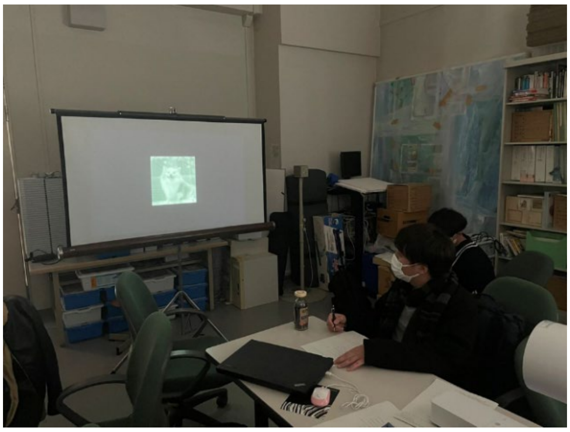

Figure 8:The re-testing in December 2020

3.2 The projected image and the intention of its creation

In the re-experiment, the following images were created: "Dog & Cat" (Fig. 9), which was created by overlapping the eyes of the motifs as in the previous hybrid image creation; "Post & Flower" (Fig. 10), which was created so that the motifs of the high-frequency image and the low-frequency image overlap slightly; "Rice & Bread" (Fig. 11), which was created so that the motifs of the high-frequency image and the low-frequency image overlap perfectly and the motifs of the high-frequency image differ in size; and "Duck" (Fig. 12), which was created so that the motifs of the high-frequency image and the low-frequency image do not overlap. (Fig. 10), "Rice & Bread" (Fig. 11), which was created so that the motifs of the high and low frequency images overlapped slightly, and "Duck & Komainu" (Fig. 12), which was created so that the motifs did not overlap.

The projection was also processed in the same way as before, with the image expanding. At the same time, the above hybrid image was printed on a sheet of A4 recycled paper, and the subject could hold the printed paper in his hand and adjust the viewing distance freely.

Figure 9:"Dog & Cat"

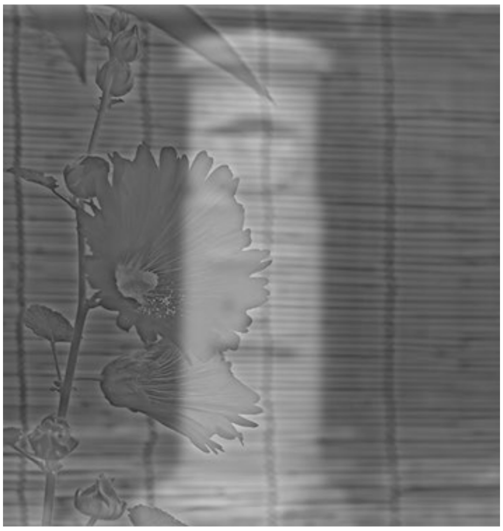

Figure 10:"Post & Flower"

Figure 11:"Rice & Bread"

Figure 12:"Duck & Komainu"

3.3 Results and discussion of the experiment

In the re-experiment, the distance from the projector to the projection surface was about 2.9 m and the brightness of the room could be easily adjusted, which made it much easier to identify the images than in the 2019 experiment. Therefore, the contrast of the image, and thus the brightness of the projection environment, has a significant influence on the identification of the hybrid image when it is projected using light.

The results of the questionnaire showed that the hybrid image with overlapping motifs was the easiest to identify, regardless of the medium, whether it was printed on paper or projected on a projector. The results of the questionnaire showed that, regardless of the medium, the hybrid image of "overlapping features and similarities of motifs" was the easiest to identify (Table 2).

4. CONCLUSION

In this study we investigated the differences in perception when projecting hybrid images. As this was the first attempt to project a hybrid image, we were not sure if the projection environment would affect the difference in perception, or if the method of making the hybrid image

Table 2: Questionnaire results from the re-experiment

Figure Number	Hybrid image works		Number of respondents who said it was easy to recognise (persons)		
	High-frequency image	Low-frequency image	High-frequency image	Low-frequency image	Both
4	Owl	Red Panda	0	1	5
9	Cat	Dog	1	0	5
10	Flower	Post	0	1	5
11	Rice	Bread	1	2	3
12	Komainu	Duck	0	3	3

would have an effect on the first experiment. The most important thing was to create an environment that was easy to recognise. This meant that it would be difficult to project the image in places where the light level was difficult to adjust, or outdoors in daylight.

ACKNOWLEDGMENTS

The 2019 hybrid image projection experiment was carried out in collaboration with Mitsui Fudosan Co., Ltd. We would like to take this opportunity to express our deepest gratitude.

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[4] Unsplash https://unsplash.com/ (Reference: 30 July 2021)

[5] PAKUTASO https://www.pakutaso.com/ (Reference: 30 July 2021)

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NIGHTSCAPES AS IMAGES OF CITIES - IMAGE ANALYSIS OF ACTIVITIES REPRESENTED IN NIGHTSCAPES

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ABSTRACT: Considering that each light on a building window or street is an expression of individual life and that nightscapes of cities are integrated urban activities, this study analyzes the light composition of nightscapes to examine the characteristics of the various images of cities. These nightscapes change with distance, use, and time. Through image processing analysis of nightscapes in the Tokyo metropolitan area, the composition of the bright areas and their colors are considered to be significant factors that represent the characteristics of the nightscapes.

Keywords: Nightscape, Image of City, Image Processing.

1. INTRODUCTION

> *Here and there, lights were beginning to come on in the walls of glass, cutting bright squares out of the dark monoliths.*
>
> Ryu Murakami, *Coin Locker Babies*[1]

The nightscape of a city seen from afar is like stardust or glittering jewels. Meanwhile, light compositions inside building windows and street activities should represent individual life. The nightscapes of buildings and streets seen up close differ based on their use and may change over time.

Two photos in Figure 1 show examples of nightscapes in Tokyo for the same view on a weekday and a weekend (these photos are B06 and B07 of the analyzed nightscapes described below). The three buildings on the right are high-rise condominiums of 28 and 42 stories; the 30-story building on the left accommodates mainly offices for a major company, and the 28th to 30th floors are a hotel. The windows of the offices are uniformly lit with fluorescent colors, whereas the windows of the condominiums are lit in different combinations and colors. The hotel windows are lit with lamp colors; on weekdays, the rooms are sparsely lit, as the photo shown here was obtained during the state of emergency declared for the COVID-19 pandemic.

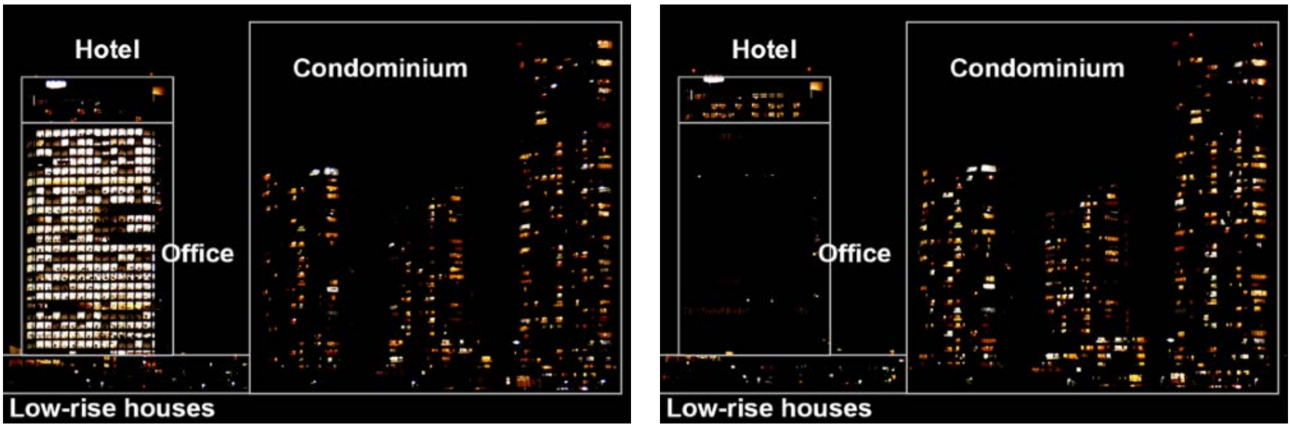


Figure 1: Complex Nightscapes of Condominiums, Offices, and a Hotel (left: Weekday, right: Weekend).

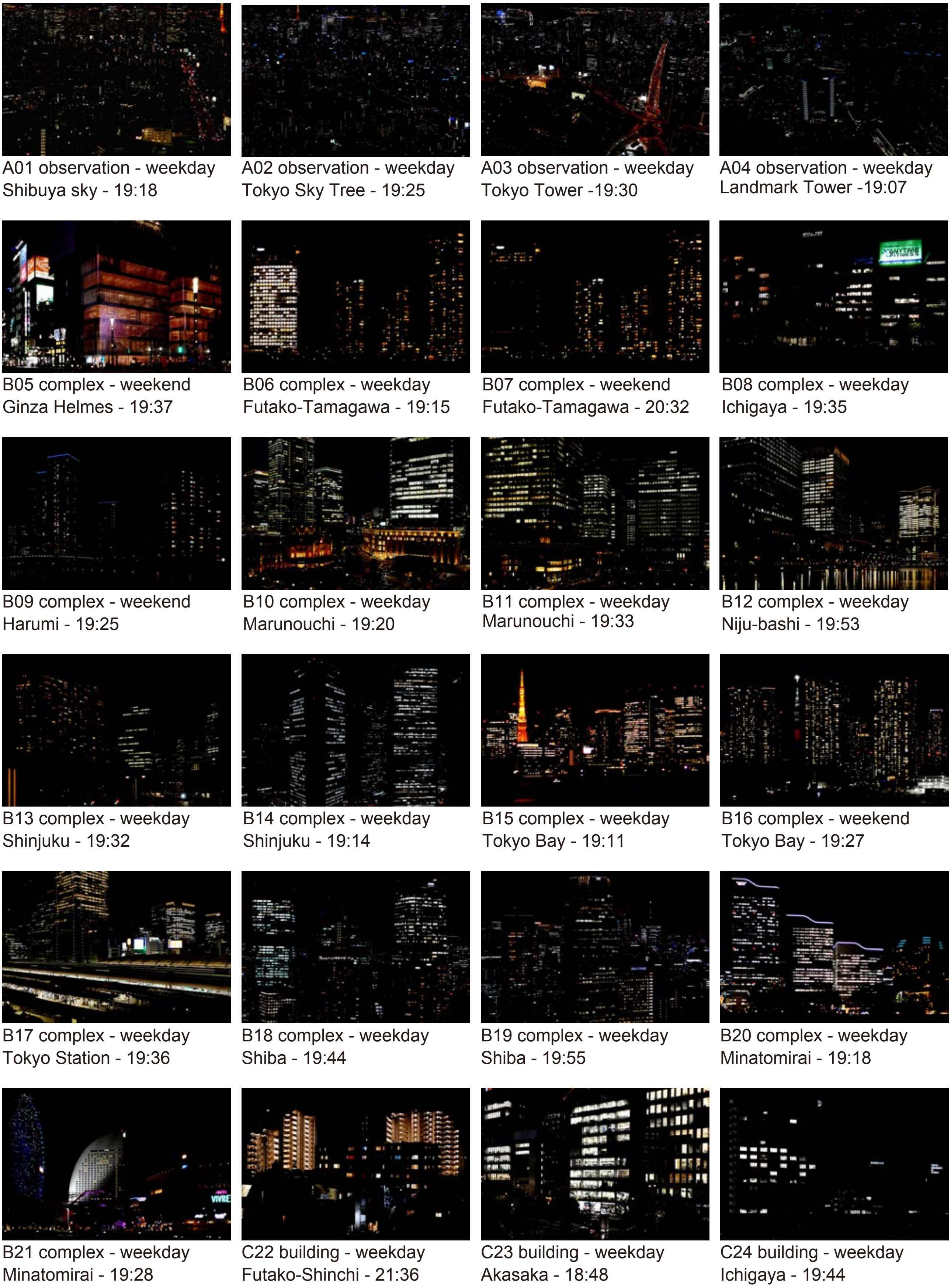
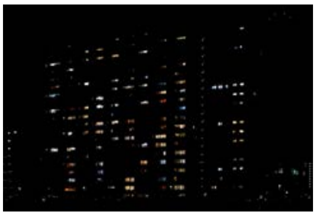


Figure 2-1: Nightscapes in the Tokyo Metropolitan Area (1).


C25 residence - weekend
Harumi - 19:40


C26 hotel - weekend
Olympic Village - 19:26


C27 dept. store - weekend
Mizonokuchi Marui - 19:38


C28 residence - weekend
Musashi-Kosugi - 19:43


C29 residence - weekend
Musashi-Kosugi - 20:47


C30 hotel - weekday
Palace Hotel Tokyo - 19:54


C31 office - weekday
Odaiba Fuji-TV - 20:48


C32 hotel - weekend
Hilton Hotel Odaiba - 19:54


C33 hotel - weekday
Hilton Hotel Odaiba - 20:48


C34 residence - weekday
Odaiba - 20:48


C35 office - weekday
Tokyo City Hall - 20:14


C36 dept. store - weekend
Shinjuku Odakyu - 19:37


C37 station - weekend
Shinjuku Station - 19:27


C38 dept. store - weekend
Shinjuku Takashimaya - 19:32


D39 illuminated - weekday
Senso-ji Temple - 19:11


D40 illuminated - weekend
Kachidoki Bridge - 19:11


D41 illuminated - weekday
Rainbow Bridge - 19:33


D42 illuminated - weekday
Wedding Hall - 19:27


E43 street - weekday
Asakusa Nakamise - 19:23


E44 street - weekday
Asakusa - 19:28


E45 street - weekend
Kabuki-cho - 19:28

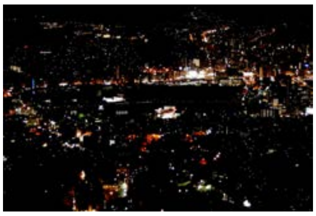

E46 street - weekend
Golden-Gai - 19:43


E47 street - weekend
Shibuya Center St.- 19:57


E47 street - weekend
Shinjuku - 19:28

Figure 2-2: Nightscapes in the Tokyo Metropolitan Area (2).


A90 observation
Chicago Willis Tower (2005)


A91 observation
Nagasaki (2019)


B92 complex
Hong Kong Downtown (2017)


B93 complex
Hong Kong (2017)


B94 complex
Aberdeen Jambo (2019)


C95 residence
Aberdeen (2019)


C96 hotel
Singapore (2017)


D97 illuminated
Xi' an Bell Tower (2017)

E98 street
Hong Kong (2006)


E99 street
Hong Kong (2019)

Figure 3: Nightscapes in Chicago, Nagasaki, Hong Kong, Singapore, and Xi'an.

Figures 2 (2-1 and 2-2) and 3 show the images of the nightscapes used in this study for analysis.

Assuming that the pandemic is changing urban activities, we photographed these nightscapes as graphics expressing the images of cities. As these photos include turned-off lights due to store closures, telework, or work time restrictions during the pandemic, these images are considered to represent more diversity than usual days.

2. OBJECTIVE

Considering that each light on a building window or a street is an expression of individual life, and that the nightscapes of cities are integrated urban activities, this study analyzes the light composition of the nightscapes to examine the characteristics of the various images of cities. These nightscapes change with distance, use, and time.

In the field of architectural and urban planning, some studies have discussed the characteristics of nightscapes as urban and architectural spaces. Many of these studies use the semantic differential (SD) method to find a spatial evaluation measure (psychological measure) and find the spatial characteristics that explains it. For example, Ando (2003)[2], one of the authors, pointed out that the psychologically perceived brightness of nightscapes is affected not only by physical luminance but also by the sharpness of the bright and dark areas, and the intensity of the contours of bright areas.

However, here, we do not focus on psychological measures but on the physical composition of the graphical images.

3. FIVE TYPES OF NIGHTSCAPES

We selected 48 images for analysis from a large number of photos taken in the Tokyo

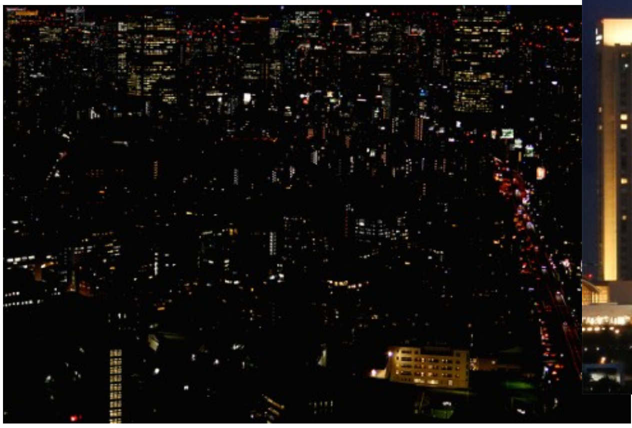


Figure 4: Observation View (A01)
View from Shibuya Sky, weekday, 19:18.

Figure 5: Building View (C32)
Hilton Hotel Odaiba, weekend, 19:54.

Figure 6: Light-up View (D41)
Odaiba Rainbow Bridge, weekday, 19:33.

Figure 7: Street View (E46)
Kabuki-cho Golden-gai, weekend, 19:43.

metropolitan area (Tokyo, Yokohama, and Kawasaki) between May 2020 and August 2021 during the pandemic (Figures 2-1 and 2-2; numbers 01-48 following A-E). For comparison, we added ten images taken in Nagasaki (Japan), Chicago (U.S.A.), Xi'an (China), Hong Kong, and Singapore before 2019 (Figure 3; numbers 90-99 following A-E).

We categorized these nightscapes into the following five types denoted by A to E. Although this classification is not rigorous, we intended to determine the diversity of nightscapes.

- Type A (observation view): The most distant views among the five types. As an example, Figure 4 shows a night view from the top of a skyscraper.
- Type B (complex view): Horizontal views of multiple-use buildings from medium distances. Figure 1 showed an example of this type.
- Type C (building view): Horizontal views of a single-use building(s) of residence(s), office(s), hotel(s), etc. As an example, a hotel during a holiday is shown in Figure 5.
- Type D (illuminated view): A view of a single building that has been intentionally illuminated as a landmark. Images of this type are considered as designed nightscapes. For example, Figure 6 shows a bridge over Tokyo Bay lit up in red to raise awareness about the pandemic.
- Type E (street view): A view along the direction of a street. Images of this type include many commercial elements, such as shopping windows and billboards. For example, Figure 7 shows a popular bar area on Saturday, May 15,

Table 1: Calculated Data.

		Bright Area Num B.N.	Bright Area Avg B.A	Bright Area Dev B.D	Color Ratio C.R.	Color Dev C.D
Type A : Observation View						
A01	Shibuya Sky	3777	16.4	0.25	56.6%	0.46
A02	Tokyo Sky Tree	3864	13.3	0.07	31.5%	0.11
A03	Tokyo Tower	4351	17.9	0.29	39.1%	0.35
A04	Yokohama Landmark Tower	2116	13.2	0.05	32.0%	0.05
A90	Chicago Willis Tower	4607	39.3	0.84	45.3%	1.39
*A91	Nagasaki	2319	35.9	0.54	41.4%	0.60
Type B : Complex View						
B05	* Ginza Helmes-Shop-Street	2792	78.0	1.87	55.9%	2.00
B06	Futako-Tamagawa Office-Residence-Hotel	903	87.4	0.17	36.0%	0.67
B07	* Futako-Tamagawa Office-Residence-Hote	586	58.9	0.12	67.9%	0.50
B08	Ichigaya Office-University	651	95.7	1.73	41.6%	0.31
B09	* Horumi Residence Complex	684	24.1	0.09	42.1%	0.07
B10	Marunouchi Office-Station	3028	45.4	0.55	45.8%	1.18
B11	Marunouchi Office-Station	2688	34.6	0.20	42.2%	0.75
B12	Niju-bashi Office-Water	2192	38.4	0.49	33.2%	0.62
B13	Shinjuku Office-Residence	730	31.7	0.11	60.2%	0.30
B14	Shinjuku Office Complex	1777	33.5	0.09	10.6%	0.05
B15	Tokyo Bay Office-Residence	835	96.6	0.87	53.8%	1.04
B16	* Tokyo Bay Residence-Landmark	1641	33.2	0.09	30.9%	0.38
B17	Tokyo Station Office-Station	2574	39.2	0.52	41.9%	1.06
B18	Shiba Office-Residence	1478	38.7	0.11	20.1%	0.12
B19	Shiba Office-Residence-Hospital	1767	26.3	0.09	35.2%	0.18
B20	Minatomirai Office-Hotel	678	123.8	0.76	25.2%	0.26
B21	Minatomirai Office-Hotel-Amusement Park	1242	60.1	1.73	30.4%	0.14
B92	Hong Kong Downtown	3932	35.9	1.12	52.0%	3.33
B93	Hong Kong Office-Residence	3998	20.3	0.18	46.5%	0.63
B94	Aberdeen Residence-Restaurant	1480	35.1	0.25	52.6%	2.95
Type C : Building View						
C22	Futako-Shinchi Residence	692	178.8	2.64	57.9%	1.50
C23	Akasaka Office	1580	91.0	0.97	12.2%	0.40
C24	Ichigaya University	328	72.0	0.30	5.2%	0.02
C25	* Harumi Residence	510	44.3	0.13	40.1%	0.13
Type C : Building View						
C26	* Harumi Oympic Village	1356	14.3	0.06	12.2%	0.01
C27	* Mizonokuchi Marui Department Store	408	142.3	1.26	26.1%	0.28
C28	* Musashi-Kosugi Residence	1032	38.7	0.17	58.0%	0.47
C29	* Musashi-Kosugi Residence	463	81.0	0.47	59.6%	0.38
C30	Marunouchi Tokyo Palace Hotel	465	50.5	0.13	64.8%	0.28
C31	Odaiba Fuji-TV Headquater	1527	94.4	1.98	63.3%	1.51
C32	* Odaiba Hotel Hilton	606	143.0	1.77	54.6%	1.37
C33	Odaiba Hotel Hilton	388	97.3	1.36	31.4%	0.26
C34	* Odaiba Residence	735	62.2	0.49	32.9%	0.32
C35	Tokyo City Hall	958	27.7	0.04	11.2%	0.02
C36	* Shinjuku Odakyu Department Store	1021	66.0	0.34	17.2%	0.11
C37	Shinjuku Station	762	100.1	1.03	48.1%	0.21
C38	* Shinjuku Takashimaya Department Store	802	31.4	0.13	38.2%	0.06
*C95	Hong Kong Aberdeen residence	933	122.1	1.31	54.6%	0.90
*C96	Singapore Marina Bay Sands Hotel	2328	31.1	0.36	76.0%	2.01
Type C : Illuminated View						
D39	Asakusa Senso-ji Temple	1041	103.3	1.94	74.2%	2.87
D40	Kachidoki Bridge	3170	104.8	6.29	38.4%	0.38
D41	Odaiba Rainbow Bridge	685	173.0	3.22	78.2%	3.17
D42	Yokohama Notre-Dam Wedding Palace	1751	118.5	3.68	46.9%	2.49
D97	Xi'an Bell Tower	1128	87.5	0.66	79.4%	4.00
Type E : Street View						
E43	Asakisa Nakamise	1732	53.7	0.70	85.2%	0.88
E44	Asakusa Street	2491	50.0	0.83	70.2%	1.61
E45	* Kabuki-cho Ichiban-gai	1924	62.5	1.00	51.1%	1.46
E46	* Kabuki-cho Golden Street	1592	43.5	0.65	43.3%	0.59
E47	Shibuya Center-gai	2598	98.0	5.45	48.3%	2.67
E48	* Shinjuku street	1567	59.1	0.74	35.2%	0.39
*E98	Hong Kong Street (1)	1386	145.6	4.30	69.3%	4.90
*E99	Hong Kong Street (2)	2144	40.5	0.45	55.4%	2.85

* Photos taken before 2019 for the comparison

* Photos taken on Weekend

2021, when most bars were closed because of the declaration of the state of emergency.

We mainly focus on types A to C, which represent diverse compositions of lights depending on the distance and use of buildings.

4. IMAGE PROCESSING METHOD

We coded a program to analyze the light composition of the nightscapes using the Python programming language. For the development environment, we used Anaconda[3] (a Python distribution), Jupyter Notebook (a web application for writing programs), and OpenCV[4] (Open Source Computer Vision Library, an image processing library).

4-1. Outline of Calculated Data

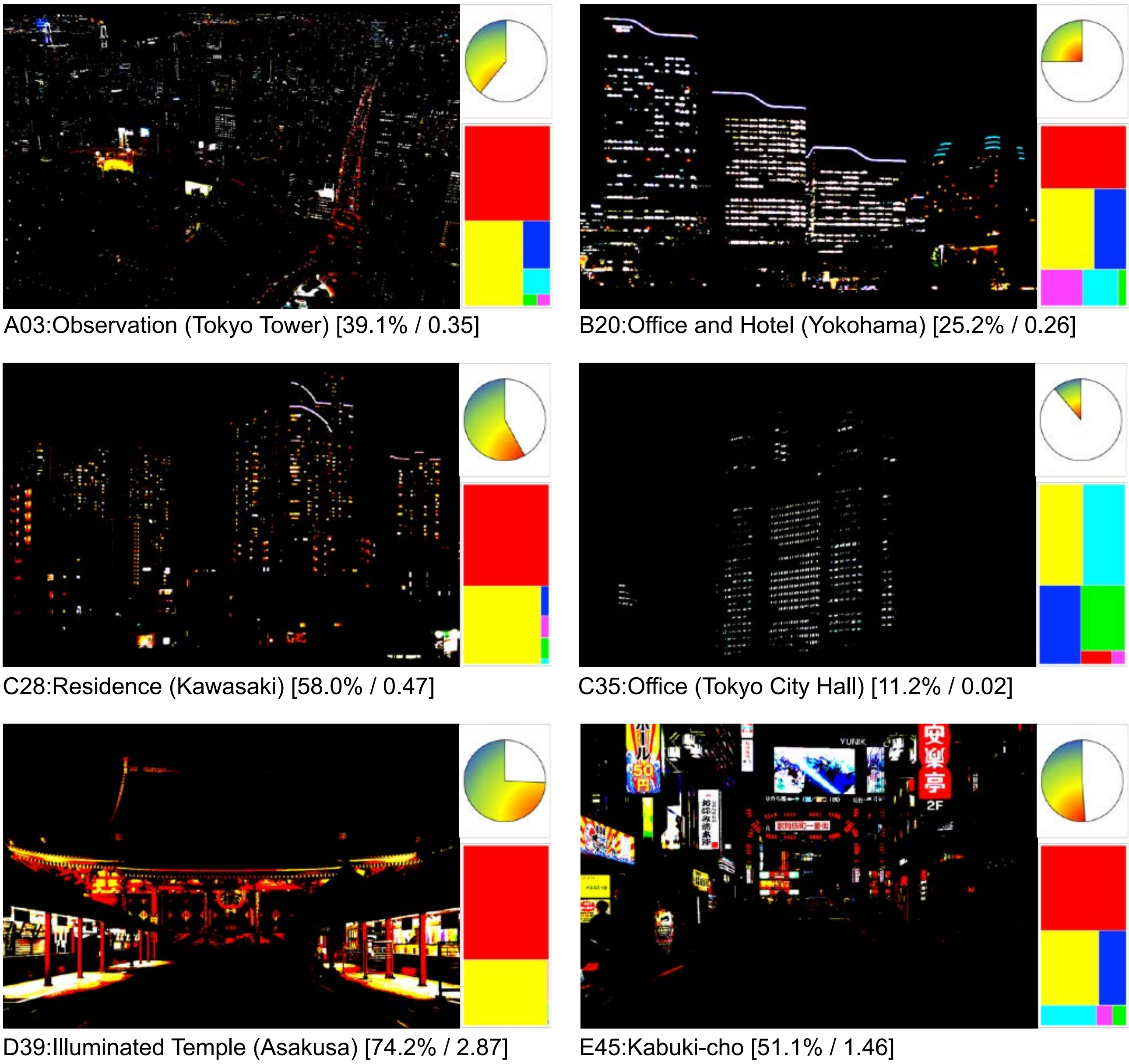
Table 1 shows the calculated data, which are discussed in detail in the following section.

First, as examples are shown in Figure 8, we extracted the contours of the bright areas to calculate the following characteristics by using the *findContours* function of OpenCV: Bright area Number (B.N.) representing the number of bright areas; Bright area size Average (B.A.) representing the average number of pixels in the bright areas; and Bright area Deviation (B.D.) representing the multiplier of the standard deviation to the mean. A higher B.D. means that the size of the area variation is greater.

Second, as shown in Figure 9, we analyzed

A02: Observation [3864/13.3/0.07] B12: Complex [2192/38.4/0.49] C23: Office [1580 / 91.0 / 0.97]

Figure 8: Number, Average Size, and Deviation of Bright Areas [B.N. / B.A. / B.D.].



A03:Observation (Tokyo Tower) [39.1% / 0.35]
B20:Office and Hotel (Yokohama) [25.2% / 0.26]
C28:Residence (Kawasaki) [58.0% / 0.47]
C35:Office (Tokyo City Hall) [11.2% / 0.02]
D39:Illuminated Temple (Asakusa) [74.2% / 2.87]
E45:Kabuki-cho [51.1% / 1.46]

Figure 9: Colored Ratio and Color Deviation [C.R. / C.D.].

the composition of colors by calculating Colored Ratio (C.R.), representing the ratio of the number of the colored pixels to the white pixels, and Color Deviation (C.D.), representing the deviation of colors.

A pixel color in graphics is generally described by an RGB value, which has an 8-bit or a 256-step of the three primary colors: red, green, and blue. We reduced pixels other than black in seven colors (blue, red, magenta, green, cyan, yellow, and white) by binarizing the RGB values of each pixel: 0-127 to 0 and 128-255 to 255.

4-2. Aspect Ratio and Resolution

Before analysis, we set the aspect ratio (width:height) of the analyzed images to 3:2 and the resolution to 1080 × 720 pixels.

4-3. Adjustment of Brightness

The brightness of the photos depends on the exposure, shutter speed, and ISO (International Organization for Standardization) sensitivity settings of the camera. The color of light

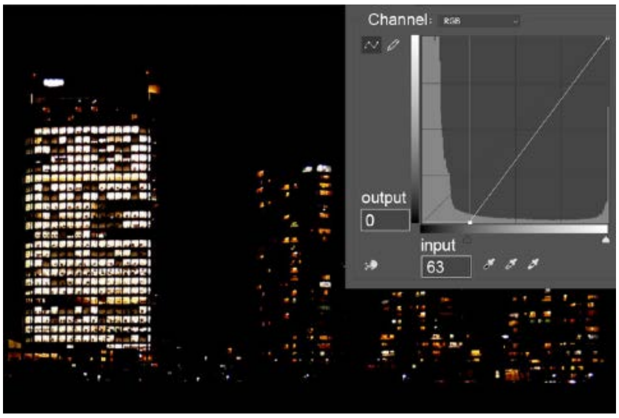


Figure 10: Adjustment of Brightness (B06).

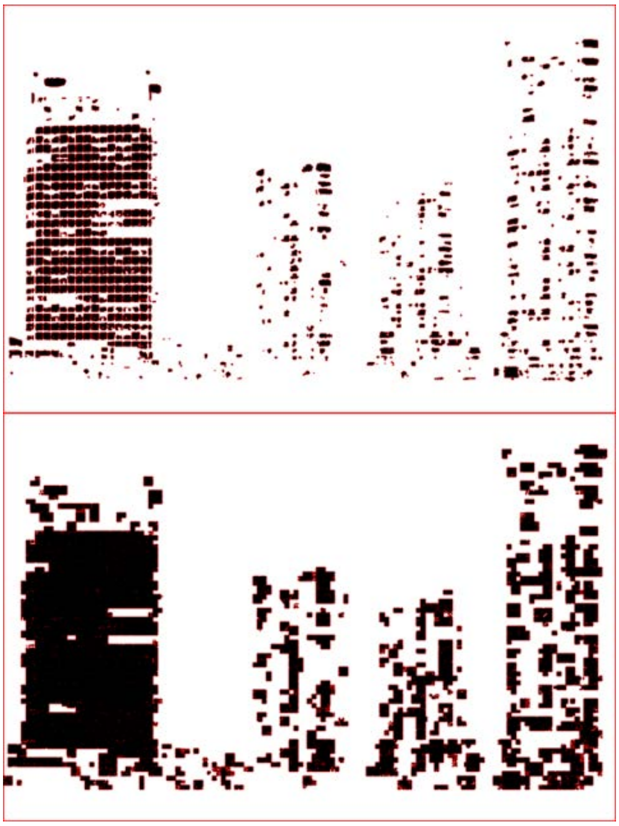


Figure 11: Comparison of Contours (B06), without/with low RGB value pixels.

changes depending on the white balance setting too.

To extract the bright areas, we took photos by setting the exposure relatively low to not be too bright and close to the sense of brightness. Although the degree of brightness is not an issue in the analysis described below, we removed vague bright areas, such as stagnations in the sky and human shadows. We considered brightness below 25% (brightness below 64 on the 256-step) as noise and adjusted it to zero by using an image processing software (Adobe Photoshop[5]), as shown in Figure 10.

4-4. Extraction of Bright Areas

B.N. (Bright area Number) indicated by the red contours in the topmost figure of Fig. 11 (B06, also shown in Figs. 1 and 10) was 903. However, the contours extracted here do not cover all pixels in the images, but pixels with RGB values between 64 to 255. If we count all pixels with a brightness greater than zero, the contours would be enlarged, as shown at the bottom figure of Figure 11. Note that the result of removing areas with RGB values less than 128 is almost the same as when removing less than 64, as we found the correlation coefficient to be 0.97.

5. COMPOSITION OF BRIGHT AREAS

As shown in the examples in Figure 8, Type A (observation view) has a large number, small size, and deviation. Type B (complex view) has a smaller number, medium size, and deviation. Type C (building view) has the smallest number, greater size, and deviation.

B.N. (Bright area Number), B.A. (Bright area size Average), and B.D. (Bright area Deviation) by the five types are shown in Figures 12 to 14. In these figures, the image moves from distant to close view from left to

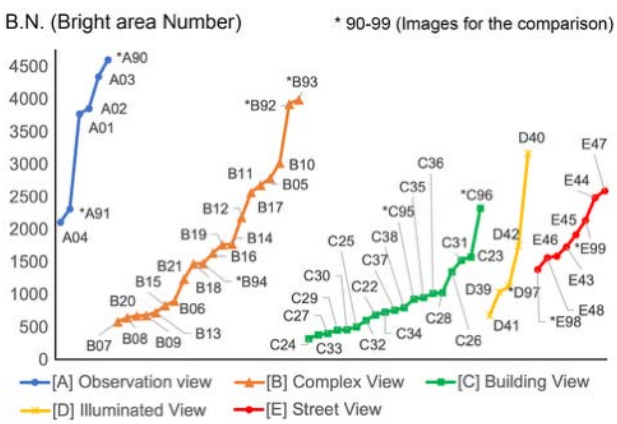


Figure 12: Number of Bright Areas.

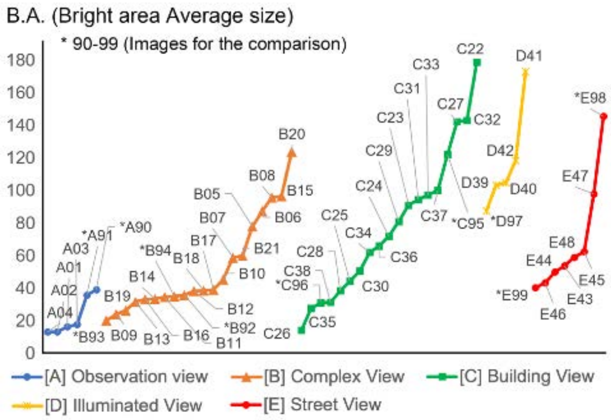


Figure 13: Average Size of Bright Areas.

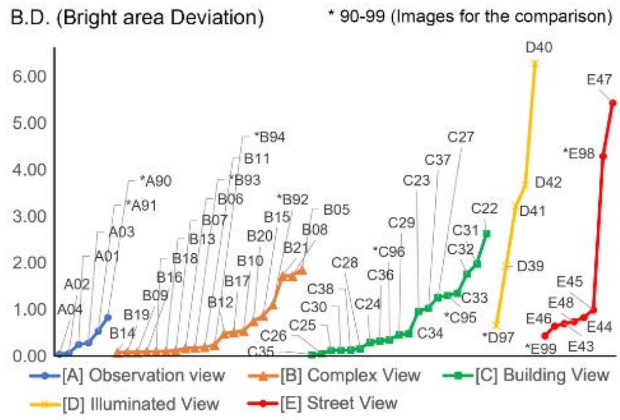


Figure 14: Deviation of Bright Areas.

right on the horizontal axis, as Type A is a distant view, Type B is a middle distant view, and Types C to E are closer views. And note that each image is sorted according to the value in ascending order within each type.

Expectedly, when the viewing distance becomes closer, the number decreases, while the size and deviation increase. However, as seen in Figures 12 to 14, the sizes and variations in Types B and C are more diverse, making the composition more complex. The compositions are most varied, especially in Type D (illuminated view) and Type E (street view) with the close-distance view.

Thus, as the iconography of nightscapes, the short distant view, which directly expresses people's activities in the city, is considered to be more diverse in composition. In contrast, the distant view, which depicts a broader scope, has a relatively simple composition.

6. COMPOSITION OF COLORS

6-1. Colored Ratio and Deviation of Colors

The pie chart in Figure 9 shows C.R. (colored Ratio) and C.D. (Color Deviation) The box chart shows the composition of the six colors.

In C35 (Tokyo City Hall), C.R. and C.D. were quite small, as most of the lighting in this office was white. B20 (Office and Hotel) had relatively small C.R. and C.D., as an office mainly occupies this image. In contrast, in C28 (residential complex), C.R. and C.D. were not small, as most residential lighting has bulb colors. The box chart indicates that the variation of colors in red and yellow is dominant in houses and hotels.

C.R. and C.D. by the five types are shown in Figures 15 and 16.

In Type A (observation view), C.R. is 31–57%, which is not small in absolute value, but

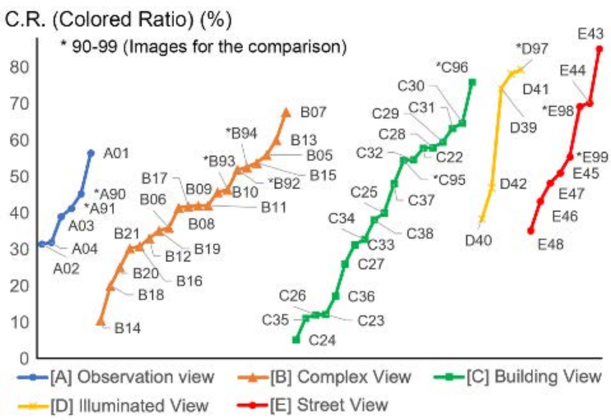


Figure 15: Colored Ratio of Five Types.

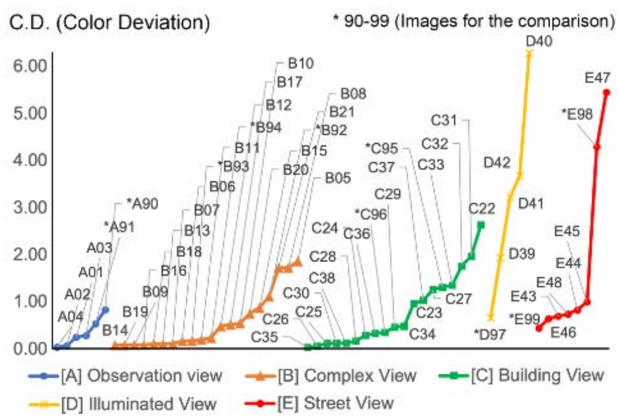


Figure 16: Deviation of Colors.

C.D. is 0.05–0.46, which indicates the variety of colors is relatively tiny.

In Type D (illuminated view), the values are 38–78% / 0.38–3.17. This indicates that lighting is designed with various colors. In Type E (street view), the values are 35–85% / 0.39–2.67, displaying rich and varied colors. The designed illuminations and street lights seem to add colors to the nightscapes.

6-2. Colors in Building Views

As shown in Figures 15 and 16, the colors are more diverse in Type C (building view), which looks at single or multiple building elevation(s), than in Type A (observation view), which is a distant view. Thus, closer views have more diverse colors.

C.R. by building use (office, residence, hotel, store, etc.) for Type C is shown in Figure 17. C.R. is small, i.e., white is dominant in C24, C35, and C23, which are typical offices. Meanwhile, C31 is an exception, as it is a T.V. station headquarters with illuminated lights. The colors are richer in residences and hotels. C26 is an exception as it is the athletes' village during the Olympic Games, and the lights in the rooms are sparsely lit in white.

7. BRIGHT AREAS AND COLORS

A scatter plot of B.N. on the X-axis and C.R. on the Y-axis is shown in Figure 18.

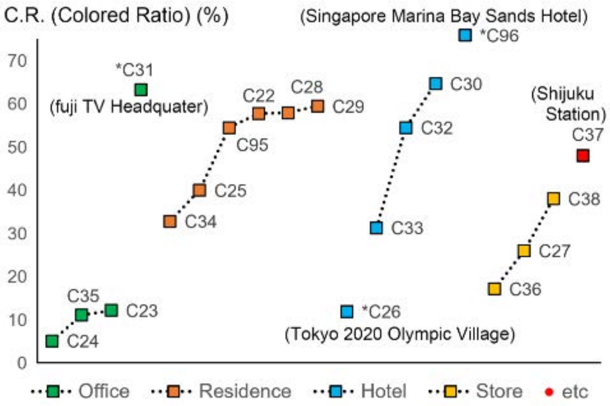


Figure 17: Colored Ratio in Building Views.

Type C (building view), which is the closer view, has few bright areas and rich colors. Type A (observation view), which is the distant view, has a number of bright areas and the color composition is intermediate. Type B (complex view), which is the middle view, has the characteristics of both the building and observation views.

The nightscapes used for comparison (numbers 90-99 following A-E) have unique characteristics. Chicago (A90), with its prominent streetlights, has a remarkably high B.N. The complex views of Hong Kong (B92, B93), which has more high-density and high-rise buildings than Tokyo, have an incredibly high B.N. Marina Bay Sands Hotel in Singapore (C96), which has an exceptionally large B.N. and high C.R, is considered to have a peculiar nightscape as a tourist attraction.

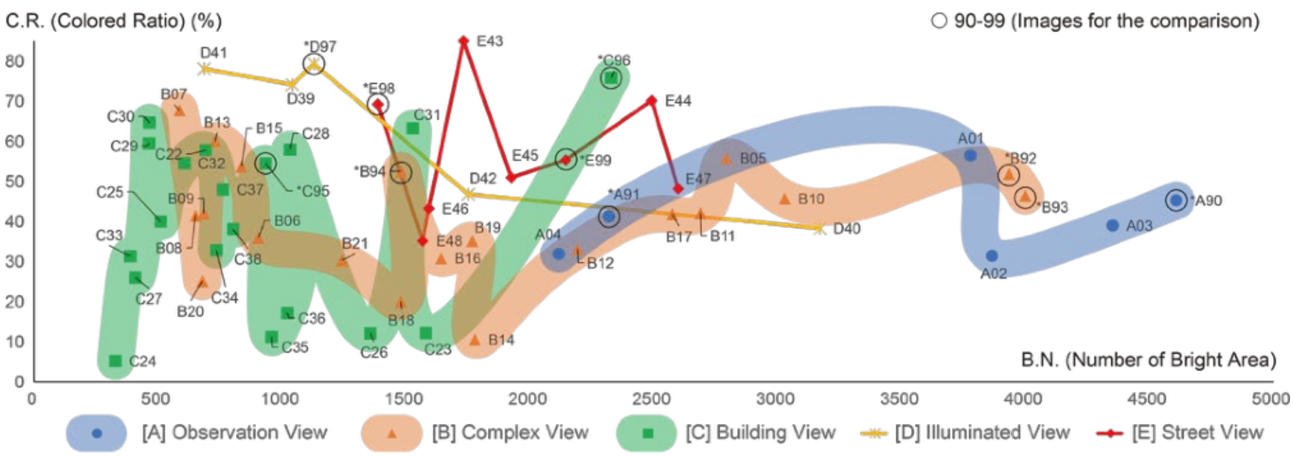


Figure 18: Number of Bright Areas and Colored Ratio.

8. CONCLUTION

The characteristics of nightscapes in Tokyo as graphic iconography to represent the images of cities, which are composed of bright areas and their colors, were numerically analyzed. The nightscapes had diverse characteristics depending on the distance, time of day, and type of building.

As we move from distant to near views, the number of bright areas decreases and their size and deviation increased. In the complex view and the building view, their sizes and deviation widely varied depending on the time of day, the array of the buildings, the building scale and their use, etc. In addition, the illuminated view and the street view had unique compositions.

Diversity in the nightscapes by distance and building use was also seen in the color composition. In the near view (the building view, the illuminated view, and the street view), where there were few bright areas, the colors were often rich. The color composition of the distant view (the observation view), which had more bright areas, was moderate. The complex view combined the characteristics of both the observation view and the building view. In the views of office buildings, the colors were often monotonous but rich in the hotels and residences. The colors of the residential buildings were most varied.

The composition of light in the nightscape is considered to be a projection of people's lives in the city. One can perceive the nightscape as an expression of the image of the city as a diverse and ever-changing complex.

In this study, we initially intended to compare nightscapes during and after the pandemic. However, as of August 2021, the state of emergency continues in Tokyo. Therefore, we have not been able to photograph the post-pandemic nightscapes. We will address this issue and the Comparison of Tokyo and other cities worldwide in the future.

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THE PHOTOGRAPHED 3D OBJECT ATTACHED WITH GEOMETRIC TEXTURES IS PERCEIVED LARGER THAN ITS ACTUAL SIZE

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ABSTRACT: When estimating the size of an object in a photograph, we sometimes make systematic errors. An example is the "diorama effect," in which an actual scene in a photograph appears to be smaller than in real life, imitating a diorama model. In this study, we report on the hypothesis that a three-dimensional object in a photograph can appear larger than its actual size, termed the "magnification effect." Specifically, the size of objects consisting of block-type toys with illusory patterns on the surface (optical illusion blocks) is overestimated when viewed in a photograph. This illusion was discovered through oral reports from participants in a series of workshops that used optical illusion blocks. Subsequently, we conducted a series of psychological experiments to confirm this report on the "magnification effect." We prepared five objects for the experiments, and participants with no prior experience with optical illusion blocks were selected. Using centimeter as the metric unit of measurement, the participants were instructed to estimate and report on the size of the objects for each photograph. The results showed that the median reported size was 2.40 of its actual size. Interestingly, when the same participants performed the same size estimation task for familiar objects, such as industrial products that are seen daily, no size overestimation was observed. Thus, the experimental results successfully affirmed the size overestimation reported in the workshop series. Furthermore, these results suggest that size overestimation occurs only when the object is unnatural and unfamiliar to the participants.

Keywords: Construction Toy, Structure, Spatial Cognition, Perceived Architecture, Graphic Science Education.

1. INTRODUCTION

This report indicates the plausibility of a third party perceiving an illusionary object in a photograph to be larger than its actual size (hereafter referred to as the "magnification effect"). The differences existing between our subjective perception and the physical measurements of the size of an object is a long-established fact, and several studies have been conducted on this theme [e.g., 1-3]. Several studies have shown that the perception of distance and size can be established using depth cues in the visual system. These studies have become the standard for other research, such as pictorial cues in perspective drawing. Recent studies on object size estimation are mostly related to human cognition, such as knowledge of the object to be viewed, haptics, cognitive context, and memory [e.g., 4-8]. Some studies have been conducted on the diorama effect in object size perception [e.g., 9]. The diorama effect is known to cause errors when estimating the size of a photographic subject. However, as per our knowledge, few studies have been conducted on the magnification effect.

The magnification effect was discovered based on a workshop (WS) we conducted on illusions. We have developed a WS-type educational program in which participants learn of the possibility of a difference between the physical shape of a three-dimensional (3D) object and the 3D image produced by a two-dimensional (2D) retinal image, depending on the texture of the object's surface, by assembling 3D objects using block-type toys (hereinafter referred to as "optical illusion blocks") whose textures are the graphic elements that constitute the illusion [10-11].

The WS is an educational program wherein participants deepen their understanding of a subject through experience and group work. The aim is to deepen learning through collaboration with others, which can also promote the emergence of knowledge. Usually, participants in a WS are not experts on the theme. With the aid of the facilitator, the participants decide what they want to learn [12].

In our WS series, participants observed the illusory 3D objects (hereafter referred to as "illusionary objects") created with the optical illusion blocks. They subsequently took pictures from the viewpoint where the illusion was most effective. Several third parties who saw these photographs commented that they thought the blocks were bigger than the actual blocks when they had seen them in the photographs. This report indicates the possibility of an illusion that a third party perceives the size of an illusionary object in a photograph to be bigger than it is (the "magnification effect"). In this study, we examined the plausibility of the magnification effect.

1.1 A comparison between the diorama and magnification effects

In the diorama effect, the actual scene and item in the photograph are perceived to be smaller than they are in the physical world as if it were a diorama. Several factors can cause the diorama effect: the height of the viewpoint, blur in the photo, saturation, specific colors, overall luminance, texture, lack of depth cues, perceptual framework, discomfort, and cultural and social background [2,5].

The direction of the magnification effect opposes that of the diorama effect. Although there is no guarantee that these two phenomena are based on the exact mechanism, there are some apparent similarities, such as the occurrence of both phenomena on natural objects captured by photographs. They are illusory phenomena in the size estimation of natural objects. In the magnification effect, depth cues and the perceptual framework (cognitive context) are assumed to be involved in the illusion.

2. CONFIRMATION OF THE OVERESTIMATION PHENOMENON

The purpose of this study was to confirm the magnification effect observed in photographs of illusionary objects.

2.1 General Experimental Method

In the experiments, we used photographs of illusionary objects created in previous WSs. These photographs were selected based on the following criteria: (1) no objects other than the stimulus, such as the Lego® baseplate, must be reflected in the photograph, and (2) the photograph must not be taken at a crooked angle. In the experiments, we prepared five objects consisting of 16 blocks each. The participants were undergraduate art students who had no specialized knowledge of optical illusions and never participated in a WS using these blocks. The experiments were conducted in classrooms that had two displays; one was a large screen set up in the center of the front of the classroom, and the other was a monitor hanging from the ceiling at the rear of the classroom on either side. A projector was used to project the images on the screen. The same image was presented on the screen and the display. The participants were instructed to examine the images displayed near their seats.

Each stimulus was presented for 10 seconds. For every stimulus, the participant estimated its apparent size and reported the estimated size in the response form. Before these experiments, the participants were informed that the actual height of the block constructed for each object was uneven, even if the size of the presented photographs was uniform.

The research ethics review approval for the series of experiments performed in this study was given by the first author's affiliated institution at the time of the experiments (1 芸術情第 20-1 号).

2.2 Experiment 1: Apparent height ratio to actual size for each object

The participants were 111 undergraduate art students. Based on the data from 111 participants in the experiment (aggregate including missing values), we calculated the ratio of apparent height to actual size for each stimulus (Figure 1). The apparent height ratio to the actual size was considered as 1.0 when the participants considered the object to be the same height as its actual size. Figure 2 shows the apparent height ratio relative to the actual size for each stimulus.

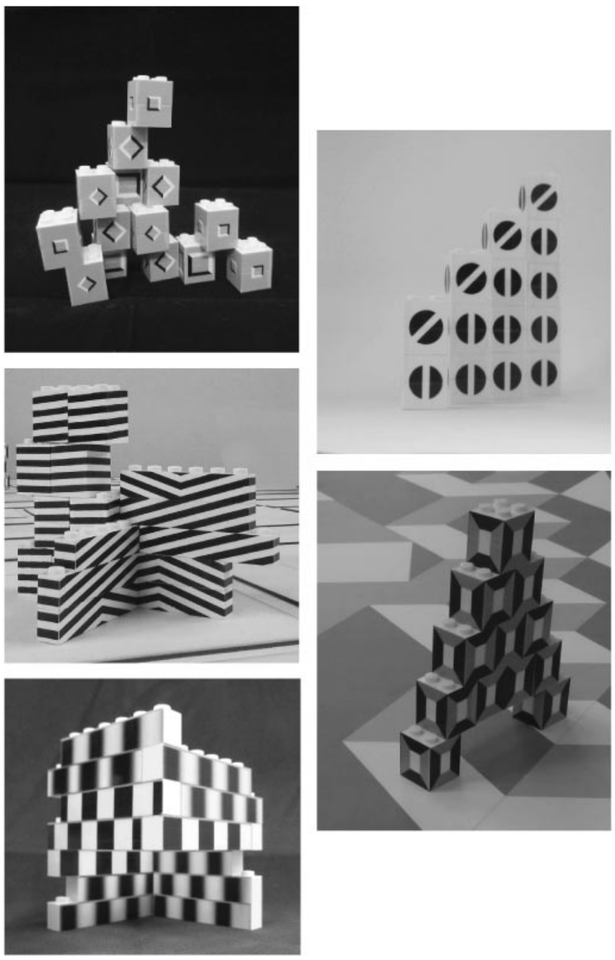

Figure 1: Photographs used in the experiments.

As a result, the reported sizes of the illusory objects were between 0.21 and 31.25 times larger than their actual sizes. The median of the reported size was 2.40 of its actual size [$F(1,101) = 66.16$, $p < .01$]. These results show that the magnification effect was observed by third parties who had no knowledge of the optical illusion blocks and had never participated in the WS.

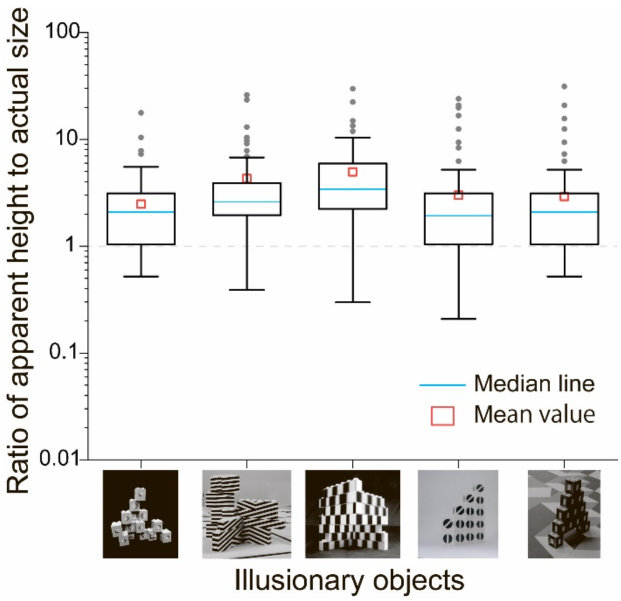

Figure 2: Ratio of the apparent height to the actual size of the illusionary object in the photograph (y-axis on log10 scale). The gray dots indicate values that are more than 1.5 times the quartile range away from the first or third quartile.

In Experiment 1, we provided as few explicit cues as possible, except for the protruding parts of the blocks in the photographs. Those protruding parts were potential clues for size estimation. However, the participants were not given any information about the manufacturer or size of the blocks used. Therefore, it is unlikely that the participants estimated the size of the illusionary object from the number of protrusions on the blocks. In other words, it is highly probable that the participants assumed the size of the illusion blocks in the photographs and the size of the assembled 3D objects with no external influence and unintentionally guessed and answered the questions.

The apparent size perception of a static image is related to the size of the visual object in the retinal image and the perceived distance to the visual object [1, 3]. In the absence of distance cues for objects, judgments of the size of unfamiliar objects are independent of those of depth distance [13]. The 3D illusionary objects created by the optical illusion blocks should have been unfamiliar to the participants. Therefore, they did not refer to the size of the retinal image or the distance to the object when estimating the size of the illusory 3D object in the photograph in Experiment 1. The unfamiliarity of the stimuli could be the cause of the magnification effect.

The other possibility is that the method used to present the stimuli might be the main cause of the magnification effect observed in this experiment. The method used here was not the standard method used in laboratory experiments. Although we endeavored to ensure that the results were not affected by the method of stimulus presentation, experiments in less well-controlled situations, such as laboratory experiments, may contain unexpected artifacts. Therefore, we cannot rule out the possibility that those artifacts could cause a magnification effect solely based on Experiment 1.

One way to examine which of these two possibilities is the actual cause of the magnification effect is to observe whether or not the effect occurs when the stimulus is a familiar 3D photograph using the same method as in Experiment 1. If the method of presentation is the cause of the magnification effect, then it should occur for any photograph, including those of the familiar object. On the other hand, if the unfamiliarity of the stimuli is the main cause, no magnification effect would be observed with the photographs of the familiar object. To verify this, we conducted the experiment as described above.

2.3 Experiment 2: Estimating size when an object is familiar

In this experiment, we examined the estimated size of the familiar object in the photograph using the same method as in Experiment 1. We asked participants of Experiment 1 to estimate the numerical values of apparent heights using photographs of familiar industrial products (pen, plier, stool, pylon, bookshelf, and whiteboard) as their subjects.

The method of presenting the stimuli and the experimental location was the same as in Experiment 1. The ratio of the apparent height to the actual size of each stimulus was calculated from the median of 107 participants who had no missing values for each experimental stimulus. The results are shown in Table 1.

Table 1: Apparent height ratio to actual size and standard error for each object. SE is standard error.

Stimulus	Medians of Apparent Height Ratios	SE
pen	0.97	0.03
plier	1.03	0.04
stool	1.33	0.06
pylon	1.67	0.07
bookshelf	1.00	0.03
whiteboard	0.94	0.02

These results show that there is almost no discrepancy between the actual and apparent sizes of the industrial products. There was a statistical difference in the size estimates between the industrial product stimuli [F (5, 530) = 112.68, p <.05]. The means of apparent height ratios ranged from 0.94 to 1.67. The largest ratio observed in this experiment (1.67 with the "pylon" stimulus) was less than the smallest effect size (1.93) observed in Experiment 1. The ratios observed with four of six stimuli were not significantly larger than 1. Independent samples t-tests revealed that the apparent height ratios of Experiment 1 were significantly higher than those of Experiment 2 [t (559.610) =13.02, p < .001].

These results suggest that our participants could estimate the size of familiar industrial products more accurately than that of the unfamiliar 3D illusionary objects used in Experiment 1. Thus, it is unlikely that the atypical method of stimulus presentation used in this study is a direct cause of the magnification effect.

2.4 Experiment 3: Difference in apparent size with and without the illusion pattern

The results of Experiment 1 showed that the apparent height ratio differed based on the stimulus figure. Experiment 2 showed that the estimation of the size of the illusionary objects tended to be more uncertain than that of familiar products.

The next question was whether the magnification effect is induced by the presence or absence of the illusion pattern. In Experiment 3, we compared the apparent sizes of the illusionary objects with those of 3D objects without a pattern. First, non-patterned (without-pattern) 3D objects were assembled in the same structure as the Experiment 1 stimulus using white blocks. We then took photographs from the same angle as the previous experimental stimulus.

The experiment had a design of 2 (pattern: with/without) × 2 (five types of conditions for building an optical illusion block: Type 1, Type 2, Type 3, Type 4, Type 5). The participants were 35 undergraduate art students who had not participated in the previous experiments.

Based on the data from the 35 participants in the experiment (aggregate including missing values), we calculated the ratio of apparent height to actual size for each stimulus. The apparent height ratio to the actual size was considered to be 1.0 when the participants considered the object to be of the same height as its actual size.

Figure 3 shows the apparent height ratio relative to the actual size for each stimulus. The median ratio of the apparent height to the actual size was larger than 1 for all stimulus figures, indicating that the magnification effect was observed in both with- and without-pattern objects.

Next, we tested whether the magnification effect was different between the conditions with and without the geometric pattern on the object surface. We calculated the estimated size ratio for each individual by dividing the estimated size when the geometric pattern was attached to the object surface by that for the same object with the same shape but without geometric patterns on the surface.

Figure 4 shows the mean estimated size ratios for each type of assemblage. The results showed that the mean ratios were larger than 1 for four out of the five types of assemblages, which indicates that the magnification effect is roughly larger in the with-pattern objects than in the without-pattern objects. The estimated size ratio with Type 3 assemblages was less than 1. Including this condition, large individual differences were observed. Therefore, we performed the two-way repeated ANOVA to clarify the statistical significance in our data. The ANOVA with the factors of the illusory pattern and the way the blocks were combined revealed the main effects of how the judgments of the apparent size of the illusionary objects (Figure 3) are the same as in Experiment 1 (Figure 2). The ANOVA with pattern factors and ways of assembling blocks revealed the main effects on ways of assembling blocks [$F\,(4,132) = 14.35$, $p < .05$], and the interaction of the pattern and ways of assembling blocks [$F\,(4,132) = 5.00$, $p < .05$]. The presence or absence of the illusory pattern was not significant. Analysis of the simple main effects confirmed that the presence or absence of the pattern was significant in Type 1, Type 3, and Type 5 combinations [$F\,(1,34) = 8.64$, $p < .05$; $F\,(1,34) = 4.20$, $p < .05$; $F\,(1,34) = 6.37$, $p < .05$]. In addition, the simple main effect of assembly on without-pattern objects [$F\,(4,132) = 11.67$, $p < .05$] and the simple main effect of assembly on with-pattern objects was also significant [$F\,(4,132) = 8.20$, $p < .05$].

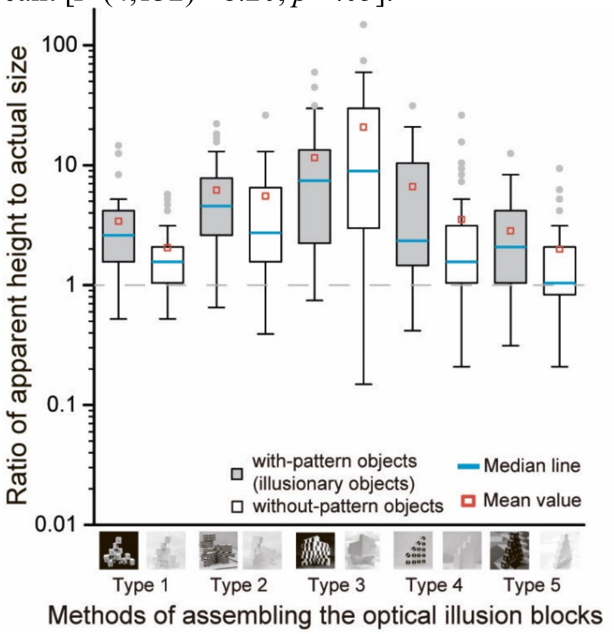

Figure 3: Ratio of the apparent height to the actual size of the with-pattern objects and without-pattern objects in the photograph (y-axis on log10 scale). The gray dots indicate values that are more than 1.5 times the quartile range away from the first or third quartile.

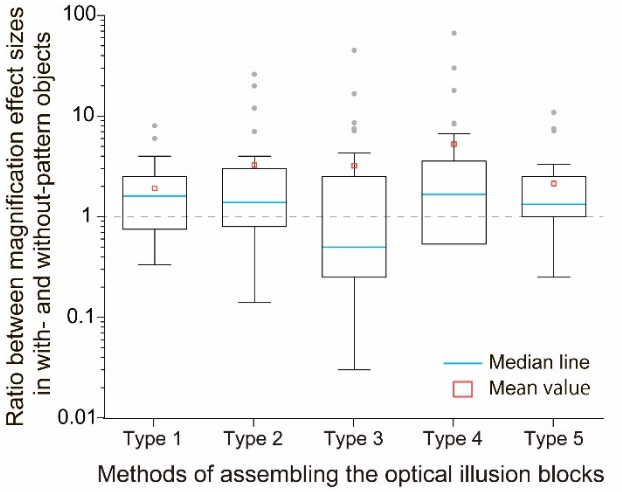

Figure 4: Ratio between the magnification effect sizes in with- and without-pattern objects (y-axis on log10 scale). The gray dots indicate values that are more than 1.5 times the quartile range away from the first or third quartile.

The results pattern roughly showed that the apparent size of the with-pattern object could be larger than that of the without-pattern object, yet the difference was fairly robust. We could not find significant differences in the magnification effect between with- and without-pattern objects. In addition, the relationship was reversed in one object (Type 3). The magnification effect tends to be stronger in the presence of an illusory pattern. However, the difference is apparently not robust and vulnerable to the context in the photograph containing the object shape as well as the type of geometrical pattens.

Notably, the presence of that exceptional case suggests that the magnitude of the phenomenon varies depending on the combination of blocks. Pairwise comparisons using a Bonferroni correction indicated significant differences in the object's apparent size when the pattern was larger than that of the without-pattern object for Type 1 and Type 5, and the object's apparent size without the pattern was larger than that of the other for Type 3. Pairwise comparisons using a Bonferroni correction indicated significant differences in the objects without patterns. The differences in apparent size were significant for all combinations except Type 1 and Type 4, Type 1 and Type 5, Type 2 and Type 4, and Type 4 and Type 5. Furthermore, the exact pairwise comparisons indicated significant differences in the with-pattern objects. The differences in apparent size were significant for combinations other than Type 1 and Type 4, Type 1 and Type 5, Type 2 and Type 3, Type 2 and Type 4, Type 3 and Type 4, and Type 4 and Type 5.

These results indicate the way the block are assembled has a large influence on the size estimation. In other words, the magnification effect of the illusion pattern would be weak when the type of assemblage is inadequate.

2.5 General discussion

The results of a series of experiments indicate that the magnification effect occurs in photographs of illusionary objects, and the illusionary pattern strengthens the effect size. In the present experiment results, the overestimation effect on the block solid itself was consistently and robustly observed (Figure 1, 3). Therefore, we believe that the results of this experiment sufficiently demonstrate the existence of the size magnification effect itself. On the other hand, we found large individual differences in the present results. These individual differences make it difficult to interpret the results, especially in Experiment 3. We should not say that every geometrical pattern on the object surface strengthens the magnification effect in the apparent size estimation. The problem may be addressed by collecting data from a larger number of subjects.

The large individual differences in the data might be the result of not controlling the viewing distance. The cues of depth distance to the observed object, such as binocular disparity and convergence, vary with changes in viewing distance. When observing a real object, these depth cues have a significant effect on the size estimation. Conversely, it is unclear how these cues affect the apparent size of an object in a photograph. Therefore, the effect of viewing distance on the magnification effect remains unclear. Although the viewing distance was not controlled, the magnification effect of our experiment was observed consistently. However, the relationship between viewing distance and the overestimation effect may be an intriguing point in further discussing the magnification effect. The details of this issue will be clarified as the overestimation effect is examined in a subsequent experiment in a more controlled environment.

In the WS we have conducted so far, we first showed past cases on a display monitor and explained them. In addition, the participants took photographs of their creations. Finally, they compared the physical appearance of their creations to their appearance in the photograph. Hence, based on this, we speculated that a magnification effect may have occurred on the illusionary objects that the participants observed. However, when participants created the illusionary objects, there were various cues, including tactile sensations and body movements. Therefore, it is natural to assume that they are consciously aware that the size of the block or 3D object is the same as the actual size. In other words, there may have been differences in the perceived size of the illusionary object between seeing it physically and seeing it on a display monitor or in a photograph, resulting in a different impression.

Several participants in our WS series using optical illusion blocks analyzed their work in progress or made corrections while observing their completed work through the viewfinder of a camera. The view appeared as a boxy garden-like world through the camera's viewfinder, detached from the real world. The possible reason participants looked through the viewfinder was to concentrate on completing their work without worrying about the magnification effect.

3. CONCLUSIONS

This report discusses the magnification effect, which is the perception of the size of an illusionary object in a photograph as larger than the actual size.

The apparent height ratio differed based on the stimulus. It was discovered that the estimation of the size of the illusionary objects tended to be more uncertain than that of familiar products. Future research can be conducted to examine the presence of the magnification effect in photographs of objects with patterns that do not produce the illusion.

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AUTOMATIC GEOMETRIC CALIBRATION OF SPATIAL AUGMENTED REALITY FOR ARCHITECTURAL DESIGN VISUALIZATION

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ABSTRACT: Spatial Augmented Reality (SAR), a branch of Augmented Reality (AR), has great potential for collaborative architectural design visualization by projecting Building Information Modelling (BIM) images onto real objects (e.g., small-scale mock-up models). In SAR, the building surface texture is pre-produced and assigned to projectors such that the texture matches with the physical building model in the 3D real world. To enable SAR registration, geometric calibration for the alignment between projected images and physical models is essential. Previous research efforts have proposed various approaches for the geometric calibration of SAR, ranging from manual calibration of reference points to automatic projection mapping. Although marker-based calibration method has been developed for AR, it is more challenging to apply to SAR. Using geometric calibration information, the output display panel of SAR is in the real world, while its outcome display remains on a 2D screen of AR. To tackle this challenge, we propose a marker-based approach for SAR-based 3D BIM visualization, which uses a projector-camera system and a marker detection method to achieve automatic geometric calibration and mapping on 3D building models. Markers are attached on the corners of the model's detected surfaces, and the projector-camera system can be easily placed on any position within the shooting and projecting range. We used a series of computer vision methods for image processing and object detection, including perspective distortion correction, image segmentation, position estimation, and projective transformation. We also conducted an experimental test to perform and evaluate the whole process and the outcome model appearance intuitively. Moreover, we validated registration accuracy by measuring the projection error. The preliminary result showed satisfying accuracy of the projection on the front surface of the model and realness of SAR-based 3D BIM visualization. However, there was test error on the side surfaces that need to be further eliminated, and potential solutions were proposed. The proposed method involved an alternative for 3D BIM visualization in a shared environment to facilitate more efficient architectural design collaboration between participants.

Keywords: Spatial Augmented Reality, Marker-Based Detection, Automatic Geometric Calibration, Architectural Design, 3D Visualization.

1. INTRODUCTION

Visualization has been utilized to improve data interpretation, and the usage and approaches for visualization have advanced significantly in many areas [1]. In the architecture domain, visualization aids the representation of building information, transmission of ideas, and analysis of data. Among various visualization technologies, building information modeling (BIM) is widely and popularly used with 3D imagery and building information management [2]. During the building design phase, BIM-based architectural visualization allows constructive and productive cooperation among project stakeholders for data interchange and alteration [3]. However, BIM still displays a 3D BIM model onto a 2D plan, resulting in limited 3D perception. The model visualization is thus not delivered in a form that participants can fully comprehend on a real-world scale [4].

To improve the stereo visualization of 3D models produced by BIM software, Immersive Virtual Reality (IVR) and Augmented Reality (AR) have been actively used as extended platforms for architectural design visualization [5]. In particular, AR technology has been applied to the architecture, engineering, and construction industries for over 10 years as an interactive tool that combines virtual and real environments by superimposing digital information with the real world. It allows users to visualize projects more clearly and intuitively [6]. Spatial AR (SAR) technology has been developed from AR concept projects and computer-generated images of real objects or environments using projectors, with the aim of providing a more tangible visualization of specific designs [7]. Compared with traditional AR technologies, the main advantage of SAR is that it allows users to be detached from physical display devices (e.g., hand-held or head-mounted displays) by embedding them into a physical model [8]. This unique feature of SAR provides a wider field-of-view with lower latency and a shared observing experience among participants, which is well suited for multi-user applications [8,9].

In SAR application, geometric alignment is a significant process that matches the location of projected images with physical objects in the 3D real world [7]. Geometric calibration for SAR is similar to the calibration (registration) of traditional AR, but is more challenging [10,11]. In traditional AR, the view of the camera matches with the view of users, so it only requires registration of virtual objects with a real world only from the user's view. However, SAR requires the alignment between a projector (i.e., the source of virtual images) and a reference camera or sensor (i.e., a means to obtain geometric information from a real world). In the SAR domain, existing geometric calibration mostly relies on manual alignment, which matches reference points from both object and projector views, or a sophisticated calibration process that entails tedious complicated computations using a projector-camera system. For a more practical application of SAR in architectural design visualization, it is necessary to develop a more user-friendly and streamlined approach for geometric calibration.

In this regard, we propose a maker-based geometric calibration method for SAR for the visualization of BIM models using a projector-camera system. The proposed method allows the automated calibration of a camera-projector system to achieve better alignment accuracy and minimize tedious human effort and computation. We tested the feasibility of the proposed approach through an experimental demonstration using a small mock-up model and evaluated the accuracy of geometric alignment. Based on the results, we explored the approach's potentials and technical challenges.

2. LITERATURE REVIEW

2.1 Spatial Augmented Reality

Spatial augmented reality, also known as projection mapping, has been developed from AR technology. It enables real-world environment to be augmented with computer-generated virtual information by projecting virtual contents straight onto physical space or objects [7]. This technology provides a variety of benefits for presenting building design ideas. It is possible to change appearance attributes, such as color, texture, and annotations; add or adjust delicate detail texture adaptively; and enable users to have physical contact with enhanced objects in entirely virtual scenes that often do not offer enough tactile sense [12].

To visualize design models, designers traditionally color and annotate physical prototypes using paint and ink [13]. The use of SAR changes the surface appearance of physical prototypes by projecting virtual textures directly onto a physical model, thus enabling rapid prototyping of the design model [14]. A limitation of the traditional painted model of physical prototypes is that either an additional mockup must be created or the initial mockup should be repainted when the design is changed. Additionally, alternative design scenarios could not be displayed rapidly on one physical model. Using SAR for model prototyping can address these limitations [15].

Previous studies have explored the use of SAR in design visualization. Verlinden [16] developed a system that provides designers a preview of different materials on contractible automobile prototypes, where a turntable with orientation tracking is employed to support the rotary movement of the physical model. Marner and Thomas [17] introduced a technique to sculpt the appearance of physical foams through virtual simulation of the foam's surface design so that the model can be simultaneously modified in both real and virtual worlds.

When rendering virtual images on a 3D object using a projector, the user can either be moving or static. The projector may be positioned anywhere on the display surface in a front-projection or rear-projection system, and the projected surface may be planar or non-planar. Geometric alignment between the projected image and the object is therefore necessary. One way to achieve geometric alignment is through geometric calibration technologies [7]. Traditional AR utilizes headgear or monitors to superimpose produced images onto the physical system. Developers frequently use cameras to track objects because computer vision techniques are versatile and non-intrusive. Image processing methods can be applied to SAR since the enhanced objects are still extracted from reality. Computer vision methods can be used for geometric calibration or tracking. However, when using video projectors to display computer graphics or data onto physical surfaces, the appearance of the virtual objects can be different, necessitating the modification or improvement of methods [10].

2.2 Geometric Calibration Technology

The components of AR and SAR—scene information acquisition, geometric alignment of virtual and real scenes, and scene display—are generally consistent. As such, geometric calibration technologies for AR can be adopted and developed for SAR. Vision-based geometric calibration technology has been used for AR. Researchers classify vision-based technology into two categories: marker-based method and natural feature-based method [18,19].

Vision-based geometric calibration is based on computer vision. It uses the camera on the device to process images or videos, obtain tracking information, and determine the position of the virtual scene to be superimposed in the real environment [20]. This technology can dynamically correct errors while registering, using a combination of image processing and computer vision methods. It is currently the mainstream technology used for geometric calibration in AR. Marker-based geometric calibration entails placing artificial signs in the real-world scene and then using the camera to recognize the signs in the image. It combines the principles of camera calibration. It has high robustness and low processing power requirements [21]. Natural feature-based geometric calibration does not need to place markers in the real environment in advance because it uses some natural features in the scene to calculate the camera posture information and complete the calibration. It matches feature point sets of the target object to determine the spatial position of the camera. Table 1 presents a comparison between marker-based and natural feature-based methods.

Table 1. Comparison of marker-based, natural feature-based methods

Geometric Calibration Method	Advantages	Disadvantages
Marker-based method	- Better real-time performance - Lower computational complexity - High accuracy	- Problems of occlusion in the tracking process
Natural feature-based method	- No destruction of the integrity of the real scene - Wider application range	- High computational complexity - Poor real-time performance - High system delay

Marker-based method has high accuracy and acceptable computational complexity and real-time performance. The physical building model is fixed most of the time by using SAR, and multiple projectors are used if surrounding surfaces of the building must be augmented. The problem of occlusion in tracking barely affects projection.

Even though marker-based calibration has been widely used in AR systems, its applicability on SAR is more challenging, especially for projection mapping on 3D objects (e.g., mock-up building models. In the AR system, image processing and calibration are implemented on a mutual 2D screen plane. However, in the SAR system, the camera and the projector share two different image planes. The object in the real world also has a 3D coordinate system that is different from both camera and projector, which results in a more challenging marker-based calibration of SAR

3. METHODOLOGY

The proposed flowchart of marker-based SAR for building design visualization is shown in Figure 1. Details are explained in the following sub-sections. The projection panel is coplanar to one of the model's surface. The panel is then removed once the photo of the projection area has been taken.

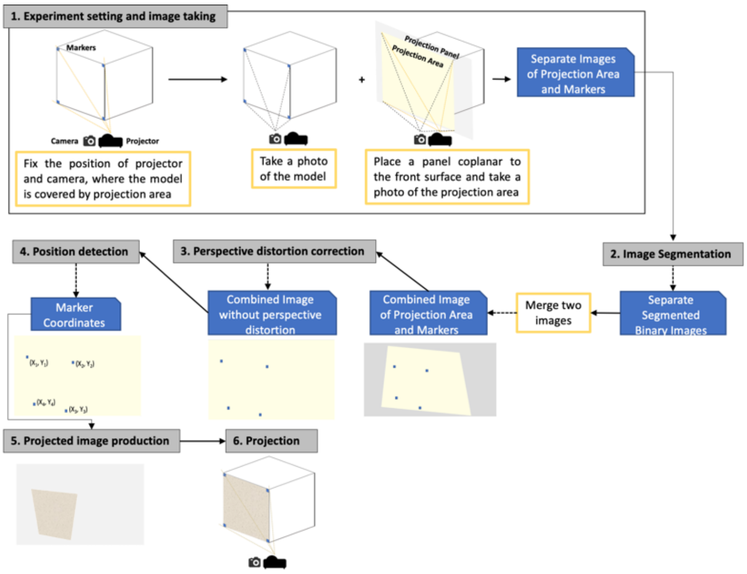


Figure 1. Flowchart of marker-based SAR for building design visualization

3.1 Perspective Distortion (Keystoning) Correction

Unless the shooting angle of the camera is fully and perpendicularly aligned to the target object surface, the resulting image appears distorted or keystoned [22]. To correct camera keystoning effect, the irregular quadrangle shape of the projection area captured in the image is transferred so that it has a rectangular shape. The relationship between the projection area in the image effected by perspective distortion and the projection area which we expected to be rectangle, is as essential as the relationship between the location of a scene point in one camera and its location in the other camera. The transformation matrix can be represented as follows [23]:

$$\mathrm{H} = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & 1 \end{bmatrix} \tag{1}$$

where $I_i = (I_{i_x}, I_{i_y})$ are the coordinates of the points in the original image having perspective distortion, and $C_i = (C_{i_x}, C_{i_y})$ are the coordinates of the points in a defined perspective corrected image that corresponds to point I_i, where $i \epsilon 1,2 \ldots n$. The transformation between these points is formulated as follows [24]:

$$\begin{bmatrix} C_{i_x} \\ C_{i_y} \\ 1 \end{bmatrix} = \mathrm{H} \begin{bmatrix} I_{i_x} \\ I_{i_y} \\ 1 \end{bmatrix} \tag{2}$$

Once four-point information of the projection area is provided for both distorted and expected corrected images, transformation matrix H can be calculated. Accordingly, the whole image transformation can be accomplished by applying projective transformation with matrix H on every pixel of the original image. In this research, the output of this process is an image of a rectangle. The process is illustrated below.

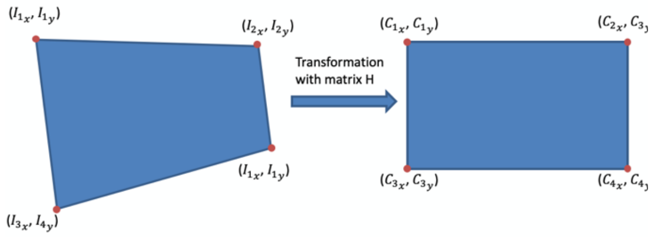


Figure 2. Illustration of image projective transformation

3.2 Marker Detection

3.2.1 Image Segmentation

The target regions that must be separated are the projection area and the markers. To achieve this, we used color-based image segmentation methods due to the highly distinguishable color features of the projection area and the markers compared with the region adjacent to their edge. Since it is possible that the color features of a few pixels are similar to the projection area and the markers on the image background not adjacent to the target region, image segmentation methods process images starting from the selected pixel area. We adopted a flood fill method to roughly segment the target regions and then used active contours method to further refine the segmentation to marginal pixels.

Flood fill is an automatic technique where one specifies the starting points, and the method segments areas with similar intensity values. It determines and changes the region connected to a given node in a multi-dimensional array with consistent attributes. The three essential elements of the flood fill algorithm are the start node, target color, and replacement color. The algorithm explores all pixels in the array that are linked to the start node through the route of target color and then alters them with a replacement color [25].

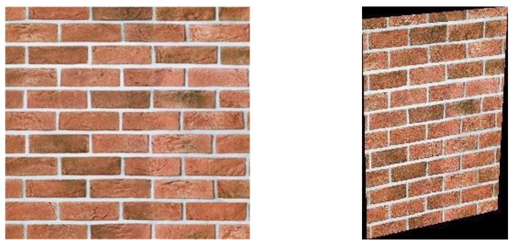
Active contour model is used for delineating an object outline from a possibly noisy image. This approach entails deforming an initial contour C0 toward the boundary of the object to be detected. The deformation is achieved by trying to minimize a functional design so that its (local) minimum is obtained at the boundary of the object [26,27].

3.2.2 Position detection

The method used for position detection is called blob analysis. It analyzes an image that has undergone binarization processing. A blob refers to a lump. Blob analysis is most basic image processing method for analyzing the shape features of an object, such as the presence, number, area, position, length, and direction of lumps [28]. It can be used for position detection of lump areas in binary images so that the coordinates of markers can be extracted.

3.3 Projected Image Generation

The shape of original design images is first transformed to match the irregular quadrangles formed by linking four detected points. As explained in Section 3.1, shape transformation in quadrangles can be processed when the four corner points for each quadrangle are known. Before transformation, 2D texture images are derived from each surface of the 3D BIM model, using a perpendicular viewing angle for surfaces. The resolution of each surface's image picture is measured as a × b (width × height); therefore, the coordinates of the image before transformation are (0, 0) (a, 0) (a, b) (0, b) with clockwise rotation from the top left corner. The coordinates of the expected image corners are described in Section 3.2. A testing sample of building texture is shown in Figure 3.



(a) (b)

Figure 3. Brick texture image before transformation (a) and after transformation (b)

If there are two or more surfaces that need to be projected, each surface must be transformed, and outcome images are combined in one image with contiguous edge lines.

The texture image is placed on a white panel that has the same proportional size as the corrected keystoning image of the projection area. The position of the texture image is generated according to the coordination information of the markers with respect to the projection area. Finally, the image is transferred, ensuring the same ratio and size as the projection area shown on the computer screen, and avoiding position changes in the projector and the building model.

3.4 Error Estimation

Projection error is estimated by the deviation in feature points. Assume that feature points P_i' are on the outcome projection image captured by camera, and feature points P_i are the ones expected to match x′ in the same view of the camera. Therefore, projection error e can be represented as the average distance between x′ and x formulated as follows [29]:

$$e = \frac{1}{N}\sum_{i=1}^{N} d(P_i', P_i) \quad (3)$$

$$d = \sqrt{(x_{P'} - x_P)^2 + (y_{P'} - y_P)^2} \quad (4)$$

where $d(P_i', P_i)$ refers to the Euclidean distance between points P_i' and P_i.

In this study, a projection panel is placed coplanar to the surfaces of the physical model to capture the outcome projection image of each surface within the respective spatial planar so that the projected image can be shown completely without spatial twist.

4. RESULT AND DISCUSSION

4.1 Preliminary Test

Following the proposed methodology, a physical model of a cube-type building with the dimensions 84×85×107 mm was used for the experiment. Four square markers were attached on the corners of the cube's three surfaces. The position of the projector and the web camera was fixed during the whole process. The settlement of the physical model, projector, and web camera is shown in Figure 4.

Figure 5 (a) and (b) show the results of image segmentation for the projection area and markers. Figure 5 (c) is the merged image of the projection area with markers after keystoning effect correction. The image resolution of Figure 5 (c) is 620×348, while the outcome of position detection for the four markers are (190, 60) (394, 90) (381, 348) (206, 307) with respect to the rectangle panel with four-corner coordinates of (0, 0) (620, 0) (620, 348) (0, 348). Figure 5 (d) and (e) shows the produced image to be directly projected and projection outcome.

Figure 4. Equipment setting

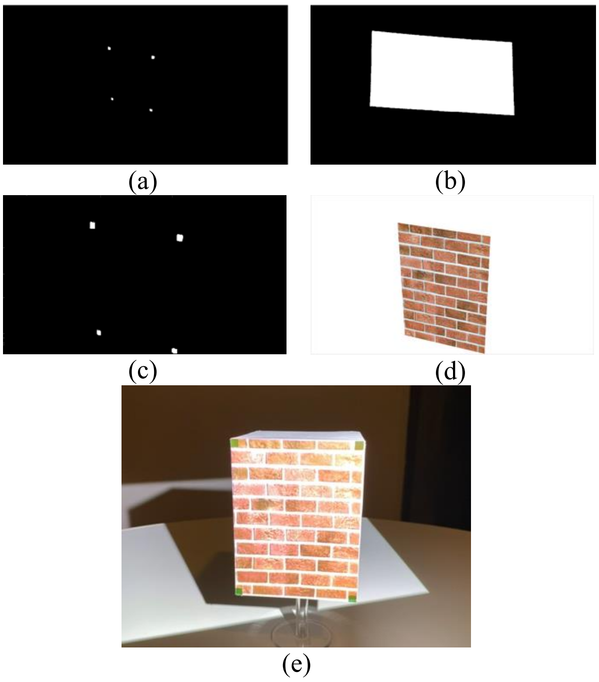
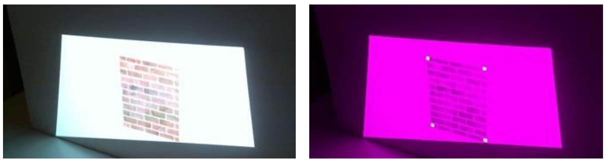


Figure 5. Image segmentation for the projection area (a), image segmentation for the markers (b), merged image of the projection area with markers after keystoning effect correction (c), and produced image for projection, produced texture image, projection outcome (e).

4.2 Error Estimation

Error estimation of the augmented surface was conducted. Figure 6 shows the projected image on the reference panel compared with the position of the physical model represented by markers. Table 2 presents information on error estimation. Corner points of the surface were selected as feature points, so d is the Euclidean distance between the feature point on the projected image and the model.



(a) (b)

Figure 6. Image projection on reference planar (a) compared with actual projection and marker position (b)

Table 2. Error estimation of front surface

Feature Points	P	P’	d
Point 1	(543, 124)	(546, 131)	7.92
Point 2	(823, 163)	(821, 168)	5.30
Point 3	(808, 474)	(803, 476)	5.16
Point 4	(566, 430)	(567, 436)	5.95

$$e = 6.08$$

The longest distance of the two points on the model’s front surface in the photo is 448.87; therefore, the relative errors are

$$e_{Relative} = \frac{6.08}{448.87} \times 100\% = 1.35\%.$$

4.3 Discussion

A 1.35% projection error relative to a 84×85×107 mm physical model, with the longest distance of 119.5 mm on the front surface, is equivalent to a 1.6 mm magnitude of error. This value is small, so it does not influence the observation of model appearance.

Setting the projection reference panel on the front surface, as described in the methodology, did not solve the projector keystoning problem on the top and side surfaces; hence, keystoning may have caused projection error. To test the error, three additional markers were attached on the corner of the model. Following the same methodology, the resulting projected image was generated (Figure 7). Error estimation was also conducted and calculated, as shown in Table 3.

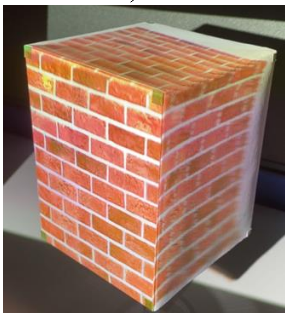


Figure 7. Texture projection of three surfaces

Table 3. Error estimation of side and top surfaces

Surfaces	Feature Points	P	P’	d
Side	Point 1	(823, 163)	(800, 202)	44.93
	Point 2	(885, 67)	(866, 108)	45.82
	Point 3	(864, 354)	(847, 377)	28.82
	Point 4	(808, 474)	(787, 498)	32.07
Top	Point 1	(543, 124)	(539, 140)	16.97
	Point 2	(823, 163)	(813, 184)	23.40
	Point 3	(885, 67)	(873, 97)	32.32
	Point 4	(648, 36)	(641, 57)	21.76

$$e_{Side} = 37.91$$

$$e_{Top} = 23.61$$

The longest distance on the model’s side and top surfaces is 414.96 and 365.31, respectively; therefore, the relative errors are

$$e_{Side\ Relative} = \frac{37.91}{414.96} \times 100\% = 9.14\%$$

$$e_{Top\ Relative} = \frac{23.61}{365.31} \times 100\% = 6.46\%.$$

Projection accuracy on the front surface is higher than on the side and top surfaces from a visual view. This is because the camera keystoning effect on the different planes of a stereoscopic object is not the same. Keystoning on the front surface was solved since the reference projection panel is only coplanar to the model's front surface. However, keystoning on the side and top surfaces was not fully corrected, and the results showed significant deviations on these surfaces.

To correct the error, a reference projection panel can be placed coplanar to the side and top surfaces. This also allows the measurement of the keystoning effect on these surfaces and the calculation of the corrected feature point coordinates. Alternatively, three known 2D point coordinates on one surface of a dimension-known cube is sufficient for the calculation of the rotation angle of the cube relative to a defined original position. Knowing the relative rotation angle of the building model can help determine the rendering angle of the 3D model on the projected 2D image. This method can be used for obtaining the other feature point coordinates of the model, independent from the markers shot in the image, to decrease the keystoning effect.

5. CONCLUSION

Both AR and VR technologies have extended BIM for architectural design visualization, allowing an immersive viewing of the building model and supporting design collaboration among different project stakeholders. As an AR-based technology, SAR can provide a more intuitive and common view of the model and expand the observation panel to an unlimited, real 3D scene without the need for uncomfortable body-attached display devices. Geometric alignment is a significant component of SAR, ensuring the projection of the texture image on the physical model at the specific accurate location. Current SAR software, however, rely on manual geometric calibration, which is tedious and unintelligent.

In this research, we developed a maker-based automatic geometric calibration method for SAR application on architectural design visualization. Rectangular markers were attached on the physical model to be detected by the camera. Using a projector-camera system, the correspondence between the coordinates on the projected image and their location on the physical model can be calculated to generate a projected texture image with consistent projector position. In this marker detection approach, we used image segmentation to separate the markers and the projection area from the image background and proceeded to position detection of the markers relative to the projection area. We also applied projective transformation algorithm to correct camera keystoning and project keytoning issues on the front surface of the building model. The reversed algorithm of keystoning correction can help generate the projected texture image with known four-corner coordinates. We projected three surfaces of a cube-type model and estimated the projection error. The projection on the building front surface is highly accurate, while there is projection error on the other surfaces due to the projector keystoning effect. Calculating the rendering angle of the virtual building model rendering on a 2D image projection might solve the issue.

ACKNOWLEDGMENTS

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COMPUTER GRAPHICS

SIGNED HOMOGENEOUS PARAMETERS FOR BERNSTEIN-BEZIER CURVES AND SURFACES IN AN ORIENTED PROJECTIVE SPACE

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ABSTRACT: This paper discusses the parameter spaces of Bernstein-Bezier curves in an oriented projective space. Bezier curves are widely used in computer graphics and computer aided design. The rational Bezier curve is a natural extension of the Bezier curve. Rational Bezier curves can be formulated as a rational function using conventional Cartesian coordinates. By using homogeneous coordinates, the curve can represent a curve in projective space. One advantage of using the homogeneous coordinate representation is that a homogeneous parameter can be used to represent the curve and adds a new degree of freedom for control of the shape. An oriented projective space uses signed homogeneous coordinates and has the advantage of being able to consistently incorporate the notion of direction and orientation in shapes. Although homogeneous parameters were used in projective space in previous studies, signed this study creates both a curve and surface representation in oriented projective space. The parameters of the curve are considered to be signed homogeneous parameters and has a different domain. A comparison is conducted for representations using signed and unsigned homogeneous coordinates. The new representation is therefore a curve in a two-sided space. The basic Bernstein polynomials are defined and then incorporated as a curve. A surface representation is also formulated.

Keywords: Bernstein-Bezier curve, Homogeneous coordinates, Oriented projective space, Two-sided space, Projective geometry

1. INTRODUCTION

This paper discusses the parameter spaces of Bernstein-Bezier curves in an oriented projective space. Bezier curves are widely used in computer graphics and computer aided design. The rational Bezier curve is a natural extension of the Bezier curve. Rational Bezier curves can be formulated as a rational function using conventional Cartesian coordinates. By using homogeneous coordinates, the curve can represent a curve in projective space. One advantage of using the homogeneous coordinate representation is that a homogeneous parameter can be used to represent the curve and adds a new degree of freedom for control of the shape. An oriented projective space uses signed homogeneous coordinates and has the advantage of being able to consistently incorporate the notion of direction and orientation in shapes. Although homogeneous parameters were used in projective space in previous studies, signed this study creates both a curve and surface representation in oriented projective space. The parameters of the curve are considered to be signed homogeneous parameters and has a different domain. A comparison is conducted for representations using signed and unsigned homogeneous coordinates.

2. BASICS FOR SHAPES IN ORIENTED PROJECTIVE SPACE

2.1 Signed Homogeneous Coordinates

A point in oriented projective space is represented by a set of coordinates which we will denote as $[X\ Y\ Z\ w]$. Each point has multiple representations. Two sets of coordinates represent the same point if there exists a *positive* number α so that

$$[X_0\ Y_0\ Z_0\ w_0] = [\alpha X_1\ \alpha Y_1\ \alpha Z_1\ \alpha w_1].$$

It is common practice to consider the point represented by $[X\ Y\ Z\ w]$ to be the point represented by ordinary coordinates $(x, y, z) = \left(\frac{X}{w}, \frac{Y}{w}, \frac{Z}{w}\right)$ for the case where $w > 0$. Hence, the set of all points where $w > 0$ have a one-to-one correspondence to the points in three-dimensional Euclidean space. On the other hand, we consider the coordinates with $w < 0$ to represent a point at $(x, y, z) = \left(\frac{X}{w}, \frac{Y}{w}, \frac{Z}{w}\right)$ in a separate three-dimensional space. Thus, an oriented projective space is sometimes referred to as a *two-sided space*. For convenience, we refer to the points $w > 0$ as being on the front-side, and the points $w < 0$ as begin on the back- or rear-side. When $w = 0$, the coordinates represent points at infinity in the direction of vector (X, Y, Z).

2.2 Line Segments and Triangles

A natural extension of the concept of a line segment is useful in computer graphics and computer-aided design. In Euclidean space, the convex combination of two points $v_0 = (x_0, y_0, z_0)$ and $v_1 = (x_1, y_1, z_1)$represent a line segment:

$$v = (1 - t)v_0 + tv_1$$

where $0 \leq t \leq 1$.

We start with signed homogeneous coordinates of two points $V_0 = [X_0\ Y_0\ Z_0\ w_0]$ and $V_1 = [X_1\ Y_1\ Z_1\ w_1]$ and create a convex combination $V = [X\ Y\ Z\ w]$.

$$V = (1 - t)V_0 + tV_1$$

In the case where all points generated by the equation have $w > 0$ i.e. when ($w_0 > 0$ and $w_1 > 0$), the set of points coincide with what we could consider a line segment on the front-side. If we extend to all values of w, the equation also included generalized line segments that are completely on the back-side, cross from the front to the back, or consist completely of points at infinity(Fig. 1).

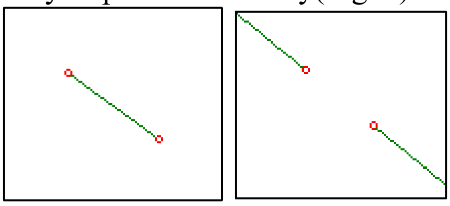

Figure 1. Examples of Generalized Line Segments

Since positive multiples of signed homogeneous coordinates represent the same point, it is easy to see that the following equation encompasses all possible representations of the points of the expanded line segment. For example, when we fix the value of $t_0$to be any positive value such as 1, any positive value of $t_1$produces signed homogeneous coordinates of a point on the line segment.

$$V = t_0V_0 + t_1V_1$$
$$t_0 \geq 0, t_1 \geq 0\ (t_0, t_1) \neq (0,0).$$

When $t_0 = 0$and $t_1 > 0$, the representation is the as the endpoint V_1. When $t_0 > 0$and $t_1 = 0$, the representation is the as the endpoint V_0. We will call this construct a *homogeneous line segment*. Examples of homogeneous line segments are shown in Figure 1. Just like signed homogeneous coordinates, positive multiples of the homogeneous parameters of a curve represent the same point on the curve. The signed homogeneous parameters can be considered signed homogeneous coordinates in a one-dimensional oriented projective space. Therefore, parameters of the homogeneous line segments are a homogeneous line segment in a one-dimensional oriented projective space.

A similar extension can be conducted to create a convex combination of three points to obtain a *homogeneous triangle*.

$$V = t_0V_0 + t_1V_1 + t_2V_2$$
$$t_0 \geq 0, t_1 \geq 0, t_2 \geq 0\ (t_0, t_1, t_2) \neq (0,0,0).$$

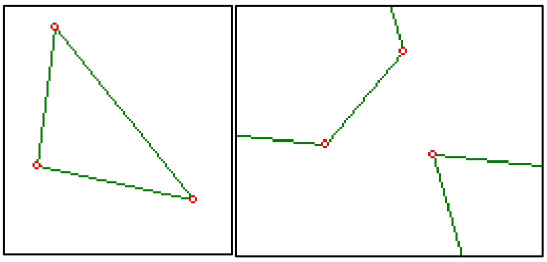

Figure 2. Examples of Generalized Triangles

At this point, is obvious that there is a generalization of this formula such that

$$V = \sum_{i=0}^{n} t_i V_0$$
$$t_i \geq 0 \text{ for all } t_i \text{ and}$$
$$(t_0, t_1, \ldots, t_2) \neq (0,0,\ldots,0).$$

This defines the *homogeneous n simplex* in oriented projective space. A line segment is the special case of $n = 1$ and a triangle is the case of $n = 2$.

2.3 Bernstein-Bezier Curves and their Extension to ordinary Projective Space.

A degree n polynomial Bernstein-Bezier curve in Euclidean space is defined in terms of the Bernstein polynomials

$$B_{nk}(t) = {}_nC_k t^k (1-t)^{n-k}$$

where ${}_nC_k$ is the binomial coefficient

$${}_nC_k = n!/k!\,(n-k)!.$$

If $q_0, q_1, \ldots, q_n$ are the coordinate vectors $n+1$ control points in the plane or three-space, or four-space, the Bernstein-Bezier curve is formulated as

$$q = \sum_{i=0}^{n} B_{ni}(t) q_i$$

where $0 \leq t \leq 1$. The Bezier curve in three-space is therefore defined for $q = (x, y, z)$ and $q_i = (x_i, y_i, z_i)$ for $i = 0, 1, \ldots, n$.

In the case where the coordinate vectors are homogeneous coordinates so that $Q = [X\ Y\ Z\ w]$ and $Q_i = [X_i\ Y_i\ Z_i\ w_i]$, the equation defines a rational Bezier curve where

$$Q = \sum_{i=0}^{n} B_{ni}(t) Q_i$$

and

$$(x, y, z) = \left(\frac{X_i}{w_i}, \frac{Y_i}{w_i}, \frac{Z_i}{w_i}\right)$$

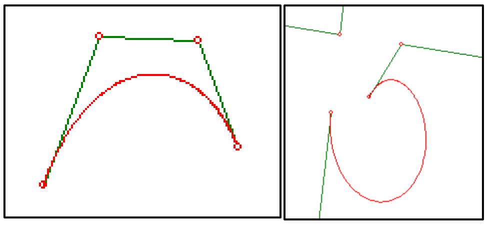

Figure 3. Examples of Bezier Curves in Projective Space

The homogeneous parametrization shown in [1] represents a curve in an ordinary projective space using homogeneous coordinates and the homogeneous Bernstein polynomials as follows:

$$HB_{nk}(t,s) = {}_nC_k t^k (s-t)^{n-k}.$$

The resulting curve becomes

$$Q = \sum_{i=0}^{n} HB_{ni}(t,s) Q_i.$$

These polynomials are a straightforward replacement of t in the original Bernstein polynomial with st. Therefore, the span of the parameters of the curve is $0 \leq t \leq s$ while $(t,s) \neq (0,0)$.

Further on in [1], the polynomial is changed to a simpler and more generalized form such that

$$HB_{nk}(t,s) = {}_nC_k t^k s^{n-k}.$$

With this polynomial, the parameters of the curve $0 \leq t, 0 \leq s$ or $0 \geq t, 0 \geq s$ subject to $(t,s) \neq (0,0)$. Both s and t must be positive, or both negative. The endpoints of the curve are when either $s = 0$ or $t = 0$. This representation of the Bezier curve can be considered a projective transformation of the parameters of the curve. The discussion in [1] largely consists of the treatise of these transformations and how they can be used.

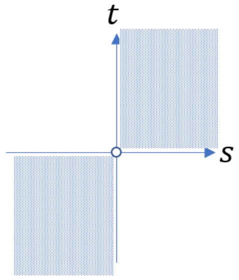

Figure 4. Parameter Space of Bezier Curve in Projective Space.

Since this curve is defined as a curve in ordinary projective space, the curve is defined using ordinary homogeneous coordinates. Therefore any non-zero scalar multiple of the homogeneous coordinates of the curve represents the same point (positive and negative).

2.4 **Bernstein-Bezier Curves and their Extension to Oriented Projective Space.**

The same homogeneous Bernstein polynomial can be applied to obtain a curve in oriented projective space. The curve is represented by the same equation as shown below.

$$Q = \sum_{i=0}^{n} HB_{ni}(t, s)Q_i.$$

The difference in oriented projective space is that only positive multiples of coordinates represent the same point.

There are two possible applications here. The equation can be used to represent two curve segments, one on the front-side, and the another on the back-side. This will give rise to unfortunate complications when the curve is used to represent curves in solid models. The simpler solution is to use only positive multiples of the coordinates as a curve. The span of the parameters of the curve in this case is $0 \le t, 0 \le s$ subject to $(t, s) \ne (0,0)$.

In the case of a first-degree curve, the resulting curve is identical to the homogeneous line segment described in a previous section. The equation is also identical. For further generalization, the parameterization and the binomial coefficient are shown differently in the following equation, but the result is the same.

$$HB_{n,i,j}(t_0, t_1) = \frac{n!}{i!\,j!} {t_0}^i {t_1}^j.$$

$$i + j = n$$

$$Q = \sum_{i=0}^{n} HB_{n,i,j}(t_0, t_1)Q_i.$$

$0 \le t_0, 0 \le t_1$ subject to $(t_0, t_1) \ne (0,0)$.

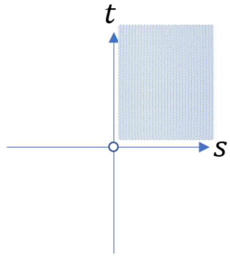

Figure 4. Parameter Space of Bezier Curve in Projective Space.

2.5 **Bernstein-Bezier Surface and their Extension to Oriented Projective Space.**

The same homogeneous Bernstein polynomial can be extended to represent a triangular surface patch by introducing additional parameters to the polynomial. Symmetry between the

$$Q = \sum_{i=0}^{n} HB_{n,i,j,k}(t_0, t_1, t_2)Q_{ijk}.$$

$$HB_{n,i,j,k}(t_0, t_1, t_2) = \frac{n!}{i!\,j!\,k!} {t_0}^i {t_1}^j {t_2}^k$$

$$i + j + k = n$$

This surface has previously been introduced as a Steiner surface patch based on homogeneous coordinates. In the case here in oriented projective space and signed homogeneous coordinates, the parameters of the surface are in the following range.

$$t_0 \geq 0, t_1 \geq 0, t_2 \geq 0 \ (t_0, t_1, t_2) \neq (0,0,0).$$

It is easy to see that a first-degree patch is a homogeneous triangle described in a previous section.

3. DISCUSSIONS

Subdivision of a curve or surface can be considered a projective transformation of the parameters.

The same method of interference detection between shapes in oriented projective space and be used on these curves and surfaces. This method is effective even for curves and surfaces with points at infinity within the representation. It is not necessary to change the representation of the curve to Euclidean coordinates during these interference tests.

Points at infinity can be used as well as the undefined point $[0\ 0\ \ldots\ 0]$ unlike a rational curve or surface defined in Euclidean space.

The evaluation of each of the equations involves only multiplication, addition and subtraction. Incremental generation of points on a curve and surface can be conducted using integers. There is no need for the division operation in the manipulation of these equations. Division is only necessary if the final result must be changed into Euclidean coordinates.

4. CONCLUSIONS

"Conclusions" should contain the main idea of the paper either by repeating concisely what was previously explained or by compiling the deductions or inferences from the previous partial conclusions. Try to motivate the readers by highlighting the practical applications of what was presented in the paper.

ACKNOWLEDGMENTS

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DATABASE CREATION AND CLASSIFICATION OF CUBE CONNECTED MODELS

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ABSTRACT: Two-dimensional or three-dimensional models with connected cubes (polycube) are often used for graphic recognition problems. For example, in the evaluation of brain function, a mental-rotation problem in which a rotated polycube is used for the recognizing the shape of a model. In the cube-connection model(poly-cube), the types increase rapidly as the number of connected cubes increases. However, there are few studies on its number and properties. In this research, we constructed a database of polycubes in which 5 to 10 cubes are connected. As a result, it was found that there are more than 2.5 million types of cube-connection models with 11 cubes. All cube-connection models(poly-cubes) were categorized by symmetry, center of gravity, etc. By using this database, the problems using the cube-connection model(poly-cube) can be automatically generated.

Keywords: Polyominoes, Polycube, Computer Graphics, 3D Modelling, Database.

1. INSTALLATION

The polyominoes is often used for problems that question the recognition of figures and spaces. In the two-dimensional figure problem, 2-dimensional polyominoes are used, and Tetris is a famous game which uses the polyominoes.[1] The mental rotation problem is famous as a problem of three-dimensional figures and sometimes 3-dimensional polyominoes (polycube) are used. The mental rotation problem is a problem that makes people think about the operation of rotating a figure in his brain, and is used to evaluate the function of the brain.

The authors have been researching 3D CAD for education. As an application, we have developed an application that generates mental rotation problems. As an example, the mental rotation problem with 3-dimensional polyominoes (polycube) is shown in Fig.1. It is a question of rotating two figures and asking whether they are the same solid, a solid in a mirror image relationship, or a different solid. The correct answer of Fig.1 is the mirror model.

Studies of such 3-dimensional polyominoes : polycubes have been around for a long time, and in 1972 Lunnon showed that there were 166 independent models of six polycubes (hexacubes), theoritically.[2],[3] After that, K. Gong calculated the number of independent models up to 16 polycubes by computer analysis.[4]

In this research, we build a polycube database that can be used in computer applications that use polycubes. Furthermore, the number of faces and the number of vertices were obtained as an index of the classification of polycubes and their complexity.

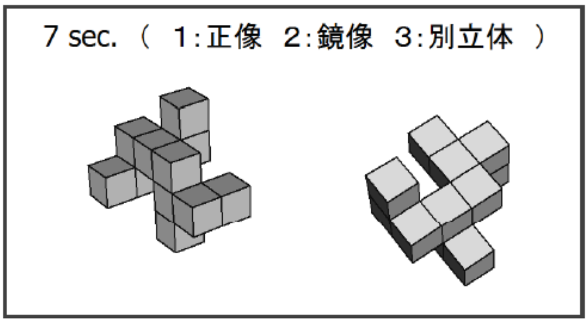


Figure 1: Sample of the mental rotation problem.

2. 3-DIMENSIONAL POLYOMINOES

The types of polycubes (3-dimensional polyominoes) increase rapidly as the number of cubes N increases. As an example, Figure 2 and 3 show all types of polycubes when N = 3 and N = 4. When N = 3, there are two types of models, and when N = 4, there are eight types of models. Comparing the models of Fig. 3, it can be seen that they do not overlap even if they are rotated with each other. In this way, a model that does not overlap with each other even when rotated is defined as another type of polycube.

At the number of cubes N = 5, there are 29 independent polycubes. Figure. 4 shows 10 types of polycubes out of 29 types for N=5. In this way, it can be seen that as N increases, the types of polycubes increase rapidly.

The purpose of this research is to create a database of polycubes as shown in Figs. 3 and 4. Table 1 shows the number of independent polycubes for the number of cubes N. At N = 10, there are 346,543 types, and at N = 11, there are over 2.5 million types. However, the polycubes with N = 10 are complex and diverse enough, and the author considers that a database of polycubes up to N = 10 is sufficient for application to problem creation of polycubes.

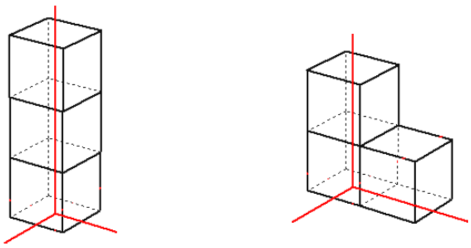


Figure 2: Two polycubes for N=3.

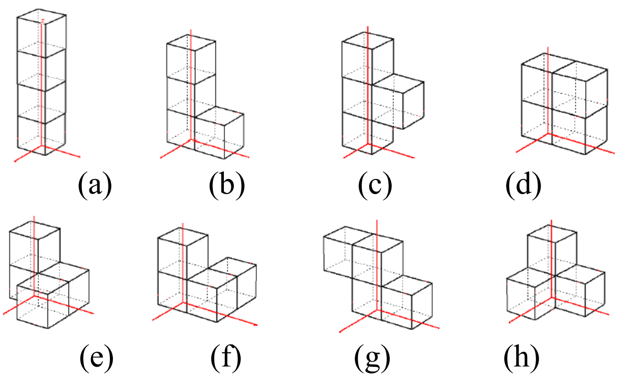


Figure 3: Eight polycubes for N=4.

Table 1: Number of polycubes for N.

Cube Number N	Number of 3d Polycube
3	2
4	8
5	29
6	166
7	1,023
8	6,922
9	48,311
10	346,543
11	2,522,522 [4]
12	18,598,427 [4]

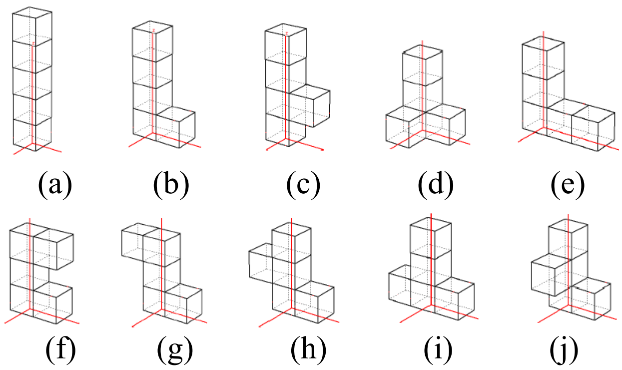


Figure 4: 10 out of 29 polycubes for N=5.

3. CREATION OF DETABASE OF POLYCUBESE

Purely mathematically, it is not possible to obtain a mathematical method for deriving the number of models in Table 1 and the specific model shape. In this research, we solve the problem by numerical calculation. The calculation method is a method of generating N polycubes by connecting one cube to an independent polycube made of N-1 cubes. The calculation procedure for generating an N = 5 polycube using an N = 4 polycube is shown below.

(a) Examine the connectable faces of N = 4 poly-cubes
(b) Generate a polycube in which one cube is connected in order to the connectable faces.
(c) Compare the generated polycube with the previously generated / registered polycube.
(d) As a result of comparison (c), if there is the

same polycube, return to (b) and generate the next polycube.

(e) If the same polycube does not exist as a result of comparison (c), register it as an independent model of that polycube and return to (b) to generate the next polycube.

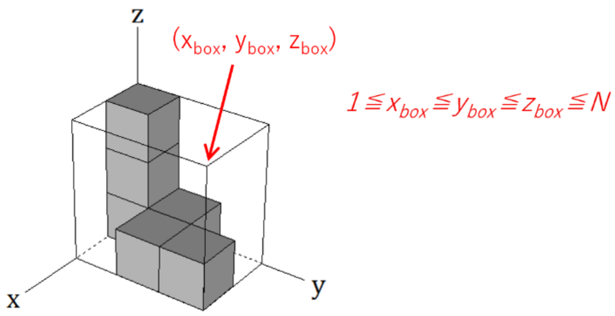
(f) Perform operations (a) to (e) for eight types of polycubes with N = 4.

The number of connectable faces of a polycube, n_f, is given by the following equation, where N is the number of cubes and n_c is the number of connecting faces.

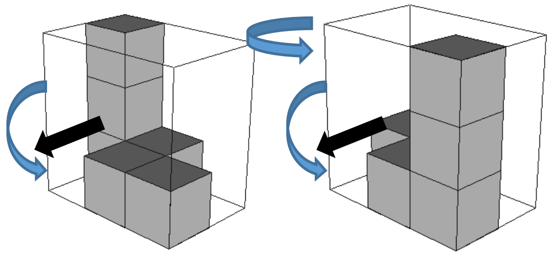
$$n_f = 6 \cdot N - 2 \cdot n_c \qquad (1)$$

In the polycubes of N = 4 in Fig. 2, n_f = 18 in the case of the polycubes other than Fig. 2(d), and n_f = 16 in the case of the model of Fig. 2(d). By generating 18 x 7 + 16 = 142 polycubes and calculating the overlap each other, we can obtain 29 polycubes as independent polycubes. In the calculation process from (a) to (e), the important and computationally intensive one is the comparison between the polycubes in process (c). In this research, we used a bounding box (a cube surrounding the polycube) to compare the shapes of the polycubes. Only polycubes with the same bounding box can be compared. To further limit the objects to be compared, it is possible to limit the polycubes to the same relative positions of the centers of gravity. However, in this study, the center of gravity was not used, and a comparison was made with the bounding box and the rotation operation. Rotate the direction of the bounding box so that the Z direction is the maximum and the X direction is the minimum size as shown in Fig. 5(a). With this operation, the rotation operation for comparison can be standardized as shown in Fig. 5(b). If the size of the bounding box (X, Y, Z) satisfies X <Y <Z, that is, if the lengths of each side of the bounding box are different, rotate 180 degrees in the X-axis direction and compare twice. Further, it may be rotated 180 degrees in the Z-axis direction and then rotated 180 degrees in the X-axis direction to compare twice, for a total of four comparisons. If the two axial sizes of the bounding box are equal, then eight comparisons are required (two set of 90 degree 4 times), and if all the axial sizes are equal, then 6 x 4 = 24 comparisons are required from the combination.

Perhaps the computational process performed by K. Gong is based on a similar algorithm. Regarding the number of polycubes, K. Gong's calculation results and our calculation results are in agreement.



(a) Definition of the bounding box



90 deg. 4 times in X 90 deg. 4 times in X

(b) The rotation and 8 times comparisons for the case of $1 < X_{box} < Y_{box} = Z_{box}$.

Figures 5: Direction of the bounding box and rotation for comparison of polycubes.

4. CLASSFICATION OF POLYCUDES

A polycube with a cube number N up to 10 was searched, and data for each polycube was acquired. Table 2 shows the number of polycubes with a cube number N of 1 to 12.(Results of N=11,12 from K.Gong[4]) The three-dimensionally independent polycubes were indicated as "3d Polycubes", and the two-dimensional polycubes (Polyominoes) were indicated as "2d Polycubes". A symmetric solid in which the mirrored solids are the same is defined as "3d Symmetric Polycube", and an asymmetrical solid in Table 2.

Table 2: The number of polycubes with cube number N.

Cube Number N	3d Polycube	2d Polycube	3d symmetric Polycube	Asymmetric Polycube	4d Polycube
1	1	1	0	0	1
2	1	1	0	0	1
3	2	2	0	0	2
4	8	5	1	1	7
5	29	12	5	6	23
6	166	35	23	54	112
7	1,023	108	83	416	607
8	6,922	369	331	3,111	3,811
9	48,311	1,285	1,230	22,898	25,413
10	346,543	4,655	4,968	168,460	178,083
11	2,522,522	-	-	-	1,279,537
12	18,598,427	-	-	-	9,371,094

which the mirrored solids do not overlap is indicated as "Asymmetric Polycube". In addition, those with the same polycube as the mirror image solid were classified as "4d Polycubes". There is no particular meaning of "4d" and is taken from the "4d rotation" used by K. Gong.[4]

Let's see which category the eight polycubes with N = 4 in Figures 2(a) to (h) fall into. Five types of (a), (b), (c), (d), and (g) are "2d Polycube", (e) and (f) are "Asymmetric Polycube", and (h) is "3d Symmetric Polycube".

The classification of "4d Polycube" is useful as a database. Because if a polycube is registered as mirror image asymmetric, a mirror image polycube can be easily created. However, in this research, we think that it is easier to use if all polycubes can be selected by the index, and construct a database as data of "3d Polycube" numbers.

When creating test questions with polycubes, our interest is to know how difficult a given polycube is. Generally, the larger the number N of cubes, the more complicated the polycube produced. However, even if the number N of cubes is large, a two-dimensional polycube has a simpler structure than a three-dimensional polycube. We try to quantify the complexity of polycubes by the number of faces, vertices, and edges. In order to find the boundary elements of a polycube, the cubes that make up the polycube are synthesized by a boolean operation. The number of faces, vertices, and edges of the synthesized solid was calculated. In the boolean operation of polycubes, the irregular connection relationship occurred when the addition process was performed with its just size. Therefore, the size of the cube was increased by 1% and the boolean operation was performed. By the boolean operation, a short edge structure is generated where the cubes intersect intricately. In order not to count this short edge, We made a program to count the short edges and remove the edge and one vertex from the count. As a result, the number of surfaces and vertices could be obtained accurately.

Figures 6 show the image being calculated of boolean operations. The solid on the far left shows a polycube made by stacking cubes, and the solid on the front right shows the same polycube synthesized by boolean operation. The faces and the number of vertices of the polycube after the boolean operation were registered in the database. The data that can be read in Excel (the original data of the database) is the data of one polycube written in one line, and the contents are the number of cubes, cube coordinates, bounding box, mirror image index, number of faces and number of vertices. From this data, the classification in Table 2 can be known under the following conditions.

(a) 2-dimensional polycube: X size of the bounding box is 1.
(b) 3-dimensional symmetric polycube: The X size of the bounding box is greater than 2 and the mirror image is the same as itself.
(c) Asymmetric polycube: Polycube other than (a) and (b).

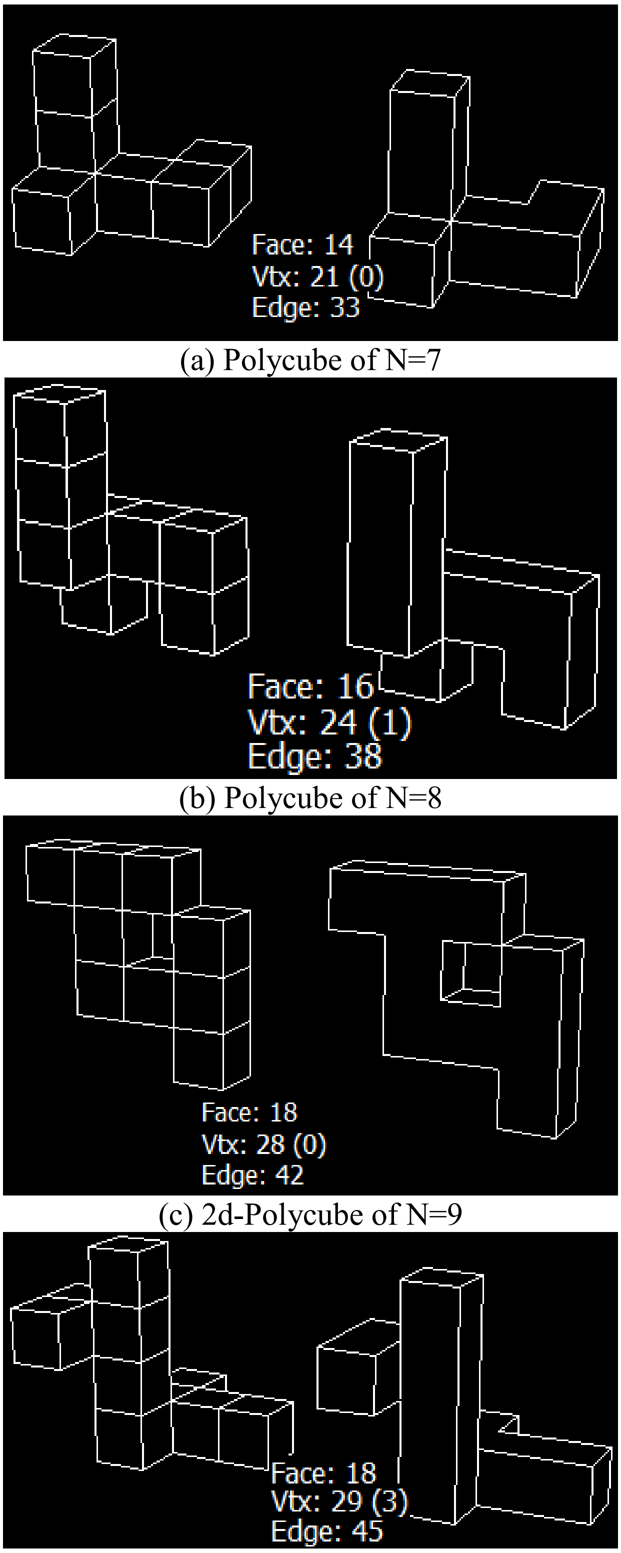
Table 3 shows the partial data of the polycube with the number of cubes N = 7. This data has 1023 lines of data, of which 15 lines are shown at the index of from 1 to 5, 401 to 405, and 801 to 805. Figure 7 shows images of the index of 5, 401, 801 and 805 polycubes. No.805 polycube is "3d symmetric Polycube" because the number of Mirror polycube is the same as No.805.

5. CONCLUSIONS

The purpose of this research is to create a database of polycubes. Data for polycubes with cube numbers N up to 10 were generated. Furthermore, as information that characterizes these polycubes, the size of the bounding box, the number of the mirror image, the number of faces and the number of vertices when combined were obtained and converted into data. By using the generated database, it is possible to generate a polycube by specifying a number, or to generate a polycube by specifying a bounding box or the number of faces. It is also possible to search for similar polycubes by applying the polycube comparison process. The method for evaluating the complexity of polycubes needs to be further studied in the future, however the number of faces and the number of vertices (number of ridges) obtained in this research may be useful for evaluating the complexity of polycubes.

Table 3: Created data of polycubes of N=7.

No	N	Cube1	Cube2	·	XBx	YBx	ZBx	Mir	FaN	VtN
1	7	0,0,2	0,0,3	·	1	1	7	1	6	8
2	7	0,0,1	0,0,2	·	1	2	6	2	8	12
3	7	0,0,1	0,0,2	·	1	2	6	3	10	16
4	7	0,0,1	0,0,2	·	1	2	6	4	10	16
5	7	0,0,1	0,0,2	·	1	2	6	5	10	16
·	·	· · ·	· ·	·	·	·	·	·	·	·
401	7	0,0,1	0,1,1	·	2	3	4	402	18	25
402	7	1,0,1	1,1,1	·	2	3	4	401	18	25
403	7	1,1,0	1,1,1	·	2	3	4	404	18	24
404	7	0,1,0	0,1,1	·	2	3	4	403	18	24
405	7	1,1,0	1,1,1	·	2	3	4	383	14	22
·	·	· · ·	· ·	·	·	·	·	·	·	·
801	7	1,1,1	1,2,1	·	2	3	3	815	15	26
802	7	1,2,1	0,2,1	·	2	3	3	802	15	26
803	7	1,1,1	1,2,1	·	2	3	3	814	15	25
804	7	1,0,1	1,1,1	·	2	3	3	817	14	22
805	7	1,0,1	0,0,1	·	2	3	3	805	14	24



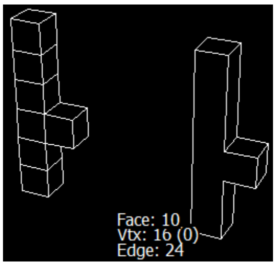
(a) Polycube of N=7

(b) Polycube of N=8

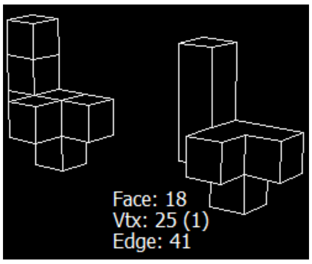
(c) 2d-Polycube of N=9

(d) Polycube of N=10

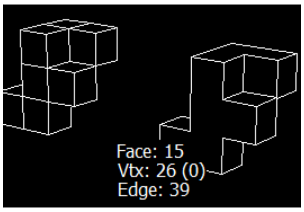
Figures 6: Polycubes of N=7, 8, 9 and N=10 and results of their Boolean operation.



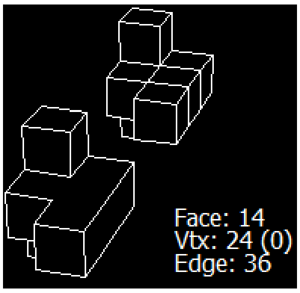
(a) No.5



(b) No.401



(c) No.801



(d) No.805

Figures 7: Image of polycubes listed in Table 3.

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https://xfs.jp/sNBzT

A GRAPHICAL COMPUTING METHOD AND IMPLEMENTATION OF STATICS PROBLEM

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ABSTRACT: Statics is a branch of theoretical mechanics, which studies the equilibrium law of a system of mass points when subjected to forces, and it has a wide range of applications in engineering and technology. In practical applications, the statics problems are often calculated by analytical method and the calculation results are expressed in the form of graphs, but this way of thinking of numerical calculation and graphical expression of split form is not in line with human thinking habits. Force is a vector quantity, which is generally represented by a line with direction, and this is the intuitive connection between mechanics and graphics. Descriptive geometry mainly studies the use of plane graphics to solve spatial geometric problems, so graphics can be given mechanical meanings, and then corresponding graphical models can be constructed according to the principles of statics, and the mathematical analytical relationships of statics can be converted into positioning and measurement problems between geometric elements. So that descriptive geometry can be used to solve statics problems.

Based on the theoretical basis of "Graphical Statics" by Karl Cullman, we combines graphic statics with computer graphics technology. A geometric approach is used to refine the basic types for graphical solution of statics, and the corresponding basic graphical calculation units are summarized. A geometric engine based on geometric computation is constructed and a graphical solution for statics problem is proposed. This method overcomes the tedious and abstract nature of the analytical method, and organically integrates mechanics and graphics to achieve the geometric solution of geometric problems. This way of thinking, which returns to the essence of the problem, follows the development trend of today's engineering design (CAD) and engineering analysis (CAE) fields.

Based on the above research, a graphically assisted calculation tool for statics problems is developed based on the AutoCAD platform. The tool use the funicular polygon method to calculate complex force system problems. It is tested for the more common plane force system and space force system problems in statics, and the test results show that the method retains the intuitiveness of the vector method and the high accuracy of the analytical method, and has good engineering application value.

Keywords: Statics, Graphical Solution, Geometry, Calculation.

1. INTRODUCTION

Graphical engineering statics is a long-standing discipline that originated in the latter half of the 19th century, and it took nearly a century from the establishment, development, and heyday of the discipline to its subsequent decline. The main reason for its decline is that the accuracy of the manual drawings initially used in the graphical engineering statics has failed to meet the requirements of modern manufacturing processes, but with the rapid rise and development of computer technology today, graphical engineering statics seems to have a new opportunity for development. For example, Zanni[1] proposed a general graphical method for the static analysis of axial loads in planar structures, and Akbarzadeh[2] applied graphical statics to three-dimensional space by using force diagrams in the form of polyhedron to design spatial structures subjected to tensile or compressive forces only under external loads. Fivet[3] proposes a geometric method for constraint-based design of interactive structural equilibrium using graphical statics. Mele[4] proposed a generalized non-programmed algebraic method to graphically solve structural mechanics, and Saloustros[5] applied graphical statics to numerically analyze the structural damage of the Beaufort Abbey Church in its structural damage analysis. In the literatures[6]-[11], the application of graphical statics to analyze, design, and optimize the design of mechanical structures is mentioned. In recent years, some scholars have developed the principles of projective geometry using algebraic methods, making the development of graphical statics from 2D to 3D gaining theoretical support and gradually developing a system of graphical statics methods in 3D space [12]-[15].

The combination of computer graphics and graphical engineering statics can not only overcome the shortcomings of large errors in manual drawings, but also effectively improve their efficiency. Force as a vector quantity, which has a natural intrinsic connection with the graph, will be able to establish a one-to-one correspondence between the two and convert the mathematical analytic relationship into a problem of positioning and metrics between the elements of the figures. In contrast, the mathematical calculation method is generally used to obtain only an abstract numerical solution, while the graphical solution method can visualize the entire solution calculation process graphically, and the calculation results are also graphical, which is obvious intuitive. Thus, graphical engineering statics can simplify complex problems and obtain an intuitive and visual calculation result. However, the use of computers only for drawing to realize graphical statics is not the ultimate goal, nor can it effectively promote the development of graphical statics. Therefore, it is worthwhile and necessary to study how to realize automatic computerized graphical engineering statics and visualize the graphical process and results.

2. THE RELATIONSHIP BETWEEN STATICS AND DESCRIPTIVE GEOMETRY

In recent years, the related research on graphic statics has attracted widespread attention from scholars, especially the study of graphic statics based on descriptive geometry is very interesting[16]-[19]. The three basic elements in statics are: force, moment, and force couple, which are essentially forces. A moment is the tendency of a force to rotate an object around an axis of rotation or a fulcrum, so a moment can be equated to a force that deviates from the center of rotation. Similarly, a force couple is a pair of parallel forces of equal magnitude and opposite direction, but not co-linear, acting on the same rigid body. According to the definition of force couple, it is known that a force couple is a pair of parallel forces of equal magnitude and opposite direction, whose equivalent results in a pair of forces. Descriptive geometry is the study of the theory and methods of representing shapes and solving spatial geometric problems on a plane, and is also the basis of projection theory for mechanical drawing. If graphs (points, directed lines) are used to represent forces, and the position relations and dimensions between the graphs are used to analyze and calculate the static problems, and the calculation results are displayed in the form of graphs, the graphical calculation method can be realized to solve the static problems, avoiding the complex analytical process in the static calculation, and expanding the application boundary of the descriptive geometry.

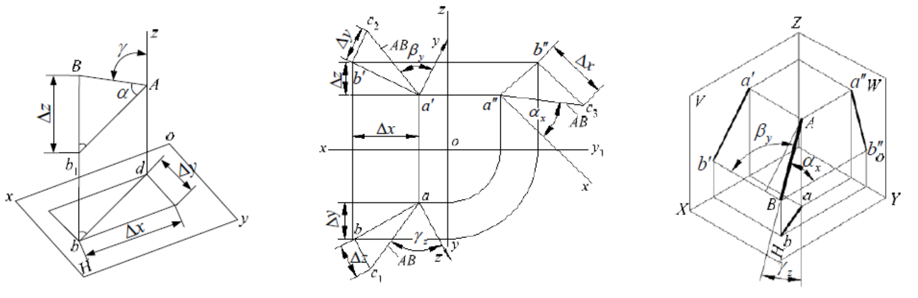
For analysis, the statics problems are divided into two categories: plane force systems and space force systems. For the plane force system, the corresponding force situation is simple, the force carrier can be removed from the plane force diagram, retaining the point of action of the force, the line of action of the force. For the spatial force system, the projection of dimensionality reduction can be used to simplify the complex force problem in space into a joint solution of multiple 2D plane force problems, and the simplification process is based on the law of orthographic projection in engineering drawing. As shown in Figure 1, the space force system is projected into three views (main view, left view, top view), and its space geometry is converted into a 2D planar graphical problem, so that the complexity of the problem is greatly reduced, and finally the force relationship in each view is solved separately, and the location of the 3D coordinate point of a force action line in the integrated three views, which is the force state of the space force system. Since all the solution data of the graphical statics depend on the points and lines in the force model, the position and dimensional data of the points and lines must be uniformly calibrated to ensure their graphical accuracy, so that the numerical solution of the model can be obtained by restituting the graphical solution to the corresponding scale.

As shown in Figure 1, the inclination of the line *AB* ($A(x_1, y_1, z_1)$, $B(x_2, y_2, z_2)$) to the three projection planes *H*, *V*, and *W* are α , β and γ respectively. Figure 1(a) shows the inclination angle of the line *AB* to plane *H*, and its magnitude can be expressed by formula (1).

$$\cos\alpha = \frac{ab}{AB} \quad (1)$$

Similarly, $\cos\beta = \frac{a'b'}{AB}$, $\cos\gamma = \frac{a''b''}{AB}$ (2)

Where, $AB = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$.



(a) (b) (c)

Figure 1: The parameters relationship between the force lines

3. GRAPHICAL MODEL OF THE STATICS PROBLEMS

In order to further refine the solution steps of the graphical statics, some basic mechanical solution units can be extracted from the planar force system and spatial force system problems, and the corresponding algorithms can be designed according to these basic solution units, which is conducive to the realization of computer-aided calculations. Therefore, the solution of different mechanical problems is converted into the invocation of the corresponding algorithms, which widens the application boundary of descriptive geometry and finds a better carrier for the inheritance and development of descriptive geometry.

3.1 Graphical model of the planar force system

Force, as the most basic physical quantity in graphical statics, contains three elements: the magnitude of the force, the direction of the force, and the point of action of the force, which correspond to the force line in the graph, the length of the line, the orientation of the starting points of the line, and the ending point of the line, as three graphical characteristic elements. For the planar force system, generally known for a number of points of force, to solve magnitude and direction of the force, etc., the general need to solve the unknown force is within two, more than two unknown force will not be considered sufficient conditions and solved. As shown in Figure 2, the planar force system are now grouped into two categories: planar parallel force system and planar convergent force system. Commonly used graphical statics methods include the triangle method, force polygon method, three-force concurrent method, and funicular polygon method, as shown in Figure 3. By constructing the force polygon and selecting the poles, drawing the ray of each force, the direction of the ray is the direction of the funicular line, then drawing a line along the direction of the funicular line, finding the intersection of the line where each funicular line is located and the line of action against the stress, and connecting the intersection points, which constitutes the funicular polygon of the force, and each side of the funicular polygon is the funicular line. The properties of the original force system can be determined by analyzing the relationship between the positions of the first and last funicular lines, and then further graphical solutions are made, and this method is also applicable to the solution of moments.

For the convenience of analysis and solution, the planar force system is divided into three typical basic solution units.

(1) Several known forces (containing the magnitude, direction and point of action of the force), solving for a force with a known point of action (magnitude and direction of the force), defined as the basic solving unit 1.

(2) Several known forces (containing the magnitude, direction and point of action of the force), solving for two forces with known points of action and the direction of one force is known, defined as the basic solving unit 2.

(3) Several known forces (containing the magnitude, direction and point of action of the force), solving for two known points of action of the force (magnitude and direction of the force) is defined as the basic solving unit 3.

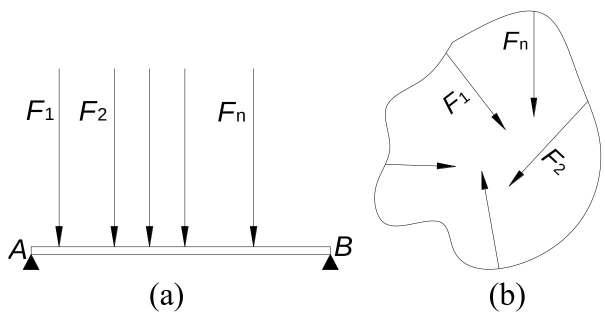


Figure 2: Planar force system. (a) Schematic diagram of the planar force system. (b) Schematic diagram of the convergent force system.

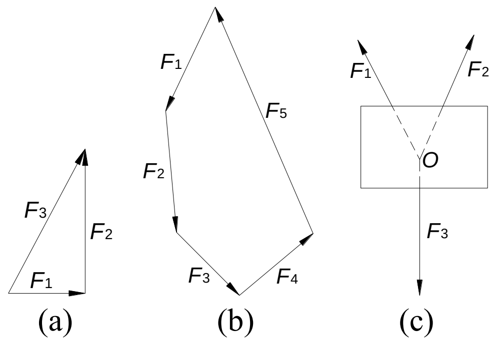


Figure 3: Common methods for graphical statics. (a) Triangle method. (b) Force polygon method. (c) Three-force concurrent method.

In general, any planar force system can be reduced to the scope of the above three basic solution units by a series of equivalent transformation or simplification principles. Therefore, according to the equilibrium conditions of the plane force system: the force triangle must be closed, the force polygon must be closed, the three forces must converge, and the force funicular polygon must be connected and closed in sequence, etc., the corresponding algorithms can be designed.

3.2 Graphical model of the spatial force system

In practical applications, planar force systems are less common, and spatial force systems are usually the most common. Therefore, it will be necessary to apply the solution model and basic algorithm in this paper to the solution of spatial arbitrary force systems. The fundamental problem is that the solution of spatial arbitrary force system can be abstracted as the problem of locating and measuring spatial figures, and the descriptive geometry provides a deciphering idea, that is, the concept of expressing 3D shapes (figure) with 2D graphic information, which is also the core idea of engineering graphics. As the force is a vector quantity, it can be represented by a line with direction, so a spatial force system problem is a problem of solving the actual dimensions of a spatial line. Obviously, the three-view projection model can be more easily applied to this.

For solving the problem of spatial force system, the method of projection dimension reduction can be used to simplify the problem, use 2D method to solve 3D problems, and use the azimuth relationship of 2D points and lines to map the azimuth relationship between 3D points and lines. The basic idea is: project the spatial force model to the mutually perpendicular three projection surfaces to get the three-view projection model, so as to convert the spatial problem into the planar problem described in section 2.1, assign the corresponding algorithms according to the basic solution unit it belongs to, solve the 2D point-line relationship of each projection view respectively, and finally restore the points and lines in the 2D three views to the 3D space. In this way, the goal of reduced-dimension and simplifying the analysis and solution of the spatial force system model is achieved.

4. GENERALIZATION AND DESIGN OF BASIC GRAPHICAL ALGORITHMS

Drawing on the thinking of using the three basic elements of point, line and plane in descriptive geometry to express any complex parts, the problems of any complex planar force system and spatial force system are abstractly decomposed into a number of basic objects for study, and these basic problems are generalized and the corresponding graphical algorithms are designed to form a generalized flow of graphical statics.

Firstly, let's introduce the equivalent simplification process of the convergent force system: all force lines of known direction and magnitude are selected according to their position relationship (parallel or intersecting), so that these known forces are equivalent to one force, and the principle of equivalent simplification is: the parallel force system is simplified by the funicular polygon method, and the intersecting force system is simplified by the parallelogram method. Simplified explanation of the funicular polygon method is shown in Figure 4. F_1-F_6 are known six parallel forces, which can be simplified to $F_{1\text{-}6}$ by the funicular polygon method. The length of $F_{1\text{-}6}$ is the total length from F_6 to F_1 in the force polygon, and the direction is from F_1 to F_6. The point of action is determined by the closed intersection point P of the funicular polygon. The specific drawing process is that each side of the funicular polygon is parallel to the corresponding ray. The parallelogram method is simplified as shown in Figure 5. It is known that three forces F_1, F_2 and F_3, all three do not intersect, but their extensions will intersect. Therefore, the simplification is carried out by taking any two of their force extensions to intersect. First, the forces F_1 and F_2 will be synthesized as F_{12} according to the parallelogram law, and then F_3 and F_{12} will be synthesized so that they will finally be simplified to the force F_{123}, whose orientation is shown in Figure 5. In this way, all the known forces in the graph can be simplified, so that the number of force objects is significantly reduced, which facilitates the calculation of subsequent algorithms, reduces the complexity of the force system, and improves the versatility of the algorithms.

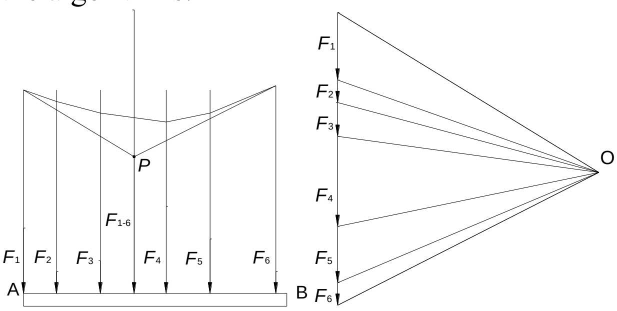


Figure 4: The funicular polygon method simplifies the parallel force system.

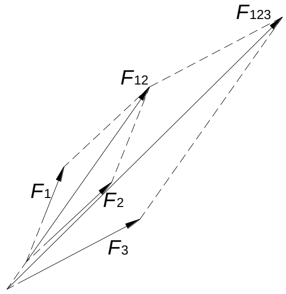


Figure 5: The parallelogram method simplifies the convergent force system.

4.1 Single-point algorithm

Single-point algorithm (for the basic solution unit 1): the force system has a force at one point to be solved, as shown in Figure 6, if there is a known force F_1 after the equivalent simplification of a view of the force system, at this time, the point P to be solved must fall on the line of force F_1, otherwise the mechanical state is not balanced.

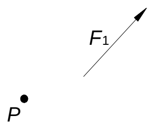
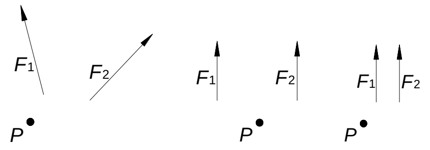


Figure 6: Application of the single-point algorithm.

4.2 Point-line algorithm

One point and one line algorithm (for the basic solution unit 2): the force system has a force line at one point and the length of another line to be solved, as shown in Figure 7, where the magnitude and direction of force F_1 are known, the direction of force F_2 is known, its magnitude need to be computed. As shown in Figure 7 (a), F_1, F_2 are not parallel, then the force line at the point P to be sought must intersect with F_1, F_2 in order to balance, we can first make force line F_1, F_2 intersection, and then connect the intersection point with the point P, this line is the force line at the point P, its magnitude can be obtained through the triangle method. As shown in Figure 7(b), if the forces F_1 and F_2 are known to be parallel and located on both sides of point P, then the principle that the funicular polygon must be closed can be used to solve it, and the funicular edge needs to start from point P. The specific graphical process has been introduced in the previous section; as shown in Figure 7(c), if the forces F_1 and F_2 are known to be parallel and located on the same side of point P, then the force system is not reasonable and cannot be solved.

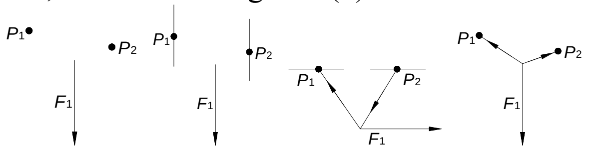


(a) (b) (c)

Figure 7. Application of the point-line algorithm.

4.3 Double-point algorithm

Double-point algorithm (for the basic solution unit 3): there are two force lines at the known point in the force system to be solved, as shown in Figure 8(a), the force lines across points P_1 and P_2 are to be drawn, and the known force is F_1. Because the direction of the force line across the point to be sought is unknown, it can be assumed that the direction of the two force lines to be sought is parallel to the known force F_1 in the opposite direction, as in Figure 8(b), and they can be solved by the funicular polygon method. When the force lines at the point to be solved appear in Figure 8(c) after the assumption of the parallel condition, the funicular polygon method will fail, and it is changed to the three-force concurrent method. If the force lines at the two points to be solved are not parallel to the known force lines, the three-force concurrent method is used, as shown in Figure 8(d).

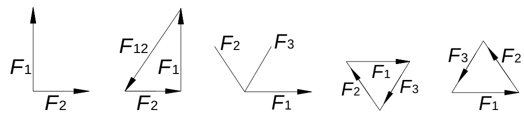


(a) (b) (c) (d)

Figure 8: Application of the double-point algorithm

4.4 Triple-point algorithm

Triple-point algorithm: It is more commonly used in the graphical statics, which can be used to solve the two-coordinate component force synthesis planar resultant force or three-coordinate component force synthesis spatial resultant force, and can also be used in the three-force concurrent model where one is known to strive for the other two force occasions. As shown in Figure 9(a), two planar intersecting component forces F_1, F_2, can use the triple-point algorithm to compute its resultant force, according to the characteristics of the force polygon connected at the beginning and end point and closed, it can be known and the force F_1, F_2 constitute the equilibrium state of the force F_{12}, as shown in Figure 9(b), so the magnitude of resultant force of force F_1, F_2 is F_{12}, its direction is opposite to F_{12}. As shown in Figure 9(c), a force F_1 is known, and use the three-force concurrent method to compute F_2 and F_3, the direction force lines F_2 and F_3 can be translated so that they form a closed triangle connected with F_1 at the beginning and end, as in the two cases of Figure 9(d) and (e), and the results are the same.



(a) (b) (c) (d) (e)

Figure 9: Application of the triple-point algorithm. (a) Planar bi-component force. (b) Triangulation of the resultant force. (c) Three-force concurrent. (d) Illustration 1 of three-force concurrent. (e) Illustration 2 of three-force concurrent.

4.5 Moment algorithm

Moment equilibrium algorithm: This algorithm is more commonly used in graphical statics for solving the magnitude of a force in a known direction according to the moment equilibrium condition. As shown in Figure 10, the moment of force F_2 on point o is known to be ab×oa, that is, the area of quadrilateral oabc. According to the parallelogram area equal graphing method, it is known that the area of quadrilateral odef is equal to oabc, then the length of force F_2 is the length of edge od of quadrilateral odef.

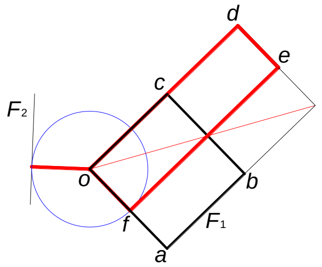


Figure 10: Moment balance graphing method.

5. GRAPHICAL STATICS AND GRAPHICAL EDUCATION

Descriptive geometry occupies a crucial position in graphical education, however, with the rapid development of modern manufacturing technology and intelligent manufacturing technology, the status of graphical education as a professional foundation has become lower and lower, and some teachers engaged in graphical education even think that the purpose of graphical education is only to implement national drawing standards. For a long time, graphics, as a professional basic knowledge, which reminds people of the intuitive function of graphical representation, has made many people ignore its scientific value. However, the effective use of descriptive geometry in graphical statics will make graphics an engineering computational tool and enhance the disciplinary influence of graphics, therefore, applying descriptive geometry to statics is a good choice for the reform of graphics education.

In order to better apply the descriptive geometry to solve the statics problems, the corresponding basic algorithms are compiled into a drawing program. According to the teaching characteristics, the computational process of the statics problem is decomposed into a corresponding flow tree. By planning different sequences of algorithms for different statics problems, the purpose of solving general statics problems can be achieved. Two teaching examples are presented to further demonstrate the significant advantages of the descriptive geometry in statics problems. As shown in Figure 11, the two parts *AB* and *AC* of the ladder are hinged at point *A*, and connected by horizontal ropes at points *D* and *E*. The ladder is placed on a smooth horizontal surface, one side of which is hung with a heavy object, the gravity is *G*=800kN, other dimensions as shown in Figure 12, not counting the weight of the ladder, seek to compute the tension *T* of the rope.

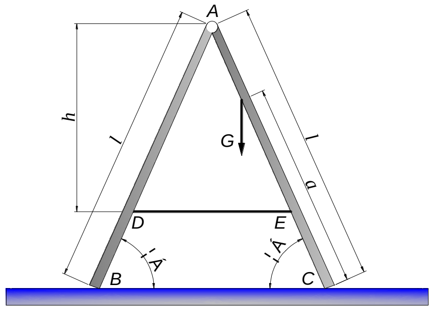


Figure 11: Example diagram of a planar force system problem.

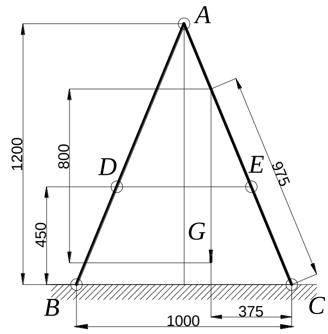


Figure 12: Force analysis model of planar force system. (descriptive geometry method)

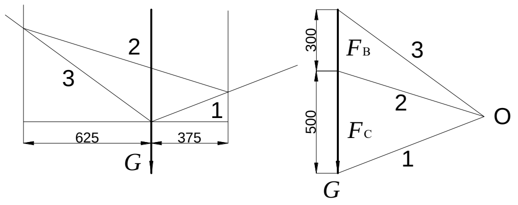


Figure 13: Funicular polygon method of graphically calculating the force state of the ladder pivot point.

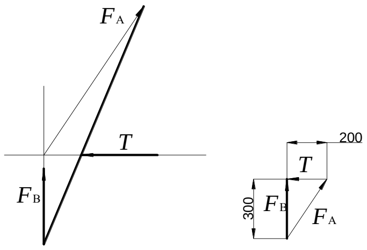


Figure 14: Three-point algorithm for calculating rope tension.

As shown in Figure 13, considering the force model of the whole ladder, F_B=300kN and F_C=500kN can be obtained by using the funicular polygon method; on this basis, the left half of the ladder's foot is selected as the object and its force state is analyzed. The direction of F_A, F_B, T can be determined by the three forces balance convergence theorem, and T=200kN can be graphical computed by triple-point method, as shown in Figure 14.

As shown in Figure 15, a simple crane, the rods dimension are: *AB*=*BC*=*AD*=*AE*, *A*, *B*, *C*, *D*, *E* are connected with the ball hinge, the projection of triangle *ABC* is line *AF*, the angle of *AF* and axis *Y* is θ=30°, not counting the weight of each rod, the weight of lifting is P=10kN. When the position shown in the figure is balanced, try to compute the force of each rod.

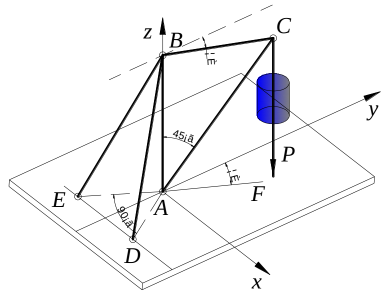


Figure 15: Example diagram of a spatial force system problem.

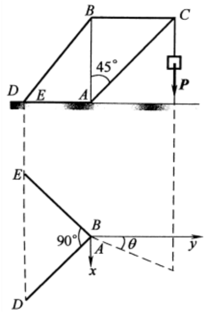


Figure 16: Force analysis model of spatial force system. (descriptive geometry method)

According to the descriptive geometry, the force model is projected orthogonally to obtain its two views, as shown in Figure 16. Then, the plane actual shape of △*ABC* is obtained by projection transformation, as shown in Figure 17, and the force triangle $\triangle c_1'd_1'e_1'$ is constructed according to the dimensions of *CP* , and F_{CB}=10kN and F_{CA}=14.14kN can be obtained by using the triple-point algorithm.

As shown in Figure 18, find out the intersection line *BF* of △*ABC* and △*BDE* planes, decompose the obtained F_{CB} to the rod *AB* and intersection line *BF*, construct the right triangle $\triangle g'g_0'g_1'$ on the V-directional projection plane , and use the three-point algorithm to get F_{AB}=12.25kN; use the projection transformation to get the actual shape of △*BDE*, decompose b_1b_{10} to b_1d_1 and b_1e_1 according to the parallelogram method, and get F_{BD}=3.66kN, F_{BE}=13.66kN.

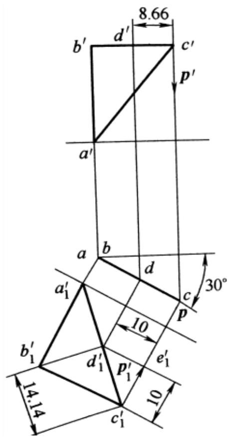


Figure 17: Projection transformation method and triple-point algorithm to calculate the force of rods.

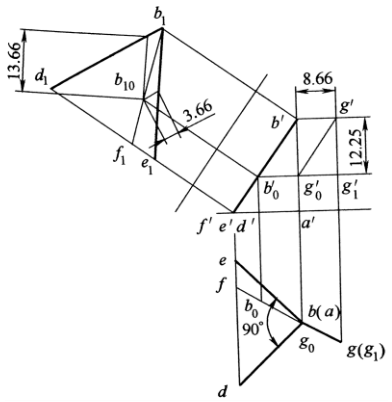


Figure 18: Projection transformation method and parallelogram method of graphically calculating the force of the rods.

It is a small program based on Pascal language for solving internal forces of trusses by graphical statics method. It uses ETABS software for modeling, automatically calculates internal forces of trusses and draws the corresponding static diagram of trusses. However, the applicability of Graphic Statics is limited to the calculation of internal forces of 2D trusses only, and it needs to be modeled by third software. In contrast, it can be found from the above examples that the method of static graphical solution proposed in this paper is applicable to the solution of planar force system and spatial force system problems, and the step-by-step calculation thinking of the algorithm adopted is more in line with the teaching rules, which is conducive to the students to master the essence of the descriptive geometry step by step.

6. CONCLUSIONS

In this paper, we analyze some common features involved in the process of solving the statics problems, adopt the thinking of descriptive geometry to analyze it graphically, summarize and generalize several basic algorithms, and use the basic algorithms of graphical computation to calculate the statics problems. According to the verification of the cases of statics problems, the following conclusions can be drawn: the method of solving the statics problems by descriptive geometry is feasible, reliable in accuracy, intuitive, and much less complex in computation than the analytical method.

This paper has made corresponding contributions in the following aspects.

(1) Apply the thinking of descriptive geometry to the calculation of statics problems, and effectively combine traditional descriptive geometry with statics in teaching, which help to expand the theoretical boundary of descriptive geometry and is conducive to the reform and innovation of traditional mechanics education.

(2) Use multi-view projection theory in descriptive geometry to solve spatial force systems, overcome the limitation that traditional graphical statics is only applicable to planar force system, and make the descriptive geometry-based method of graphical statics applicable to both planar force system and spatial force system problems.

(3) Propose several common computational units and design them as corresponding graphical algorithms, and replace part of the repetitive human drawings with the programmed computation of the algorithms, which not only save the

time but also ensure the accuracy of the diagrams, which is helpful to assist daily teaching.

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KNOWLEDGE RECOMMENDATIONS BASED ON INTELLIGENT PROOFREADING OF INSTRUMENT-TOOL-DRAWING ENGINEER-ING DRAWINGS

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ABSTRACT: This paper presents a framework for knowledge recommendations based on intelligent proofreading of instrument-tool-drawing engineering drawings integrated transfer learning. By train-ing the feature extractor of the source domain image, the network weight of the feature extractor is transferred to the engineering drawing evaluation model and the knowledge transfer of similar do-main is completed. The logistic regression classifier is trained and the intelligent evaluation model is established based on self-adjustment of neural network weight parameter. Then the standard elements of an instrument-tool-drawing engineering drawing such as geometric feature projection and line type are recognized. Knowledge is analyzed and helpfulness scores of knowledge are calculated by using the cognitive information gain measurement model. Knowledge recommendations that are optimally helpful relative to the results of proofreading are generated. The experimental results show that the average proofreading time is 0.95s, and the error comprehensive weighted recognition rate is 98.86%. The proposed method is effective and accurate in recommending knowledge that takes into account the results of proofreading.

Keywords: Knowledge recommendations, Intelligent proofreading, Transfer learning, Education of descriptive geometry and graphics

1. INTRODUCTION

Engineering drawings are the basis for the production of mechanical products. Standardized drawing is an important basis to ensure the correct, complete and unified product drawings. It is important for information transmission among product design, manufacturing and inspection. Problems such as font, line type, visibility and layout in engineering drawings result in drawing recognition errors, which seriously affect the quality of production. Although computer-aided design is being widely used in the process of mechanical drawing, engineering drawing as the basic skill of mechanical design is an important basis of computer-aided design. In practice, instrument-tool-drawing drawing leads to difficult recognition of different kinds of geometric features. Therefore, it is helpful to retrieve information of interest such as the appropriate knowledge to engineers from proofreading of engineering drawings using knowledge recommendations [1].

In recent years, geometric feature extraction based on machine learning [2-3] and automatic proofreading technology [5-7] have attracted wide attention from academia and industry. DeLatte et al. [8] proposed a new convolution neural network method based on Crater U-Net for geometric feature extraction and recognition of spatial objects. Jin et al. [9] presented an automatic detection method for small-scale geometric features in high-resolution images based on deep neural network, which effectively improved the recognition accuracy by using multitime sample extraction technology. Palestra et al. [10] presented a geometric feature extraction method based on feature combination. Zhang et al. [11] proposed a new deep 3D-CNN framework to identify the processing characteristics from the geometric features of CAD models, which supported for real-time computer-aided process design. Natarajan et al. [12] applied the multi-voting mechanism to the features extracted by the convolution neural network in order to effectively eliminate overfitting and improve the performance of metal surface anomaly detection system. On the other hand, Song et al. [13] proposed CNN-LSTM network based on network cloud architecture to discriminate correctly and correctly for jobs in order to meet the needs of multiple teaching. Lin et al. [14] proposed an automatic abnormal video job detection system, which realized the automatic detection and feedback of abnormal video jobs, avoided the manual pick-up of abnormal jobs by teachers, and improved the efficiency of job scoring. Jing [15] proposed an intelligent proofreading method based on non-negative semi-supervised document clustering, designed an automatic scoring method for short answers, and achieved the automatic scoring of MOOC. Moreover, several automatic proofreading software [16-18] are developed, which preprocess CAD engineering drawings into graphic data.

The literature review above shows that the application of image geometry feature extraction and automatic proofreading technology, especially in proofreading of engineering drawings, is still in its infancy. The existing methods have problems such as high rate of misrecognition of features and low efficiency of automatic proofreading. Due to the low accuracy and robustness of proofreading of engineering drawings, it is difficult to find the required knowledge and recommend them to engineers. This paper presents a framework for knowledge recommendations based on intelligent proofreading of engineering drawing integrated transfer learning. An intelligent proofreading model based on neural network weight parameter adaptive is established and used to recognize the standard elements of instrument-tool-drawing drawing such as geometric feature projection and line type. Knowledge is analyzed and helpfulness scores of knowledge are calculated by using the cognitive information gain measurement model. Knowledge recommendations that are optimally helpful relative to the results of proofreading are generated. The experimental results show that the proposed method is effective, with high error recognition rate and robust performance. The experimental results show that the average proofreading time is 0.95s, and the error comprehensive weighted recognition rate is 98.86%. The proposed method is effective and accurate in recommending knowledge that takes into account the results of proofreading.

2. THE PROPOSED METHOD

2.1 Procedure of the proposed method

The flow of the proposed knowledge recommendation method based on intelligent proofreading of engineering drawings integrated transfer learning is shown in Figure 1.

Step1, engineering drawings are pre-processed. Background, noise and interference are re-moved based on the improved threshold iterative algorithm. Then the image segmentation is completed, and the feature projection image of instrument-tool-drawing drawing is extracted.

Step2, a part of samples is selected for training, and the trained models are used to predict the remaining samples. Due to the small number of training samples, there is a serious class imbalance problem that limits the performance of the deep learning model. However, retraining the entire network requires a lot of time and computing resources. Therefore, this paper employs transfer learning to train samples, which uses a small amount of data to achieve the ideal training results. By training the feature extractor of the source domain image, the network weight of the feature extractor is transferred to the instrument-tool-drawing drawing evaluation model to complete the knowledge transfer of similar domain. An intelligent evaluation model is established based on adaptive neural network weight parameter, and applied to recognize the standard elements of engineering drawings such as geometric feature projection and line type.

Step3, the intelligent proofreading of engineering drawings is performed. According to results of proofreading, knowledge is analyzed and helpfulness scores of knowledge are calculated by using the cognitive information gain measurement model. Then knowledge recommendations that are optimally helpful relative to results of proofreading are generated.

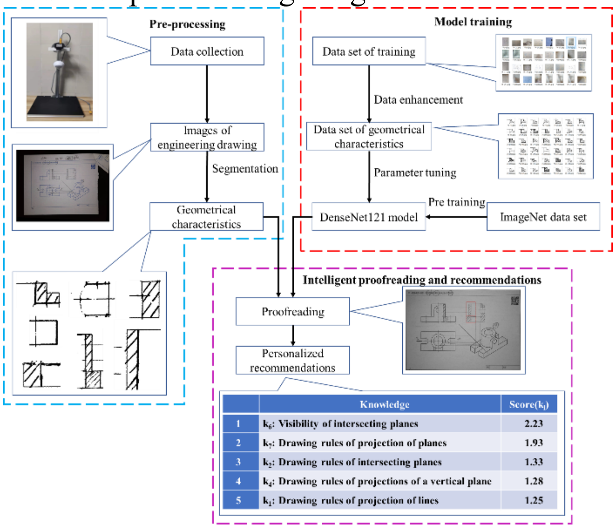


Figure 1: Flow of the proposed method.

2.2 Pre-processing of engineering drawings

Due to the considerations of the geometric characteristics that are insensitive to the color information of the image, gray image is employed by gray transformation to reduce the computational load of subsequent operations. It enhances the contrast of the image and reduces the difference between different color lines. In addition, the image needs to be smoothed due to the noise interferences of the original image such as redundant strokes or eraser marks. Processing with a Gaussian filter is employed to eliminate noise and protects line edge information. The image edge is extracted by Canny operator [24]. All the connected regions are extracted, and the areas with less than the threshold area are discarded. Thus, the area with the smallest remaining area is the target area. Affine transformation is performed after obtaining the corner coordinates of the target area. When the image correction is completed, the target area is adjusted to a fixed size in order to make the same target area coordinates of each scoring point.

Traditional recognition algorithms are widely used in recognition of basic geometries such as straight lines and circles. However, the recognition effect is poor to deal with complex geometries such as dashed lines and dotted lines. In this paper, threshold segmentation method is applied to extract features of engineering drawing. Binary image processing of threshold segmentation method not only reduces the interference of uneven illumination and removes redundant lines, but also reduces the size of the picture and accelerates the later network training. Firstly, the target is extracted according to the scoring point area coordinates. Then, the brightness and contrast are adjusted to reduce the interference caused by the brightness of the paper center area caused by the supplementary light. Finally, the scoring point image is binarized using the maximum interspecific variance method [25], and a binary image of the target lines is obtained.

In generally, the larger the data size of the drawing, the stronger the generalization ability of the intelligent proofreading model. Due to the small number of initial samples, data enhancements are needed to expand the dataset of engineering drawings. However, image operations such as reverse, clip and flip will destroy the features of engineering drawings such as dashed line and solid line. Thus, in this paper, a small range of data enhancement methods, such as rotation, horizontal slipping, vertical slipping, and adding noise interference are employed. The pseudocode for the data enhancement algorithm is as follows:

Algorithm 1: Data Enhancement

```
Input: initial image img,
       number of enhanced images total
Output: enhanced images imgEnhanced
width = img.shape[0]          //width of initial image
height = img.shape[1]         //height of initial image
imgEnhanced = Set             //set of enhanced images
while len(imgEnhanced) < total do
    x = random(-width // 30, width // 30)
    y = random(-height // 30, height // 30)
```

```
        proportion = random(0, 50) / 1000
        img1 = imgTranslate(img, x, y)      // slipping
        img2 = imgRotate(img, -5, 5)        // rotation
        img3 = imgNoise(img, proportion) // adding noise
        imgEnhanced.add(img1, img2, img3)
    return imgEnhanced
```

2.3 DenseNet Model

The DenseNet121 model [21] with 121 layers is employed in this paper. The first layer uses 7×7 convolution and 3×3 is pooled to reduce the feature dimension. The DenseNet121 model contains four dense blocks, each of which contains a convolution layer of 1×1 and 3×3, in order of 6, 12, 24, 16. Between adjacent dense blocks, a translation layer consists of a 1×1 convolution layer and a 2×2 pooling layer. There are direct connections between any two layers of the network, where the input of each layer is the sum of the output of all the previous layers and the feature map learned by that layer is also passed directly as input to all the layers behind it. This connection structure enables feature reuse, which deals with the problem of gradient disappearance caused by the increase of network layers, and leads to fewer feature maps for learning of each layer. Thus, it greatly reduces the number of parameters and improves learning efficiency.

The weights obtained from training on the ImageNet dataset are used as the initialization parameters for identifying the model, and then the model is fine-tuned on the scoring point dataset. Before freezing, n layers are trained, and only the parameters of the last layer are trained. The learning rate is set as 0.001 and Epoch is set as 25. The uses the cross-entropy loss function is employed as the loss function and its value of loss is calculated as

$$H(p,q) = -\sum_{i=1}^{n} p(x_i)\log(q(x_i)) \tag{1}$$

where p is the true value and q is the predicted value.

The random gradient descent method is applied to update network parameters and calculated as

$$\theta_j^{'} = \theta_j + \alpha(y^i - h_\theta(x^i))x_j^i \tag{2}$$

where j is the index of the layer, θ_j is the weight parameter of j-th layer, $\theta_j^{'}$ is the updated weight parameter of j-th layer, α is the learning rate, i is the index of the neurons in each layer, $h_\theta()$ if the neural network operation.

2.4 Recommendation generation

In this paper, the Shannon's information entropy concept is introduced to measure the amount of information in knowledge. Entropy was first developed for communication. It can be seen as the amount of information needed to represent an event. Thus, the average amount of information contributed by a knowledge unit u in a category ci will be:

$$H(C|u) = -\sum_{i=1}^{m} P(c_i|u)\log P(c_i|u) \tag{3}$$

Cognition is the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses. Cognitive processes use existing knowledge and generate new knowledge. Cognition is typically assumed to be information processing in engineer's mind or brain. Information gain is derived from entropy. It is originally defined as how many bits would be saved if both ends know the existence of an instance. It is employed as helpfulness criterion of knowledge in this paper.

In the knowledge classification, information gain can be understood as the expected entropy reduction by knowing the existence of a knowledge unit u_j. In this paper, information gain is applied to evaluate the amount of information provided by a knowledge unit. Information gain of knowledge unit u_j is defined as [22]:

$$\begin{aligned} IG(u_j) &= H(C) - H(C|u_j) \\ &= -\sum_{i=1}^{m} P(c_i)\log P(c_i) \\ &\quad + P(u_j)\sum_{i=1}^{m} P(c_i|u_j)\log P(c_i|u_j) \\ &\quad + P(\overline{u_j})\sum_{i=1}^{m} P(c_i|\overline{u_j})\log P(c_i|\overline{u_j}) \end{aligned} \tag{4}$$

where $P(c_i)$ is the probability of knowledge in category c_i in knowledge space, $P(u_j)$ is the probability of knowledge which contains knowledge unit u_j among all knowledge, $P(\overline{u_j})$ is the probability of knowledge which does not contain knowledge unit u_j among all knowledge, $P(c_i|u_j)$ is the probability of knowledge which contains knowledge unit u_j and which is in category *ci* out of all knowledge containing u_j, and $P(c_i|\overline{u_j})$ is the probability of knowledge which does not contain knowledge unit u_j and which belong to category *ci* out of all knowledge which do not contain u_j.

The cognitive information gain value could represent the knowledge unit's ability of correctly predicting if knowledge belongs to a knowledge category that is used in the engineering drawings. We assume that the summation of the cognitive information gain values of all knowledge units in knowledge could indicate the knowledge's helpfulness. As a result, to calculate the helpfulness of knowledge k_l in test set, the score calculation equation is defined as follows:

$$Score(k_l) = \sum_{j=1}^{n} \left(IG(u_j) f(k_l, u_j) f(t, u_j) \right) \qquad (5)$$

where $f(k_l,u_j)$ is a binary function, if knowledge *kl* contains knowledge unit *uj*, $f(k_l,u_j)$=1, otherwise 0; and $f(t,u_j)$ is a binary function, if engineering drawing *t* requires knowledge unit u_j, $f(t,u_j)$=1, otherwise 0.

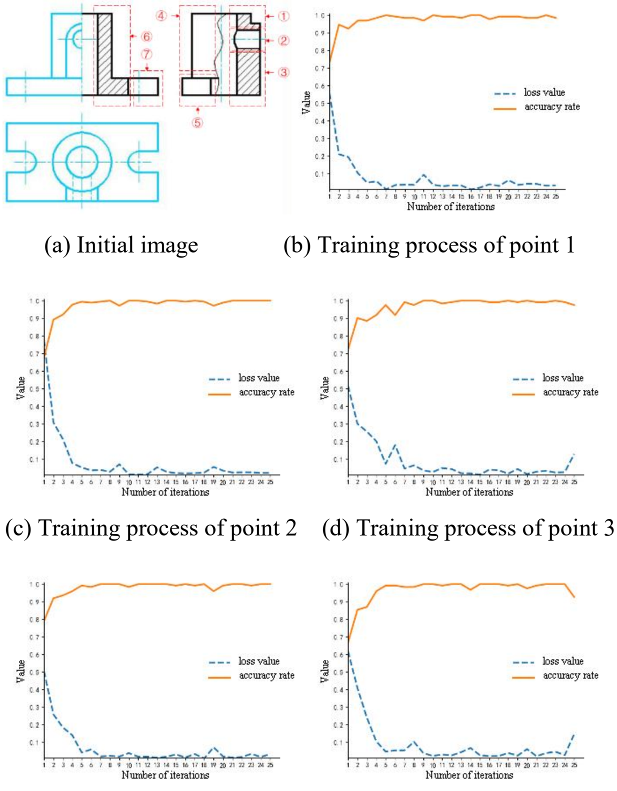
Equation (5) can be seen as the total helpfulness information delivered by knowledge k_l. It can be used as a measurement model to predict the helpfulness of knowledge. As a result, all the cognitive information gain of knowledge units of training set is calculated, and then the score values of knowledge of test set will be and returned as the form <k_l, $Score(k_l)$>. Finally, knowledge is ranked based on the corresponding score values and knowledge with higher score values are more helpful than others.

3. EXPERIMENTS AND RESULTS

In this paper, the algorithm is implemented with Python programming, and a machine learning network is built with PyTorch deep learning framework. It is trained and run on Windows10 64 bit operating system, Intel(R) Xeon(R) E5-2630 V4 CPU @ 2.2GHz processor, 64GB RAM, 4×NVIDIA GeForce GTX 1080 Ti workstation. Images of engineering drawings were obtained by an image acquisition device with an industrial camera (resolution: 3264×2448, autofocus).

3.1 Experiment 1

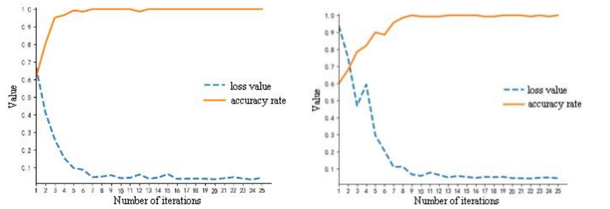
In order to verify the effectiveness of the proposed intelligent proofreading method, the 7 points in Figure 2(a) were trained, separately. During the training process, change of the loss value and accuracy rate as shown in Figure 2. The accuracy of the model gradually increases, the loss value gradually decreases, and each group of models gradually reaches a steady state after 10 rounds of training. The accuracy of each group of models was more than 98% after full training.



(a) Initial image (b) Training process of point 1

(c) Training process of point 2 (d) Training process of point 3

(e) Training process of point 4 (f) Training process of point 5



(g) Training process of point 6 (g) Training process of point 7

Figure 2: Results of training process.

3.2 Experiment 2

In order to verify the efficiency and accuracy of the proposed intelligent proofreading method, a comparative experiment is designed. The method in this paper is compared with the manual proofreading, and three tests with increasing degree of difficulty are performed. Each test uses 50 new samples to test. Figure 3 shows the comparison of time-consuming between the manual proofreading and the proposed method. As shown in Figure 3, 50 samples took 35s, 50s, 58s using the proposed method, while the manual proofreading took 224s, 298s, 472s. Moreover, the average proofreading time of the proposed method is 0.95s and it is almost 85% lower the manual proofreading. Figure 4 shows the comparison of correction rate between the manual proofreading and the proposed method. As shown in Figure 4, the correction rate of intelligent proofreading is 98.4%, 98.86%, and 99.2%, which is close to the rate of manual proofreading. Thus, the proposed method can greatly improve the efficiency of the proofreading while retaining a high accuracy.

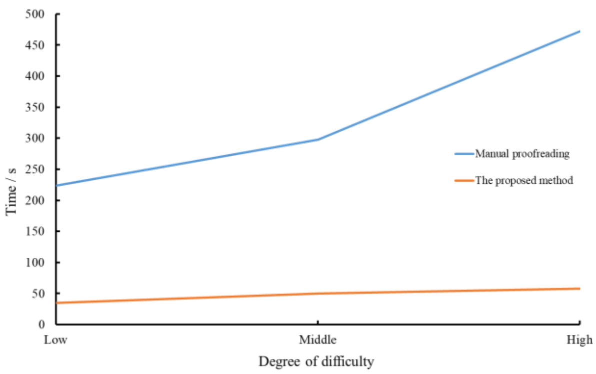


Figure 3: Comparison of time-consuming

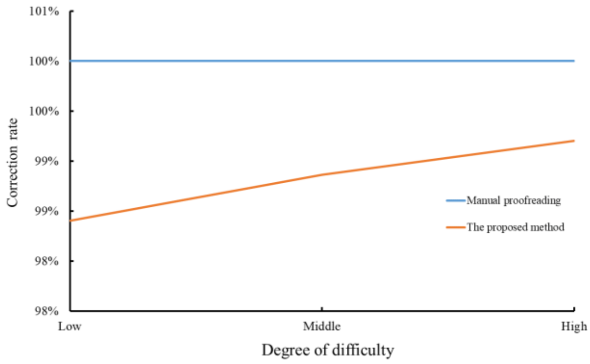


Figure 4: Comparison of correction rate.

In addition, Figure 5 shows the proofreading result of the low degree of difficult. According to results of proofreading, knowledge is analyzed and helpfulness scores of knowledge are calculated by using the cognitive information gain measurement model and listed in Table 1. As shown in Table 1, knowledge “k_6: Visibility of intersecting planes” has highest score. Another 4 relevant knowledge has smaller score.

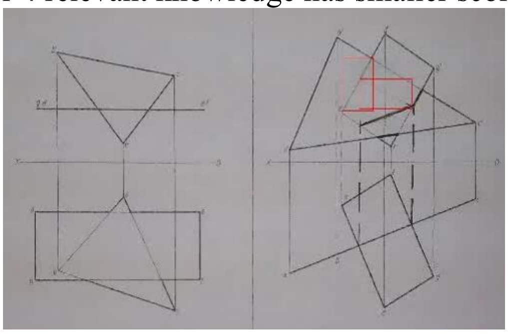


Figure 5: Proofreading result of the low degree of difficult.

Table 1: Recommendations of knowledge.

	Knowledge	***Score*(k_l)**
1	k_6: Visibility of intersecting planes	2.23
2	k_7: Drawing rules of projection of planes	1.93
3	k_2: Drawing rules of intersecting planes	1.33
4	k_4: Drawing rules of projections of a vertical plane	1.28
5	k_1: Drawing rules of projection of lines	1.25

4. CONCLUSIONS

Aiming at the problems of high error rate and low efficiency of automatic evaluation of image features in intelligent evaluation of Engineering drawings, an integrated migration learning method for intelligent evaluation of engineering drawings is proposed, which achieves the accurate recognition of standard features of engineering drawings such as geometric feature projection and line type. The experimental results show that this method is an effective intelligent evaluation method for engineering drawings. It has high accuracy and robustness in the evaluation, and effectively improves the efficiency of the evaluation of Engineering drawing.

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AN ANALYSIS OF VISUAL INTEREST DETECTION IN 2D GAME CONCEPT ART

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ABSTRACT: Visual interest has always been a vital topic in the field of image analysis. The visual center and visual guidance are necessary for composition when the 2D artist designs the game concept art. Previous researches, like different saliency methods, are all seeking high accuracy recognition or primary object detection. Some researches are based on experiments or different types of saliency methods to identify visual interest rules. This research is inspired by bags of color models and analyzes the frequency and color contrast in local regions to recognize visual interest. Our research starts from the artist's thinking. We try to enhance the recognition of the visual interest in the game concept art. Also, the authors intend to improve accuracy by using the original module, and demonstrating the relationship between artists' pictorial skills and visual interest.

Keywords: Visual interest, Game concept art, Color contrast.

1. INTRODUCTION

As a game concept art designer, the author has been working on game concepts for many years and looking for how to describe paint rules objectively. Many excellent research and systems work for pictures, photos, or design inspiration in recent years. Most of these image studies are aimed at the photo, picture in magazines, or object recognition. For example, one research analyzed the color harmony using a combination of the local region to evaluate the photo's aesthetic quality [1]. They mentioned the method bags of color, which is inspired by the bags of feature model. These researches are looking for the relationship between objective pictures and subjective feedback from audiences. The objects of these studies are mostly photos, but there are differences between photos and concept artworks. Concept art includes different styles, especially fantasy and cartoon, using significantly different colors and object shapes in their artwork. Most of the photos describe the world objectively, but most game concept art is subjective designs. Our research also hopes to fill up the lack of research in digital artworks. Of course, with the advancement of science and technology, many systems are aimed at game concept design. For example, the website called artbreeder. This website can generate game concept art of different styles by inputting two pictures or more than two references. Users can change the attributes that they already set up to get the result in different art styles. These generators undoubtedly provide great help for the conceptual design of the game. For instance, game concept artists can generator an excellent draft for their starting. The Game designer can also quickly produce imaginary sketches to communicate effectively with the concept artist via this system. However, some result also has many limitations, and in many aspects, it does not follow the basic principles of artistic design. So, it is not available for game concept art. They leave some space for improvement in the generated results.

One of the critical parts is the visual interest. First of all, visual interest refers to one or several areas on the screen where the viewer will spend time and attention. A good game concept art designer will deliberately use various factors such as color, composition, object, and light to guide the viewer's attention in the pictures. Therefore, visual interest is an indispensable factor in game art concepts, and it has always been considered during the design process. In the visual interest, the game concept designer will use the composition, different color combinations, and painting techniques to emphasize the entire picture's visual interest, generate rhythm and make the picture attractive.

This research focuses on the detection of visual interest in game concept art. We try to design an original module from the artist's sight, using the art principles to create the algorithm for the visual interest. Furthermore, these visual interests can provide the weight function of the picture for our subsequent research. The weight function of the visual interest is obviously higher than the non-visual interest. Finally, we evaluate the result by an experiment.

2. RELATED WORKS

There are many related or similar studies in recent research, including Saliency, image recognition, the study of the visual center in traditional artworks, composition, and aesthetics. The following will briefly overview these researches or experiments and describe the relationship and differences between their studies and our study.

2.1 Saliency

Saliency is an analysis of the virtual objects in a series of pictures. It uses image processing technology and computer vision algorithms to locate the most "significant" area in the picture. The salient area refers to the eye-catching area or the more important area in the picture. The objects of this type of research are mainly photos. Saliency's research has many different methods and is constantly optimizing the final results. At the same time, segmentation is also a part of saliency research. Researchers try to segment the saliency object from photos.

There are three mainly saliency detection algorithms in the saliency module of OpenCV:

Static saliency: this algorithm relies on image features and statistical information to locate the saliency area in the image.

Motion saliency: The target of this saliency method focuses on the videos or a series of frames. This algorithm tries to detect and track mainly moving objects as the saliency areas.

Objectness: This type of saliency algorithm calculates proposal areas; these are considered the saliency area.

At the same time, the research of saliency is constantly evolving and updating, such as: Assessing visual balance with high-level cues [2], Depth Enhanced Saliency Detection Method [3], Saliency Improvement Through Genetic Programming [4].

The main difference between saliency's research and our research is the target samples. In saliency research, authors are looking for a way to detect the particle objects in the photos. It depends on the analysis of edge detection, pixel information, and other methods to confirm the weight function of the object in the photo. Specially in most extensive dataset MSRA, most samples have a clear mainly object in the pictures. However, the game concept artwork is almost large scenes, and usually, there is no single object in the picture. Game concept art usually connect all the object in the painting. In the game concept design, the author believes that this research is around the key word “attention”. It refers to an area in which there can be one or more objects. The concept art design is a subjective creating process, but it also follows certain objective principles during the painting process.

2.2 Object recognition

Object recognition is part of vital references for our research. There are some researches on object recognition in images. Previous research [5] proposed that 16*16 would be the best segmentation for object recognition in images or photos. However, it was mentioned in a paper just presented 2020 that the picture segmentation should depend on the target object [6]. Cutting with a smaller level will save the calculation cost and achieve similar results when the image is elementary, such as apples and oranges. A 4*4 subdivision is sufficient for larger objects to identify the object's content in the picture.

Based on these studies, our research will adopt a 4*4 level segmentation to subdivide and analyze the image. In the future, we do have plans to continue to enrich the research on the results of different level segments.

2.3 Visual center in traditional artwork

Participants were asked to write down feedback after viewing the digital versions of eight artworks [7], one example as in Figure 1. In addition, participants were required to write down the images of these pictures and record the audience's language reactions and eye movements.

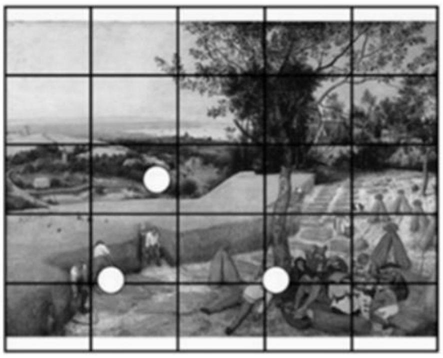

Figure 1: An example of visual interest research [7]

The research attempt to analyze the way that audiences obtain information. They get the result by using the processing model and visual aesthetics principle. According to this model, the perceptual-cognitive processing of artistic stimuli starts with the rapid generation of essential responses, and they are looking for the connection between aesthetic methods and audience responses.

This research is more closely related to our research than saliency. To a certain extent, we are also looking for the connection between design principles and audiences' feedback. Nevertheless, our methods and module are based on the artist's way of thinking. Because the painting principles have already set the ways to connect with the audience. One of the critical processes is guiding the audience's thinking. So, the final goals of the two studies are quite similar, but the starting points and methods are entirely different.

2.4 Composition

Whether in saliency or many image studies, some art skill principles have always been ignored. The study "the saliency detection based on photographic composition" [8] includes the basic composition principle and saliency algorithm. It mentions that composition is one factor that can affect people's attention. The composition has always been an unavoidable problem, such as triangle composition, golden ratio, and the rule of third. Composition is indeed one of the ways to guide the sight, but artists do not only use composition to guide the audience's sight. In the module of our research, we include the influence of some composition factors. At the same time, we combined the other art principles to improve the accuracy and reliability of our result.

2.5 Aesthetics

Aesthetics has always been a relatively subjective topic. Aesthetic-related research is usually linked to color harmony. Aesthetic led a lot of research similar to color combinations and color panel color schemes, such as the relationship between color harmony and aesthetic quality[1]. These studies are meaningful. They can help AI to judge the quality of the picture or support the artist. Aesthetics is not only the result of one aspect of color. The visual center, composition, portrayal, contrast, and many other aspects contribute to the quality of the picture. Therefore, we are also looking for the connection between visual interest and the aesthetics of the picture. A clear visual center usually accompanies good game concept artworks to guide the audience's sight. We follow the basic theory of game concept design to confirm this.

3. METHOD

The principles of this research are based on basic principles of art painting. We follow the step below when we design the 2D concept artwork. Here the author briefly introduces what principle the game concept designer uses to guide the audience's attention:

The size of the color area. A large area of the same color, such as the blue sky, is often not the visual interest. On the contrary, a small area that has intense colors is more attractive to people's eyes.

Different ways of composition. For example, the well-known triangular composition, symmetrical composition, the rule of third. These composition methods are also critical considerations when designing visual interest.

The Contrast of saturation, lightness and hue. In the fundamental theories of art, unlike the RGB of computers. We, as humans, use HSV or HSL to understand and learn the rules of colors. It is Hue, saturation, and lightness. At the location of the visual center, by using many color HSL changes, attract people's attention.

As shown in figure 2, our module tries to restore the three most important attributes in the game concept design. Based on the above factors, we first use the composition to establish the visual interest of the entire picture. Then we use large and small areas of color to enhance the rhythm of the picture and enhance the contrast between the visual center and the non-visual center.

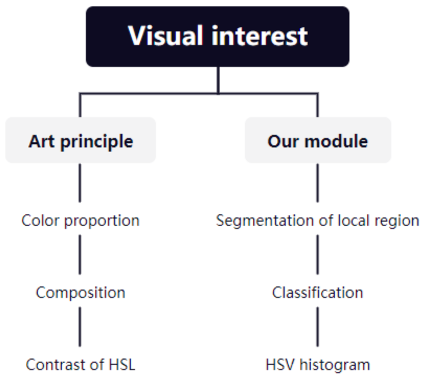

Figure2: The framework shows how we match design rules and algorithms.

At the same time, the proportion of colors, saturation, lightness, and hue also vary extremely in two different areas. This also means that we can follow this thought to find the visual interest of the picture. Based on these principles, we designed this module to achieve the functions we need. The module consists of four steps to imitate the design principle.

3.1 Image segmentation

Based on previous studies [6], in image processing algorithms, researchers generally segment the pictures and then analyze and classify each local region to get the conclusion. This series of methods inspire our study. The study [6] mentioned that scenes could be detected within a level of 4*4 segmentation, achieving an accuracy rate of object recognition around 91.4%. 4*4 segmentation can ensure the algorithm's efficiency and keep the high accuracy simultaneously. So we adopted a 4*4 segmentation in this experiment.

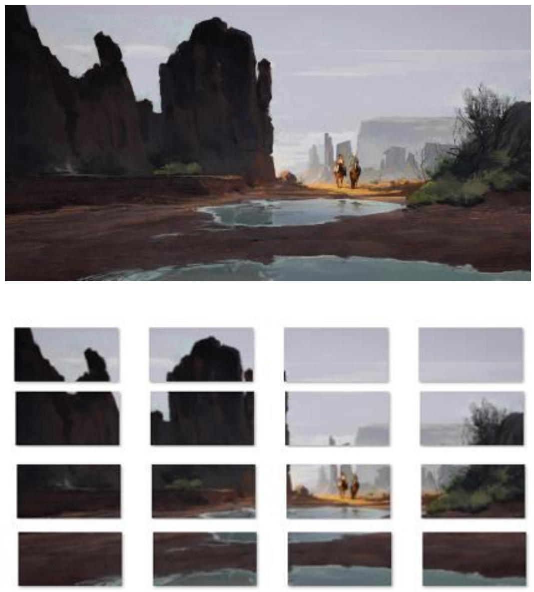

Figure3: A sample of picture segmentation

3.2 Perceptual hash algorithm

The perceptual hash algorithm is the way to test the similarity of two local regions. The function of this algorithm is generating a "fingerprint" string for each image, and then comparing the "fingerprints" of different images. In hash algorithms, it separates into three different types: Ahash. Phash and Dhash. Among them, Dhash has high accuracy and speed. So we are using Dhash, which follows the step below to test the similarity of our samples. The first step reduces the size of the local region to 8 pixels * 8 pixels. This step tries to remove the details and retain essential information such as structure and shading. At the same time, we can abandon differences in local region size. Second, we conduct graying processing in order to optimize the speed of the entire module. Third, comparing the color intensity of the previous pixel and the second pixel makes them true (1) or false (0) depend on the differences of intensity. So, we can get a string with 64 values to describe the information in the local region. In the last, calculate the similarity of two local regions. We get the 64-bit hash value of each local region by comparing it in pairs. Then record them separately to determine the similarity between regions. Finally, we make sure that each local region has been compared with other local regions.

3.3 Classify local region

Based on the hash value obtained in the previous step, we arrange the hash value, which is the similarity of the local region, from high to low. We start from the two local regions with the highest similarity and put them into the dictionary. If the next local region matches the previous local region, put them in the same dictionary. If the following local region does not match any existing dictionary, create a new dictionary. Next, we conduct this operation until all local regions are classified.

3.4 Detect visual interest

Finally, we determine the visual interest areas based on the local region's frequency in the dictionary. The dictionary with the least local region is the target area. If multiple results are detected, based on the rules of composition in art principle, the visual center is generally not designed in the four corners of the picture. Assuming that the image segmentation level is m*m when multiple results appear, our module will prioritize excluding the dictionaries that contain local regions below: 0, m-1, m(m-1), m*m-1. For example: In our study, we adopted a 4*4 sample cut. Therefore, our module will first exclude the four local regions of 0, 3, 12, and 15 at the four corners with multiple results. Then, we use the HSV histogram to confirm the magnitude of the color change in the local region. The non-visual interest area has no big color change, shown as in figure 4. However, as shown in Figure 5, there will be drastic hue, saturation, and value changes in the local visual interest region. By comparing the two pictures, we can clearly distinguish the region of visual interest and the region of non-visual interest.

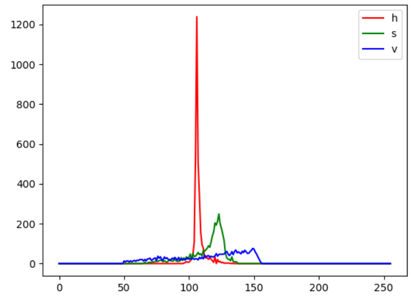

Figure 4: HSV changes in non-visual interest

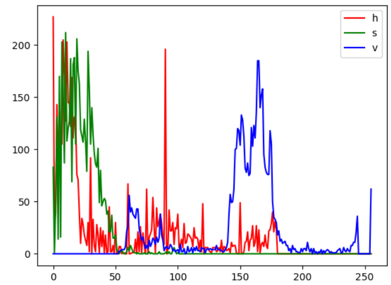

Figure 5: HSV changes in visual interest

4. EVALUATION

We prepared 100 game concept design drawings from Artstation as samples since the dataset for concept art is lacking. Artstation serves as a sharing community for outstanding game concept design works. In order to ensure the quality of samples. The samples are also arranged according to all artists' evaluations from highest to lowest. We removed the pure landscape samples from all these concept arts. For instance, there are only large areas of mountains and trees in the picture. Instead, the selected sample should contain story-telling in the concept art. Many themes existed in the game concept design, such as outdoor scenes, indoor scenes, characters, monsters. Also, there are many artistic expressions, such as cartoons, horror, exaggeration, realism. The samples we extracted in this study are based on the original game paintings with storytelling and do not specify particular themes and styles; since there is no relevant research on game concept design drawings, this research will first try to include most of the types and themes from a broad perspective. Future research will gradually subdivide the classification of research samples. At the same time, the author also believes that with the deepening of sample classification. The accuracy will also be improved. We conduct our modules one by one to get the visual interest of each picture. We used the online questionnaire survey and invited 50 participants. They do not have any art and design knowledge. The questionnaire has 200 pages, and the odd number pages are the original game concept from the artist. The even number pages are the results from our module. Two examples are listed in figure 6. Each participant had 3 seconds to observe each game concept artwork in the experiment. Then, participants were asked to answer whether the results met their expectations. Finally, record the results for comparison.

Figure 6: Two examples in the questionnaire.

We tried to compare the conclusions with the saliency research, although the samples and methods are different. At least, their result can be part of the references. Moreover, with the development of saliency research, it has gradually begun to be divided into specific categories: different types of saliency focus on a distinct area such as people, animals, objects. Among these samples, there is a distinction between positive and negative samples. It can calculate precision and recall curves to evaluate the result. At the same time, with the gradual reduction of the target sample range, the accuracy and precision has gradually improved in saliency research.

In the evaluation of saliency, f-measure (1) is often used to evaluate the saliency algorithm.

$$F_\beta = \frac{(1+\beta^2)\,Precision \times Recall}{\beta^2 \times Precision + Recall}, \quad (1)$$

At the same time, control the value of β in the formula to change the weight of precision and recall. Usually, β = 0.3 is used to calculate the f value of the entire algorithm. In contrast with other studies, especially in the game concept artwork, an excellent commercial work must have its visual interest. That means there is not negative sample and all the samples should be positive samples in our experiment. So, we can only summarize the accuracy and the precision in the conclusion.

5. RESULT

After collecting the data of 50 participants, we concluded that the accuracy of our module is 91.48%. And we calculate the precision follow the formula (2) below:

$$precision = \frac{TP}{TP + FP} \quad (2)$$

Precision is 74.83%. We collected several volunteers who participated in the experiment onsite; precision is higher than the result from the questionnaire. We will continue to recruit more participants to join our eye-tracking test.

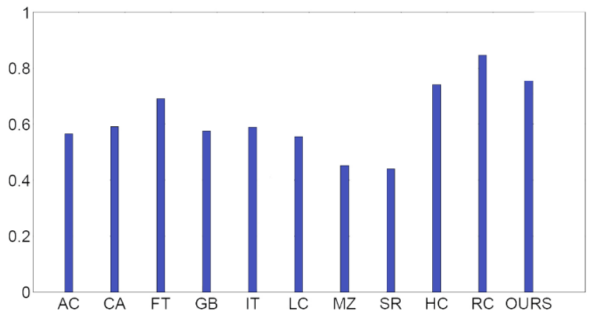

Figure 7: The precision of different Saliency methods

We compare the result with other saliency researches, as shown in figure 7. These saliency method results are as follow: AC, CA, FT, GB, IT, LC, MZ, SR, HC, RC [8]. Unfortunately, we cannot compare recall and f-measure since we have no negative samples.

6. CONCLUSIONS AND FUTURE WORK

This study attempts to create a module of visual attention by starting from the artist's creative thinking and targeting game concept art. The module includes the core painting principle, and the module is used to simulate the painting process to detect the visual interest in the picture. This research attempts to open up new areas of game concept art. At the same time, it paves the way for future research in the game design and painting domain.

However, this research also has certain limitations. First, different degrees of segmentation will lead to different results. In our preliminary test, too high and too low-level segmentation will lead to inaccurate results. Secondly, objects in the artworks, like characters, animals, machinery, monsters, are inevitably involved in game concept design. They also cause different weights for visual interest detection. If they happen to be segmented during the segmentation stage, they will have relatively low weight during analysis and cause misdetection. Finally, the dark art style has few HSV changes in painting, so it is not easy to detect the result with this method.

In the future research plan, we will be divided into two primary directions. The first is to continue to optimize the module and try to improve the accuracy and precision. The second is to analyze the differences between the colors of the visual interest area and the non-visual center area. We are continuously looking for the relationship between the color usage pattern and the visual center.

ACKNOWLEDGMENTS

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GRAPHICS EDUCATION

THE DEEPENING PROCESS OF VERIFICATION ABILITY FOR ARCHITECTURAL DRAWING:
LEARNING PERIOD, GRADES OF SUBJECTS, THE BIG FIVE

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ABSTRACT: This research aims to clarify architectural students and non- architectural students abil-ities to grasp their positions by connecting architectural drawings to real space. That ability is called the verification ability for an architectural drawing. This study clarifies the relationship between the verification ability for an architectural drawing and the Big Five. By doing so, we will study a new teaching method for architectural educations in consideration of the individuality of students and the viability of a way using the Big Five traits.
As a result of the analysis, it has become clear the deepening process of the verification ability for architectural drawing of architectural students tends to change in the third grade and stay constant in the fourth grade. In addition, the study has succeeded in clarifying a specific association between the Big Five traits and the verification ability for architectural drawing. In addition, agreeableness was related to the verification ability for architectural drawing. Herewith for teaching based on the big five traits can be considered for a new method of teaching which takes into account the individu-ality of the students.

Keywords: Verification ability for architectural drawing, the Big Five, Deepening process

1. INTRODUCTION
1.1 Background and Purpose
These days, in Japan, the range of academic abilities by enrolled students of architectural courses of universities broadens. Besides that, regarding the subjects of architectural design ex-ercise, for given themes as the requirements, the interpretations and focuses by students are vari-ous depending on their own learning levels and interests for architectural professional knowledge. Next, education methods on aca-demic institutions in Japan have been called group-emphasized-type conventionally. How-ever, these days, as individuality-respected-edu-cation is emphasized, improvement of instruc-tion curriculums has been made in consideration of the individuality and diversity of students. Nevertheless, in current situation, individuality-respected-education is limited to "searching good points", which has not gotten to make ed-ucation adjusted by student's individuality. There is a diversity in processes and goals of study of students. Therefore, from now, it is expected that instructors will be required the diversity of instruction methods of architectural education, or new instructional methods of architectural education in consideration of individuality of student independently of the academic ability. Accordingly, in order to develop the deeper understanding about the Big Five, we considered comprehending fostering process of verification ability for an architectural drawing and connectedly analyzing the Big Five, the most powerful scientific description of personality that is widely used all over the world as the new architectural instruction method considering student's personality.

The primary purpose of this study is to clarify the difference of verification ability between students who have professional education and no professional education in architecture, and its relationship with the Big Five. The secondary purpose is, regarding students who have professional education in architecture, to grasp the understanding about relationship between verification ability and academic records of their courses, which clarifies the fostering process of verification ability in college. In a series of studies, this thesis extracts students who have professional education in architecture among the test subjects and mentions fostering process of verification ability, verification ability and the Big Five, and relationship between verification ability and academic records of their courses.

1.2 Preceding studies

1) Study related to verification ability

Regarding verification ability for architectural drawing, there is Somchith Sitthvan's study[1]. The study method uses the test subjects as university Laotian students in Lao PDR who have professional education and no professional education in architecture, which researches with Plan Interpretation Test (PIT) using Mental Cut-ting Test (MCT) and house drawing of Japan that is uniquely developed by Sitthvan. Addi-tionally, the result is compared with that of a freshman of fundamental course of Osaka Uni-versity and analyzed. As the result, for PIT, it is cleared that PIT scores of Laotian students in architecture course and those of freshmen of fundamental course of Osaka University are almost the same. Though Laotian students who have professional education in architecture are com-prehensively able to judge on multiple floor plans of an architectural drawing, students who have no professional education in architecture are able to judge only information on a floor plan view.

2) Study related to personality patterns of students who have professional education in architecture

As the discussion related between personal-ity patterns of students who have professional education in architecture and design process of the design subject, there is Hirokazu Abe's study[2]. The study method uses students of multiple universities who have professional education in architecture and experienced design subject of architecture design exercise in university as test subjects, which researches with uniquely developed personality trait tests by reference to Myers-Briggs Type Indicator (MBTI), and questionnaires about design process. Also, they have conducted the follow-up study of design process with five students of the third grade who have professional education in architecture. As the result of the analysis, it is clear that students who have professional education in architecture have the following tendencies. There is a certain relationship between the personality traits and design processes of the students of have professional education in architecture. Herewith, it suggested a hint for instruction of architectural design exercise. On the other hand, it points out a problem that using personality traits in architectural can give unnecessary prejudice to the instructor.

3) Study related to the Big Five

As the discussion related to the Big Five and academic records, there is Mrera Komarraju's study[3]. The study methods conduct researches for the Big Five and study processes with 308 undergraduates. The research results are related to the newest GPA and analyzed respectively. The results were found as follows. Two of the Big Five traits, conscientiousness and agreeableness were positively related with all four learning styles (synthesis analysis, methodical study, fact retention, and elaborative processing), whereas neuroticism was negatively related with all four learning styles. The Big Five together explained 14% of the variance in grade point av-erage (GPA), and learning styles explained the additional 3%, suggesting that both personality traits and learning styles contribute to academic performance. These results suggest that being intellectually curious fully enhances academic performance when students combine this schol-arly interest with thoughtful information pro-cessing.

1.3 Positioning of Study

From the past study, we thought that the necessity to investigate whether the basic knowledge in architecture is obtained by socialization with aging. In addition, regarding verification ability for an architectural drawing, we hoped to confirm the difference between students who have professional education and no professional education in architecture, in association with personality traits.

Figure.1 shows verification ability for architectural drawing in this study and its positioning of the study. Verification ability for architectural drawing was considered to have the following two situations. For “A : Space imaging based on architectural drawing”, the past studies with that were often seen. One of those is Mrera Komarraju’s study. For understanding its own position by “B : Referring to architectural drawing in actual space”, it seems like looking a map in a city. Then, this study focused on “B : Referring to architectural drawing in actual space”. In this study, the research method is to let students who have professional education and no professional education in architecture be the test subjects, for ability of understanding its own position by referring to architectural drawing in actual space, conduct experiment using an actual house and survey by questionnaire. This thesis analyses only those students who have professional education in architecture.

Table.1 shows the term definitions in this study. In this study, “Verification ability for architectural drawing” is analyzed on the basis of three indicators of the verification ability (“necessary time, behavioral pathway distance, number of times of swinging up and down”) that are obtained from experiment. Figure.2 shows this experiment data and this study’s constitution.

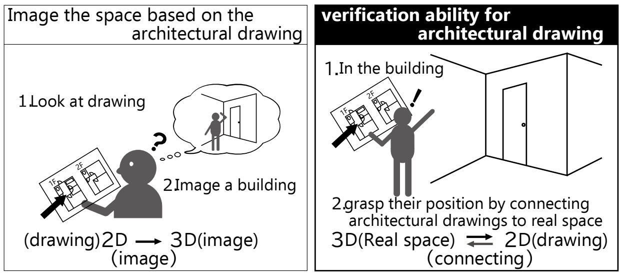


Figure 1: Verification ability for architectural drawing in this research.

Table 1: The term definitions in this study.

terminology	Description
verification ability for architectural drawing	Ability to grasp its own position in the actual space by comparing it with the architectural drawings at hand.
necessary time	Necessary time of entire experiment from entering to leaving a house by the test subject.
behavior pathway distance	Distance of route taken by the test subject during experiment.
number of times of swinging	Number of the times that the test subject looks around during experiment, which is classified into looking up and down, and right and left.

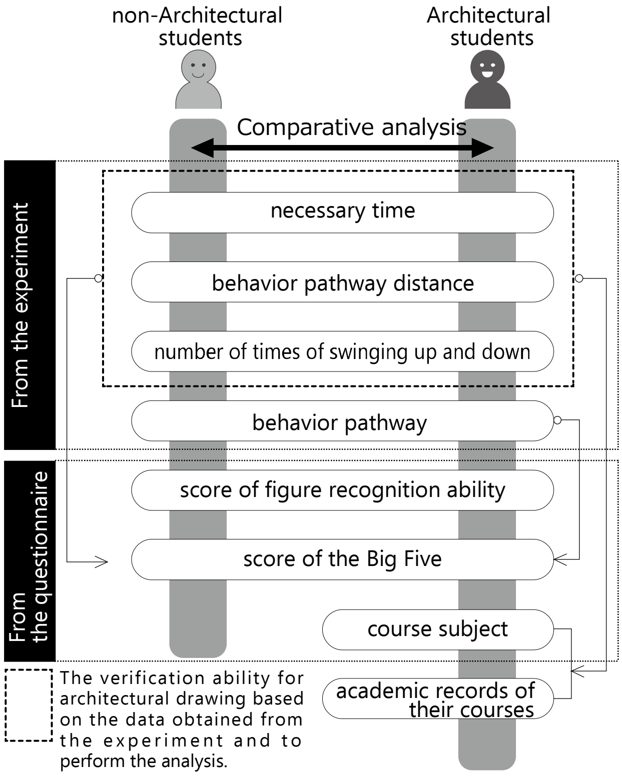


Figure 2: This experiment data and this study’s constitution.

2. METHODS

2.1 Overview of Material

In the experiment, the test subjects who hold drawings move in the building. For this reason, as the conditions, the building as experimental object must be familiar usually and the layout of the main room must not be guessed easily. Therefore, the building as experimental object does not have common Japanese layout. The building as experimental object has a unique layout and internal specifications which is a unique detached house in Hyogo in Japan. Figure.3 shows the floor plan and the features of the house for the experiment. The first floor is a private room, which allows for migration around the closed hall. The second floor consists of living room, dining and western-style room 5, which is widely opened. Opened spiral staircases is installed at the center of the house. Also, the sliding doors on a route with check points are same specifications. Thus, this house is unique in that the impression of openness differs between the first floor and the second floor, and that the sliding doors with the same specifications as one of the open spiral staircases makes it challenging to recognize the layout and direction. From this, subjects' behavioral pathways are likely t to be diverse.

2.2 Experiment method

Figure.4 shows the flow of experiment. After receiving an explanation on the outside of the house, in front of the entrance of the house, the test subject is equipped with a helmet with a CCD camera, and QR code reading terminal. Next, the test subject gazes at the floor plan of the house that has check points in Figure.3 for a minute. After this, the test subject enters the house from the entrance, moves around the house in order of the checkpoints shown in the experimental route drawing, and reads the QR codes shown at easy-to-see positions with the terminal. At this time, outside the house, the recorder records such as behavioral pathway and behavioral characteristics of the test subject during the experiment. Furthermore, the recorder

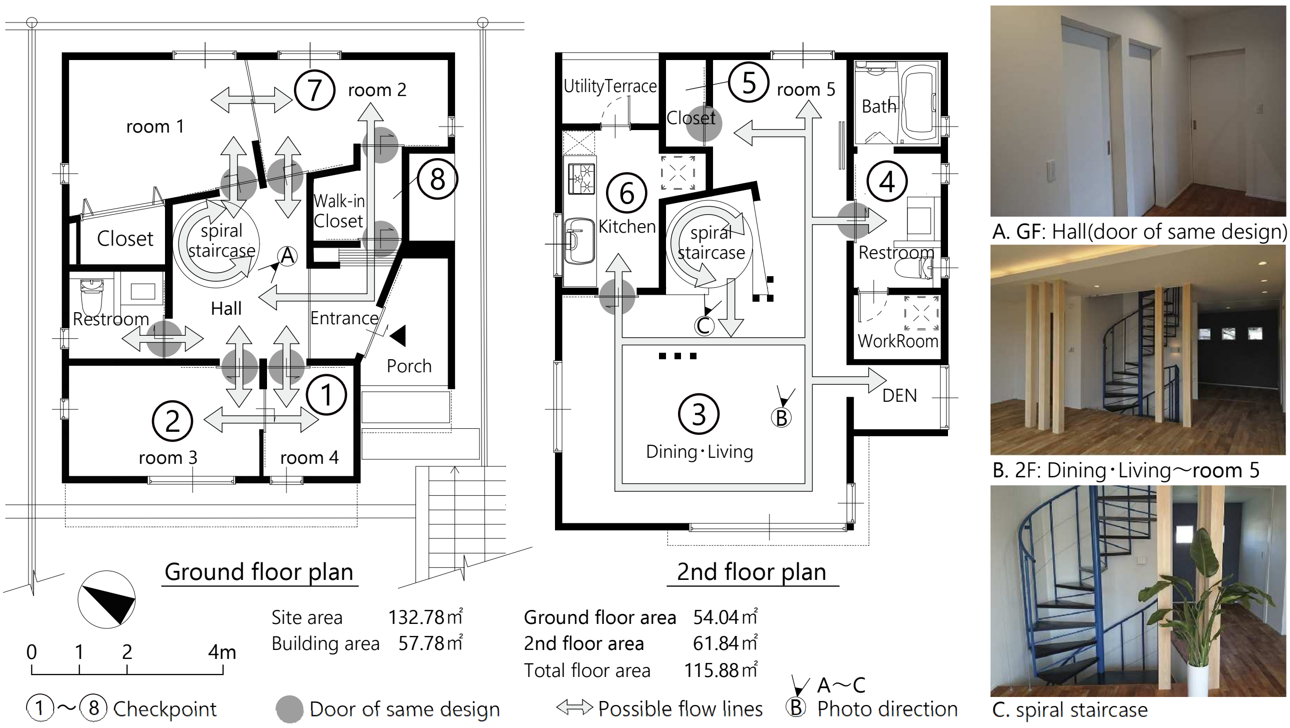


Figure 3: Floor plan and the features of the house in the experiment.

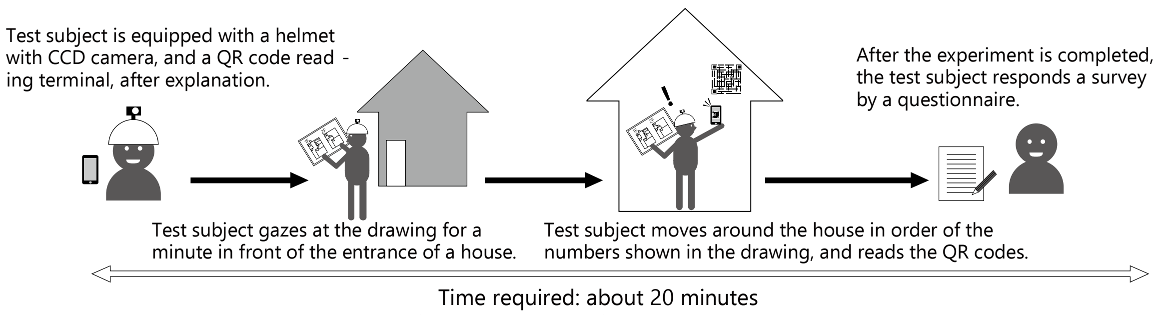


Figure 4: Experiment method.

records the necessary time for the test subject from enter to exit of the house, the time when the QR code was read and the behavioral characteristics during the experiment. After the experiment is completed, the test subject responds the personality trait and graphic recognition problems, and the student who has professional education in architecture responds the survey including its own course subject by a questionnaire.

Table.2 shows the attributes and the number of the experiment subjects. While the students who have professional education in architecture must belong to architectural course, other students who have no professional education in architecture must be similar age and belong to the different course. The analysis was performed excepting outliers. For calculation method of outliers, the upper limit value and the lower limit value with the reliability of 95% were calculated based on the necessity time by the grade and attribute of the test subject.

3. RESULT

3.1 Three indicators of verification ability

Necessary time and behavior pathway distance are analyzed. Figure.5 shows a correlation diagram with the vertical axis representing the necessary time (second) and the horizontal axis representing the behavioral pathway distance (m). The coefficients of determination were [First grade : R^2=0.37，Second grade : R^2=0.57，Third grade : R^2=0.00，Fourth grade : R^2=0.79]. Herewith, it shows the tendencies that coefficients of determination of students who have professional education in architecture increase with each grade excepting the third grade and shorter necessary time makes behavioral pathway distance shorter. In addition, the coefficients of determination of the fourth grade students were significantly higher.

Necessary time and number of times of swinging up and down are analyzed. Figure.6 shows a correlation diagram with the horizontal axis representing the number of times of swinging up and down (count) and the vertical axis representing the necessary time (second). The coefficients of determination were [First grade : R^2=0.51，Second grade : R^2=0.35，Third grade : R^2=0.47， Fourth grade : R^2=0.92], it shows that larger number of times of swinging up and down tends to make necessary time longer in all grades. In addition, the coefficients of determination of the fourth grade students were significantly higher. It is clear that the maximum number of times of swinging up and down were [First grade : 24 count，Second grade : 15 count，Third grade : 12 count，Fourth grade : 11 count], which

Table 2: Overview of the experiment.

		K (Number of people)	N (Number of people)	total	Experiment Day
Grade	1	5 [M: 5 / W: 0]	8 [M: 2 / W: 6]	13	7/24.25/2018
	2	11 [M: 6 / W: 5]	9 [M: 3 / W: 6]	20	11/3.10.11/2018
	3	8 [M: 7 / W: 1]	6 [M: 3 / W: 3]	14	20.21/10/2018
	4	6 [M: 5 / W: 0]	10 [M: 7 / W: 3]	16	10.11.16/11/2018
total		30 [M: 24 / W: 6]	33 [M: 15 / W: 18]	63	10 days

K: Architectural students N: non-Architectural students M: Man W: woman

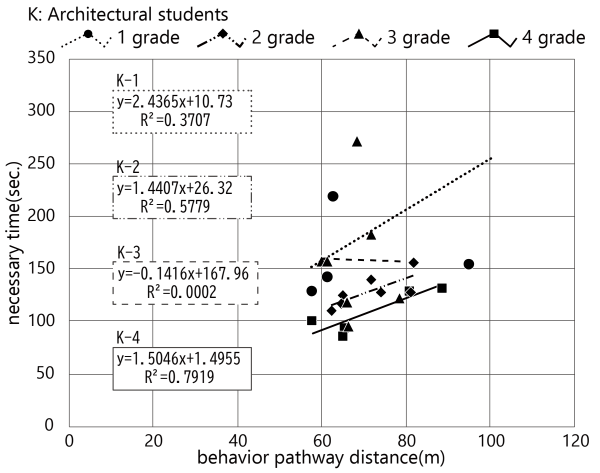


Figure 5: The correlation diagram (second, m).

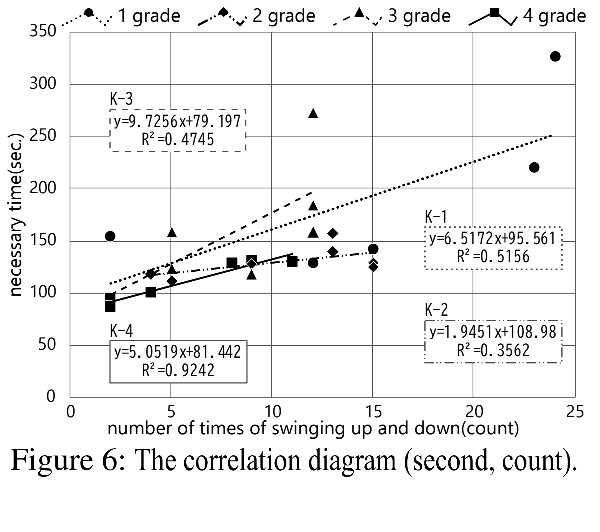


Figure 6: The correlation diagram (second, count).

are decreased with each grade.

3.2 Academic performance

The relationship between verification ability and academic performance of course subjects [GPA, Graphic science I (for the first grade), architectural design exercise] is analyzed. All test subjects are analyzed.

The relationship between verification ability and GPA is analyzed. Figure.7 shows a correlation diagram with the horizontal axis representing GPA (point) and the vertical axis representing the necessary time (second). Also, it was assumed that the first grade student's GPA was obtained immediately after the experiment, GPAs of the second to fourth grade students are obtained in the semester immediately before the experiment. Necessary times of the third and fourth grade students tend to become shorter as their GPAs increased. On the other hand, necessary times of the first and second grade students tend to become longer as their GPAs increased. Figure.8 shows a correlation diagram with the horizontal axis representing GPA (point) and the vertical axis representing the number of times of swinging up and down (count). It shows that number of times of swinging up and down tends to decrease with each grade and as their GPAs increased. Of these, it was found that the correlation becomes higher in the third grade.

The relationship between verification ability and graphic science performance is analyzed. Figure.9 shows a correlation diagram with the horizontal axis representing performance of Graphic science II (for the second term of the first grade) (point) and the vertical axis representing the necessary time (second). Necessary times of the third and fourth grade students tend

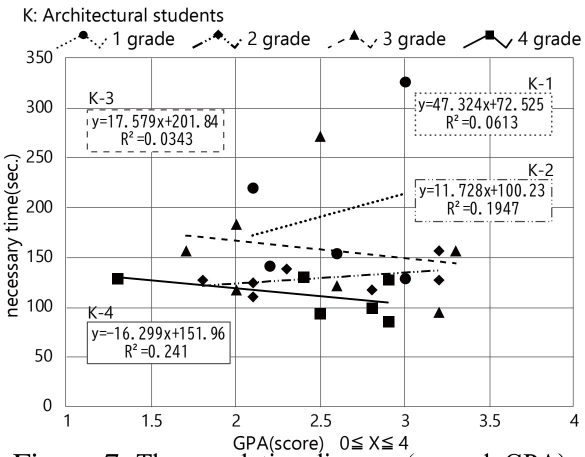


Figure 7: The correlation diagram (second, GPA).

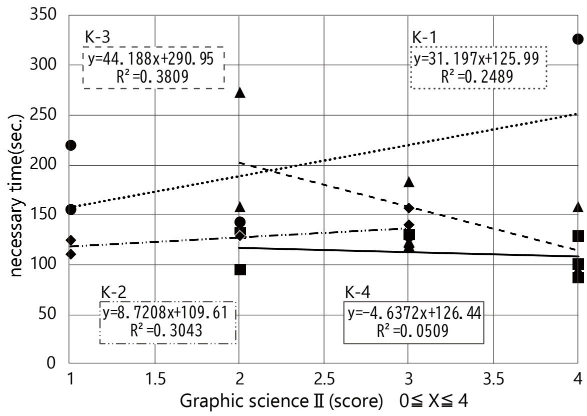


Figure 9: The correlation diagram (second, Graphic science Ⅱ).

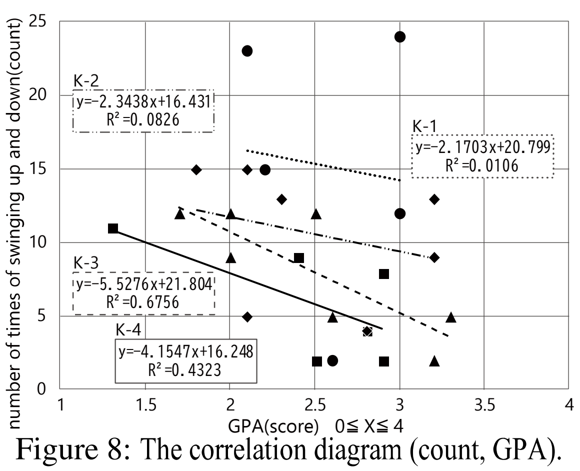


Figure 8: The correlation diagram (count, GPA).

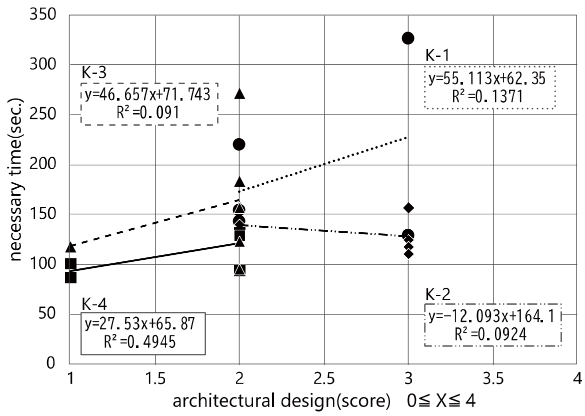


Figure 10: The correlation diagram (second, Graphic science Ⅱ).

to become shorter as their performances become higher. On the other hand, Necessary times of the first and second grade students tend to become longer as their performances become higher. Also, it is found that Graphic science I (for the first term of the first grade) has same tendency to Graphic science II.

The relationship between verification ability and performance of architectural design exercise is analyzed. Figure.10 shows a correlation diagram with the horizontal axis representing the performance of architectural design exercise (point) and the vertical axis representing the necessary time (second). Also, for the performance of architectural design exercise, it was assumed that the first grade student's performance was obtained immediately after the experiment, performances of the second to fourth grade students are obtained in the semester immediately before the experiment. It shows that higher performances of architectural design exercise of the first, third and fourth grade students tend to make necessary time shorter. Of these, the coefficients of determination of the fourth grade students were significantly higher.

3.3 The Big Five

The relationship between three indicators of verification ability and the Big Five is analyzed. All test subjects are analyzed. Table.3 shows the tendencies of the traits. Besides that, it is assumed that the Big Five do not specify the characteristics, but give certain frameworks to their characteristics. Table.4 shows that average values of the Big Five scores of Japanese people aged 18 to 22.

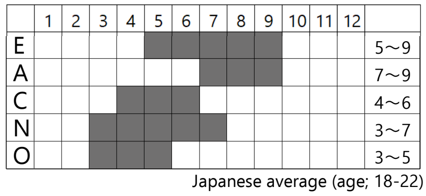
3.3.1 Variance analysis and Multiple comparison

For necessary time, the top 10 people and bottom 10 in order of the shorter time are analyzed. Figure.11 shows the results of analysis. Analysis of variance of the Big Five revealed that p value was (p=0.000＜0.05), which shows the significant difference. Furthermore, multiple comparison test revealed that A:Agreeableness (p=0.04＜0.05), which shows significant difference. Average values of the Big Five scores are

Table 3: The tendencies of the traits.

Domain		High scores
E	Extraversion	Sociable. Positive. Active. Leadership. Concentration power.
A	Agreeableness	Psychosocial. Cooperative. Empathetic. Trusting. Helpful.
C	Conscientiousness	Can act in accordance with social customs and rules. Self-discipline. Think carefully before acting.
N	Neuroticism	Anxious. Emotional stability. Less complaining. High satisfaction with human relations.
O	Openness	Creative. Imaginative. Eccentric. Interested in advanced technology.

Table 4: The average values of the Big Five scores.



E:Extraversion and A: Agreeableness (E：2.9，A：2.4), which show that the upper group have high scores.

For behavioral pathway distance, the top 10 people and bottom 10 in order of the shorter distance are analyzed. Figure.12 shows the results of analysis. Analysis revealed that p value was (p=0.001＜0.05), which shows the significant difference. Furthermore, multiple comparison tests revealed that the Big Five do not have the significant differences and average values of the Big Five scores also have no differences.

For number of times of swinging up and down, the top 10 people and bottom 10 in order of the smaller number of times are analyzed. Figure.13 shows the results of analysis. Analysis of variance of the Big Five revealed that p value was (p=0.001＜0.05), which shows the significant difference. Furthermore, multiple comparison test revealed that E:Extraversion and A:Agreeableness (E：p=0.03＜0.05，A:p=0.04＜0.05), which show significant differences. Average values of the Big Five scores are E:Extraversion, A: Agreeableness and C: Conscientiousness (E：3.5，A：2.6，C：1.7), which show that the upper group have high scores.

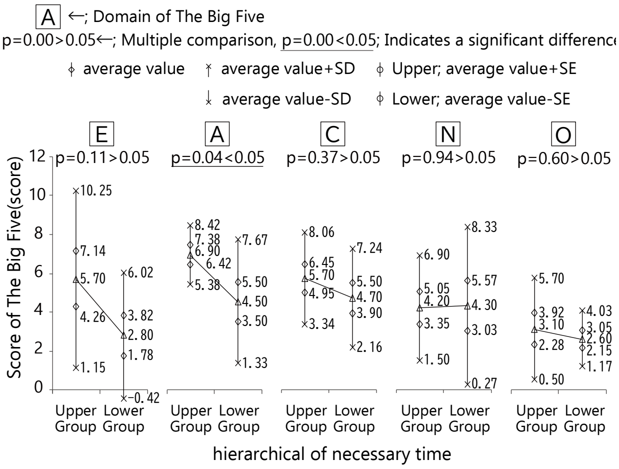


Figure 11: The variance analysis and multiple comparison. (necessity time)

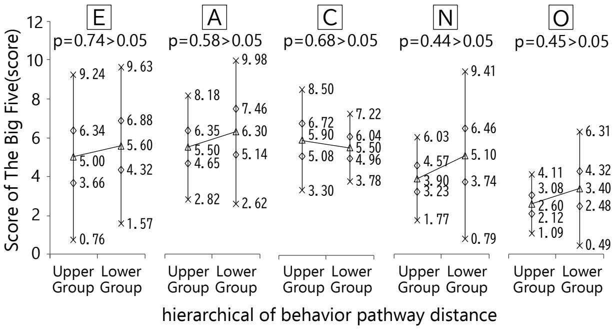


Figure 12: The variance analysis and multiple comparison. (pathway distance)

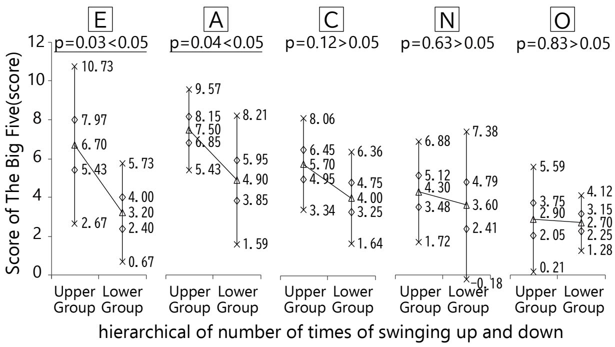


Figure 13: The variance analysis and multiple comparison. (number of times of swinging up and down)

3.3.2 Cluster analysis

Cluster analysis was conducted in order to understand the relationship between the Big Five and verification ability in detail. Figure.14 shows the dendrogram. Cluster types are able to be classified into three types; KN : Neuroticism type [7 people], KA : Agreeableness type [12 people], KE : Extraversion type [11 people]. Next, for three indicators of verification ability, the tendencies of students who have professional education in architecture of the upper and lower groups that are classified and the middle groups that are not classified into the upper or lower are analyzed. The ratios of three indicators of verification ability that are classified into the upper groups are [KN : 28. 6%, KA : 52.8%, KE : 48.5 %], KA becomes the biggest one. The ratios of three indicators of verification ability that are classified into the middle groups are [KN : 42.9 %, KA : 25.0%, KE : 18.2%], KN becomes the biggest one. The ratios of three indicators of verification ability that are classified into the lower groups are [KN : 28.6%, KA : 22.2%, KE : 33.3 %], KE becomes the biggest one. Next, the students who have professional education in architecture, whose all three indicators that are classified into the upper groups are [KN : 0%, KA : 25.0%, KE : 36.4%], KE becomes the biggest one.

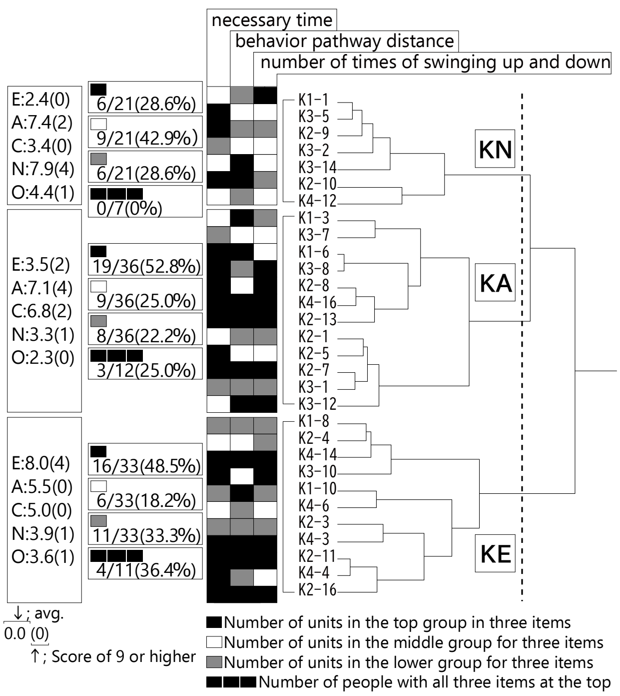


Figure 14: The dendrogram.

3.3.3 Cluster type and Behavioral pathway

Characteristic of the behavioral pathway by test subject during experiment is analyzed. Figure.15 shows the expected experimental pathway. Since <Shortest pathway> in the figure passes through checkpoints that are ① to ② and ⑧ to the entrance, the test subject must read the experimental route drawing accurately. For <Entry to western-style room 1> that is not the subject to the checkpoint, it is expected to require the ability to compare the experimental route drawing with its own position on the first floor with poor visibility after going down a spiral staircase from the second floor. <Unexpected behavior> is like a case that the experimental route is significantly deviated, such as entering a bathroom or study.

Figure.16 shows the behavioral pathway during experiment per cluster type. The ratios of the test subjects that selected the shortest pathway through checkpoints of ① to ② (western-style room3 to western-style room4) and ⑧ (closet in the first floor) are [KN : 28.6%, KA : 41.7%, KE : 36.4%], KA becomes the biggest one. The ratios of the test subjects that entered each room twice and went through each position twice are [KN : 57.1%, KA : 16.7%, KE : 45.5 %], KA becomes the smallest one. The ratios of the test subjects that entered western-style room 1 (not the subject to the checkpoint), are [KN : 57.1%, KA : 75.0%, KE : 72.7%], KN becomes the smallest one.

4. DISCUSSIONS

4.1 Three indicators of the verification ability

Necessary time and behavioral pathway distance are described. Students who have professional education in architecture excepting the third grade are considered to have the ability step by step to read the experimental route drawing accurately and quickly as they become the upper grade. Of these, it is considered that the fourth grade students have certain abilities to collate the experimental route drawing with actual apace in a short time and to go around the route of checkpoints.

Necessary time and number of times of swinging up and down are described. Students who have professional education in architecture tend not to look the experimental route drawing and the necessary times tend to become shorter as they become the upper grade. Of these, it is considered that the fourth grade students have certain abilities to confirm the experimental route drawing with small number of times and to judge the route of checkpoints.

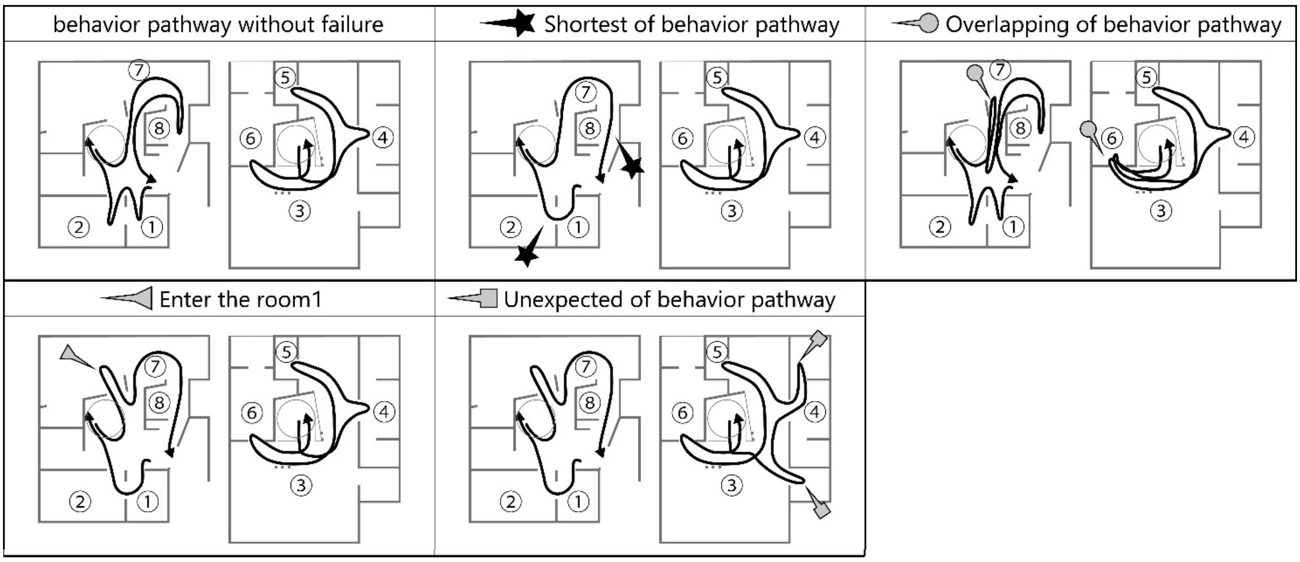


Figure 15: The expected experimental pathway.

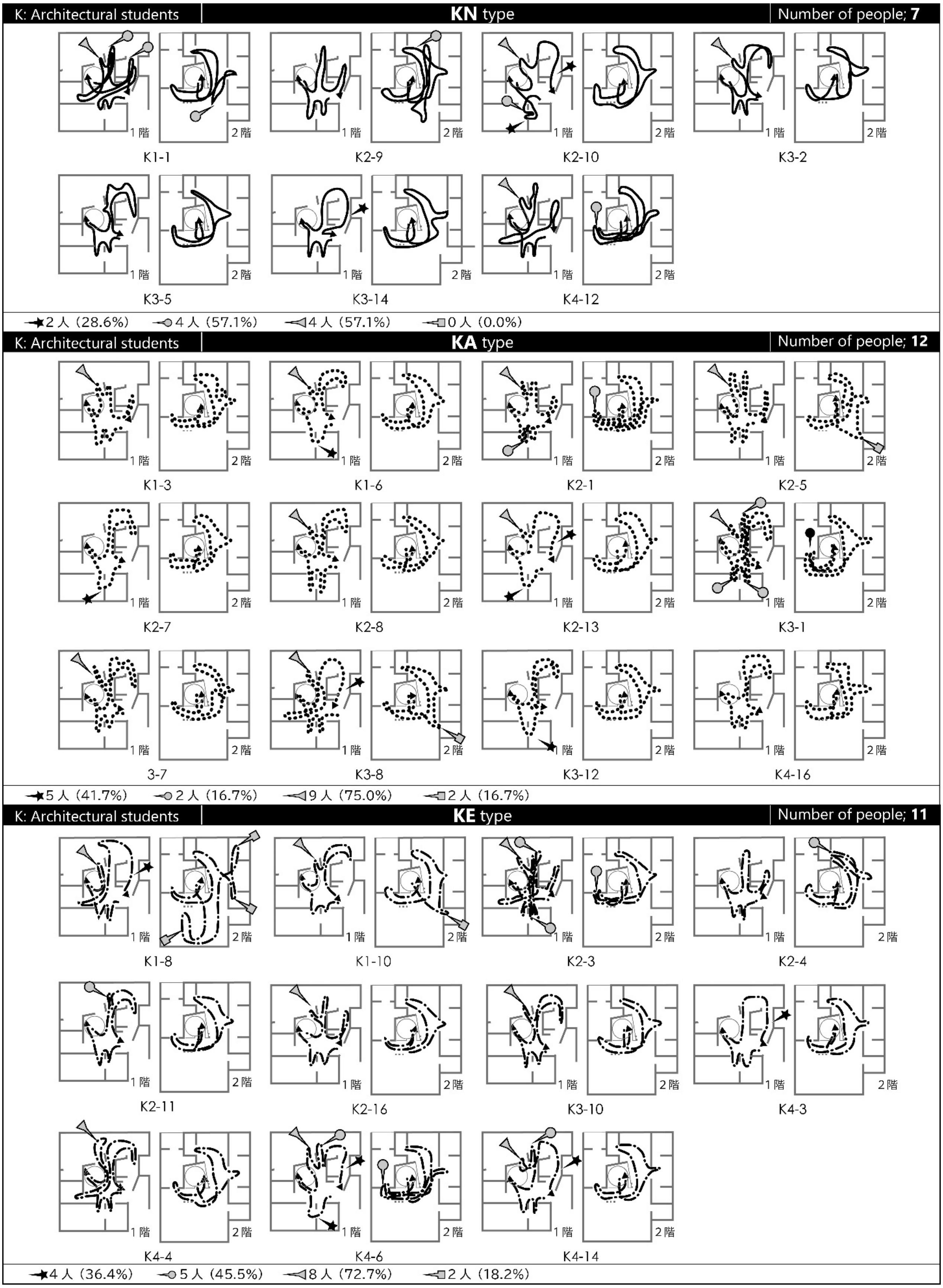


Figure 16: The behavioral pathway during experiment per cluster type.

4.2 Verification ability and Academic performance

The relationship with GPA is described. Necessary times of the third and fourth grade students tend to become shorter as their GPAs increased. On the other hand, necessary times of the first and second grade students tend to become longer as their GPAs increased. Accordingly, for GPA and necessary time, it is considered that the first and second grade students collate carefully the experimental route drawing with inside of the house for a long time as their GPAs increased. For GPA and number of times of swinging up and down, number of times of swinging up and down of all grade students tend to decrease as their GPAs increased. Herewith, it is considered that the third and fourth grade students read the experimental route drawing accurately with small number of times and collate it with inside of the house in a short time, as their GPAs increased.

The relationship with Graphic science is described. For Graphic science I and II, a correlation diagram of necessary time and number of times of swinging up and down with academic performance tends to have similar positions and slopes on the approximate straight lines in each grade. Correlation diagrams of Graphic science I and II with necessary time and Graphic science I and II with number of times of swinging up and down also tend to be similar.

The relationship with architectural design exercise is described. Necessary times of the first, third and fourth grade students tend to become longer as their academic performances of architectural design exercise become higher. Of these, the coefficients of determination of the fourth grade students were significantly higher. Numbers of times of swinging up and down of the first and fourth grade students tend to increase as their academic performances of architectural design exercise become higher. Of these, the coefficients of determination of the fourth grade students were significantly higher.

4.3 Verification ability and the Big Five

The test result of variance analysis and multiple comparison of the Big Five is described. The test subject with high score of A : agreeableness tends to have shorter necessary time and smaller number of times of swinging up and down. The test subject with high score of E : extraversion tends slightly to have shorter necessary time and smaller number of times of swinging up and down.

The result of cluster analysis of the Big Five score is described. The test subjects are classified into three types of clusters. KN type tends to be emotionally stable, which each of three indicators is classified into the middle group in many cases. KA type tends to be agreeable and sociable, which each of three indicators is classified into the upper group in many cases. KE type tends to be sociable and enthusiastic, which each of three indicators is classified into the upper or lower group in many cases and the middle class in a small number of cases. In addition, all of three indicators of KE type are classified into the upper group in many cases.

The relationship of behavioral pathway during experiment per cluster type is described. For KA : Agreeableness type, the ratio of the test subjects who selected the shortest pathway is high, and the ratio of the test subjects who selected overlapping pathways is not small. Therefore, it is considered that KA type tends to be able to read the experimental pathway drawing accurately, take a shortcut by grasping the characteristics of the actual space, and select a rational pathway. As a result of the analysis, it can be said that there is a certain relationship between verification ability for architectural drawing and the Big Five.

5. CONCLUSIONS

First, it is cleared that the verification ability of students who have professional education in architecture tend to change in the third grade and becomes constant in the fourth grade. Also, it is cleared that the tendency of verification ability obtained from graphic science performance mainly handled in the first grade is similar to the tendency obtained from GPA calculated in academic performance of all course subjects in the upper grade. Herewith, it is considered that proficiency level of graphic science in the preliminary step of professional education affects the fostering process of the verification ability and the improvement of learning effect of graphic science leads to the improvement of the verification ability. Also, the verification ability cannot be established within the scope of home economics in the general secondary education, in order to obtain the verification ability, architectural professional education as much as the second grade of architecture college (junior college or technical school) is necessary.

Second, for the verification ability for architectural drawing of students who have professional education in architecture and the personality trait, we were able to clarify a certain relationship. This allows instructors to consider the possibility of instruction using the Big Five as a new method of architectural education that takes into account the individuality of students. For classification of behavioral pathway of students who have professional education in architecture during experiment per cluster type, KA type tends to be able to read the experimental pathway drawing accurately, and select a rational pathway by grasping the characteristics of the actual space. Also, variance analysis and multiple comparison revealed that students with high score of A : agreeableness who have professional education in architecture tend to be able to select the shortest pathway. Accordingly students with high score of A : agreeableness can focus the traffic line of a building in the subject of architectural design exercise. In other word, it can be considered that they can grasp the flow of entire space of a building and proceed with the project. On the other hand, in the subject of architectural design exercise, the instructor must encourage students with low score of A : agreeableness who have professional education in architecture to care traffic line such as the flow of person's movement in a building.

ACKNOWLEDGMENTS

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3D VIDEO PRODUCTION TRAINING WITH POV-RAY

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ABSTRACT: In digital content education, images, music, and videos have been created. This paper conducted 3D animation creation classes with POV-Ray and examined how easy and short the 3D animation creation class with POV-Ray could be. This report is a curriculum analysis of 3 patterns of 3D modeled 3D images using POV-Ray as 3D video production exercises: 15 exercises for 6 months, 15 exercises for 2 days, and 3 exercises for 3 weeks. The side-by-side method was used as the 3D format. For 3D image confirmation, the side-by-side compatible projector and LCD shutter glasses were used. In the first case, it took time to grasp the stereoscopic situation, but the latter two cases could be easily cleared. From these results, it was found that the work can be easily made by lowering the hurdle for creating Side by side. This paper found that 6 hours was not enough to make 3D video using POV-Ray from the 3D principle.

Keywords: CG Education, Animation, Side by Side, 3D movie, POV-Ray, Power Point

1. INTRODUCTION

In digital content education, images, music, and videos have been created. This paper conducted 3D animation creation classes with POV-Ray [1, 2]. And this examined how easy and short the 3D animation creation class with POV-Ray could be.

This report is a curriculum analysis of 3 patterns of 3D modeled 3D images using POV-Ray as 3D video production exercises: 15 exercises for 6 months, 15 exercises for 2 days, and 3 exercises for 3 weeks. is there. The side-by-side method was used as the 3D format. For 3D image confirmation, the side-by-side compatible projector and LCD shutter glasses were used.

2. EXAMPLES

Here is an example of 3D video production education conducted in 22.5 hours, twelve hours, and six hours.

2.1 22.5 hours of exercise

The first attempt, 90 minutes and 15 times of 22.5 hours exercises for half a year, was taken by art students belonging to Department of Arts and Design, University of Toyama. In 3D modeling and CG production, POV-Ray was explained from the beginning and used for production (Table 1). However, they used Adobe's

Table 1: "3D video production training" curriculum (2014).

1	Explanation of how to proceed with the training and how to write a report
2	Explanation and execution of computer environment for practical training, explanation of flowchart used for report
3	What is POV-Ray?
4	POV-Ray data structure and creation method
5	POV-Ray objects
6	POV-Ray scene file
7	POV-Ray movement, rotation, reduction / enlargement
8	POV-Ray loop
9	POV-Ray conditional branching
10	POV-Ray set operation
11	POV-Ray pattern and texture settings
12	Animation with POV-Ray
13	Perspective, Stereo, 3D Explanation
14	Final assignment production
15	Presentation

premier to make the video of the side by side. The students prepared a PC for pro-duction. As other equipment, one side-by-side compatible projector and one LCD shutter glasses were used for each person. The two students took time to adjust the three-dimensional effect, but both were able to make works (Fig.1, 2)[3].

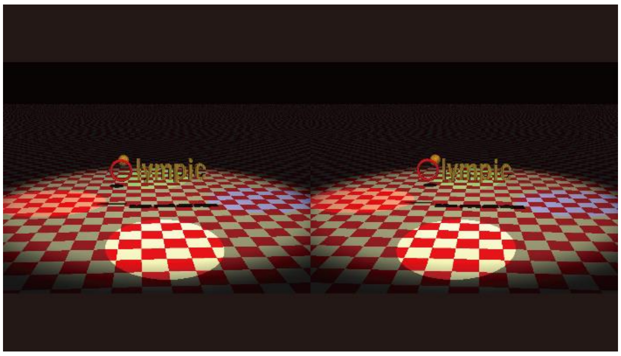

Figure 1: Olympic (3 seconds).

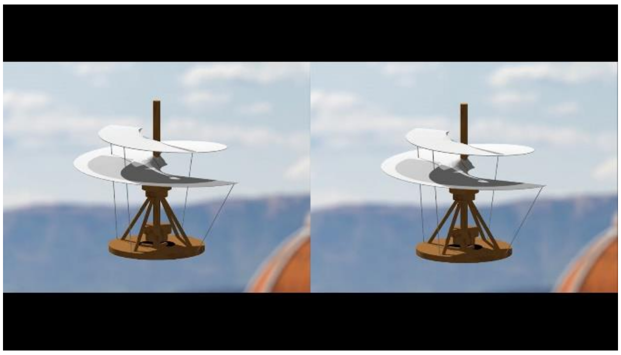

Figure 2: Leonardo da Vinci's helicopter (11 seconds).

2.2 Twelve hours of exercise

Next, 12-hour exercises for 2 consecutive days were conducted in face-to-face classes at the Open University of Japan (Table 2). Students were targeted at seniors, not necessarily art-based. The PC prepared at the Open University of Japan used one with POV-Ray installed in advance. For 3D modeling and CG production, POV-Ray was explained from the beginning and used for production. However, they used Power Point to create Side by Side format and video without video editing software. As other equipment, we used two side-by-side compatible projectors and one LCD shutter glasses for each person. Of the eleven students, seven attended on the first day and six completed the final work on the second day (Fig. 4-8).

Table 2: “3D video production using POV-Ray” curriculum (2020).

1	Basic knowledge of 3D images
2	Basic operation of POV-Ray
3	How to make animation with POV-Ray
4	3D animation creation and file conversion with POV-Ray
5	Production and guidance (storyboard)
6	Production and guidance (POV-Ray modeling)
7	Production and guidance (3D image creation with POV-Ray)
8	Production and guidance (3D format conversion)
9	Video and POV-Ray data submission and review

Figure 3: Presentation 1 (11 seconds).

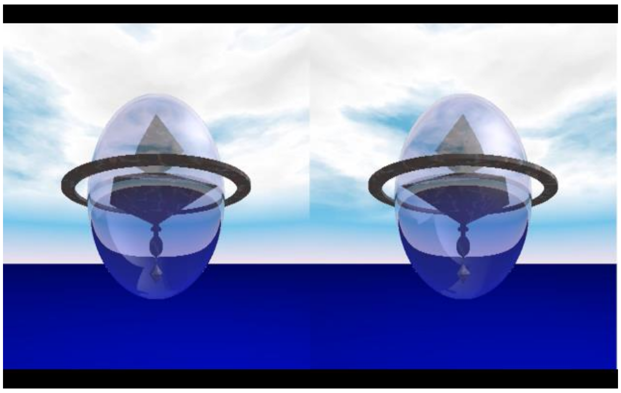

Figure 4: Star compass (5 seconds).

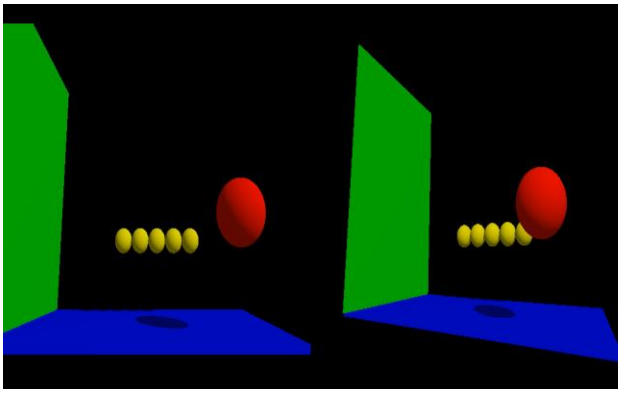

Figure 5: Bound 6 (5 seconds).

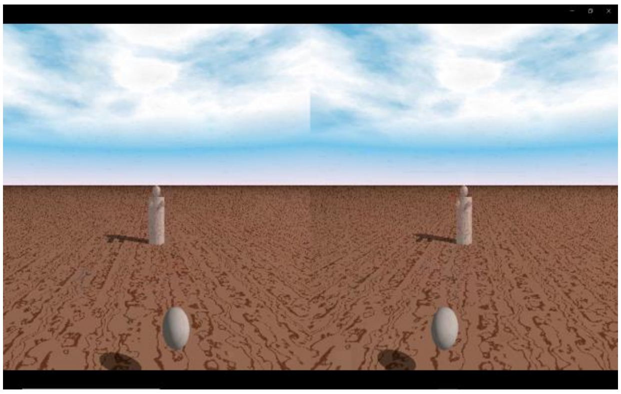

Figure 6: anime_D (6 seconds).

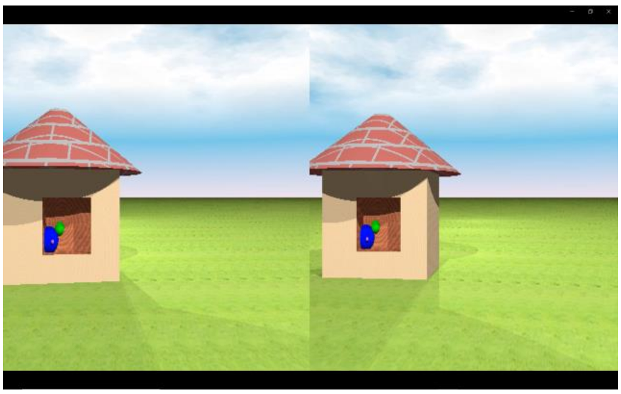

Figure 7: Presentation 1 (1 second).

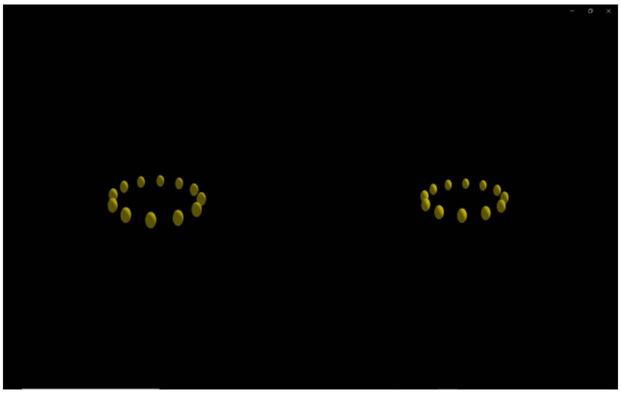

Figure 8: Presentation 1 (5 seconds).

2.3 Six hours of exercise

Finally, the 6-hour exercise once every 3 weeks for 2 hours and 3 times was conducted in an extension course at the University of Toyama (Table 3). The students were targeted at seniors who are not necessarily art-related. It was assumed that the PC was prepared by the students and POV-Ray and PowerPoint were installed in advance. As other equipment, one side-by-side compatible projector and one LCD shutter glasses were used for each person.

The three students used POV-Ray to create 3D still images (Fig.9), non-3D videos with sound (Fig.10), and 3D videos (Fig.11). It turns out that the exercise time is short to create a 3D video.

Table 3: "3D video production using POV-Ray" curriculum (2021).

1	Ray tracing POV-Ray basics
2	Ray tracing POV-Ray application
3	3D video production and critique

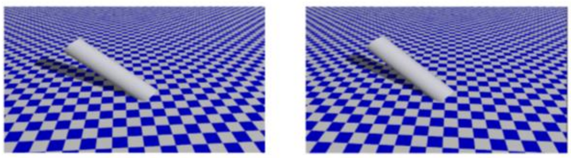

Figure 9: Stereo with POV-Ray.

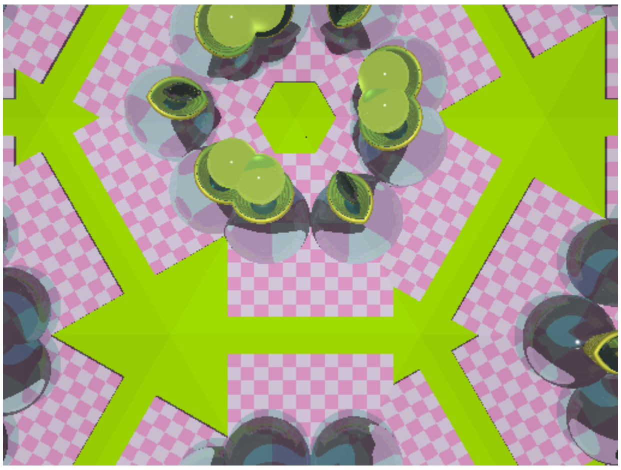

Figure 10: Perfume bottle anime.

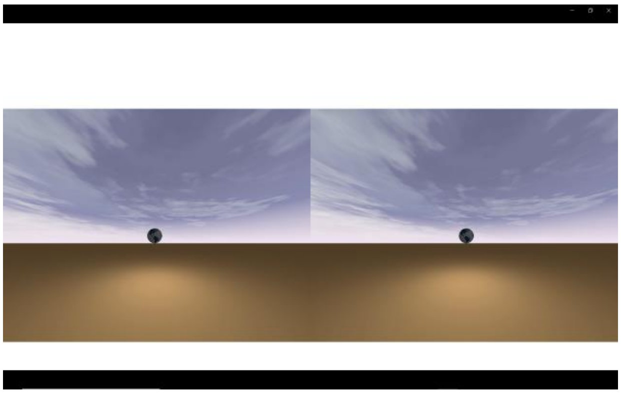

Figure 11: movie with POV-Ray.

3. CONCLUSIONS

In the first case, it took time to grasp the stereoscopic situation, but the latter two cases could be easily cleared. From these results, it was found that the work can be easily made by lowering the hurdle for creating Side by side. This paper found that 6 hours was not enough to make 3D video using POV-Ray from the 3D principle.

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LOCAL HISTORICAL HERITAGE PRESENTED IN 3D BY STUDENTS

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ABSTRACT: In the students' lessons, we describe the dynamism gained from attempting to transform the region's historical heritage into 3D. We thought that the history and culture of the region would become a vital force for the students living in the region, looking at the lifestyles and wisdom of the people living in the region. During the Nara period, the provincial capital of Hitachi Province was located in what is now part of the city of Ishioka. During the Nara period, the Kokufu of Hitachi Province was located in what is now part of the city of Ishioka. Kokufu was located in each region approximately 1300 years ago. Ishioka prospered as a political and cultural center. In ancient times, the rulers traveled from one palace to the next to all the shrines in each country. One of the important duties of the Chief Executive of the Cabinet Office was the management of Shinto shrines and the management of festivals in Japan. The shrine palace, there is a stone called a "sit stone" that is considered to be the seated stone of Yamato Takel. Yamat Taker is an ancient Japa-nese Imperial Family and a legendary hero of ancient Japanese history who reportedly carried out an expedition to the East. It is said that Yamato Takel sat and rested on the way to the east when he entered the offensive. There are many shrines where Sit rock are located elsewhere, and Yamato Takel legendary is located all over the country. The heritage of that history is scanned 3D with a handheld camera to produce a 3D model. The glTF file can be easily captured using the software of the student's mobile terminal. Operationality is a handheld device used by students and requires several exercises. In this way, the ease of 3D allows the student to modify his/her own operation without any discomfort. The result is the creation of a glTF file for the legacy of history. In addition, the space can be viewed on a VR by shooting a slide using a mobile phone camera. A-Fream is used for VR. You shoot the subject from the panorama mode of the camera on the mobile phone. Take out the captured image and tag with A-Fream. By covering 360° of vision and providing a sense of immersion in a near-realistic world, it is easier to explain. Students indicated that "superficially not realistic, but essentially realistic" and that VR "provides an experience that is unlimited and near-realistic".

Keywords: Graphics Education, VR, glTF, Anecdote.

1. INSTALLATION

We thought that the history and culture of the region would be important in observing the lifestyles and wisdom of the people living in the region, and that it would be a vitality for students. In the students' lessons, we describe the dynamism gained from attempting to transform the region's historical heritage into 3D.

Ishioka City, Ibaraki Prefecture, was once located in the country. Japan's national government was located in each region approximately 1300 years ago, when a national system was established. Ishioka, where the Hitachi national government was established, prospered as a political and cultural center.

2. REGIONAL HISTORY AND CULTURE

2.1 Report from the Council for Cultural Affairs

The Ministry of Culture received a report from the Culture Council on the function and role of culture in society in the future [1].

The following is a summary of the points related to this paper.

Culture is extremely important for human beings to live like humankind, and it creates a sense of solidarity between people and forms the basis of a society in which people can live together.

In order to construct a society that values culture, Japan will preserve and actively utilize cultural heritage, and will promote the conservation and utilization of cultural heritage from a comprehensive perspective, as well as the preservation and utilization of cultural heritage through the voluntary participation of people.

2.2 Sosha Shrine in Ishioka City

Ishioka City, Ibaraki Prefecture, was once located in the country.Japan's national government was located in each region approximately 1300 years ago, when a national system was established. Ishioka, where the Hitachi national government was established, prospered as a political and cultural center. One of the important duties of the Chief Executive of the Cabinet Office was the management of national shrines and the management of festivals. When the head of the Cabinet Office assumes office, there is an event called "Shrine," in which visitors visit shrines in Japan to worship the gods. The Shinto shrines in Japan, which are supposed to worship shrines, were assembled together and enshrined as a general shrine. In ancient times, the rulers traveled from one palace to the next to all the shrines in each country. In order to make this more efficient, a general shrine enshrined in the gods of Japan was established near the national branches of each country, and the enshrined shrines were collectively enshrined. The city of Ishioka in Hitachi is the region where the company was located.

The general company has a "seatstone" that is considered to be the seat stone of Yamato Takel. Yamataker is an ancient Japanese Imperial Family and a legendary hero of ancient Japanese history who reportedly carried out an expedition to the Kuma and East. It is said that Yamato Takel sat and rested on the way to the east when he entered the offensive.

3. VR AND AR

3.1 OBJ and glTF

The OBJ file format is a simple data format that represents only the 3D geometry. The 3D geometry is the location of each vertex, the UV position of the vertex of each texture coordinate, the vertex normal, the plane forming each polygon defined as the vertex list, and the texture vertex.

The 3D model format already has a generic format, such as .obj, .fbx, and .dae, and a 3D modeling tool-specific file format, such as .3ds and .blend.

However, these file formats, even in general-purpose formats, are inefficient for use on the Internet because offline use is a prerequisite.

On the other hand, for Internet distribution, there is a glTF (GL Transmission Format). glTF is a format that represents 3D models and scenes by JSON. JSON (JavaScript Object Notification) is a lightweight data exchange format. The glTF is intended to compress 3D scenes, minimize application run-time processing using APIs such as WebGL, and provide an efficient and interoperable asset distribution format. The glTF is loaded into open-source WebGL engines such as Three.js, BabylonJS, Cesium, PEX, xeogl, and A-Frame. The glTF is a file format that is available to the Internet and is fully open and accessible to anyone.

3.2 Placement of models in 360-degree CG space

In order to create a virtual CG space in VR and AR, it is necessary to place objects for all directions of 360 degrees. In order to learn this fact experientially, we set the following tasks for students in the "CG Expression" class.

i.) Create models and scenes using the 3DCG software "Maya".

ii.) The theme for the CG scenes can be chosen from any existing story.

iii.) A spherical camera is used for rendering and output as a 360-degree CG image.

iv.) Use the viewer software to check the 360-degree visibility of the output image.

The rendering range of a flat CG image is determined by the angle of view (wide angle or telephoto) of the camera, and a 360-degree CG image can be considered the ultimate wide angle because everything in all directions can be seen. As a result, students will be able to understand that difference in size of the view due to perspective, which is a characteristic of wide-angle lenses. Students will also be able to understand that the space where no object is placed in the scene is very conspicuous.

Through this task of this assignment, students will be able to gain knowledge about object placement and scene construction in virtual space.

In this work, a 360-degree image is divided into two parts to create a daytime and a nighttime scene at the same time within a single scene(Fig.1).

Fig.1:Taketori Monogatari:A Japanese Folktale

This work was created by selecting a scene with many walls blocking the view(Fig.2).

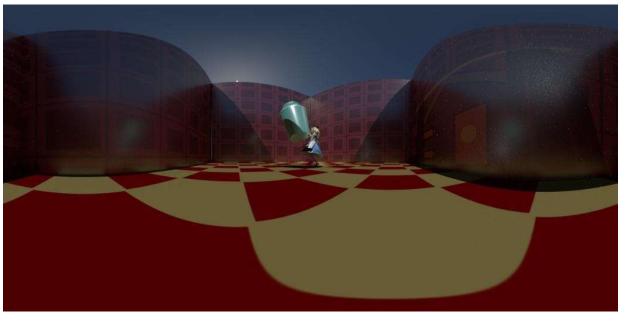

Fig.2: "Alice in Wonderland" by Lewis Carroll

3.3 Representation of VR and AR by A-Frame

AR is a technology that matches the real space perceived by a person with the virtual space by a computer and expands the real space. It adds "something else" to the information perceived by people in the real world and gives new value to the real world. In addition, VR is a technology that realizes virtual reality in a space that a person can perceive on a computer.

Web VR is a technique for drawing 3D content on a Web browser. One such technique, A-Frame, is a framework that can implement AR and VR simply by describing the HTML tag.

A-Frame is implemented based on Three.js. Only by reading open source aframe.min.js and aframe-ar.js can VR and AR be used on the Web.

3.4 What students have learned

In this university, the second year or later courses on "wearable computing" are selected.

"Wearable computing" involves acquiring techniques and techniques for mounting electronic devices among the necessary technologies.

The goal of the study is to know how to sense the body, understand how to handle and implement various sensors, and propose the possibility of wearable computing by students themselves.

Three persons in charge are responsible for this class.

For each of these, we use materials such as those for trial manufacture of AR and VR, those for trial manufacture by attaching them to the body, and those for trial manufacture of wearable computer systems.

They are also instructing students to propose possibilities for their own technologies.

Students are studying the use of materials that allow them to experience AR and VR prototypes.

4. ASSIGNMENTS GIVEN TO STUDENTS AND THEIR PREPARATION

4.1 Contents of the assignment given to the students

Students were given two 3D titles. StudentsYou take a 360-degree photograph. Students take some images in a 3D file. It was then used to create the A-Frame VR and AR.

Glitch was used to display VR and AR. Glitch is a service that can create and publish web applications using Node.js.

The VR source was displayed as the following issues.

```
<!DOCTYPE html>
<html>
<head>
<meta charset="utf-8" />
<title>VR</title>
<script src="https://aframe.io/releases/1.2.0/aframe.min.js"></script>
</head>
<body>
<a-scene>
<a-sky src=”file.jpg” ></a-sky>
</a-scene>
</body>
</html>
```

The AR source was displayed as the following issues.

```
<html>
<script src="https://aframe.io/releases/1.2.0/aframe.min.js"></script>
<script src="https://jeromeetienne.github.io/AR.js/aframe/build/aframe-ar.js"></script>
<body>
<a-scene>
<a-assets>
<a-asset-items id=" stone"
     src="file. glb"></a-asset-items>
</a-assets>
<a-entity gltf-model="# stone" scale="0.1 0.1 0.1"></a-entity>
<a-camera
   position="0 10 30"
   cursor-visible="true"
   cursor-scale="5"
   cursor-color="#0095DD"
   cursor-opacity="1">
  </a-camera>
  </a-scene>
  </body>
</html>
```

Third-year students are given six months of free research as a precursor to their graduation studies.

Free research is a challenge that will ultimately lead to graduate research.

This year's agenda is "3D creation of what exists as the historical heritage of the region."

The equipment is your own smartphone.

Here are two topics for 3D.

i.)You take pictures using the panorama feature of a photo software installed on a smartphone.

ii.)The 3D scanner software installed on the smartphone takes three-dimensional pictures.

Thereafter, the materials are processed into VR and AR.

4.2 Photographing equipment

Photographing equipment is a cell phone owned by a student. Cameras and 3D scanners installed on mobile phones.

The camera is in photography mode and panorama mode. To use the camera, take a photo while traveling around the shooting area for a long time. Temporary misalignment has the disadvantage of shaking.

The 3D scanner was downloaded. This 3D scanner must be able to rotate the subject in a smooth fashion without any blanks.

This is because there are objects that are not good at the 3D scanner, and no one can operate the scanner to assure a certain level of quality. Beyond the performance of the 3D scanner, the ingenuity and skills of the user are important.

4.3 Preparing for skills to accomplish tasks

As a problem-solving technique, students were given two hours of photography know-how and one hour of content creation. The first shooting know-how was taken using my camera software. It seems to be the first time a student operates, and knowing the timing of the photograph is at the heart of this time. The second time, the 3D scanner software was downloaded and photographed. The pictures were taken in a chair, but it took a considerable amount of time to scan.

Finally, the content is prepared.

A pre-prepared HTML file is provided and a photograph is displayed. The learning time is one hour. This time provides an overview of the content of the results of the final task.

5. PREPARING FOR SKILLS TO ACCOMPLISH TASKS

As a problem-solving technique, students were given two hours of photography know-how and one hour of content creation.

The first time photographs using camera software, students seemed to have operated for the first time, and knowing the timing of the photograph is at the heart of this time.

In the second round, the 3D scanner software was downloaded and shot, and a chair was taken, but it took a considerable amount of time to scan.

Finally, a pre-prepared HTML file will be available for shooting, and one hour of learning will be available, which provides an overview of the results of the final task.

6. CONTENT PHOTOGRAPHED BY STUDENTS

6.1 VR Content

To create VR content, the specified file name is rewritten in the set of HTML files in order to raise the image taken by the camera on the Net.

Fig.3: Photos used in VR

6.2 AR Content

Creating AR content begins with changing the 3D format. It can only be left as an OBJ format file from a 3D scanner. It is a software specification. So I used Autodesk Tinkercad to convert to glTF format. It just reads an OBJ format file from Tinkercad and outputs it to glTF format.

Fig.4: 3D surface dataset of the Set on the Rock

7. HAS THE STUDENT CHANGED?

The memories of the students' shrine palace are as follows.

i.) The Ishioka Omatsuri is called the Hitachi Sosha Palace Festival.

ii.)The festival is so attractive to native people that it is said that "New Year's Day or Obon's Day does not require you to return to your home, but we will return to the Omatsu Festival."

iii.)The stone in the seat of Yamato Takel is a stone.

In addition, a lot of knowledge was added in the following points. The following is a summary of the students.

Ishioka City, Ibaraki Prefecture, was once located in the country. Ishioka, where the Hitachi national government was established, prospered as a political and cultural center. One of the important duties of the Chief Executive of the Cabinet Office was the management of national shrines and the management of festivals.The Shinto shrines in Japan, which are supposed to worship shrines, were assembled together and enshrined as a general shrine.In ancient times, the rulers traveled from one palace to the next to all the shrines in each country.In order to make this more efficient, a general shrine enshrined in the gods of Japan was established near the national

branches of each country, and the enshrined shrines were collectively enshrined.
The city of Ishioka in Hitachi is the region where the company was located. The general company has a "seatstone" that is considered to be the seat stone of Yamato Takel.

Yamataker is an ancient Japanese Imperial Family and a legendary hero of ancient Japanese history who reportedly carried out an expedition to the Kuma and East.
It is said that Yamato Takel sat and rested on the way to the east when he entered the offensive.

8. DISCUSSION

At this stage, 3D scanners have objects that are not good enough to ensure a certain level of quality when operated by anyone.

Even if a 3D scanner is introduced in an attempt to simply leave the input process to the device, it is difficult to do so.

For this purpose, the ability to know the performance of the 3D scanner and to operate it will be important. After scanning, modeling techniques are needed to generate 3D data. Nowadays, 3D scanners cannot scan black, transparent, or glossy objects. That is, the shape of the object to be measured cannot be completely scanned. As with the number of pixels in the digital camera, the more precisely the camera can acquire, the larger the capacity of the points, and the more reproducible the shape. It is necessary to read the shape with high accuracy at the minimum number of scans required.

There is a need for a scanning technique for a person who operates there. Operational knowhow, such as understanding of the optimal scanning method and control software characteristics according to the shape of the object, is very important to reduce the synthesis error.

However, the student finished taking pictures in a singular fashion.

We made them aware of how they would answer questions from the people who asked them about what they had taken and what they could do, and we prepared several answers.

With respect to the materials of VR and AR, students were interested and interested in the subject.

9. CONCLUSIONS

By covering 360° of vision and providing a sense of immersion in a near-realistic world, it is easier to explain. Students indicated that "superficially not realistic, but essentially realistic" and that VR "provides an experience that is unlimited and near-realistic”.

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INNOVATION AND PRACTICE OF TEACHING METHODS FOR ENGINEERING GRAPHICS TEACHERS UNDER THE NEW TECHNOLOGY PARADIGM

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ABSTRACT: With the promotion of new technology, especially information technology, to teaching means and methods, the traditional model library is replaced by electronic resource library characterized by VR and AR. Engineering drawing is still indispensable as the basis and standard for enterprise processing and quality control. Aiming at the change of online, offline and hybrid teaching mode of engineering graphics, the innovation mode of teaching method under the new technology paradigm is studied, and experimental exploration is carried out. We develop new techniques and methods for blended curriculum teaching, taking account of both depth and breadth. Based on Cloud Architecture 'brain', we provide optimized teaching scheme for different majors. In the organization of teaching content, we pay attention to the combination of systematicness, basis and engineering. In the application of teaching methods and means, we give full play to the auxiliary role of "virtual representation" in graphic thinking. Hybrid online and offline discussion teaching based on multiple evaluation and project traction is studied. It effectively solves the problems of graphics literacy and spatial thinking ability training of new engineering talents.

Keywords: New paradigm, MOOC, Engineering graphics, New teaching methods

1. INTRODUCTION

Engineering graphics is a basic core course for engineering students. There are 27 national teaching achievement awards all over the country, which come from the exploration of teaching reform of engineering graphics. We endeavor to make engineering graphics course become a golden course. Through the process of learning the course, students are cultivated to explore knowledge, build ability, form quality and have patriotism. Artificial intelligence and information technology have improved the teaching means and methods of the course. Augmented reality (AR) can be defined as a technology which overlays virtual objects into the real world [1]. The electronic resource library, which is characterized by augmented reality (AR) and virtual reality (VR), has completely replaced the traditional model library [2-4]. Three-dimensional (3D) modeling design method has been widely used. However, engineering drawing is the carrier of innovative thinking, which is still irreplaceable in the industrial field. They are regarded as a graphic universal language, which can be used to tell others what to make and how to make it [5]. The production of processing and quality control enterprises still use engineering drawings as standards. But the existing medium and form of engineering drawing changed.

The teaching mode of the course changes from the traditional offline teaching mode to the online and offline mixed teaching mode, and even directly online teaching. Students who learned in a blended modality showed a significantly higher level of knowledge [6-8]. Graph interaction tools are greatly developed, but they are not widely used. The technological paradigm of the course has great changes. It is necessary to explore the teaching method innovation and practical exploration of engineering graphics under such emerging technological paradigm. It is important to realize the implementation of the new engineering research results. There are three methods to explore. The content of ideological and political teaching is integrated into the teaching process of engineering graphics course. Students' learning initiative and enthusiasm are stimulated. The innovative culture is cultivated and guided.

Ideological and political teaching contents are integrated into the teaching process [9]. Casting soul in people and giving full play to the role of curriculum education are taken as the basic idea of implementing the fundamental task of moral education. Cultivating outstanding talents with patriotism, global vision, innovative spirit and practical ability is taken as the guide. Engineering ethics guides engineering talents to practice socialist core values. Cultivating students' innovative characters by integrating humanistic spirit to improve the ability of solving engineering problems, and create a new curriculum ideological and political model under the background of 'new engineering'.

Engineering graphics course is the basis of engineering practice. The development of modern industry condenses innovative thinking around the development of engineering drawings, and the application of information technology in engineering starts from engineering drawings [10]. So it is a basic course of engineering. In the field of curriculum teaching, the curriculum status of engineering basic courses is determined due to the 'digital' natural connection of its graphics and the source carrier of innovation. How to find a breakthrough in the cultivation of innovative talents in engineering graphics and engineering in the future through the x-intersection of engineering graphics curriculum content and professional knowledge (mechano-x), two programs were finished for the research.

Engineering graphics also has the characteristics of digital features including computer aided design (CAD), 3D and two-dimensional (2D) modeling [11]. They associate the digital world of the graph with the real physical world completely. The second character is innovation gene. There are substantial growth of work which is aimed at improving undergraduate science, technology, engineering and math (STEM) education [12]. Drawing is the language of engineers and the carrier of thinking. Drawing and conception support us to understand and transform the world, and become the source of innovation. The important task of our course teaching is to stimulate students' curiosity and imagination and cultivate students' critical thinking. These are indispensable qualities for career success.

Under the background of new engineering, we should create golden course and give full play to information technology's support for golden course. The engineering graphics course combines with cultivating the thinking ability, expression power and engineering ability of engineering talents. The three teaching elements of engineering graphics integrate of AR, VR, Internet plus and modern CAD aided design technology to effectively promote the innovative reform of curriculum 'teaching' and 'learning' activities [13].

In the study, according to the requirements for training talents in the field of engineering, big data, Internet plus, artificial intelligence and VR/AR are integrated to curriculum teaching paradigm. Massive online courses and electronic resources are included in content. We build cloud architecture with knowledge management based on big data and artificial intelligence technology. Students have the chance to adopt the latest CAD and virtual VR/AR 'immersive' learning method to experience the creative design fun and sense of achievement of 'what you see is what you get'. New technologies and methods of hybrid course teaching are applied in teaching activities to stimulate students' curiosity and imagination and cultivate students' critical thinking. These characters are essential for career success.

2. FOUNDATION OF PRELIMINARY WORK

Engineering graphics course integrates Internet and information technology shown in Figure1.

The course has new type of teaching materials and courseware resources, self-directed learning resources, virtual simulation training platform, national first-class online quality course and online evaluation based on graphic recognition. Internet and information technology brings diversified methods and means for teaching and learning of engineering graphics course.

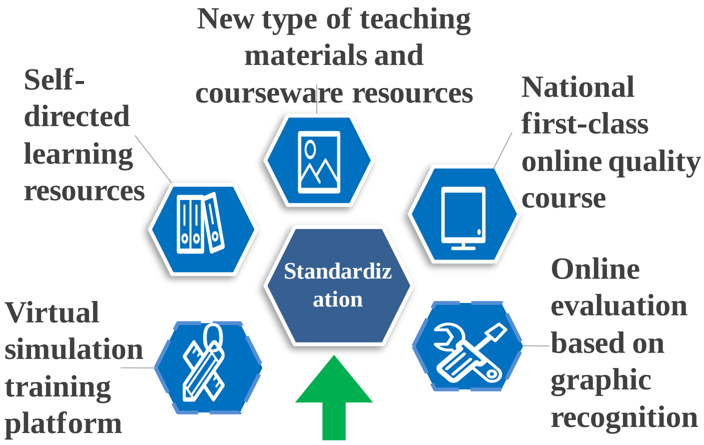

Figure 1: Engineering graphics course integrating Internet and information technology

Teaching method is reformed for engineering graphics under the support of information technology. The engineering graphics course has the platforms of MOOC, SPOC, model repository, graphic interaction platform, and cloud platform for knowledge management (Figure 2). These platforms make teaching content, teaching activities and teaching environment (course cloud platform) are organically integrated in the course. Student can learn the knowledge by themselves anytime and anywhere.

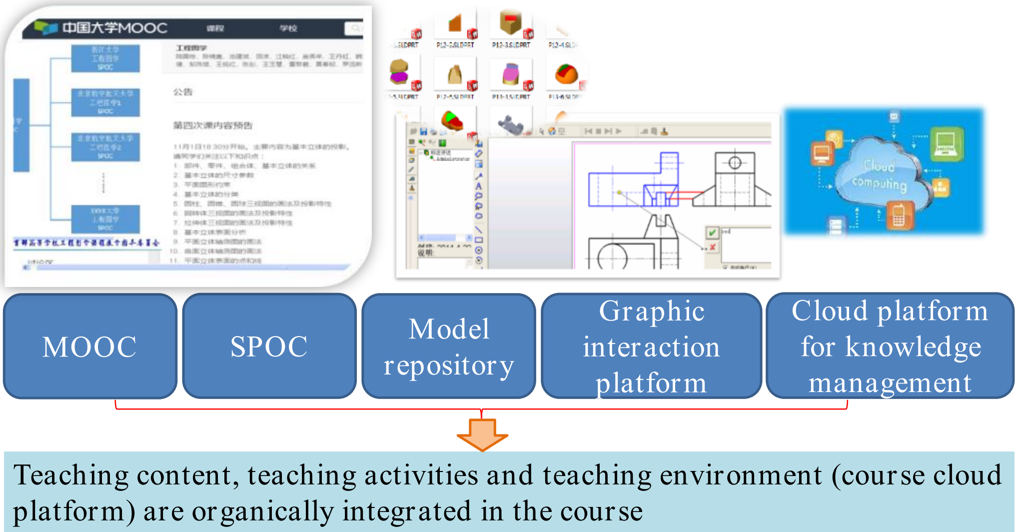

Figure 2: The engineering graphics course has the platforms of MOOC, SPOC, model repository, graphic interaction platform, and cloud platform for knowledge management

In 2014, students were taught in different places at the same time, which was the Integrated Innovative Curriculum Reform Project of Ministry of Education and organized by engineering graphics course Teaching Steering Committee of Ministry of Education. It started from Zhejiang University, Shanghai Jiaotong University, South China University of technology, Northwest University of technology and Zhejiang University of Technology and then expanded to 36 colleges and universities across the country. Through three 'simultaneous and remote' online lectures in 2014 and 2015, it aimed to promote the innovation of teaching which was supported by modern educational technology, and build hybrid learning mode, mobile learning mode and collaborative learning mode. We hope to promote the teaching exchange and cooperation between colleges and universities, and promote the application of new SPOC in colleges and universities across the country.

There are plenty of high-quality online courses and resources of engineering graphics courses. There are more than 80 online engineering graphics courses in China, including national high-quality online open courses, resource-sharing courses, and video open courses. A number of high-quality open online courses, such as engineering graphics course, mechanical drawing and CAD, architecture design and drawing, and illustrated geometry and architectural drawing, have been launched on MOOC platforms such as Aicourse.com, Xuetang Online and Yuclassroom. During the coronavirus outbreak period in 2020, engineering graphics courses were taught on the MOOC platform, MOOC+SPOC teaching method, Ding talk, Tencent courses, ZOOM live broadcast and other methods in more than 200 colleges and universities in China. These teaching methods and platforms provided strong resources guarantee for 'ceaseless teaching, ceaseless learning' during the epidemic. Therefore, it is urgent to reform and explore the innovative teaching methods under the new teaching paradigm.

Immersive VR/AR virtual simulation experiment platform boosts 'picture' sense cultivation. Simulation laboratories of engineering graphic course have been set up in more than 34 universities in China. Many universities, such as Tianjin University, China University of Petroleum (east China), Shandong Construction University, Hebei University of Technology, and Zhejiang University of Technology combined with engineering graphic course with professional training and finished 'development of virtual simulation platform' based on their own characteristics and advantages. The online simulation architecture and assembly simulation of course experiments were explored.

3. IDEAS AND MEASURES OF REFORM

The main idea of reform is shown in Figure.3. For the innovation and practice of teaching methods of knowledge related engineering graphics course for the cultivation of new engineering talents, teachers act as the guides and use online teaching resources (online courses, VR/AR forms, resource on cloud system, simulation laboratory), hybrid teaching methods (online courses, VR/AR forms, resource cloud system) for teaching. Teachers obtain feedback by teaching evaluation from students. Guided by project tasks and based on heuristic teaching, students are encouraged to actively participate in the learning process, complete specific objectives and tasks, and participate in the evaluation of the learning process. Learning effectiveness is evaluated by combining with online objective evaluation, process evaluation of teacher-student interaction, and summative evaluation. Students are trained to master learning ability, and cultivated to have research-based learning, rather than endless knowledge. Through value shaping, ability training and knowledge imparting, new teaching paradigms of diversified training, teacher-student interaction, in class and out of class interaction, and the integration of results and processes are formed.

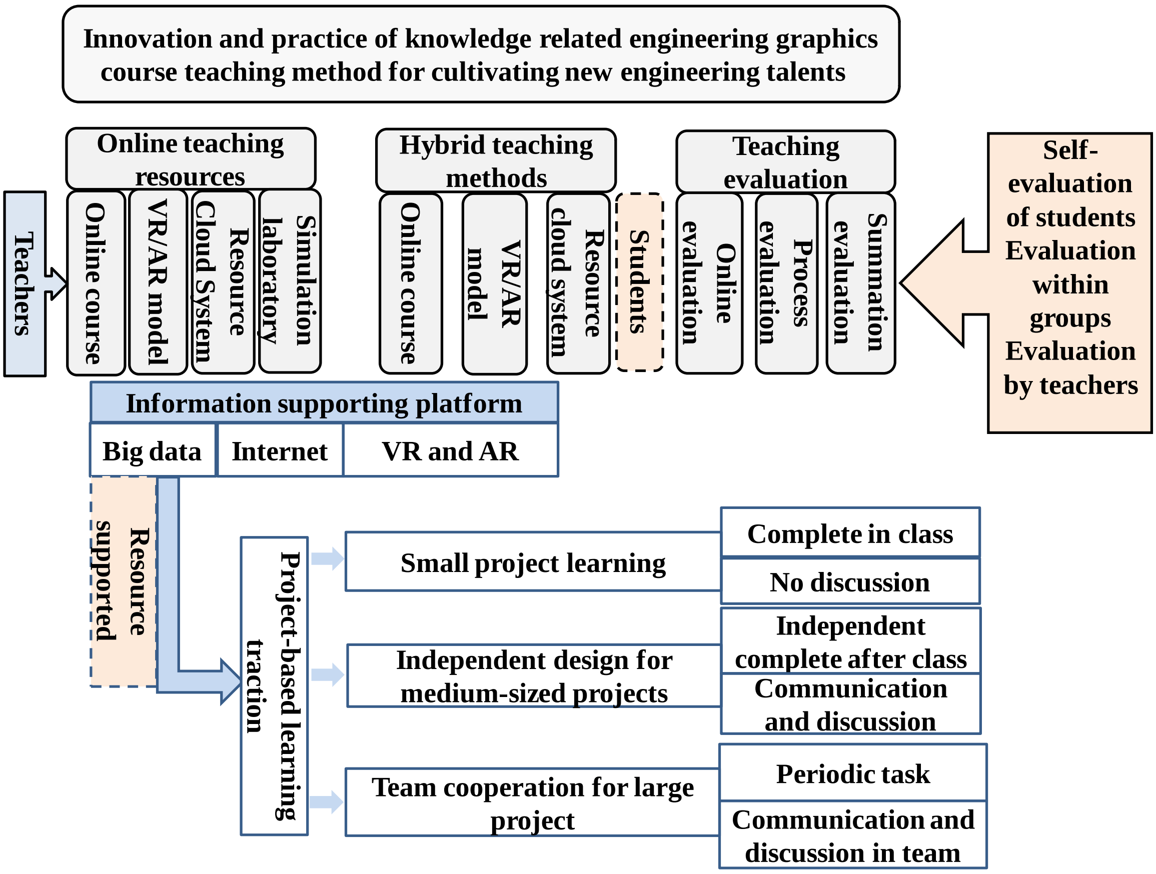

Figure 3: Main idea of the reform

The engineering graphics course has the knowledge fusion and expanded 'knowledge association', which serve students' independent learning. Figure 4 shows the internal cognitive relation diagram and knowledge relation diagram of engineering graphics course and other related professional courses. The core knowledge framework of engineering graphics course is constructed. The mapping relationship between engineering graphics course knowledge and graphics thinking ability of engineering college students is established. And the correlation between graphic thinking ability and innovative thinking ability of new engineering college students is also constructed.

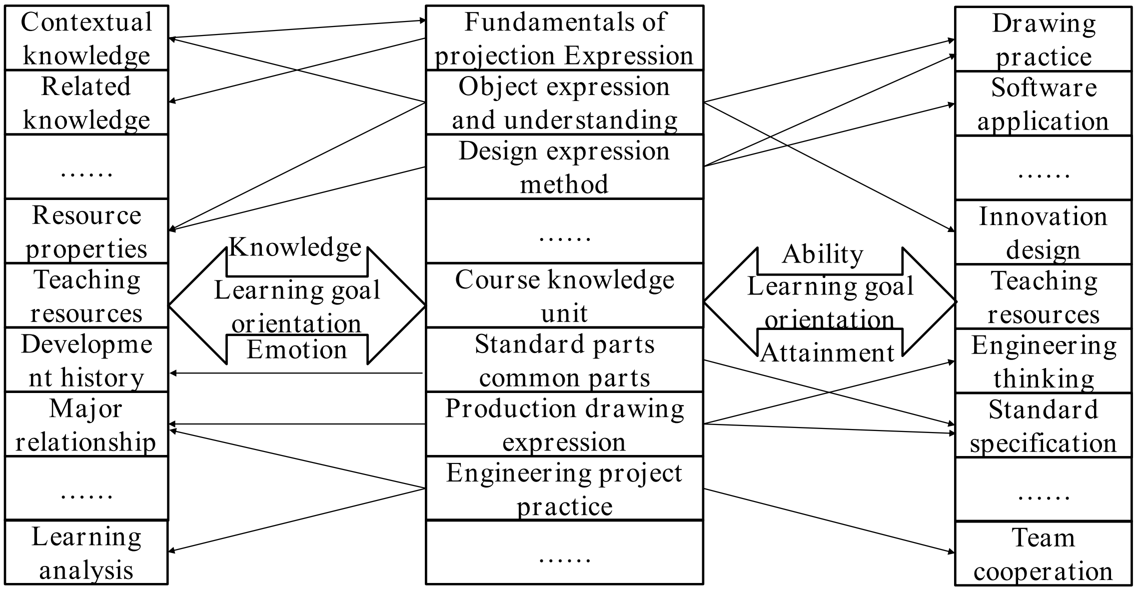

Figure 4: Internal cognitive relation diagram and knowledge relation diagram of engineering graphics course and other related professional courses

The core of exploration of new teaching mode is discussion on effective teaching method. Heuristic, interactive, research-based, exploratory, problem-based, situational and project-based teaching methods are applied. Core knowledge points and abilities must be adhered to in the process of teaching exploration. Knowledge, ability, practice and innovation projects are organically integrated to realize the integrated training. In the organization of teaching content, it integrates the new technology of 'virtual reproduction' and pays attention to the combination of systematicness, foundation and engineering. 3D model repository is built for students to obtain the objects more intuitively and easily (Figure 5). By learning the engineering graphics course, students have ideological and political spirit of patriotism, craftsman spirit, unity of knowing and doing. Teachers impart knowledge of graphics principles, engineering drawing specifications, computer-aided design. Students obtain ability and quality of teamwork, communication and drawing expression.

Figure 5: 3D model repository

Some specific measures should be taken for innovation and practice of teaching methods for teachers of engineering graphics under the paradigm of emerging technology. The construction of online classroom teaching resources is improved. Online resources are made 'live' and 'excellent' based on big data and artificial intelligence technology. Curriculum resource base and its knowledge navigation model are built based on big data and artificial intelligence. Based on VR/AR technology, innovation of teaching resources is realized, and a batch of interactive VR/AR resources with engineering graphics course characteristics is constructed. A new blended teaching model with learning-oriented and teacher-student interaction is constructed. We provide students with an immersive and authentic experience using modern information technology.

4. RESULTS AND CONCLUSIONS

(1) Final exam score

The offline education adopts the traditional teaching methods in class. Teachers explain knowledge points and teach drawing methods through PowerPoint and drawing on the blackboard. Students practice drawing and thinking immediately in class to master the main knowledge points and cultivate thinking ability. The online and offline hybrid teaching mode gives full play to online resources. Students learn important knowledge points and methods in class. They obtain 3D model by VR/AR or electronic library. The online courses enable students to learn the difficult and important knowledge points anywhere and anytime. The online and offline hybrid teaching mode of engineering graphics was explored in Zhejiang University of Technology. The results were compared with the traditional teaching class and the experimental teaching class. The data were mainly collected for quantitative statistical analysis from two aspects including the final exam scores with separation of teaching and examination from the first semester of the 2018/2019 academic year and the awards of students' innovation competitions in the recent three years.

In order to ensure the fairness and justice of the exam results, the final examination of engineering graphics course adopted the method of separating examination and teaching, and flow marking. Closed-book examination was adopted, and the examination time was 120 min. The results of 6 traditional teaching classes and 6 experimental classes were randomly collected for statistical analysis (Table 1). As can be seen from the table, the excellent rate (>90 points) of 25% in the experimental teaching class was significantly higher than that of 6.7% in the traditional teaching class. The good rate (80-89 points) in the experimental teaching class was 29.2%, which was significantly higher than that in the traditional teaching class (10.3%). One person failed in the experimental teaching class and 16 failed in the traditional teaching class. The statistical results show that the experimental teaching class can arouse students' initiative and enthusiasm, and effectively improve students' academic performance and interest in learning.

Table 1 Comparison of final exam results of traditional teaching class and experimental teaching class of engineering graphics course in one semester

Scores	<60	60-69	70-79	80-89	90-100	Average score	Standard deviation
Traditional teaching class	11.6%	23.4%	48%	10.3%	6.7%	70.12	8.9
Experimental teaching class	2%	8.3%	35.5%	29.2%	25.00%	79.58	10.42

(2) Student innovation ability and competition

Through continuous teaching exploration, the teaching of the course strengthens the cultivation of students' ability of graphic thinking. Students have improved greatly in product configuration design and innovation. Students master product design modeling and graphic expression, which lay a good foundation for subsequent course learning and professional training.

The main objects of the teaching experimental class were students from college of Mechanical Engineering. They have won 28 National First Prizes, 16 National Second Prizes and 10 National Third Prizes in Extracurricular Science and Technology Competitions in the recent three years. Eleven programs were selected in National College Student Innovation and Entrepreneurship Programs. Thirty-one projects were selected into University Students Science and Technology Innovation Activity Plan (New Seedling Talent Plan) in Zhejiang Province. 321 patents (including 103 invention patents) were applied, and 228 authorized patents (including 51 invention patents) were obtained. Students show a good sense of innovation, innovation ability and teamwork, rigorous and serious work style. The results show that the performance of the class with hybrid teaching mode of engineering graphics course is significantly better than that of the traditional teaching class. We summarize and form new online, offline and mixed teaching modes of engineering graphics courses which are suitable for different levels and categories of schools and majors. New teaching methods under the new paradigm of efficient technology are explored and formed based on the core of teaching, the medium of resources and their online platforms, the main body of self-directed learning, and the means of 'immersive' reproduction of virtual simulation. An online teaching resource sharing is improved and further optimizes the intelligent cloud system platform of knowledge navigation. 10 typical teaching cases have been promoted and applied nationwide for new engineering talents training courses in different levels, categories and majors to form excellent case sets. Problem sets have been published under the new teaching paradigm.

We accumulate experience in demonstration and promotion. New technologies and methods of hybrid course teaching are applied in teaching activities. Teachers lead and give full play to the advantages of online course resources, giving consideration to depth and breadth. Teachers provide optimized teaching programs for different majors based on 'brain' cloud architecture appropriately. In the organization of teaching content, we give full play to the auxiliary role of 'virtual reproduction' in graphic thinking, and pay attention to the combination of systematicness, foundation and engineering. In the application of teaching methods and means, hybrid online and offline seminar teaching based on multiple evaluations and project traction is promoted.

The engineering graphics course are taught through online and offline hybrid teaching mode. Students master the basic principles and methods of projecting spatial geometry, engineering drawings and design methods. They master the advanced computer-aided design methods and understand the cutting-edge technology related to engineering drawings. Therefore, students are cultivated to become learners who uphold socialist core values, have professional dedication and ethics, and adapt to the development of The Times.

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LEARNIG-CENTERED INSTRUCITON OF ENGINEERING GRAPHICS COURSE FOR FIRST YEAR ENGINEERING STUDENTS

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ABSTRACT: The Engineering Graphics is an essential and fundamental part of engineering education and the ability using graphics to communicate, visualize, and present technical information efficiently and effectively plays important role in building interest and confidence for first year engineering students. Teaching Engineering Graphics to freshman engineering students brings challenges to instructors as well as to students. While the instructors are confronted with a lack of material/text book that covers the broad scope of the subject matter, the students struggle to corelate newly developed skills to real-world engineering design practice. Learning/teaching 'Engineering Expression with graphics' through passion driven real world project in a learning-centered instructional pedagogy can foster integrative thinking in graphics communication in the design process as well as team collaboration. The projects in Engineering Graphics are also implemented in a senior-level Manufacturing course with the aim of building integrated curriculum framework. This paper presents some learning-centered strategies in the course design including: course material redesign with the shift from engineering drawing technique standards (engineering drawings for manufacturing) oriented to engineering expression skills with graphics, integration between lecture and lab and introduction of passion-driven real-world projects. Some preliminary results are presented on the impact of such strategies on student learning, engagement, satisfaction and performance.

Keywords: Learning-centered instruction, Engineering expression with graphics, Project-based learning, Integrated curriculum framework

GAMELAB PROJECT (1)

CIPHERS, LANGUAGE, AND TEXTURES IN GAME DEVELOPMENT

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[1]Northern Illinois University, USA

ABSTRACT: This project started with a premise with the goal of translating the idea of communicating through ciphers and codes into a video game that makes an attempt to decipher an unknown language. Working within the NAWA Game Lab Challenge which created seven groups with students and mentors from seven universities with the challenge of creating a game. As a starting point the team looked through ways that language, codes, and the mysteries of an unknown language has impacted the cultural imagination through time. Starting with this particular premise led to unique challenges to developing the themes and game narrative, as well as the game's unique cipher system. Through lengthy discussions the team was finally able to arrive at a consensus for how details of the games narrative and game play should look, which resulted in additional discussions about how handmade textures in a digital space and the function in play in learning language skills.
Initial discussions about ciphers and codes included looking at crop circles, theoretical attempts to communicate with the unknown such as the “Golden Record” that was sent into space in the seventies by NASA. The team also investigated known methods of developing ciphers. In this stage students also contributed to shared mood boards to arrive at a consensus in shaping imagery and themes. The initial concept was focused on capturing adventure and interacting with puzzles, but then it was discussed to try to delve deeper into aesthetics and narratives that related more deeply to the original premise and concept.
The new concept that was developed built on the initial premise of using ciphers and de-coding language as a way to build understanding and cooperation between different characters, and to build language skills through interacting with the developed codes and cipher in the environment. By learning the language developed for the game the player can impact the environment, unlock levels, and communicate with other characters. Themes of mystery, skill development, and interconnectivity were now the dominant ideas to mirror initial reactions to cipher discussions, and the aesthetics and tone of the game in development reflected this focus.

Keywords: Ciphers, Language, Game Design, Texture

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1. THE PREMISE

Working within the framework of the international NAWA Game Lab Project, which combines students from seven different universities into seven different teams, this project started with a premise with the goal of translating the idea of communicating through ciphers and codes into a video game that makes an attempt to decipher an unknown language. As a starting point the team looked through ways that language, codes, and the mysteries of an unknown language has impacted the cultural imagination through time. Initial discussions about ciphers and codes included looking at crop circles, artifacts like Voynich manuscript, or theoretical attempts to communicate with the unknown such as the “Golden Record” that was sent into space in the seventies by NASA. The team also investigated known methods of developing and decoding ciphers.

2. THE STARTING POINT

Starting with this particular premise led to unique challenges to developing the themes and game narrative, as well as the game's unique cipher system. Due to the open-ended nature of language as the central point, many aspects of game development were completely open in terms of aesthetic, and what the game play would actually look like. In addition to a premise centered around language and ciphers, the project started with students who were strangers to each other and to the mentors, and were representing four different countries and languages. Additionally, the interactions were taking place against a backdrop of the global pandemic and confining all of the interactions to digitally processed means across different time zones. Students were also coming from vastly different programs and experience levels. This presented a unique challenge to developing a shared vision and open discussion.

The team initially consisted of six students; Pascal Janssen from Germany, Ina Murphy originally from Moldova but currently based in the USA, Olimpia Ropek from Poland, Agata Samborska from Poland, Ola Szwagulinska originally from Poland but currently based in the USA, and Danielle Gross from the USA. Janssen came with expertise in programming, game design, and a particular interest in developing the cipher system for the game. Murphy had experience with 3D animation and 3D modeling. Ropek and Samborska both started with 2D design and Character design skills. Szwagulinska had 2D design and graphic design skills. Gross had 3D modeling and environmental design skills at the start of the project. Over the course of the project Ropek withdrew early on and Szwagulinska, and Gross both withdrew at the end of their academic semester. This particular group overall had a strong interest in narrative and character design, with limited experience in programming and designing gameplay, which put a heavy burden on the single programmer in the group. Additionally, some of the participating institutions have dedicated game design programs, whereas NIU does not and the difference in skill and experience was noticeable.

Strategies for communicating globally started with a shared google drive, zoom for meetings, and Slack and Facebook for communicating outside of meetings. Doodle polls were sent out through email and Slack to arrange meeting times, which had to be reevaluated during the different participating universities semester changes as well as for the different continents approach to daylight savings. Discord was briefly used, but was not very successful as a means of communication, which is more of a reflection of already having several methods in use than a reflection of the specific interface. Strangely as the project continued after the semester ended one of the most successful methods was emailing students directly. Noticeably there was an ongoing issue with students doing very little interaction with each other outside of the weekly zoom meetings unless specifically assigned to meet and communicate, and even with specifically delegated tasks their interaction with each other was sparse. Generally, a few students would take it upon themselves to produce work on their own as the normal mode of operating.

Perhaps as an early reflection of the starting point being language and ciphers, students quickly developed a pictographic cipher system before any other aspects of the game had formally been committed to. Discussions developed about using pictographic language when all participating groups use phonetic languages, and how to create a visually coherent unique system for the game. Upon further development the cipher system pushed more towards an ideographic system, with the ability to combine ciphers to develop more complex ideas. The original cipher system was primarily created by Jansen, who entered the project with a dedicated interest in developing a unique language, with mentoring from Giza and graphic design ideas contributed by Szwagulinska and general feedback from the rest of the group.

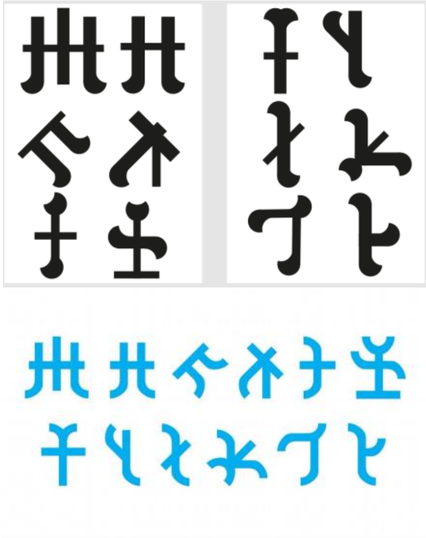

Figure 1: Jansens's initial figures followed by the refined design by Szwagulinska.

In order to literally encourage a shared vision and discussion, students contributed to shared mood boards. These mood boards were starting off points for discussions about the games and imagery that students responded to, and by extension the kind of themes associated with the chosen imagery. The method of sharing images was through the Google drive and Slack. Very quickly students clustered around adventure and escapist motifs. Several students cited their excitement for aesthetics that referenced Indiana Jones films and Lara Croft games. While there was a clear passion and nostalgia for this specific genre, there was also a counter point raised about the casual colonialism[1] reinforced by these white archeologist adventure games. This led to a discussion about what specifically was appealing in these games besides that it is reminiscent of childhood, and what it means when fabricating a narrative to reference real cultures and history as opposed to fabricating a completely different reality.

Figure 2:Moodboard Examples.

The response to this discussion initially was to create a narrative centering around an alien that looks like a blob that crash landed onto another alien culture, and would need to solve a series of puzzles that interacted with the abandoned ancient culture on that planet in order to escape. The narrative was primarily presented by Gross, as one of the few students who seemed willing and eager to contribute ideas, while the rest of the team seemed happy to have any narrative agreed upon in order to move forward. Everything from the narrative description, the character design, and the concept of the how the game play would include puzzles, was centered around avoiding the concerns raised by engaging with outdated colonialist tropes and creating a game that was aesthetically and conceptually harmless and child-like.

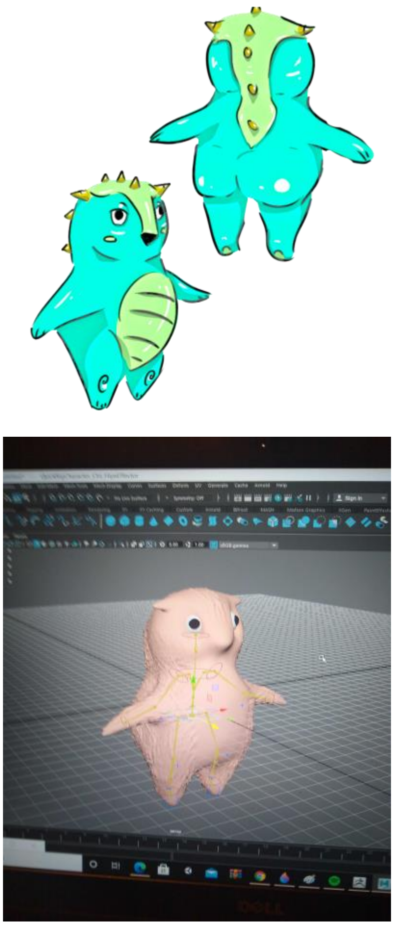

Figure 3: First Character Design.

3. ARRIVING AT CONSENSUS

While the initial conception of the game had finally materialized, both mentors believed that the team should dig deeper to find conceptual themes to center on, rather than simply developing ideas based on avoidance of problematic content. This led to several meetings of lengthy discussions, before a new concept become the central unifying theme for the game. After returning to the initial premise and discussing ideas inherent in using ciphers as fragments of mysterious communication, students came up with an entirely new concept for the game. Centering on mystery, communication, and interactivity the new narrative and environment focused on different characters working both separately and together to gain knowledge of a mysterious world and unlocking puzzles building on a developing lexicon acquired through exploration and cooperation.

The new concept was presented by Murphy that was developed built on the initial premise of using ciphers and de-coding language as a way to build understanding and cooperation between different characters, and to build language skills through interacting with the developed codes and cipher in the environment. By learning the language developed for the game the player can impact the environment, unlock levels, and communicate with other characters. Themes of mystery, skill development, and interconnectivity were now the dominant ideas to mirror initial reactions to cipher discussions, and the aesthetics and tone of the game in development reflected this focus.

The specifics of the new narrative were generally well received by the group with some pushback on using emotions as focal points for game levels. This highlighted some of the difficulty of proposing ideas and providing feedback on ideas in constructive rather than simply negative critiques, primarily in this case criticizing an idea with nothing generative suggested an no alternative narrative or unifying concept for game levels to propose. 1.

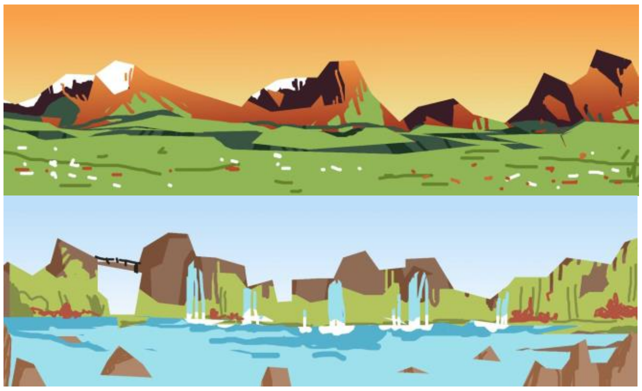

Figure 4: Environmental Level Designs by Samborska.

This understanding shaped different levels based on human experience. The first level embodied patience, and the theme of the level shaped the aesthetics of the world as well as the types of puzzles and interaction with the language and ciphers. The landscape was wintery and fairly empty, the puzzles included relied on individual gameplay as opposed to something more interactive. By acquiring the language skills and collecting ciphers embedded in the landscape the player manages to unlock the next level which centers on a different emotion eventually leading to a final level centered on harmony. 1.

Figure 4: Samborska level design.

Finally, the team had a concept and then students started producing work at a much faster pace. Samborska heavily contributed to creating concept art for the levels as well as developing the character design, and demonstrated a strong 2D aesthetic that emphasized hand drawn textures in a digital medium. These 2D textures were used to shape the 3D landscape as well as dictated the look of the character and puzzle game play. Murphy took the 2D orthographic sketches to create 3D models of the character designs. Gross proposed multiple possible applications for the cipher's application within the gameplay, switching from 3D to 2D for the puzzle design. Samborska developed 2D assets for this portion to match the aesthetic they already developed for the character and level. Despite Ropek and Samborska having withdrawn leaving the team at four, the smaller team worked together much more quickly and delegated tasks more efficiently than previously, which seems to be due to the clarity that a unified concept provided.

Figure 5: Samborska new character design.

Figure 6: Murphy 3D Model of Character

Figure 7: Proposed Cipher Focused Game.

Notably, the momentum slowed down after the different semesters for the students ended, especially for students that graduated at the end of the semester. It seems like ideally the project would be contained within the timeframe of the students' semesters, perhaps ending before their finals to avoid this issue.

Peter Haesner from Ubisoft Germany presented to the NAWA Project teams, and during that presentation it was striking how much emphasis was placed on developing the team and creating interpersonal relationships. It makes sense given his critical role as a project manager for Ubisoft, and even though the concepts he covered seem like common sense, the experience of working with this international team of students who started out as strangers to each other and to the mentors made both mentors wish that his presentation had been at the very beginning so that the beginning of the project could have been framed entirely on team building, which potentially would have made the moment where the team arrived at a consensus for the game concept earlier in the development of the process.

However, despite the long process of creating a unified vision, a concept was fully fleshed out. The themes and development of the game mirrored the experience of working collaboratively with the project. During a time when many people across the globe felt isolated and alone, students had to work in physical isolation as well as developing a method or language for developing ideas and delegating tasks within a virtual group. Developing methods and strategies for sharing ideas took a colossal amount of time and effort from the group. These experiences ended up being directly reflected in the mood, narrative, and gameplay and centered the importance of learning a shared language, both in constructing the group dynamic and in shaping the game around the premise of language and ciphers.

4. CONCLUSIONS

The starting point of this project was focused on translation of an unknown language. This premise provided a rich history of language translation, ciphers, and attempts to communicate or understand something unknown, but left many aspects of the game development open. Additionally, the diversity of the team in terms of culture, personality, skillsets, expectations, and communication styles was incredibility varied creating a lengthy period of discussion to finally arrive at a shared vision for the team. Weekly group zoom meetings, a shared Google drive, email, Slack, and Facebook messenger, and Doodle Polls were all used to communicate and share ideas, but these methods were slow to build team moral. In the future more time spent on team building and breaking down the Zoom presentation format would be useful.

The development of a unique cipher system using pictographic and ideographic ideas despite participating members all being based in a phonetic system happened early. The first idea for the game stemmed from a discussion around the appeal to the group of archaeological adventure stories. Though those ideas have long been popular in Western culture, examining them from a contemporary lens reveals some of the inherent racism in the premise. This discussion initially led to a proposed game idea revolving around an alien blob having similar adventures on an alien planet, but when encouraged to dig deeper into themes stemming from the initial premise students revised the proposal to center around mystery, communication, and cooperation. These themes not only shaped the final game idea but also reflected the experience of working collaboratively as a group against the backdrop of the global pandemic.

Once consensus had finally been reached and the team had a unified clear vision students were much more self-motivated and productive. At this point students generated game assets very quickly, communicated more with each other outside of our meetings, and developed concrete ideas for applying the ciphers into the game play. For future applications of working collaboratively emphasis on developing moral and creating a unified vision more expediently despite the challenges of the diversity of the group and the limitations of virtual communication would be the primary goal.

For both the mentors and the students this experience was invaluable for confronting the unique challenges of international game development within the context of an academic project. Students from Northern Illinois University were exposed to very diverse approaches and programs that were entirely focused on game development which is useful for both developing technical skills as well as developing experience working with collaboratively with an international team, and as mentors we were confronted with the challenges of developing a methodology of communication and team building, of which team building appears to be the most crucial component.

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ETHIC FOR GRAPHICS: FACING THE CREATIVE CRISIS THOROUGH ETHICAL DILEMMAS

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ABSTRACT: The Covid-19 pandemic broke into everyday life redesigning plans, goals, and expectations. In this context, we will share the experience of a video game creation project with students from different countries, with different profiles. Given the situation, we faced the massive abandonment of students who understandably focused their energies on immediate and urgent tasks. The uncertainty affected a large-scale project: cancellation of trips, incompatibilities of schedules, depression at school due to sick relatives or affected family economy. We ask ourselves the question how to reactivate the creative, team and collaboration will as the center of the task in such a context? How to enforce membership and participation in the project? Is it possible to advance for freedom by refusing to use any authority over the members to participate? How to adapt project approaches and keep students excited about participating despite the uncertainty? We find the answer by changing the beginning of a normal methodology, by ethics. The effects that ethics operate on normal methodology were interesting: we were no longer focused on results or objectives, or on any methodology. We know in advance that the team members, once summoned by ethical dilemmas, will give results. They have the ability to define goals for themselves, we know that they internalize different methodologies from their teachers throughout their school life. Therefore, we take the risk of playing to develop a story for a video game before worrying about times, deliverables and objectives. Although without a doubt, we define some objectives. The dynamic was that students from very different cultures chose a specific project in the emergency of the pandemic, in this case the Mask of Truth project. This one is based on a story full of ethical dilemmas through science fiction and real health issues. Step by step, session by session, the students built a story that became, thanks to the discussion of ethical dilemmas, a place to discuss and dialogue about their own uncertain context, releasing their own questions, criticisms, as well as their profound understanding of this complex world. The result was a solid team not only involved in a process, but also creating new processes, paradigms and procedures for intercultural collaboration in real time through innovative tools, proposed and dominated by them. With ethics guiding the creative process through reflection, they themselves became not only objects of education but also subjects of creation to successfully face the problems of creativity in a critical context. The general balance at the end of the experience is that fraternal ties have developed that transcend the project, giving rise to a solid community of colleagues and friends in different countries.

Keywords: Ethic, crisis, creativity, uncertainty, pandemic, videogames

1. CONTEXT

The present paper delves in the experience of an experimental project named Game Lab, implemented with the sponsorship of the National Agency of International Exchange (NAWA by its acronym in polish). Before the pandemic the objectives of the game lab were: to explore pedagogical problems in the creation of video games with students from different universities in different countries. The unexpected onset of the pandemic raised unexpected challenges for the project. Finally implemented in the first half of 2021, the main idea of the project is to register, diagnose, find and solve problems related with videogames creation. Students chose one mentor of a specific university based on some concepts proposed by the mentor. In this case, the proposed concepts where presented in form of a story with the aim to develop it and implement it as a videogame. The name was "Mask of truth". The Universities and students involved in the Mask of truth project were: Wout Janssen form LUCA School of Arts Belgium; Jacqueline Ueltzen and Jonas Wehling form Harz University of Applied Sciences, Germany; Abril Gutierrez from Northern Illinois University, USA; Sandra Czerniawska from University of Silesia, Poland; Mauricio Rabiella and Sandra Velazco form Autonomous University of Puebla, Mexico. So below we will develop three sections that show the way in which we approach the issue of encountering others thorough:

- Culture
- Ethical dilemmas
- Contemporary criticism

2. ENCOUNTER WITH OTHERS THOROUGH CULTURE

Encounter with others is an attempt to sow a seed that becomes a bridge. This process depends on daily habit of the presence of the other. That presence, due to actual situation, should be a strong echo produced in the brief moments of video meeting. The conscious that we are in front of a person with different culture, made a balance between a critical beginning and a joyful transcultural experience. So we put as the core of the experience the respect, understanding and sharing. The first topic in the meetings was the myths that every culture knows that exist around itself. Which are the "clichés" that we face in front of the world? Can we understand why they exist and can we laugh about ourselves? Mexican culture is well known for the openness to foreigners. So we dedicated many sessions to show different sides of each one culture, forgetting even goals or time restrictions of the general project. This allow to discover that the essence of the project was to know each other and learn from different cultures as the most important thing. American students, Germans, Belgians and Polish shared interesting aspects of their countries, stories and national identities in a self-critic and respectful ambient of joy and friendship. Discover the crazy habits of other countries, transformed the team and expanded our tolerance. We learned that the human desire for coexistence always reinvents itself and keeps the doors of coexistence open, producing new possibilities for history and encounters. I think this beginning was one to the succeed criteria for the *ethics as the core of creativity*, that made the students exited an anxious to meet again. Despite of the pandemic context, the screen becomes a window to travel into far and different places and know new people. Once we had a general introduction of our cultural contexts, we lead to debate about the contemporary world to find common issues and topics that concern all of us. The next two sections were developed almost simultaneously in the meetings but here we present them separately.

3. ENCOUNTER WITH OTHERS THROUGH ETHICAL DILEMMAS

In this section, we show a brief review of the topics with which the team began to develop a critical dialogue on ethical dilemmas. After this, we will see how these dialogues were creating a specific methodology that was useful to the team and were built in an environment of consensus. Ethics always have a strong link with ontology: Every human is sensitive to the question "to be or to have?" Excessively competitive global context allows to open these questions. If we are producing thousands of specialists with great technical skills, why prospects for humanistic fulfillment, narrowed and decreased? Why the progress of ones implies the slavery and injustice for others? Why every comfortable aspect of our live has enormous social cost? We concluded that the "having" has displaced the "being". Thus, open the existential problems to dialogue prepares the environment to arise ethics as the core of any creative process. Do the youth have proposals to change the world? Which things make them angry and disillusioned? The fact that this kind of problems are universal, gives the students a strong sense of opening perspectives, community, new points of view in front of topics that contemporary society permanently avoids. Besides, this topics awake the wish to participate leading to forget the initial fear to express themselves in a different language. *Mask of truth* was a great excuse to continue talking of ethical dilemmas.

4. ENCOUNTER WITH OTHERS THOROUGH CONTEMPORARY CRITICISM

In this section I present general topics that lead us to go deeper in the exercise of strengthen our capacity for dialogue, discrepancy and interchange of ideas. For many art students, fame, fortune, are synonyms of success. A complete generation abandoned in front of a monitor[i] [1] has built their concept of life following the paradigm of the *spectacle*[ii] [2] and *simulation*[iii] [3]. Extreme individualism and competitiveness at school not always provide a space of confidence. Besides, youth has the idea that the previous generation has failed building a better world. The inter-generational social fabric is torn. Amazing and impressive technical innovations haven't provided a significant paradigm to stop social and nature degradation. The more powerful processors for graphics give us more detailed textures and realistic environments but even great companies have failed to propose significant stories. High technology is not a warrantee of a good story. Internet has arisen as a fourth voice in opposition to the classic context home-school-society: there is virtual society now, come time more real than the others. Since the Internet is not made for humanism but for consumerism delve into a kind of *techno-obscurantism*[iv] [4] in some senses, a *sui generis* type of educational on-line promises emerges based on some world-famous personalities using the crisis of the education as a chance so sell on line courses. This leads to a new pedagogic subjectivity that we could call the student-fanatic. The hegemonic paradigm of success based on spectacularity never explains how a real professional or creator solves the tension between circumstances and will. Indeed, they never talk about circumstances, the uncontrollable dark side of success and life. Many schools had become fordist industries that spells people to the market of job with any critical thinking nor real creative skills. And most of creative skills developed in schools never will be used on industry. Besides, thorough *specializations* the schools enforce the social division of labor in a taylorist logic that separates the hard job form the creative job. We asked if the main competence demanded today by the industry over the great majority of professionals is obedience, low criteria and high resistance to the exploitation[v] [5]. Students are conscious that big industries lay off form one day to another hundreds of creatives or engineers with the confidence that there are hundreds more begging for a chance. The enormous and colossal growing of profits in the videogame industry during pandemic had a weak impact on the salary of workers. Young people every day more and more are sensitive to this realty. May be at the beginning they just have a vague intuition about it, like a grey shadow under the bed, but this shadow is real no matter we simulate the opposite. Can videogames change this situation as a product form massive consumption? The general idea is, yes. But new approaches are needed. Develop the critical thinking as the same importance as software skills could be an answer. So, we can conclude, at least partially, that the hegemonic paradigm of success, in fact, lead to failure and massive cheat to creators. Every day more and more students do not see themselves in AAA companies. Ethical dilemmas were a strong source of dialogue, inspiration and a strong platform to self-expression.

5. CREATING A PARADIGM TO FACE A CRISIS

Unexpectedly our first sessions in the Gabe Lab lead all of us to take time from other projects, and even to the project itself. We put this situation over the table. We accepted that we were enjoying the experience enough to dedicate more time but the time to finish a videogame was absolutely short… Some kind of pragmatism make us to think on strategies to be the best team and maintain the happiness of the experience, but after some talks we noticed that, due circumstances, be in this two roads was impossible. We formulate a question for the team: do we want to be the best or the happiest team? There are methods for both, and with more time, even both can coexist, but due the situation, time restrictions, and completely new dynamics in the "new normality" obviously both were not possible. So we bring an interesting paradigm to face this situation that we called "Little Miss Sunshine". This paradigm that we create in the moment is based on the movie with the same name. Basically is about the high portability to not be as good as the rest of the participants but we appreciate more the illusion to participate than win. With this perspective, we destroy the fear to failure and suddenly emerges the beauty of the creative journey more than the obsession with a perfect end. After a very significant time of thinking we found our first consensus: we wanted to be the happiest.

This decision brings some ethical principles for us to organize the work and to have clear what do we expect from each other:

1. Not to make a fake game play.
2. Work hard to make a real and important video game.
3. Go as far as possible with a high degree of significance.
4. Not to put over any person abusive amount of job.
5. Not to treat anyone as a replaceable.
6. Free ourselves from impress someone.
7. Whatever the result, we would be there to present it with pride, together.

This is not a simple achievement since the strongest problem during pandemic was the lack of interest of students in continue with the projects, resulting in a crisis of participants. We noticed that we were not developing a game for a cruel company but for a comprehensive initiative that, exactly, wanted to see what kind of problems appear or emerge and the way we solved them freely and creatively.

6. STRONG TEAM

Make a strong international students team that develops a sense of identity and pertinence is a matter of seriousness and gratitude with the openness of the other. We were trying to compensate the fact that meetings in person were not possible due to pandemic. When we went deeper on objectives, times, organization, duties and tasks the "Little Miss Sunshine" paradigm started to give answers to the feeling of stress and anxiety. Despite that our expectations about what we wanted to do were beyond the time and conditions we had, the fact to know that "Whatever the result, we would all be there to present it with pride" gave us the strength to face that we were depending of ¡the behavior of a virus! In every aspects of our life, —*i.e.* rate of contagious and the singular politics that each government and university where implementing—. The natural way to maintain the quality of our meeting time was good communication. Extreme situations of absence for Covid-19 problems, obviously affected the road map that the team were creating, changing and redrawing every day. The soul of the team become a document called "the plot so far" where everyone could go and add some lines to the story in absolute freedom.

7. OPEN METHOD: ACHIEVE CONSENSUS

The horizontal way of work made us noticed that most our normal life we were receiving orders under mechanisms of pressure and awards that we didn't need anymore. The truth is that creativity rarely flourish in this kind of ambient, and this ambient is rejected for creative people, even worst, this environment can destroy the creativity. Since we realized that authority was not part of our method [vi] [6], new problems appeared, mainly long discussions full of amazing ideas but very passionate dialogues that sometimes take many time and leads nowhere. I encourage students to develop their own organizations forms. First idea was to implement a democratic way. Vote to choose one of ideas in conflict. Democracy didn't work because vote for options make part of the team just obey the majority. Of course it makes everything faster… but exactly we were trying to avoid tyranny of time. So we find that consensus will be our way. One problem remains, the cost to achieve consensus was more time to meet. Those who proposed democracy, change to trust in the decisions of those that was proposing to meet often to achieve consensus. The result was to have not one but two meetings per week, the general one every Tuesday —tree ours that very often become four due to the passionate dialogues— and the so called "soft meeting" of strict one hour every Friday. This last meeting maintain tasks clear and reinforce consensus. Besides this two meetings, specific teams of work have the freedom to meet any time they decided.

8. "WANT TO DO" OR "WANT TO TRY": SKILLS MATRIX

Once the team felt confident and strong, we define more specific roles through a skills matrix (Figure 1) . The matrix shows two lines of action:

1. Want to do
2. Want to try

The normal roles to create a videogame where on the matrix (writing, art concept, programming, level design, sound, etc.) We opened the possibility to take the risk to do something that "wants to try" despite not to be so good or not to have the necessary skills. The Game Lab allow this kind of experimentation and we take it. The high level of compromise gave results on a dynamic team using

a) Their advanced skills
b) Empiric experience
c) Experiment trying new tasks to develop new skills

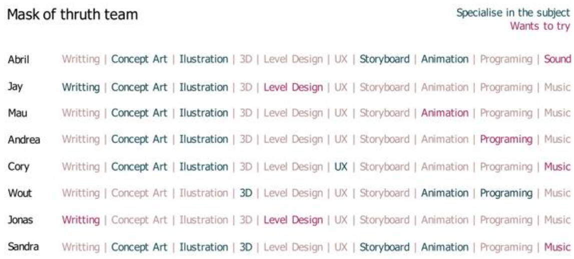


Figure 1: Skill matrix

9. ROLES, ORGANIZATION

Abril Gutierrez focused on story board and animation of cut scenes. Finally, she worked together with Jay Ueltzen to create a cut scene with sound. Jay Ueltzen did writing and project management, a skill that she develops on the road with success. Mauricio Rabiella and Andrea Velazco chose concept art. Wout Janssen focused on programming and animation. Jonas Wehling focused on writing and level design. Sandra Czerniawska focused in concept art and illustration of the Room "A". Almost all members of the team work together in the concept art of Room "A" (Figures 3 and 4). To organize ideas, debate and topics, our basic tool was Discord. For video meeting, we use Google Meet and sometimes Zoom. The first one was especially useful because it has subtitling when someone talk in English, besides, is the best tool for weak internet signals. A complex and well-organized system of storage in Google drive maintained all the files in its place making easy go and check any proposal.

10. PHYSICALLY AND MENTALLY HEALTH IN THE TEAM

During the process we were open to personal issues and everyone had the chance to share them. Depression has become an issue of public health in many countries and arises with pandemic. Despite the mentor is not a therapist, the simple fact to hear personal and hard moments had very positive effect. Sandra and Jay become extra involved in the coordination of concept art. Complex situations in the most critical moment of pandemic demanded not only coordination of art team, but general management of the tasks of all teams. We had a special workshop with Professor Dominik Wilhelm form Harz University for this part. After his workshop to project management, Jay Ueltzen, student form the same university, developed a complex and excellent board in Trello where all tasks were always monitored, thus, she reorganized the system of achieves and storage in Gmail, and folders in Discord previously created by Mauricio. Abril Gutierrez form USA shows an impressive capacity to story board and animation capturing even the most fine and subtle emotions (Figure 5), suspiring us permanently with story boards that catches the spirit of all of us. Unfortunately a delicate injury to his arm decreased significantly her participation. For all the team her peaceful recovery was more important than the whole project. We were agree on that. Despite this Abril were always working with us. Wout Janssen shows an extraordinary capacity to hear, being several times the wise voice that found consensual ways to understanding each other despite intense discrepancies in the team. During the project he attend his internship, sharing with us his works of 3D modeling with masterpiece level. Jonas Wehling seems very insecure of the task he "wants to try", rejecting in the skills matrix to highlight any task as specialist. But he resulted an excellent writer with an overflowing imagination and inquisitive spirit to find the internal congruence of any proposal for the script, besides a terrific memory for the topics on the discussions. Jay Ueltzen share with us her archive from almost a decade of RPG gaming with a group of friends. This gave her a very precise sense how to maintain a complex world in harmony and balancing. This two elements (Jay and Jonas) working together in writing, resulted in a powerful team capable to excite the general meeting with their proposals. At the end we developed together a strong story, with a high level of originality. Specially Jay Ueltzen showed an impressive capacity to manage different tasks with precision and assertiveness providing the last and definitive character design (Figure 6, 7, 8). Mauricio Rabiella shows an impressive practical knowledge about videogames with a deep sense of criticism. Andrea Velazco developed a huge iconographic research that give to the team a clear view of influences and inspirations to imagine and propose art concepts in any fields with the confidence of a serious and exhaustive research: assets, characters, environments, architecture, clothes, etc. Special mentions deserves the fact that Andrea and Mauricio were working during a year before pandemic and during the broke up about ethical dilemmas that creates the basements of the early *Mask of truth* story.

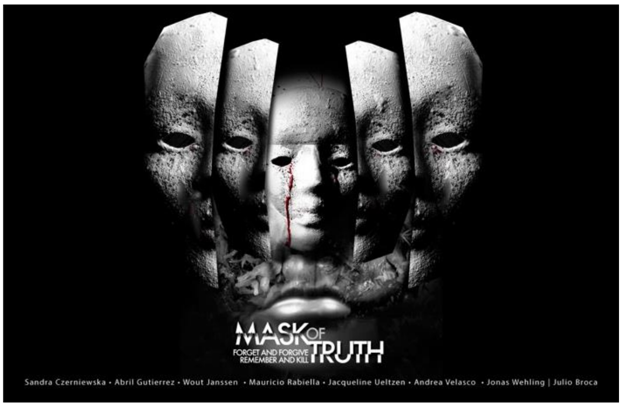
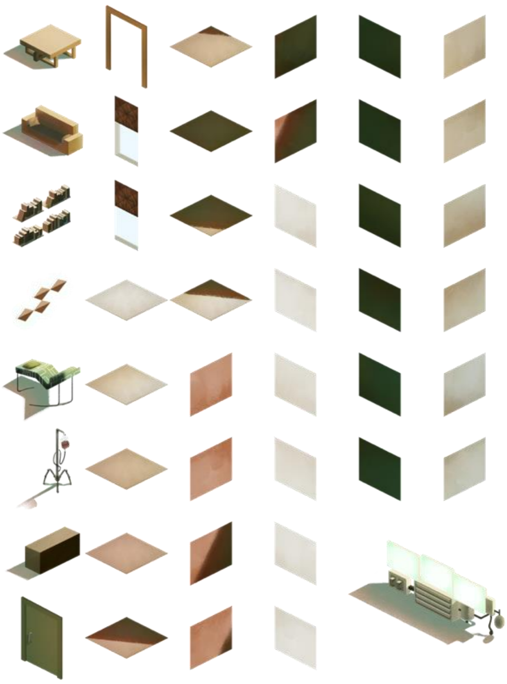


Figure2: Mask of truth. Poster by Julio Broca, 2021.



Fugure 3. Tilesets and Assets. Colour palette, Sandra Czerniawska, Assets by Sandra Czerniawska, Abril Gutierrez, Jay Ueltzen and Mauricio Rabiella.

Figure 4. Room A. Final isometric view of the room, beginning of the first stage fo the game. Art by Sandra Czerniawska. Programing by Wout Janssen, 2021.

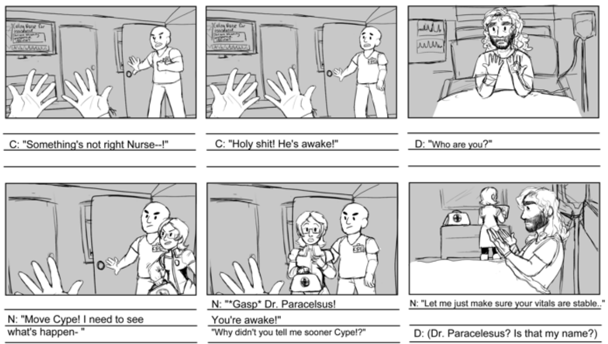


Figure 5. Storyboard of the first scene: the main character awakening, Cype and Dana assist. Art by Abril Gutierrez, 2021.

Figure 6. Dr. Paracelsus Roegen, main character. Art by Jay Ueltzen, 2021.

Figure 7. Cype, the stretcher-bearer. Art by Jay Ueltzen.

Figure 8. Dana Morgan, the nurse. Art by Jay Ueltzen, 2021.

11. ACHIEVEMENTS

- New collaboration agreement between Luca School of Arts, in Belgium with the Faculty of Arts and Design of the National University of Mexico (FAD-UNAM). This agreement is to develop a Game Lab with Mexican al Belgian students.
- Students of Harz University from Germany and Luca in Belgium will visit Mexico to develop face-to-face workshops and lectures.
- Jay Ueltzen wants to make a Startup to continue working on the game and make it real, the team is agree and will give support.
- Wout Janssen is developing a comparative study between methods an theories to create videogames highlighting “the difference of what I learned at my school in contrast to what I experienced during

the Game Lab project" according with his own words. This study could be an important input to redefine methodologies of working ambient with high uncertainty and ambitious goals related with originality and creativity.
- A strong team is a team in which people is thinking in others before thinking in products.

12. CONCLUSIONS

We experimented a new method that we are still exploring and living with new partners. Game Lab project allow us to give one step forward to experience complex situations of uncertainty on international teams and **discover a completely new methodology to work based on ethical dilemmas**. Define a methodology to experience the chance to have international teams. At the same time, opened new ways of international contributions and collective work between universities because of the high confidence that members achieve. There is a useful way to find critical situations of a team and how to create new paradigm to face even unknown challenges. This allow teams to create their own methods according to specific situations. The enormous dignity that this represents show us a complete new face of game design and game creation far form hegemonic paradigms of industrial production of cultural commodities. The team developed a strong sense of pertinence and solidarity. Some students were experiencing very hard situations at home, but, each one of us knew that a new friend was making a great effort for us. We become more than a team, a family around a project of videogame creation. The day of the final presentation all of us were there to present our results with pride, together.

ACKNOWLEDGMENTS

Thanks to Małgorzata Łuszczak and Kaja Renkas for the invitation to be part of the project as well the Polish National Agency for Academic Exchange (NAWA) for founding the Game Lab. Thanks to the University of Silesia for being the home of the project. In Mexico, Francisco Manuel Vélez Pliego, and Giuseppe Lo Brutto Director of the Institute of Social Sciences and Humanities as well the Autonomous University of Puebla in Mexico. Thanks to Gerardo García Luna, Director of the Faculty of Arts and Design and Rubén Cerrillo, both form from the National Autonomous University of Mexico, UNAM for giving new horizons to the project. Thanks to Dominik Wilhelm and Steven Malliet for being always near to help. Special thanks to Edyta Witczak for her support.

[1] [i] For more information about the topic see: Turkle, Sherry. *Alone Together: Why We Expect More from Technology and Less from Each Other*. New York Books, 2011.

[2] [ii] To undestard better the sense of the category, see: Debord, Guy. *The society of the spectacle.* Gallimard, 1992.

[3] [iii] To understand better the sense of the category see: Jean Baudrillard, *Simulacres et simulation*, Paris: Galilée, 1981. *La guerre du Golfe n'a pas eu lieu*, Paris: Galilée. 1991.

[4] [iv] To understand better the sense of the category, see: Broca, Julio. The new shadows of the cave. Topofilia, 2021. http://69.164.202.149/topofilia/index.php/topofilia/article/view/188

[5] [v] Dynamics like 24 hours of job in the so called "game jams" is presented today like something funny and good. Of course, it is fun, but at the same time, normalize super exploitation. In general, the exploitation in the big industry matters a lot for the students.

[6] [vi] To understand better the sense of the category see: Marcuse, Herbert. *L'homme unidimensional.* Minuit, 1968.

DESIGN AND IMPLEMENTATION OF AN INTERNATIONAL GAME DEVELOPMENT PROJECT UTILIZING TACIT AND FORMAL KNOWLEDGE IN JAPAN

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ABSTRACT: In this paper, we report on a project conducted at Tokyo University of Technology in the "Game LAB Project" (TUT-Game LAB), in which university students from around the world participated. Most of the participating students were graphic artists, and each student had a different direction to aim for. Therefore, TUT-Game LAB divided the students into three teams, "Sci-fi Wabi-Sabi", "Character Making", and "Game & Sound Design", according to their wishes, and assigned mentors to each team. In the end, each of the three teams was able to achieve their initial goals and produce sufficient output.

Keywords: Game Development, Japanese Traditional style, Character Making, Sound Design, Game Design

1. INTRODUCTION

In the Game LAB project, universities around the world are managing research projects. The participating students also come from all over the world. Therefore, the TUT-Game LAB project emphasized the Japanese culture and the characteristics of Japan as a region in game development and animation production.

It is widely known that Japanese animation production and game development are different from Western production styles. These production techniques have long been based in large part on the experience of artists, and have been passed down as tacit knowledge. Since the 2000s, due to the increasing sophistication of production techniques, there has been a focus on human resource development. As a result, formal knowledge from advanced Western papers and books has been emphasized [1].

This project was designed as a production project that utilizes both tacit and formal knowledge by utilizing methods and literature developed based on international research examples in order to improve the sophistication of Japan's unique content production.

2. OVERVIEW OF TUT PROJECT

In the TUT-Game LAB, eight students participated from Poland, the Czech Republic, USA and Japan. The student from Japan was an exchange student from France who participated from Japan at first, but returned to France at the end of the project and participated from France. Most of the participating students were graphic artists, and each student had a different direction to aim for. Therefore, TUT-Game LAB divided the students into three teams, "Sci-fi Wabi-Sabi", "Character Making" and "Game & Sound Design", according to their wishes, and assigned mentors to each team.

The "Sci-fi Wabi-Sabi" team worked on creating realistic, real-time scenes in the style of Science Fiction with a touch of the traditional Japanese style of "Wabi-Sabi". The team used Unreal Engine 4 to create a space that incorporates Japanese style in terms of the shape and texture of the assets and the arrangement of doors, windows, and walls.

The character Making team worked 1. literal information of Plot, and character setting, 2. According to the DREAM method, visual design for proposed character, 3. storyboard, 4. 2D character animation with background of 3D model data. The DREAM method is an excellent base for creating characters because it emphasizes collecting references and a visual library.

The "Game & Sound Design" team conducted a literature survey and analysis of works on Game Design and Sound Design. They then used this knowledge to implement "Understanding You," a prototype game demo that explores character emotions.

In this project, we used Zoom, Slack, and GoogleDrive as online communication tools. Zoom was used as a tool for the regular real-time MTG. Slack was used as a channel for each team, as well as a place for information sharing among Mentors and communication among participating students. GoogleDrive was used as a storage location for large shared data such as productions.

3. SCI-FI WABI-SABI

3.1 Introduction of "SCI-FI WABI-SABI" team

The "Sci-fi Wabi-Sabi" team worked on creating realistic, real-time scenes in the style of Science Fiction with a touch of the traditional Japanese style of "Wabi-Sabi". The team used Unreal Engine 4 to create a space that incorporates Japanese style in terms of the shape and texture of the assets and the arrangement of doors, windows, and walls.

3.2 Student's Information

The following two students from the Czech Republic joined this project.

Michal Náhlík, University of Ostrava under Virtual digital graphics studio double degree programme.

Robin Mariančík, , University of Ostrava under Virtual digital graphics studio double degree programmer.

Both students already have a high level modeling skills close to professionals but little experience with programming. Due to the small size of the team and the ease of communication because they belong to the same university, we decided to divide the work of each process evenly rather than dividing the roles.

3.3 Preproduction

3.3.1 Goal of the Project

We first discussed with the team after the students created their very first Game Design Document. Their main interest in this project is making 3D models creating animation and implementing them as a functional scene in which the player can move and interact with objects, using Unreal Engine 4.

Although the students wanted to develop the project as a VR content, we decided to develop a walk-through content with minimal interaction, because they it would be difficult for them to learn and implement programming elements in a short production period. In addition, since they are very busy with university classes and it is difficult for them to spend a lot of time on this project, they devised a rational approach by combining the production contents of this project with the tasks of the university classes.

3.3.2 Concept Art

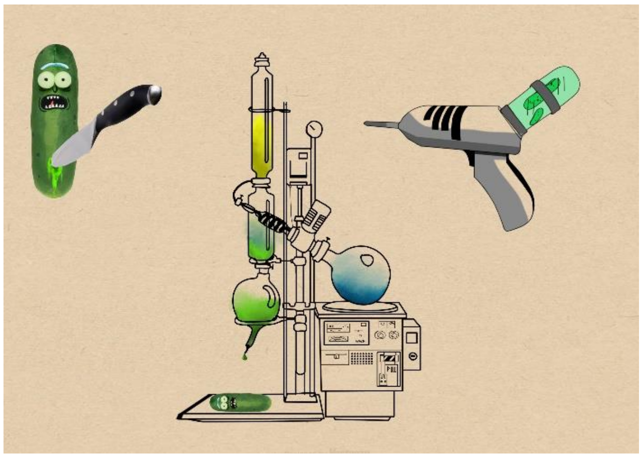
The environment of the project is a small scene of a sci-fi laboratory. This will be a rather small workshop of an individual who works there alone at night. He is not very careful and has a bit of a mess in his workshop. It is full of experiments, not all of which have succeeded (Figure 1). The workshop will need to be a pretty small room because there are only two students on the project and they want to focus on the quality of individual assets rather than quantity.

Figure 1: Concept art of the sci-fi laboratory

Although we didn’t plan to have any characters on the project, we designed some characters and figure out who they are and what they should look like, in order to make sure the environment will make sense, contrast with their atmosphere, their height, their arm length, and so on. For example, the man in the right on Figure 2 is a scientist who couldn’t stand people putting pickles in his burgers and decided to erase every single pickle from the universe just so it wouldn’t happen ever again.

Figure 2: Concept art of the characters

As for props, even though the story and the character will be pretty comedic, we put the art style fairly realistic (Figure 3) .



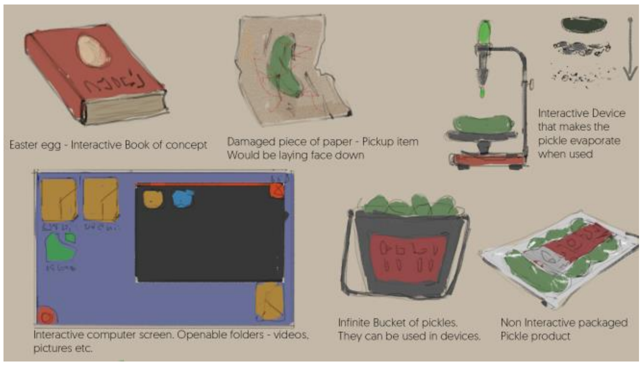


Figure 3: Concept art of the props

As we named our team “Sci-fi Wabi-Sabi”, We planned the visual style to be inspired by the Japanese concept so-called "Wabi-Sabi". We discussed several times how we implement this concept expressly. Many of the original designs only seemed just worn out and lacked the unique elements of “Wabi-Sabi”.

It is very difficult for foreigners to reflect the concept of Japanese wabi-sabi in art, though we Japanese mentors proposed some examples of concrete design elements that represent the traditional “Wabi-Sabi” culture which were created during the Muromachi period, such as the zen garden of Ryoanji Temple, the round-shape windows of Genkoan Temple, and the simple and quaint traditional tea bowls. Figure 4 is an example of a round-shape window that has been improved through our discussion.

Figure 4 : Round-shape window inspired by "Wabi-Sabi" concept

3.3.3. Modeling / Gray Boxing / Prototyping

We mainly used 3ds Max, C4D and ZBrush in the modeling process., Then we created a prototype version of the environment scene in Unreal Engine 4 using the model assets without texture maps with the combination of gray boxing according to the common game production practice (Figure 5) .

Figure 5 : Prototype version

3.3.4 Shading / Texture Mapping

For the shading and texture mapping process, we used Substance Painter and Marmoset toolbag because both students are get used to these tools. Figure 6 is some examples of finished individual graphic assets.

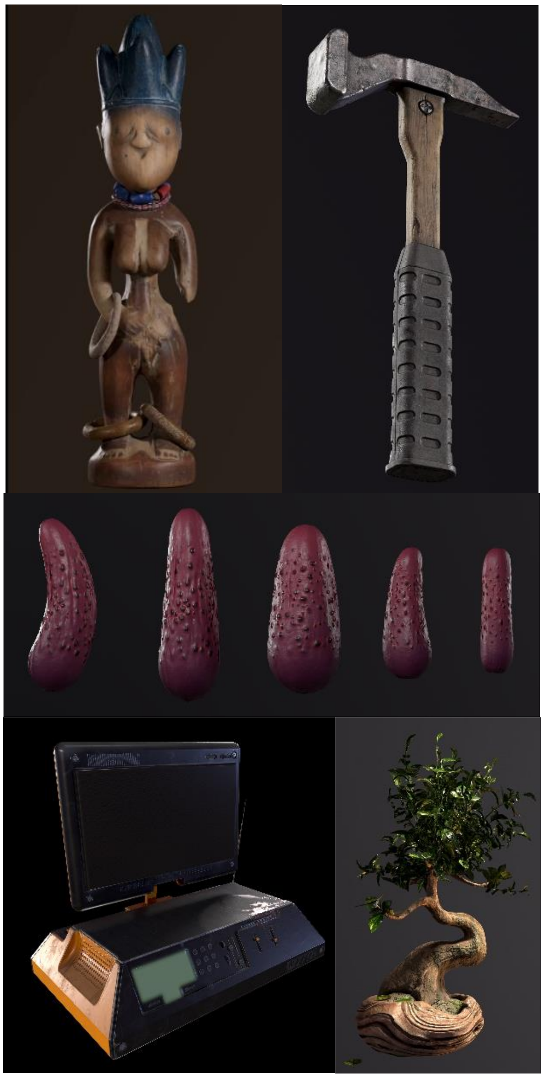


Figure 6 Finished graphic assets

3.3.5 Scene Construction

In the early stages, we tested realtime raytracing lighting. Although we confirmed that the lighting with raytracing give us a very beautiful effect, we gave up because of the performance issue. Eventually we decided to adopt Pre-Lighting method using Lightmass, which is common in current game production pipeline (Figure 7) .

Figure 7: Scene construction results

3.4 Conclusion / Future Works

Although both of the participating students were busy with university assignments, we were able to develop the work smoothly by rationalizing the way the project proceeded. We would like to extend this project as a VR content in the future.

To that end, we also plan to improve performance issue such as polygon reduction and shader optimization. At the end of this project, as an extra seminar, we had a class on some technical arts technics how to select objects with VR virtual hands and the way to spawn interactive objects.

4. CHARACTER MAKING TEAM

4.1 Introduction of Character Making Team

The purpose of this project work is to create and evaluated Game characters according to the DREAM method [2]. Character making is an essential component of digital content. Therefore, we proposed the DREAM method of a digital character-making technique capable of being continuously supervised, from the story's development as the basis of character creation to the plot/episode/character settings, character visual design. A creator needs to think a lot before drawing, so the character comes out perfectly consistent.

In this session, we will first explain the character making based on DREAM method and its template. Then, the results of the student team's character creation for the Game using the DREAM method will be described. In addition, we will discuss the evaluation and discussion of this project activity, DREAM method, etc., which was conducted online.

4.2 Character Making based on DEARM Process

4.2.1 DREAM Process and Character

DREAM Process creates characters that will appear in visual content, such as animation, feature films, television programs. DREAM consists of 5 stages which include Developing, Rendering, Exploiting, Activation, and Management. A character in visual content is an object that can move with its own mind to create progress in a story and arouse empathy from viewers. The impression that a character gives viewers is essential, which means that developing a character is not just about choosing the shape or color. Determining a character's background, facial expressions, actions, and other characteristics are just important.

4.2.2 The Template of DREAM Process

We have proposed a template for character making based on the DREAM process. In this project, students were given the task of creating a story and characters using this template. We focus on the Developing, Rendering stage, and Exploiting stage in this project. There are two categories of Literal information of character and Visual information (Figure 8).

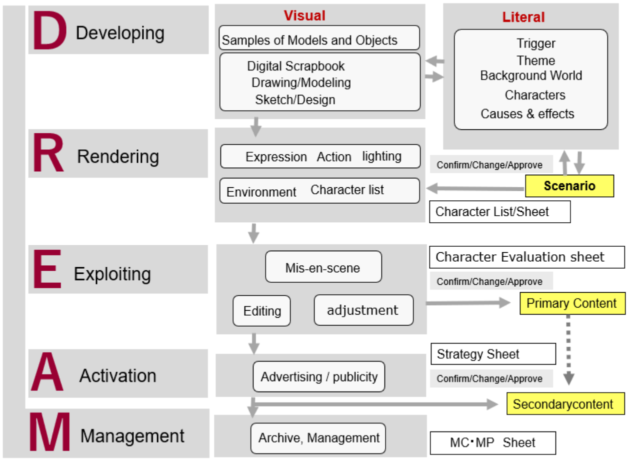


Figure 8: DREAM process.

First, we will explain the literal information of characters. Characters that appear in visual content need a variety of background information to create personality. This template of literal information is separated into three categories, which distinguish items to describe 1. Character general information, 2. Short/medium plot, and 3. character setting information [3].

Second, the template of Visual information is separated into ten categories, which distinguish items to describe 1. 2D Character Design by Collage method, 2. 2D Character Design with Facial expression and posing & Literal Setting Information with the episode, 3. Posing and Facial Expression List with Episode, 4. Character Relationship, 5. Character correlation diagram, 6. Character List, 7. 3D Character Modeling, 8. Setting and background of content, 9. Storyboard, Lighting and Camerawork, 10. CG Animation [4-8].

4.3 Students Work using Character Making template

4.3.1 Student's Information

The following four students from Poland and the Czech Republic joined this project.

1. Sabina Akhmetova, Czech Republic, Ostrava University
2. Helena Chojnowska, Poland, University of Silesia
3. Botakoz Temirkhan, Czech Republic, Ostrava University
4. Olesia Chirkovskaia, Czech Republic, Ostrava University

They are 2nd, 3rd undergraduate students, and their interests are book design, Video Game Design, animation.

They can use 2DCG systems such as Clip Studio Pro, Photoshop, and After Effects. Some students can also use the 3DCG systems Blender and Zbrush. Unfortunately, they did not learn any programming language.

4.3.2 Target of the Project Work

(1) Discussion of the Target Story

Students like games and stories that are emotional and tell an exciting story. They wanted to create something atmospheric, focused on the inside of the characters and their relationships with each other. So, they decided to make a story about self-discovery because every human comes across this problem so that everyone could relate to this story in one way or another.

We all agreed that the best way for us to tell a story and create an interesting character design at the same time is to make a platformer with visual novel elements. This is how a story of self-discovery and self-love of a little teenage girl was created. They worked on a 2d character-based storytelling game.

(2) The Feature of Their Production Process

They focused on the Plot, character making, and atmosphere of the game. Our work was based around the Plot, character creation and the story narrative behind these characters, and atmosphere of the game. They created 1. literal information of Plot and character setting, 2. According to the DREAM method, visual design for proposed character, 3. storyboard, 4. 2D character animation with background of 3D model data using the character making template.

4.3.3 The Result of Character Making

In this section, we describe the results of the students' work using the character making template. Figure 8 and 9 show Short/medium plot, and character setting information that students want to make. Figure 10 shows the gathering character images and the result of collage. Figure 11 shows the character correlation diagram and Figure 12 shows the character relationship.

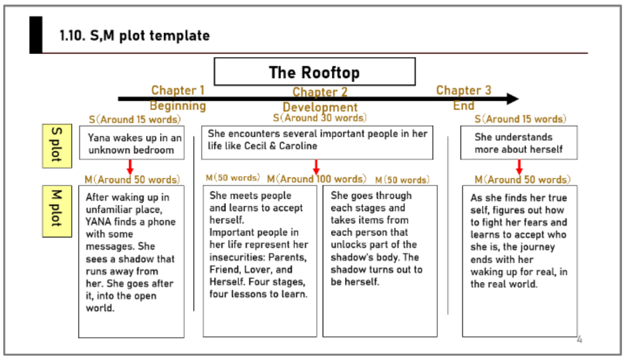
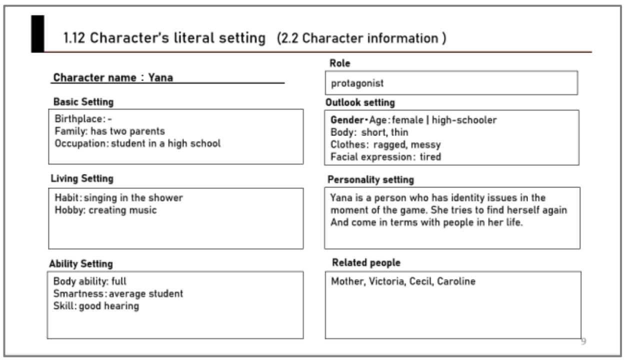


Figure 8: Plot template


1.12 Character's literal setting (2.2 Character information)

Character name : Yana

Basic Setting
Birthplace: -
Family: has two parents
Occupation: student in a high school

Living Setting
Habit: singing in the shower
Hobby: creating music

Ability Setting
Body ability: full
Smartness: average student
Skill: good hearing

Role
protagonist

Outlook setting
Gender・Age: female | high-schooler
Body: short, thin
Clothes: ragged, messy
Facial expression: tired

Personality setting
Yana is a person who has identity issues in the moment of the game. She tries to find herself again And come in terms with people in her life.

Related people
Mother, Victoria, Cecil, Caroline

Figure 9: Character setting information

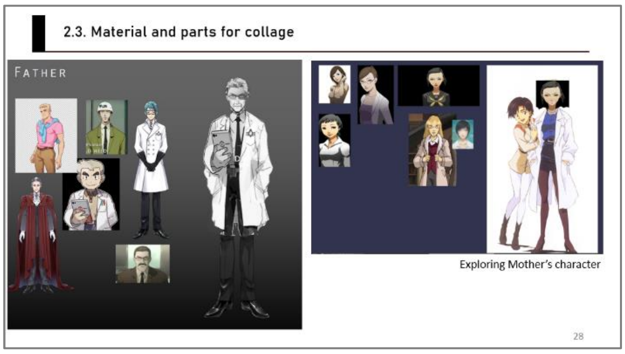


Figure 10: Gathering character images and the result of collage

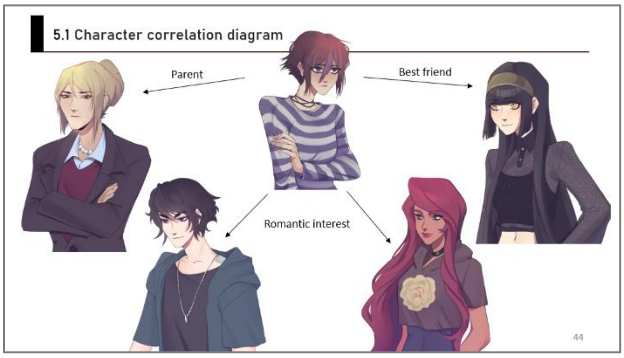


Figure 11: Character correlation diagram

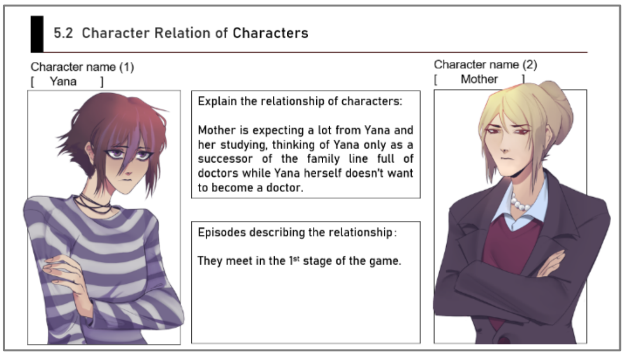


Figure 12: Character relationship

4.4 Students Comments and Evaluation

4.4.1 Management and Production Process

(1) Management of Production Process

One of us did a great job of keeping the workflow going and reminding others of deadlines. She took care of reminding us of the deadlines and supervised our progress.

(2) Production Process

The production process began with determining what each of us likes, what we can do, what we would like to do, and what to learn. We had decided on main themes and symbols and messages that we wanted to include and agreed on the concepts we liked best for further development. Our process began with deciding on a genre and Plot. They had a completed script, character's concepts and roles for the story, the whole dimension loop idea, and symbolism behind every aspect. They shared our progress and discussed it. The character making process was the most exciting and fun.

4.4.2 The group Work via the Internet

(1) Team Leader of Group Work

Team leader took care of reminding us of the deadlines and supervised our production progress keeping the work-flow.

(2) Disadvantage of the group management

Group work for me was the hardest one. Our big fault was that we could bring ourselves to decide the one who would 'direct' us all into one project.

4.4.3 Merits and Demerits of the DREAM method

(1) Advantage

I think it is very helpful to people who are not familiar with character design. Because for a person, it is hard to think of a design without thinking of other characters that they want to inspire from. We did try to use this method, but I think that it is beneficial for directors and producers to use this method to show the artists how they want to see the characters created in their story.

(2) Disadvantage

I did find DREAM too complex for creating the design. As artists, it was hard to use because we already knew who to draw and how to design a particular character.

4.4.4 Summary: Comments on This Project

The following are student's comments.

1. I was not working on anything that is that complicated before, so it gave me a big insight on how to work with a team and how to communicate with other team members.
2. It gave me an idea what to consider in my future workplace when making game visuals. I learned a lot, and now I have a better understanding of how it all works and what I want in the future, and how much I'm yet to learn.

4.5 Comments to the Result

Professor Yasuhara, as Game Designer, gave the following comments. It's so well done that it's hard to believe it was made in a six-month project. It was made with the same process that a professional game studio would follow: clear planning objectives, planning character background, character image boards, documentation of the game world, rough rendering, Image video making, and prototyping. I think it would make for a very unique and appealing piece of work. I'd recommend you all to keep working on this project to be shipped.

5. GAME DESIGN & SOUND DESIGN

5.1 Introduction of Game Design & Sound Design Team

The "Game & Sound Design" team conducted a literature survey and analysis of works on Game Design and Sound Design. They then used this knowledge to implement "Understand You," a prototype game demo that explores character emotions. The team consisted of students from France and the U.S. who were visiting Japan as exchange students. In addition to these two students, several Japanese students provided research support.

5.2 How to Proceed with the Project

We decided to divide the project into three phases.

Phase 1: Research literature and read assigned reference books. Then evaluate the content of them.

Phase 2: After the evaluation of the books, the team members discussed and checked about understanding of game design and sound design. The teachers gave lectures of the designing method on this field. Teams decided what the theme of the prototype of the game they make.

Phase 3: Create the prototype of the game demo and the review of the presentation.

5.2.1 Phase 1: Reading the Assigned Books

In the beginning of April 2021, we had a kickoff meeting to introduce ourselves, followed by an opportunity to discuss understanding academic research and how to apply the academic insights to our projects by using Zoom.

We used the book "The Gamer's Brain" [9] as a reference for game design. And “Game Sound” [10] as a reference book for sound design. The other reason for the selection is the existence of Japanese translations of English works. This is because this way, Japanese students can meet the same knowledge in less time.

Tacit knowledge in game production is unique to each game company, studio, or other production site. Although much of the tacit knowledge in game design has not been translated into words, the parts related to human perception are common. The first half of "Gamer's Brain" is a concise explanation of the basic human perception, memory, attention, motivation, stimulation, and emotion in games. These are not concrete ideas for designing games, but they are the basic knowledge for designing them.

Two participants from overseas were deeply interested in the role and function of sound in game design. Game sound is often misunderstood as having only a role in creating atmosphere and mood. Therefore, we reviewed internationally acclaimed game sound research books to deepen our understanding of methods to incorporate sound functionally into games.

5.2.2 Phase 2 :The Theme of the Game Prototype

Students and teaches discussed the differences in emotion, mood, atmosphere, and sentiment; perception, cognition, and emotional response; differences in cultural understanding; understanding game design elements that apply the above; memory, pattern recognition, surprise, and learning curves; and other topics related to game design and sound design. The lecture was given by Akinori Ito and Hirokazu Yasuhara.

Since we were all working remotely, including the teachers, we decided to use Slack to post our progress and upload our individual files to a shared folder on google-Drive and GitHub. Those allows us to update the project status regardless of the time difference, so we could check it and communicate closely with each other. All communication, including Slack, was done in English.

Our understanding about the project was that, there was not enough time to create a full-scale game. Therefore, we decided to design a game that incorporates the elements we discussed and create a prototype that implements the gimmick as a deliverable, and then evaluate it.

After consultation with the team members, the game theme is decided as “Empathy with human and non-human”. The game design was based on Romane Rakotovao’s idea which is called “Understand You” (Figure 13).

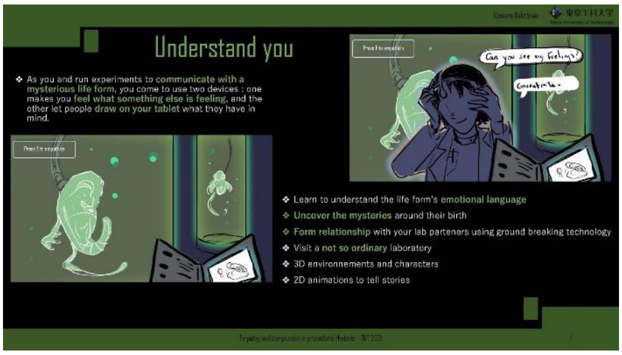


Figure 13: Understand You.

Romane created a template for a game design document, and each of team members added their own parts to it, resulting in a 57-page document (Figure 14).

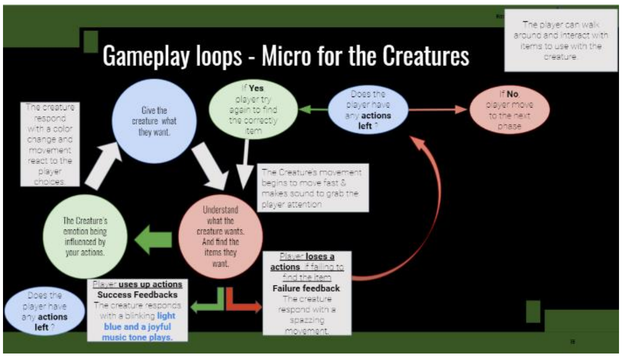


Figure 14: Game design document

The sound design was done by incorporating a reference video into the GGD document so that everyone could share the image (Figure 15) .

The Sound effect and background music adopted a method that changes depending on the emotions of the characters in the game and the time of day.

As a game that aims to convey emotions through abstract graphics, the role of sound was important. Two sound creators from Japan tested prototypes of sounds that responded to interaction and background noises that changed adaptively depending on the area.

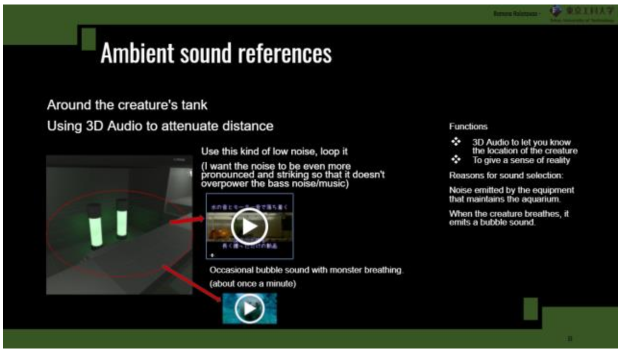


Figure 15: Sound design

5.2.3 Phase 3: Creating the Prototype Game

The game prototype was implemented using Unity, which is a free game engine that all the participating members had used before, so it was more convenient to use than other game engines.

The game prototype is based on the idea of trying to communicate with the creature using colors. The player explores a building and finds a mysterious cylinder that creature inside (Figure 16,17).

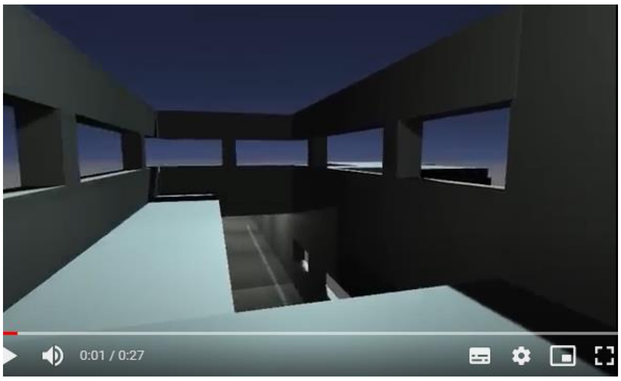


Figure 16: Sound design

Figure 17: Sound design

5.3 Student's Information and Comment

The following five students from France, Unites States of America and Japan joined this project.

Romane Rakotovao, France, ISARTDESITAL at Tokyo University of Technology
Matthew Kounechongprasert, United States of America, Northern Illinois University
Chihiro Yamada, Japan, Tokyo University of Technology
Jason Chan, The people's republic of China, Tokyo University of Technology
Ryota Sato, Japan, Tokyo University of Technology

Romane Rakotovao lead this project and made code of the prototype.
Matthew Kounechongprasert made game design document about UX.

Chihiro Yamada and Jason Chan are graduate students, and throughout their undergraduate studies they have been working on composing dynamic music for gaming purposes and researching sound effects suitable for xR devices. In this project, they create Sound design document and composed sound effect and music for the game.

Ryota Sato are 4th undergraduate students, and his interests are game design. He took care of game camera behavior. His comment is that "I have rarely used English outside of school classes before, so this was a great experience for me."

5.4 Comments on This Project

In a project with limited time, having participants from different countries working remotely on one thing was very challenging in terms of creating a prototype for a game. I believe that this attempt was successful in terms of producing the deliverables that the team was aiming for, and through their work, the students were able to experience working together with global members. Currently, many game development sites are connecting studios around the world to create games. I think it is very meaningful for students to have the experience of using various tools to solve problems. Regarding the game prototypes that we have created, and trying to integrate emotions into the game design, in this prototype we tried to express emotions with colors, but I think it is difficult to experience in this implementation. Context is very important to give the player emotions, but it requires a lot of development time. What I felt as a challenge is that a networked team needs to have a strong motivator. In this case, one student took the lead in providing templates for the documents and key ideas ahead of time, which helped us to put them together into the deliverable within the schedule.

Sound and color tend to be easily associated with emotions. In this project, the cross-cultural team members from France, Hong Kong, the U.S. and Japan were able to strongly realize that the moods and atmospheres evoked by colors and sounds differ from culture. The result was a deeper consideration of the functionality of sound for them.

6. CONCLUSIONS & DISCUSSIONS

In this Game LAB project, several universities from around the world, each with their own characteristics, gathered to plan their own projects. In addition, students with various skills and different levels of experience participated in the project of their choice. It is a great achievement that this project was realized by giving priority to the uniqueness of the project and the wishes of the participating students. Regarding TUT-Game LAB, by developing in a team with members and mentors from different cultures, they were able to experience the diversity of expression styles. As a result, we were able to reaffirm the importance of firmly defining these styles in setting the world in the game or animated film.

On the other hand, in order to carry out a project, there are necessary skills and the number of students needed. Our three projects have various purposes, and each has different issues. SCI-FI WABI-SABI requires technical skills to improve quality. In CHARACTER MAKING, the amount of work tends to increase because the settings are wide-ranging. For research and experimental projects such as GAME DESIGN & SOUND DESIGN, students are required to have research skills. In the case of such a project, it is not always possible to get enough volunteers. In the case of a shortage, it is necessary to change the content of the project or to have staff assist.

In addition, although there were some communication issues with the online implementation, it was effective enough considering the cost of travel.

ACKNOWLEDGMENTS

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IMMERSION IN THE VIRTUAL WORLD – THE INFINITE EXHIBITION POSSIBILITIES THAT 3D VIRTUAL GALLERIES OFFER – AND THEIR IMPACT ON THE VIEWERS.

Kaja Renkas[1]
[1]University of Silesia, Poland

ABSTRACT: The Game Laba Nawa Art project gives us insight into both the traditional exhibition form and its virtual counterpart.
The project aims to show the artistic activities of its members – people who use various artistic techniques, ranging from the traditional to the ones based on modern media. The presentation sys-tem of the works of art reflects this duality. The project started with a big exhibition in real world; next steps, however, will lead us to the virtual reality. 3D space, based on the Unity game engine has been designed to serve this purpose. The engine is just one of many possibilities, but it particu-larly empowers designers.
The biggest challenge while creating apps was their optimalization for mobile devices. The gallery is supposed to function as a widely available, free application.
Getting the scale and art technique right, so as to allow the viewer a `real life` immersion. Lack of human interaction.
Hardware limitation of viewers – it is still not possible for them to experience art using their senses of smell or touch.
Keywords: 3D, virtual gallery, perception, interaction, virtual space.

1. INSTALLATION

Perception of works of art and immersion are the significant aspects that need to be taken into consideration, while dealing with moving from real to virtual exhibitions.
A virtual gallery is the answer and consequence of the new medium of virtual reality. Our per-ception however is different in both of these environments.
The biggest challenge while creating apps was their optimalization for mobile devices.The gallery is supposed to function as a widely available, free application.
Getting the scale and art technique right, so as to allow the viewer a `real life` immersion.
Lack of human interraction.
Hardware limitaton of viewers – it is still not possible for them to experience art using their senses of smell or touch.

Figure 1: Space of virtual gallery

Infinite arrangement possibilities of the exhibi-tion space, as well as its dimensions – free from any restrictions.

Figure 2: Marek Sibinski/ traditional graphics - silkscreens transferred to 3D dimention

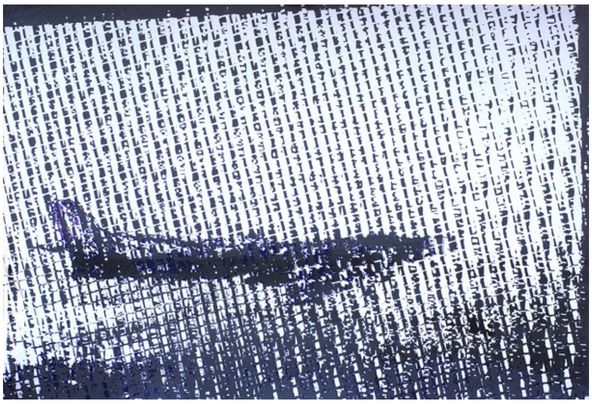

Figure 3: Marek Sibinski oryginal print/ silkscreen/100x150cm

There are museum projects that thanks to, and using the latest technologies, like VR or 3D, strive to enable the handicapped participation in cultural life. Equipped with appropriate hardware, they are able to overcome the so far unsurmountable limitations.

The virtual gallery is the answer to the new medium of virtual reality and its infinite creational possibilities. However, our perception of phenomena is different in the real and the virtual world.

At the NAWA ART exhibition, the works of 17 individual artists, as well as teams of a graphic designer, musician and animator, were presented, and these were digital, video, new media. 3D as well as the traditional workshop graphics and posters created using both traditional and digital techniques.

The artists presenting a wide range of tools fitted into the real space of the modern gallery – appropriate setting (over 300sq meters), gave them the chance to present the high quality of their work. In such environment we are on a very well known ground – the teaditional exhibitional arrangement.

Figure 4: Artists in the Gallery/Tarnowskie Góry/Poland

Figure 5: Exhibition opening/ audience in the Gallery

However the times we live in, with the emphasis on the last year in which we struggle with the pandemic, shift the balance point to the virtual realm.

It is an interesting experience, moving an actual exhibition to a 3D gallery. It is not possible to create an exact copy of such a presentation, as the virtual space is ruled by different rights and we had to get to know them while building the 3D galleries, analysing each of the works of art separately. The most difficult thing was to find the form of presentation of the originally traditionally created works and the aprropriate rendering of the scale.

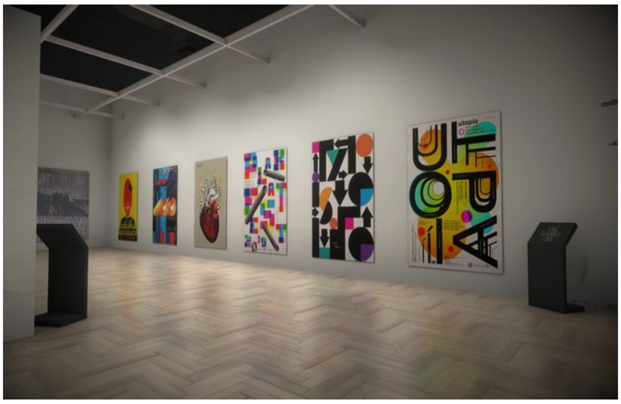

Figure 6: 3D Gallery/ Eric Olivares Lira posters in big sizes

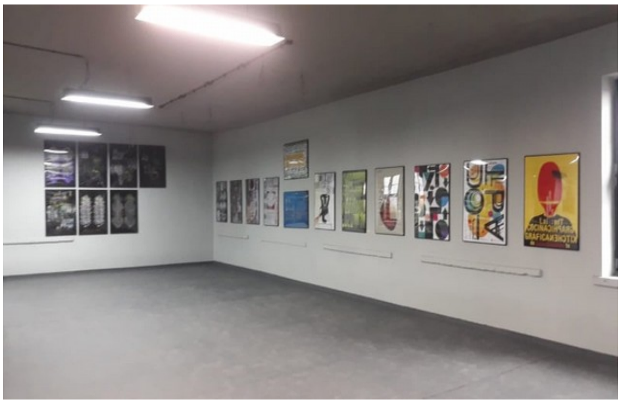

Figure 7: Tarnowskie Góry/ Eric Olivares Lira posters

Werner Schweibenz constructs the definition of a virtual museum-gallery, taking into consideration a few crucial apsects. A virtual museum is a collection of logically connected, created through different media digital objects. Its capacity to create diferent ways of connectedness and points of access makes it change the traditional methods of communication and interraction from visitors, who are flexible in their needs and interests; it does not have a specific, real place or space; its objects can be spread arounf the world.

Large format works by Czech artists – Marek Sybinski and Jan Drozd were presented at the exhibition. Their works were created using the traditional tool of serigraphy, which gained popularity relatively late – in the 20 century. This technique is included in the workshop graphics.

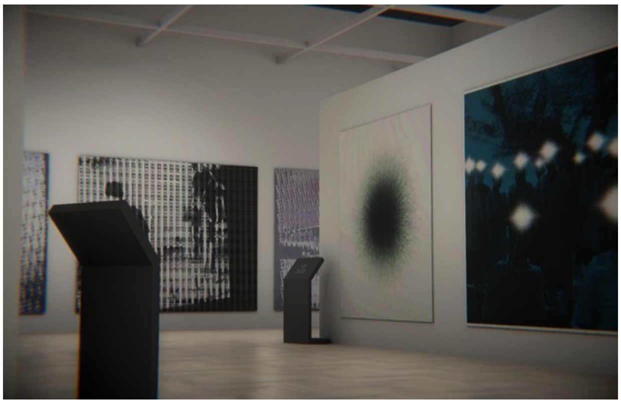

Figure 8: Jan Drozd/ traditional graphic silkscreen transferred to 3D dimention

Figure 9: Jan Drozd / traditional graphic - silkscreen presented in the gallery

What is extremely important in it, is showing the workshop niuances, and so, when transferring this kind of work into the virtual realm, you need to carefully document the original, create an extremely precise digital matrix of the work. We can encounter other problems while transferring video material into 3D. Works of Ewa Jaworska (U of Silesia) and Veronika Romhany (Belgium) were presented at the exhibition.

The former work is a video documenting the phases of destruction of a piece of art created in the urban environment. The viewer is forced to stop and contemplate the succession of events. With 3D, selecting the most crucial elements and shortening the time of the film became necessary, as the user of the application is not able to focus for as long as in a real gallery, where the environment, fewer distractions create more favourable conditions for the contemplation of the work of art. The same with the latter work by Veronika Romhana, presenting a modern interpretation of the work of Franz Kafka.

2. CONCLUSIONS

I think works originally created using digital techniques are easier to implement into 3D galleries, as we can use the original matrix, which in the case of workshop pieces of art is not possible.

The Nawa Art project is not only about presenting works in the real and virtual space; the project also involves technologies like Augmented Reality and holography. In virtual galleries the AR effect got a little simplified, reduced to short animation, as the viewers use their smartphones to navigate the space of the gallery – there is no point adding to it e.g scanning QR codes to get animated pictures. In such simplified form my works, as well as the works of prof.Małgorzata Łuszczak (University of Silesia) were presented. Animations created for the use of AR fit very well into the concept of the virtual gallery – they are short works with sound (thanks to the cooperation with musicians).

What is priceless in virtual galleries is the possibility to present works of art all over the world at once, if the application is available on smartphones running on Android and IOS. While working on the application, apart from technical problems with which we always have to deal in the designing stage, we also had to analyse the ways of presenting the works, look for possibilities enabling us to fully and effectively show the value of the work, sometimes limiting their form in the process, like with the video works.

What is crucial in 3D galleries is creating simple, intuitive navigation that makes it possible for the users, who are not gamers or who do not have frequent contact with technology to use it. The gallery is for young, as well as older generations.

3D gallery gives us the chance to go beyond the traditional scale. We can allow ourselves to break free from the physical constraints and quit worrying about size. Also, the gallery can be a game, where you unlock levels e.g by answering questions or performing tasks. This way, the experience becomes much more interactive than it is the case with traditional galleries.

A contemporary artist has a wide range of technological possibilities at hand. It is extremely interesting to explore them both in the context of the traditional workshop and the way it evolves benefiting from the infinite possibilities the digital media can offer. Still a few years ago it would have seemed impossible to experience art through your smartphone alone. Nowadays even the traditional artist cannot ignore the technology that surrounds us. What we have to do though, is to consciously observe the phenomenon of the shift from the physical to the virtual. Preserving the quality of the works of art is of primary importance.

Virtual gallery should also give people the opportunity to interact with the artist, leave the confines of alienation. What gives the traditional galleries an advantage is the chance to meet artists, talk to them. That is why it is essential to create and provide such an opportunity for the virtual galleries as well. Is is still to be done, but work on it is under progress.

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GAMELAB PROJECT (2)

DESCRIPTION OF THE METHODS USED TO IMPLEMENT THE GAME PROJECT IN THE POLISH LABORATORY AS PART OF THE INTERNATIONAL GAMELAB CHALLENGE WORKSHOP IN THE NAWA PROJECT

Marcin Goldyszewicz[1], Adrian Kuś[1] and Grzegorz Dąbrowski[1]

[1]The University of Silesia, Poland

ABSTRACT: The article describes the activities and assumptions that were adopted to conduct the workshop, focusing on the role and function of a mentor and adaptation to the conditions in which the team of students was to perform a part of the game on the subject of Mutations of nature.The main reason for changing the method was due to the quick adaptation to the new, often variable and beyond our control of the pandemic situation. Traditional and effective production planning based on story or gameplay in the new situation posed too much risk of freezing works. The main assumption was to work with the use of procedural solutions that each time created a new situation for the game. This was to get the team to solve problems using iteration of prototypes. The team had to create a coherent vision of the game itself. My role as a mentor was mainly limited to observation. I prepared the tools for the team leader beforehand and showed how to start pre-production, which helped in communication with the team. Adaptation to the changing environment and the application of procedural solutions allowed me to test whether this experiment would be successful.

The main problem accompanying the creation of the theme and assumptions of the game project "Mutations of nature" was the search for an answer to the question: How can a space for communication and creative work be created so that an international and interdisciplinary team of students creates a visually attractive and promising prototype of a computer game? The problems that I was trying to solve were divided into three categories: **implementation, situation** and **affiliation**. Examples that the developed method was to solve include: No work results. Very short time to implement a working game. Idle discussions that deviate from the assumptions of the game. Bad decisions due to inexperience. Problems with defining the role in the team, disputes about who is right or who decides about the shape of the game.

The conditions that I assumed necessary to perform the task entrusted to me and to check my research assumptions were based on three pillars: **1. Competence-** assigning the role of a leader who will be a bridge between the team, a second mentor who will help in the implementation. **2. Affordance-** creates the environment and generates its elements only then, in accordance with the affordance principle, the team reflects on the mechanics of gameplay**.** This approach will allow students to communicate more easily and effectively in a team **3. Generative procedural solutions-** using open source tools (such as: Quixel, Blender, Objects 3D, Artbreeder) and adapting them to procedural solutions. The team uses the power of the tool to quickly generate assets and the environment. Implements the game engine and creates a prototype for verification in the engine. Creating the right conditions, tools and theme for the game focused all three categories into one consistent goal. In this way, I only had time to develop assumptions for testing the effectiveness of the method.

Keywords: generative, procedural, games, method, implementation

1. INTRODUCTION

The subject of this article is a description of the activities carried out in the implementation of the game project in the Polish laboratory as part of the International Gamelab Challenge workshop in Project Nawa [1]. The article describes the activities and assumptions that were adopted to conduct the workshop. It presents the role and function of the mentor and how the assumptions were adapted to the conditions in which the team of students was to implement their own game project. Gamelab Challenge were international workshops organized by seven student teams, which under the supervision of mentors from individual universities created the game project. Universities from seven countries took part in the project, including Design of Games and Virtual Space at the University of Silesia from Poland. Each university appointed a mentor who was employed by the university in question. The workshops lasted from October 2020 to June 2021. They were divided into three stages. Each stage lasted about 3 months and ended with a presentation of the work progress of all teams. The task of each team was to create an efficient, not very extensive level of a video game and to prepare its presentation, preferably in the form of a video.

In the first version of the Challenge, Before the Pandemic (COVID-19), the topic concerned the exploitation of the natural environment and material goods. The topic was proposed at a videoconference held before the pandemic was announced in early March 2020. The planned course of the workshop was complicated by the global pandemic caused by the Sars covid-19 virus. This situation hindered communication and delayed the commencement of works. Health topics, and other emotions seemed more topical. Therefore, the original topic was changed to a new one, that is, the laboratory. The idea of the laboratory was to be a space for experiments and reflection on the then situation.

1.2 Characteristics of the Polish GameLab

Each of the mentors presented the topic in their lab. Then the mentor acted as the project supervisor in the production process of the game. The main responsibility was to take care of the condition of the team and implementation of the project in the context of the established milestones.The topic of the workshops at the Polish games laboratory was *Mutations of nature.* In the laboratory, a team of students, using appropriate tools, created organic forms in an environment of various digital programs. Experimenting with various forms of 3D objects, they had to be implemented into the game engine. The team's goal was to find interesting organic forms and transform them into a visually attractive and coherent level of play where the game environment influences player interactions and behavior. Six students and two mentors participated in the workshop. Below I present the team's composition and competences.

Student team:

Grzegorz Dąbrowski (Poland) / Leader
Unreal Engine 4 (UE4) Developer, game producer, lead artist
Seav May Taing (USA)
2D Artist, UI / UX Designer
Jakub Mucha (Poland)
UE4 Developer, gameplay programmer
Kyousuke Kurihara (Japan)
Quality assurance, developer
Katarzyna Knefel (Poland)
3D Animator, level designer, concept artist, texture artist
Takuto Watanabe (Japan)
Quality assurance, planning

Mentors:

Marcin Goldyszewicz
Created method in the Polish laboratory, Consultation / Art & Tech
Adrian Kuś

UE4 developer, concept artist, game designer, technical support for the team

In the process of implementation at various premieres, a type procedure was launched. Below is a summary of the **programs used in the implementation:**

Unreal Engine 4 - The main editor and renderer of the game. Creation and verification of prototypes. gameplay, action and character animation activities. procedural solutions at work. Physics of block behavior on opponents. in a randomly generative mutating environment and each time a completely different forest. Stages, materials (shaders), lighting or final post-processes and the engine was used [2].

For file communication and exchange:

TortoiseSVN - Project repository

Google Cloud- Assets repository in project documentation.

Discord - quick weekly meetings

Trello - organization and scheduling of tasks

Zoom - meeting and work results as well as settlement of milestons presentations

Creating 2D assets

Artbreeder- procedural sketches of sketches and the creation of visual effects for the appearance of the game

Quixel- materials and textures for 3D models

Adobe Photoshop - refining the look of the game

Krita-GUI elements

Alchemy- procedural creation of emergency sketches and visual effects of game changes

Creation and optimization of 3D assets

Blender - Procedural randomly generated game environment

Microsoft Paint 3D create a shape using the shapes you draw

MeshLab- manual optimization of 3D assets ready to be implemented into the game engine.

1.3 **Description of the problems**

The changed circumstances of the project implementation also brought other challenges for mentors and student teams. The teams could not get together and brainstorm their projects together. Therefore, mentors had to create an area of communication for the teams, set goals and define the implementation method for student game projects.

The main problem accompanying the creation of the assumptions for the game project *Mutations of nature* was the answer to the question:

How to create a space for communication and teamwork so that an international and interdisciplinary team of students creates a visually attractive and promising prototype of a computer game?

The moment of the workshops in connection with the pandemic created a completely new design situation. On the one hand: disruption of the normal rhythm of work, isolation associated with the closure of subsequent areas of public life, the constantly changing conditions of functioning under restrictions or quarantine, at first glance, created an impassable barrier and heralded a failure in creating and implementing assumptions. Planning work in a well-coordinated team already seemed to me a difficult undertaking, let alone in such a newly established team of unfamiliar students from various universities scattered around the world. On the other hand, the ineffectiveness of many previous implementation methods, which were based on planning and forecasting events, made it necessary to develop new, more effective methods in response to a dynamically changing pandemic situation. By analyzing various variants and trying to predict possible problems based on the experience and knowledge gained both from scientific work and work in the gaming industry, I came to the conclusion that I am not able to guarantee such solutions that would be effective and give real support in difficult situations in what a team or project could find. Any results based on traditional game planning and trying to fit them into a timeframe run the risk of sudden problems that could overwhelm both the mentors and the team.

2. **METHODS AND DESIGN ASSUMPTIONS**

Because the unstable situation thwarted many previously planned activities that had a direct impact, for example, on the implementation of the workshops described here. It clearly showed that any attempts to plan production based on traditional methods, knowledge or many years of experience were burdened with a high risk of failure. The reasons for rejecting the traditional manufacturing process focus on the problems diagnosed below.

1. Even the most iterative process of implementing individual stages, but based on a linear production direction, was too dependent on the ideas or assumptions of the game concept.
2. Too little time for pre-production and prototyping and too high requirements for skills and teamwork.
3. Interaction of various tasks and mutual blocking of work and interdependence of some assets on the implementation of others. So too many elements blocking the work in the engine would ultimately generate too many bugs and prevent further work. This type of situation could occur every time we deal with a random and randomly independent event such as a sudden lockdown, illness, etc.

Recognizing that even two people as mentors, we are not able to predict and control production processes enough to build commitment and trust in our guidelines in the team to allow complete freedom in shaping tasks, creating content, while believing that all these activities will be move in the only common direction of a coherent vision of the game. Searching for the most optimal and effective solutions that would help to involve all students in the team for active implementation and a sense of commitment to work, through a real impact on the shape and final overall appearance of the game.

Regardless of the skills, predispositions or previous design experience, one of the most difficult stages is to start work and carry out pre-production in such a way that instead of sterile discussions and thoughts stuck in the minds, real reference material is created, which will jointly inspire the search and further stages of joint implementation of the game. At the same time, shortening the pre-production stage due to the very short lead time.

First, each student started experimenting with algorithms that generate images and organic 3D models. These fragments then developed into more complex 3D modules that procedurally generated a random environment in the game. This allowed us to first implement the content to build the game. Then, from these resources, students created prototypes in the game engine, verifying ideas for the future gameplay and storyline in the game. This allowed us to first implement specific solutions to build the game, thus creating a fancy forest that was different each time, creating the game world. Students have at their disposal those elements of the game that, as a team, they managed to complete together. Working for specific assets and the resulting own and technological limitations allowed students to quickly reject ideas that were impossible to implement even in the conditions of the prototype. To a large extent, this awareness of measuring one's strength against intentions made it possible to focus on those activities that could be carried out on an ongoing basis.

3. **CONCLUSIONS**

The article describes the problems and activities that were adopted to conduct workshops in the Polish laboratory as part of the GameLab Challenge project in the NAWA Project. It focuses on solutions and adaptation of assumptions to the conditions in which a team of students was to create a fragment of the working game.

The main problem accompanying the creation of the assumptions of the game project *Mutations of nature* was the search for an answer to the question: What conditions must be met for the team to start working as one unit and remain focused on its mission?

How to motivate and involve an international and interdisciplinary team of students for the success of their creative work, so that they can create a visually attractive and promising prototype of a computer game?

The leitmotif of the game was: Mutations of nature. At the very beginning, guidelines and a course of action were defined.

In order to facilitate the work of students, the project uses the participation of artificial intelligence and procedural solutions in the form of ready-made work tools. From the very beginning, the team benefited from the support of artificial intelligence. Together, the activities became the foundation that from the very beginning united the visions of the jointly created project.

Despite the different and unusual method of creating and designing, the provided methods and tools turned out to be effective. Ultimately, the guidelines and assumptions that accompanied the GameLab Challenge design workshop from the very beginning were implemented. A proof of concept was created that is fully playable, represents artistic values and has a coherent vision that can be further developed. The design process was very demanding for all of us. Our activities focused on adapting and responding to changes that led to the implementation of a large, complete project in a short and limited time.

Despite this, we managed to create a project from scratch with good graphics, gameplay and most importantly, it is playable

ACKNOWLEDGMENTS

I would like to thank all mentors and students from foreign universities for participating in the entire GameLabs project and numerous participation in the summary of works in the last workshop meeting in NAWY Projects.

I am very grateful that I was able to participate with you in this challenge.

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ABOUT THE AUTHORS

1. **Marcin Goldyszewicz is** an artist and game developer. From 2017, lecturer and PhD student in Game and Virtual Space Design at the Institute of Fine Arts of the University of Silesia in Cieszyn. In 2012-2015, he started scientific work at the Faculty of Philology of the University of Silesia, and was involved in learning and popularizing games among students and scientists at many conferences and meetings in the field of design. He started in the gaming industry from 2007, working as a concept artist, level designer, graphic artist. For the last 8 years, he has worked mainly as an art director responsible for a consistent vision of the game.. As a developer, he participated in over a dozen implemented and published game projects. He built his position based on cooperation and professional experience working for such industry giants as Ubisoft (Settlers, 2012), Sony (VR 2018 projects), Nintendo (Circus, Let's Paint, Zoo Wii 2010), Bethesda (AMF Bowling World Lanes, 2008).) or Bandai Namco (Get Even, 2017). These were both games related to the global commercial market, released on platforms such as: PS4, Xbox, PC, as well as independent projects, hitting local markets in Asia, such as India, Russia (Chernobyl VR Project, 2017 The Farm 51), Taiwan (Afterfall.Enhanced Edition, NEG) or Japan, to the USA (*Arena Morte*)

and to the European market to Germany (*Duke Nukem, Red Faction,* DeepSilver 2011), Spain, France or Poland (CD Project Red, Platige Image, The Farm 51, Artifex Mundi, FWH, Tabasco Interactive, Nicolas Game *Afterfall,* 2012, *AF Reconquest*, Nawar *Duke Nukem Critical Mass 2009)*
A graduate of Nicolaus Copernicus University in Toruń (2002-2008).

2. Adrian Kuś – He was an avid gamer before he became an artist, and it was his passion for games as a medium to convey emotions and stories that led him to the place he is in now. He is a graduate of University of Silesia, Video Games and Virtual Space Design with specialization at Video Game Graphics. Even during his education he was actively helping with the development of Punk Notion games; two of which, Weakless and The Last Show of Mr. Chardish, have become commercial. Veteran of Game Jams' such as Global Game Jam, Nordic Game Jam, AmJam, ARP Game(s) Jam, Game Jam Square and LAG, during which he has created over ten projects as a member of Cropseys team, often winning prizes and awards. He is currently working on his personal projects, at the same time supporting other projects as an outsource, and is giving lectures at his Alma Mater. And all of this breaks between playing more, and more games.
3. Grzegorz Dąbrowski

RETHINKING INFORMATION DELIVERY IN CG GAME DESIGN CLASSES USING SELF-DIRECTED TEACHING METHODS AND DIGITAL NETWORKED TECHNOLOGIES

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ABSTRACT: In this paper we will describe the educational practices applied in a multidisciplinary, online, international laboratory that was organized in the context of the NAWA-funded project Game Lab (https://gamelab.us.edu.pl/).
Within the lab, students and mentors from different nationalities and backgrounds collaboratively created a game prototype, hereby implementing a development pipeline in an international, long-distance context. The lab integrated several learning goals and practices, of which the following will be shortly discussed in this paper: 1) integration of research and practice 2) developing an online workflow in the context of social distancing and international collaboration. In conclusion we provide reflection on the value of the online Lab as a future practice in visual art education.
To reflect upon the pros and cons of organizing an online laboratory as a hybrid learning practice in art education, we are going to rely on the following recent research papers concerning emerging educational practices in Covid times (e.g.: Dogonathze et al, 2021 on distance learning; Nerantzi, 2021 on peer learning processes; Li, Li & Han, 2021 on outcome-based education) [1-3].

Keywords: co-creation, organization theory, game design, art-based research, flipped learning

1. INTEGRATION OF RESEARCH AND PRACTICE: REWILDING

The lab was linked to the 'Wild Matters' research project, which served to inspire and inform the students' practical work. From a focus on *rewilding*, a term emerging from ecosystem restoration programs, the game they created explores and questions the human relationship to nature.

According to Rewilding Europe, an initiative that aims to rewild one million hectares of land throughout Europe, rewilding is about letting nature take care of itself, enabling natural processes to shape land and sea, repair damaged ecosystems and restore degraded landscapes (rewildingeurope.com).

The dilemma of whether or not we as humans intervene in nature has been developed by the students into a future scenario in which robots are sent to other planets to determine to what extent these are exploitable.

As the protagonist in this story, the player discovers how ingenious the extraterrestrial flora is, and therefore withdraws from the dominant, controlling human powers. This "withdrawing" is an obvious act of rewilding. For example, Monbiot states that: "*Rewilding, unlike conservation, has no fixed objective: it is driven not by human management but by natural processes (...) to allow it to find its own way*" (2013, p. 83) [2] In this way, the game gives us a clear message: Not to interfere at all, especially with those ecosystems that are not damaged yet.

We will provide an account of, and

reflection upon, the artistic experiment that unfolded in the process of this mid-term collaborative work - as an example of how, within the lab format, the acquisition of artistic competences can coincide with the development of a personal, skill-based learning trajectory.

2. TEAMWORK AS FACE-TO-FACE SKILL-SHARED LEARNING: THE NECESSITY OF COGNITIVE PARTICIPATION

Uncertain circumstances require quick rethinking and action to navigate uncertainty.

Crisis, just as the pandemic itself in general, requires re-action - it requires decision making in every field of life and, as consequence of distancing, sudden disruption in education is not an exception.

From this point of view, innovation reveals organically and necessarily from creative solutions when re-imagination and restructuring is necessary [1]. In other words, when it comes to creative work, limitations mean freedom as we must adapt to current circumstances.

We can see a mild and somewhat not accidental allegory here, in the case of NAWA Game Lab. On one hand, how students reacted in a creative and inventive way to the new circumstances illustrates well how fast they could resonate to the contemporary global crisis by adapting rapidly the online learning methodologies.

Following the global restrictions and adapting the latest methodologies in game development, the NAWA project with its full online format provided a perfect test-case.

According to the original concept, the students could choose from different themes/concepts offered by the participating universities.

Forming a developer team together online similar to real-life projects, students and mentors from different nationalities and backgrounds aimed to collaboratively create a game prototype, hereby implementing a development pipeline in an international, long-distance context.

2.1 Cognitive Participation

Distance learning requires a strong engagement of the students and the same applies to mid-term project development in the game industry. In the case of an online lab format, synchronous online learning entails a pipeline-format of step-to-step problem-solving, as is the case in real-life software development, for example by using SDLC agile methodologies.

The game prototype that the students envisioned at the beginning (inspired by the *rewilding* research project) had been constantly reviewed and updated by the students themselves during the period of the course. The learning experience that emerged is somewhat similar to a ‘self-directed teaching method’, or in other words, in this out-come based education format the learning is processed by the students.

This brings along a shift in responsibility whereby the mentorship mostly functions as a feedbacking position. This limited responsibility of the mentors may work effectively only in higher education or classes where students are truly motivated [3]. Motivation is crucial in any non-traditional teaching method as it requires a lot of effort from the students’ side, mainly outside of the class to invest on their own development to solve the tasks step-by-step during the course.

2.2 Teamwork

To give a practical example of self-direction in learning, the students from rewilding envisioned a fertile and rich alien world. This required numerous 3D assets to be created and they had to not only distribute the tasks. For instance, who is going to be responsible for the 3D textures and who will do the modeling and animation? They needed to keep working on their own duties from week to week in order to: 1) let the others continue to work too and 2) be able to present to the mentors what they developed since the last session.

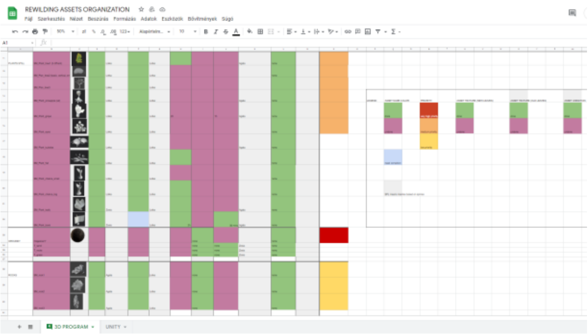

Figure 1: Students' Google Spreadsheets for asset organization

The Lab had one session per week during the course, but it had flexible scheduling. When getting closer to the end of the course and to the final presentation, the mentors and students decided to switch from a fixed time frame to a chosen appointment that suits everyone the best, also it was helpful for the students to finalize the actual task.

This sprint-like classroom proved highly effective time-management wise, which gives another positive example of the hybridization between self-directed learning method and software development methodologies in game design.

The mentors could witness a definite and fast development in organizing skills and communication, also being strongly related to each other. The more the students felt effective processing the tasks the more they felt confident and engaged.

The freedom of being equally involved and responsible for the project fueled the students and it led them to create an exceptionally strong, and visually stunning game prototype (see Figure 3, 6).

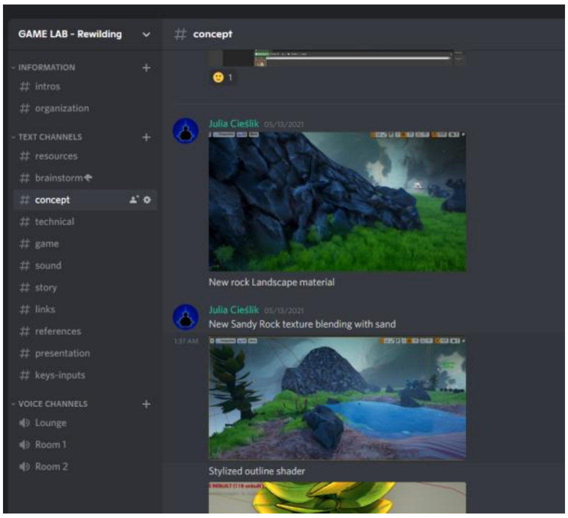

Figure 2: Screenshot from the Discord application with separate channels for different tasks.

2.3 Shared Responsibility

The smart way of distributing tasks was based on giving a lot of attention to personal skills and competencies. The students used Discord (see Figure 2) to communicate on a daily basis, and they were aware of each other's actual level of busyness in their personal life – we can refer to them as caring attention.

It is important to mention here that shared responsibility and caring are essential components in any kind of collaboration, and even though this project has been realized in educational frames, the students could manage successfully to realize their project in a highly organic way.

As a result of continuous, active participation and engagement with the project, this learning method can be considered an application of the 'flipped learning classroom concept'. The concept of flipped learning classroom denotes a different way of information delivery, whereby students can become more strongly engaged and for this reason more active, and face different types of limitations, like the shortage of time, overly complex tasks, learning new software tools like Unreal Engine, helped the students to gain expertise in their self-reflectivity and self-development skills.

3. CONDUCTION: DEVELOPMENT AND WORKFLOW IN A DIGITAL AND INTERNATIONAL CONTEXT

This paper aims to inform also about the workflow development among students and mentors who were separated both in distance and in disciplinary background, as such providing a case of a hybrid, multidisciplinary and distant learning trajectory. We aim to reveal that when it comes to organizational structures and distribution of work the iterative method the students applied (Kanban) is somewhat symmetrical to the topic they chose.

Furthermore, with the help of different online platforms such as Discord, online collaboration can be successfully realized through a more *natural* process. *Natural* in the sense of how easily the information can flow between the team members thanks to online connectedness and digital technology, and natural in the sense that it is based on their self-development and the ease of the implementation of the newly gained software knowledge.

3.1 Software Tools

In the frames of the Game Lab, students and mentors used Discord as a platform for the online class. As the project evolved, the students involved other interfaces allowing them to share thoughts online and edit their project materials together, such as Google Spreadsheets, Google Drive and GitHub (see Figure 1, 2, 4 and 5).

Being an international classroom, the language of communication was English, and students could increasingly adapt to it as they had to work with different software programs that were mostly only accessible in English. For the game development they worked in Blender, Unreal Engine 4 and 5 and they also used Substance Painter.

Thanks to the high accessibility of online teaching materials, tutorials and guides, the students could learn new skills and develop their tasks effectively and outside the class. Even though this meant a lot of freedom too, a weekly meet-up on the Discord channel became an important micro-deadline for them.

Figure 3: level design in Unreal 5.

3.2 Conduction of the Game Lab

During these one-hour-long sessions, they could describe what and how they worked on their duties, and they could also use the screen sharing tool to be able to give a more tangible presentation. These presentations were blended with tutoring, feedbacking and brainstorming.

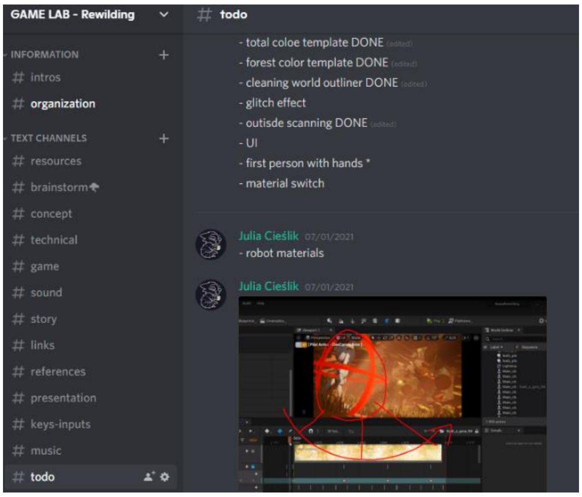

Figure 4: Listing and feedbacking using file sharing tools of Discord.

Based on the experience of this fully online, project-based classroom, Discord proved a highly useful tool, because it did function not only as a platform for communication but also as an interface to make notes, share links, and media files with the others (see Figure 4).

The written form of communication (text channels, see Figure 1 and 3) divided into certain topics like music related tasks, concept development, sources, etc., could help the students to filter out and organize everything related to the project.

3.3 Online Communication and International context

It is important to mention that when it comes to international context, it is necessary to have a certain level of communication skills in the chosen language. If there are recognizable inequalities in the capability of communication between the students, it may lead to an unbalanced group dynamics in interaction with the mentors and with other students. Also, it is important to note that just as in real life face-to-face communications, we are not the same personalities; some of us are more introverted some more extraverted and in online communication students can feel being forced to interact or to react, and it is easier to remain passive and 'unseen' than in real life.

SLIDE 10
full production stage (animation, level polishing)
+our tools.
After setting our story right, we were able to advance our level creation. While the look and feel was fine-tuned, the Unreal Engine 5 came out.

SLIDE 11
Our level didn't need it, but when Julia shared our updated project in the new version,

SLIDE 12
we instantly fell in love! Since we were aiming for a visually polished trailer, it made a lot of sense to convert the project.

SLIDE 13
With the upgrade we had the opportunity to work and experiment with many different tools.
We tested the level partition, Nanite and Lumen system in Unreal Engine 5.
We have a really developed landscape system implemented- with reactive customizable colors, sizes and textures. All of lights in the engine are fully dynamic, thanks to optimization.

SLIDE 14
Some of us had the chance to extend our knowledge about repositories and version control systems- we worked on our project using GitHub.

Figure 5: detail from their presentation during the Third Milestone, July 2021.

That's why online classrooms should focus more on engaging and motivating students in a natural and organic way, even more than in classic on-site classes.

4. EVALUATION AND RESULTS

During the period of Game Lab (from January until July 2021) both the students and mentors – while collaborating in their rewilding project – witnessed how efficient the flipped classroom method can be in outcome-based educational frames.

During the *first phase (first 2 months)*; students discovered their technical capabilities and limitations (see Figure 5), they discovered their relation to the chosen topic, and they formed a team in a practice-lead and organic way: they arrived to set up their working structures and distribution of work. During the *second phase (between March and May 2021)*; they mastered in practice face-to-face skill-shared learning methods, relying on online sources and with the weekly feedback from their mentors. They were already working on the 3D assets, the game level in the game engine and in the storyboard in a distributed way.

During the last, *third phase (between May and July 2021)* they were able to see that the initially set goal, in this case a playable computer game with AI implementation, is not a realistic expectation in terms of a close deadline, and they decided to focus on the visual development and improvement of the game world.

This was seemingly a difficult but wise decision the students made together, and it led them to keep the speed of the realization and focus on the outcome.

Undoubtedly, at the end they made a stunning, interactive game prototype (and also a trailer, see Figure 6); where the player can discover the highly detailed, realistic and picturesque alien environment and interact with it.

5. ART-BASED RESEARCH WITH FLIPPED CLASSROOM AND OUTCOME-BASED EDUCATION

Learning and teaching in self-isolation is never an easy task. When it comes to art-related education methodologies, especially visual arts, flipped classroom and project-based learning is not really an unknown method. Students studying visual arts have to adapt nearly from the very beginning a special type of self-directed, practice-based methodology (drawing, sculpting, designing, etc.) and mentoring as a practice has a rich history in art education.

If we talk about mentoring game design classes and especially mentoring game development, we are not talking about one-to-one relation, we have to talk about team leading.

Team-leading can happen in several ways and it always depends on the quality of interrelations between the participants.

In some cases, a team, let this be a classroom with students or a professional developing team, needs a strong mentorship, needs more guidance and tutoring. In this case, online platforms and communication are used more for control, double-check and one-directional information delivery; teachers lead the student in how to use a tool in a proper and effective way, team-leaders give commands about do-s and don't-do-s. This applies to art education as well, being originally practice-based.

The difference between flipped classroom methods in online education nowadays is the massive amounts of helpful sources already existing online, specialized in micro problem-solving such as how-to-s in 3d texturing, lighting in game engines etc.

The ease of access (through the internet) to these tutorials gives the students flexibility and freedom - and they don't need to rely on their mentor when it comes to practical questions.

6. CONCLUSIONS

Regarding the latest generation's nearly native skills to search on the internet, the shift from one-directional information delivery to a more blended and flipped classroom methodologies in higher education is inevitable.

Especially, when it comes to digital art and game design classes. The shift in responsibility from 'teaching' to 'feedbacking' requires a different, more empathic mindset and pedagogy from the mentors to learn not to lead but to be present in the 'team' and only step into the leader and controlling position, when the group dynamics needs it.

On the other hand, stable and wide-spread knowledge in the topic, being familiar with the online tools is also essential skills for the mentors to be able to set up a safe, professional but free environment - a frame - where the students can experiment, develop and co-create.

Figure 6: screenshot from the trailer Rewilding.

ACKNOWLEDGMENTS

This paper and the research behind it would not have been possible without the exceptional energy, motivation and engagement that the participating students showed during the class. Moreover, we would like to thank Rozan van Klaveren for presenting and sharing with the Game Lab team her extremely inspiring research topic. Last, but not least, we would like to thank the University of Silesia in Katowice for the realization, organization of the Game Lab Challenge.

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DEVELOPMENT OF 2D PLATFORM GAME BY INTERNATIONAL TEAM OF STUDENTS WITHIN GAME LAB PROJECT

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ABSTRACT: International cooperation of student teams is a great challenge and useful experience for all participants. The process of creating the playable game by people from different countries brings a lot of tasks and issues to be solved from different angles across the cultural and geographical background. Practical use of virtual communication and cooperation brings great opportunity to exchange views and ideas regardless of the distance and complexity of the actual situation in the world. Using of various platforms for communication, sharing files and documentation is necessary background of the whole project. Students had great opportunity to try out the procedures used in game industry without the stressful influence of commercial focus, they can freely develop their ideas and use their creativity. Team of organizers and mentors provided supervision of all process, prepared themes and set up the connections and communication channels and tools. Choosing of a theme that corresponds as closely as possible to nature of each student was the first step and a necessary precondition for successful and fulfilling work. All team members could use their skills on different positions in team, learn new software or try to lead other co-workers and manage their work. Cooperation and communication between seven universities was the most important goal of this project regardless of the final shape created by this cooperation. Nevertheless, an impressive series of game previews was created, which can serve as inspiration or a basis for further work and processing.

In our paper we want to describe the whole process of development of the game, the problems our team had to solve and the results, we were able to achieve depending on our possibilities and limits. Distribution of team members, setting up the communication platform and mode, discussing the first concepts, stories and ideas, creating and choosing characters, making first sketches and images, development of environment, testing of movements and animations, programming and application in engine and other activities necessary for the process of creation of the game.

Keywords: Game development, international project, creative process, team cooperation

1. INTRODUCION

Game industry is becoming an important element in the labor market in our region recently and provides many opportunities for our student to use their abilities and talents in professional practice. They get to know various art processes and technologies during their studies that they can implement in their following projects and activities.

These are the main reasons why we were very pleased to participate in the international Game Lab project. The main topic was Laboratory, in apperance on the current situation in world reflected on several levels subject of health and pandemic with its consequences such as isolation, remote communication, stress and other emotions [1]. The goal of the project was increasing expierences with the new forms of education and international cooperation.

The team of organizers and mentors from seven universities from around the world (Poland, Czech Republic, Belgium, Germany, United states, Mexico and Japan) created seven topics derived from the main theme as a basic idea for game development. Then they asked students who were interested in this area. Students were free to choose a topic and international development teams were formed on this basis. The topic we created for our team was based on idea of human soul as a laboratory, field for experiments, research and transformation. We were inspired by various traditional systems of perceiving the spiritual world coming from the area of religion, shamanism, alchemy, yoga and other concepts. We considered the way through the inner space of the human being to be a good platform for a game and we called the project Spiritual Laboratory. All teams had six month to complete their work and the time schedule was devided into six parts of one month each, which represented the various stages of development of the game (story, environment, characters, obstacles, animation, programming). Some of the activities (as programming) took place simultaneously throughout the work.

In this paper we want to demonstrate the possibilities and methods of international cooperation in the creative process, show their advantages, disadvantages and allow others to build on our experience. We will describe the topics of communication in the team, creating of the basic concept of the game, the environment, characters, animation and programming. We will also summarize our knowledge and experience from the whole process.

2. COMMUNICATION

Six students participated in our project. Mauricio Rabiella from Mexico, Hiroya Kasamatsu from Japan, Veronika Verbovská from Czech Republic, Jagoda Zirebiec, Anna Manaj and Ania Eunika Kromp form Poland. Japanese student was programmer, other students were students of arts. The team set a goal to create playable demo of the game presented in the form of short teaser.

First of all, we have to set up a communication platform. We tried several systems, but the best result we obtained using following software. Slack appeared the best solution for fast communication through chat, quick messages, sharing sketches and concepts as we can see in Figure 1. We used three channels, - General, Project and Others. General channel was mostly used for organizational information as the dates of the meetings, instructions from the organizers of the project etc. Project channel was used for discussions about work and progress, sharing samples of the fragments of the work, sketches, suggestions and comments. Other channel was used for links, notes and supplementary material.

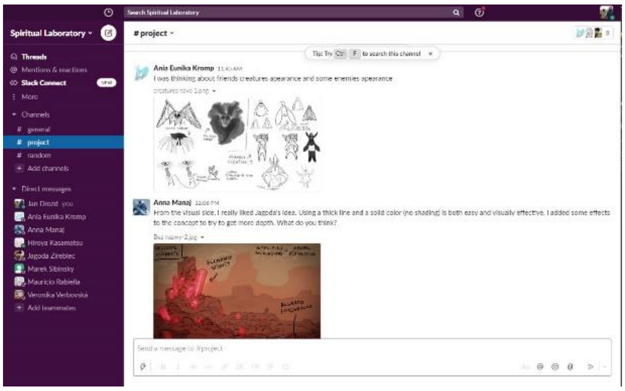

Figure 1: Communication through Slack

The best way for online meetings and discussions turned out to be Zoom, which is shown in Figure 2, because of possibility of using our university account with no time limit. We met weekly at the same time, with respect to time zones of all participant’s countries. Although such a meeting is the best right after a personal meeting (which was not possible), there have been many problems, mainly due to poor connection and sound.

Figure 2: Communication through Zoom.

The third important need was file sharing, which we solved probably the most common tool – Google disc.

During the creative process the positions in the team was distributed very naturally. Each student could choose what he wanted to work on. Sometimes, if they work simultaneously on the same task, the best result has been chosen by the other students and mentors

3. THE BASIC CONCEPT

The first step we have to work on was the basic story of the game. Each student prepared short story which described the main idea, environment and characters. After introducing it to the other members of the team, we discuss it and try to choose the best thoughts and connect it with other concepts. The idea that fascinated everyone and from which we later started was the concept of levels of the game as chakra system metaphor and the way through them [2]. Figure 3 illustrates this preparatory phase.

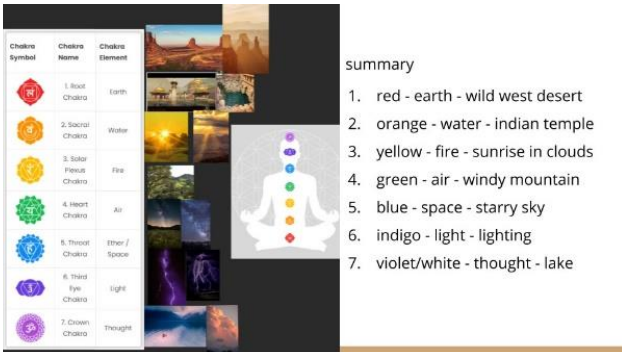

Figure 3: Basic concept

The hero – player is a shapeless ghostlike creature coming into inner space of a man from the World of Ideas (hidden world, which is just a mental background for the main environment of the game). The idea is based on Plato's concept [3]. He is going through the damaged and devastated world occupied by various creatures which represent good and evil forces in human psyche. Hero is able to take form of any being and use it's skills for the fight against the bad ones. He is collecting souls during his way and he can use these as a weapon or energy source. Allies help him on the way, they teach him how to use his skills and how to fight. Each level has a portal which is blocked by the evil boss and should be unblocked to get to another level. The game ends when the hero unblocks all chakras and free the souls – energy to liberate the human soul.

4. ENVIRONMENT

After first discussions we decided to create 2d platform game. It was essential step, because then the first sketches and images of the game environment could be designed. Character of each level was based on chakra system, as was mentioned before, which was manifested in color tuning and material of the surface which is shown in Figure 4. The idea of crystal of minerals as a base of each level surface was great, because it can be well recognized and adapted to chakra theory.

Figure 4: The third level appearance

The colors and other attributes of each chakra was implemented into the environment design and the view was arranged into separated layers as we can see in Figure 5, so the effect of perspective was made through the moving of each level. The first level was the crystal cave, when hero appears in the world of the game. He reaches first skills and knowledge here and the player can practice to control of the game.

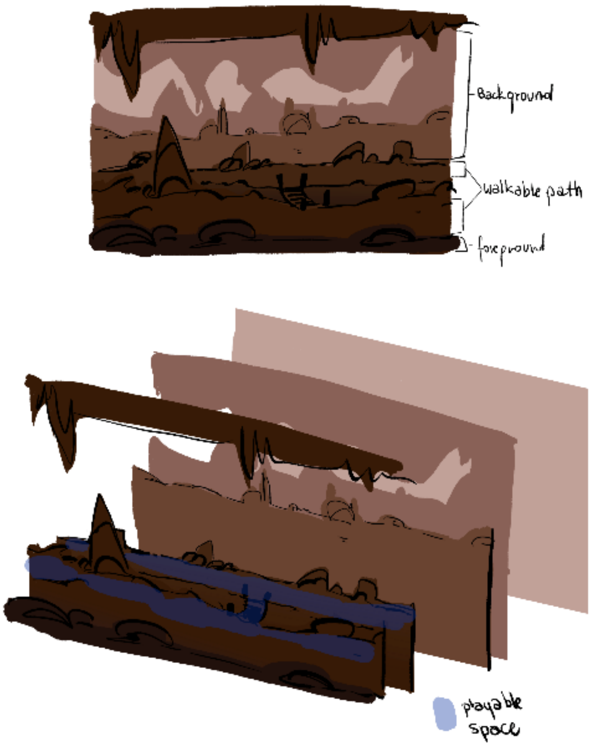

Figure 5: Layers of the level view

5. CHARACTERS

5.1 Hero

The main character is ghostlike being as mentioned above. Its form is probably based on the traditional symbolic appearance of the human soul. The first sketches of the hero are shown in Figure 6.

Figure 6: Sketches of the main character

5.2 Enemies and allies

Other characters in the game represent our inner powers and abilities and their appearance was mostly based on appearance of the creatures from the nature, such as plants, mushrooms and various animals. Hero can take the form of each creature and use their skills for the fight and overcoming obstacles.

Enemies represent our fears, phobias and other dark parts of our soul. One example is shown in Figure 7.

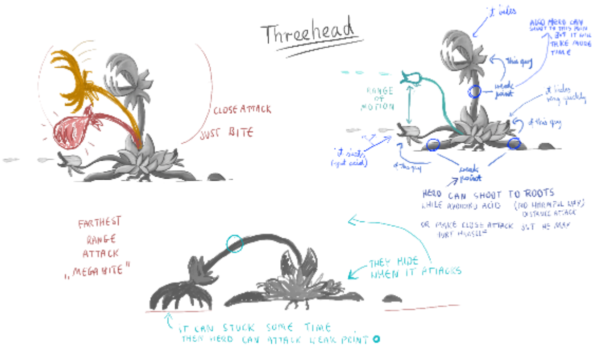

Figure 7: An example of the enemy

Allies represent the good powers and properties inside us. They can teach hero various skills or help him to defeat the enemies. An example of the allie is shown in Figure 8.

Figure 8: An example of the allie

6. ANIMATION AND PROGRAMMING

After the final design of characters, environment and obstacles has been created, some members of the team started to prepare animations. Our programmer then made the tests of movements of the objects in the game and background as we can see in Figure 9. These are the final products of our work. Unfortunately, we were close to the deadline of our project and even though we did everything in our power, we could not reach the result that we set out in the beginning of our work – making a playable demo of the game.

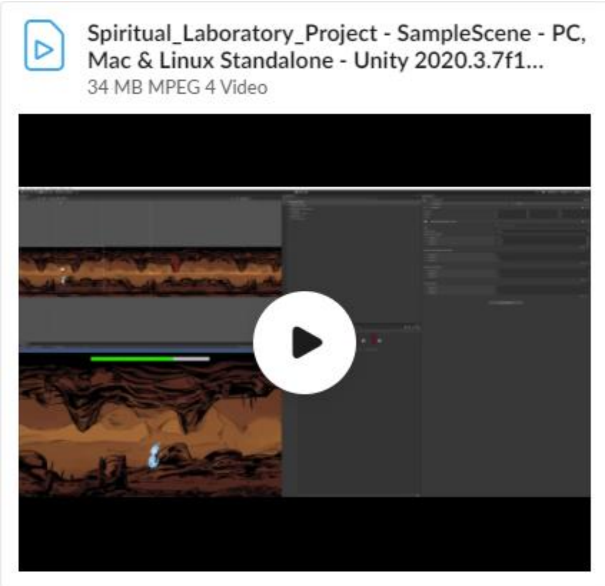

Figure 9: A test of the background movement.

7. CONCLUSIONS

Although we didn't fulfill all expected effects, we are convinced that our cooperation has a big influence and brough great results for all participants. Our team managed to get very close to the goal of the project and created a lot of useful materials. A very elaborate description of the first level of the game was created, based on a comprehensive story. A complete environment of the first level of the game was created as well as all characters that appear in it. Samples of animations of the characters and movements of the background were also created. At the area of education, we learned a lot about leading the teamwork and about process of the game development and we should have to learn from our mistakes too. The effect we didn't achieve was fully functional game control and commissioning of all game parts. We consider the distribution of positions or "professions" between teams at the beginning of the work to be the biggest weakness of the whole process. The lack of programmers in the team has proven a key issue in achieving the desired goal. Also the total time needed to finish the work proved to be insufficient and should be set according to the number of members of each team. In the end, however, it turns out, that the main goal is the process itself. All participants have undoubtedly acquired new knowledge and skills that they can apply in future work. The communication and cooperation in the international team was undoubtedly great challenge which brought us important experiences for our further projects and realizations.

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POST MORTEM: DISTRIBUTED GAME DEVELOPMENT IN INTERCULTURAL STUDENT TEAMS

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ABSTRACT: The project 'GAME LAB – International Laboratory for Game Studies and Design' was established in 2020 as a collaboration of 7 international Universities. To exchange experiences on didactics and teamwork, the first phase of the project consisted of GAME LAB mentors running workshop projects with student teams, each composed of students from the various partner Universities. But working with such interdisciplinary student teams, between multiple timezones, languages and cultures, poses various challenges. It requires new approaches to team building, organization, communication as well as different strategies for creative collaboration. The utility of developing such methodologies is also increasingly relevant in the game industry, as the potential benefits of 'distributed game development' have been recognized by AAA and independent game development studios alike. After all, a large number of contemporary videogames are developed as collaborations of various international companies and specialists. Therefore, the educational value of experiencing the intercultural differences and the challenges of distributed teamwork during student projects – as well as finding methods to deal with them – extends beyond academia. This lecture will report on our experiences, on the tools and workflows we used and our lessons learned.

Keywords: Game Design, Distributed Game Development, Intercultural Teamwork, Game Design Education