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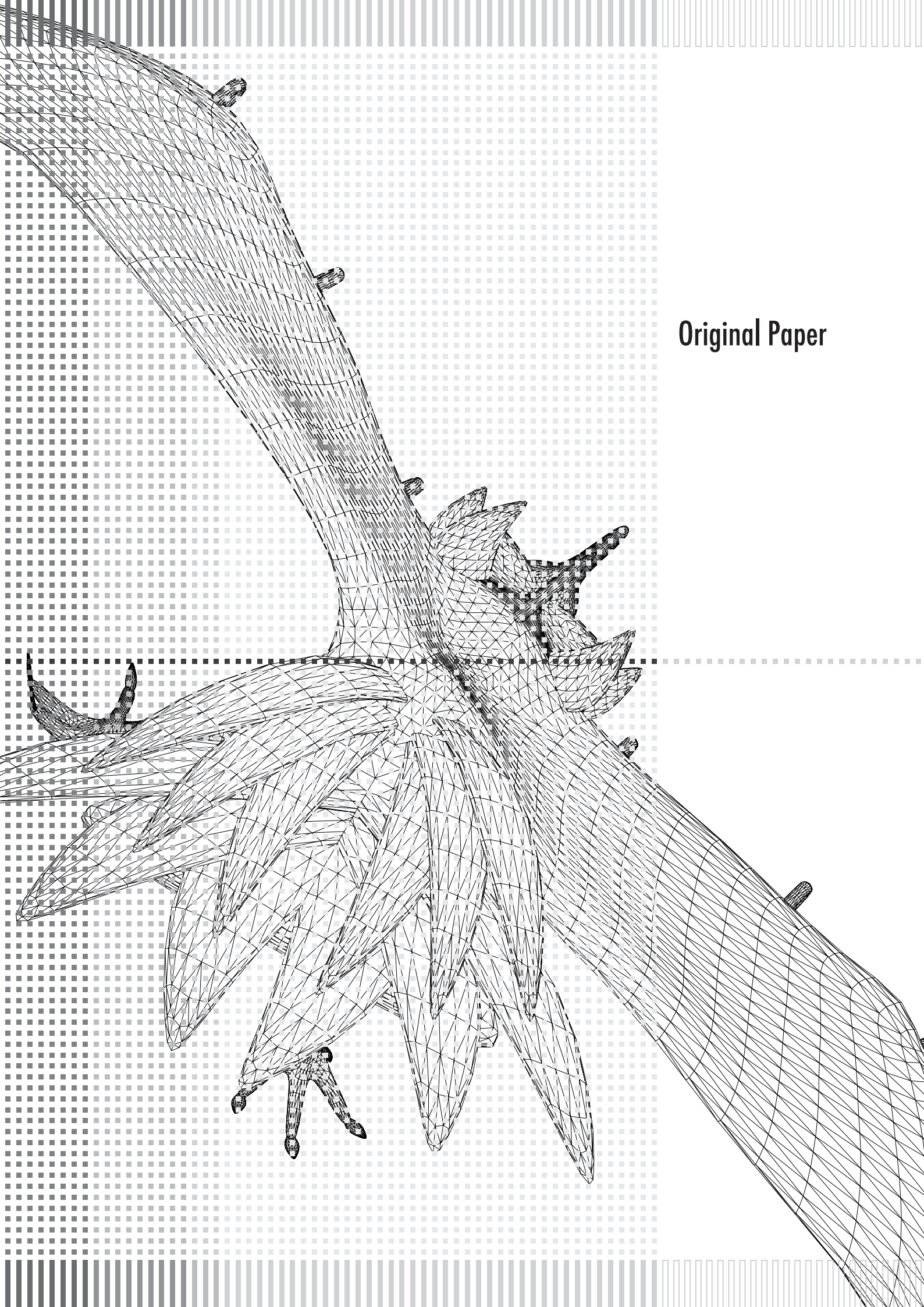
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Categories for paper

- **Original Article** A paper in this category has to be a logical and empirical report of the study, the review and the proposal by the author on the issue of digital art and design based on media technology. It also has to include the novelty and academic values which can be shared with ADADA members or the people who study digital art and design.
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Number of pages: 6 -10



Original Paper

ROBOT CHARACTER DESIGN SIMULATION SYSTEM USING 3D PARTS MODELS

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Abstract

The purpose of this research is the design support for robot on animation. We have developed a simulation system that can make a new robot design with a combine of the 3DCG robot parts and a deforming each part. Therefore, we investigated the parts of the robot that appeared in an existing animation. Furthermore, we classify the parts of the robot and created a 3DCG model of robot parts. In addition, we have developed a simulation system as a plug-in for 3dsmax.

Keywords: Character Making, Robot Character Design, 3DCG

1 Introduction

The TV series animation in Japan has been started from the "Astro Boy" in 1963. Hero of "Astro Boy" was a humanoid robot. TV series animation in 2015 has been broadcast annually about 200 works of various genres, such as "sports", "SF", "comedy", "school", "idle", "magical girl". In addition, there is a genre called "robot animation" as one of the genre. The genre of robot anime is that "giant robot" appeared on animation. The anime in appeared of "robot" that has been made the many animation work to date such as "Mobile Suit Gundam," "Macross," "Neon Genesis Evangelion". The robot is completely fictional character unlike human character. Because, giant robot does not exist in the real world. Therefore, it is necessary to professional and special knowledge on the design of the robot [1]. In many cases of the anime character design is carried out based on the meeting of the director and the producer and the designer. This meeting is very important for the character design. But, if the director or the producer isn't skillful to a drawing, the director or the producer must convey the request to the designers at words and literal material. This issue is the same in the production site of the robot anime [2].

When the director and the producer cannot present visual information to the designers, communication gap occurs. As a result, the production schedule is delayed.

In order to solve this problem, we develop a simulation system that can make a draft of the robot designs using 3DCG model for the director and the producer. Therefore, we investigated the parts of the robot that appeared in an existing animation. And we classify the parts of the robot and created a 3DCG model of robot parts. In addition, we have developed a simulation system as a plug-in for 3dsmax. This system can make draft of new

robot design with combine 3DCG robot parts and deforming each part.

2 Existing methods and previous research

In this chapter, we describe a method relating to the robot design. Hayashi wrote a book about the technique to draw a robot [3]. Hayashi classified basic parts for each part of the robot. Furthermore, he proposed a method of drawing a robot by combining the parts of the robot. Kanematsu et al. [4] created a pose library based on the analysis of the pose of the existing robot to support robot pose. Tominaga et al. [5] made a 3DCG model of parts that Hayashi was classify. In addition, he analyzed the robot that appeared in the existing animation. Then, he made more 3DCG parts based on the results of the analysis. Finally, he developed a system that can interchange or deformation of 3DCG parts of the robot. However, this system has some problems. For example, it is not possible to correct the position of a multiple parts at the same time. In addition, this system cannot make asymmetrical robot.

In this research, we collected the existing robot. Furthermore, we analyzed whole body of the robot. Moreover, we perform the classification and pattern of the robot parts. Based on the result, we create a 3D model for each part. Finally, we developed robot design simulator that be able to swapping, deformation, and movement of the robot parts. Our purpose to solve the problem of existing research and develop more easy-to-use system. Our system is able to make more detail draft of robot design more easily.

3 Analysis of robot design and modeling of 3DCG parts

Our purpose of this research is development of simulator that is

able to create draft of robot design by 3DCG robot parts combination and deforming.

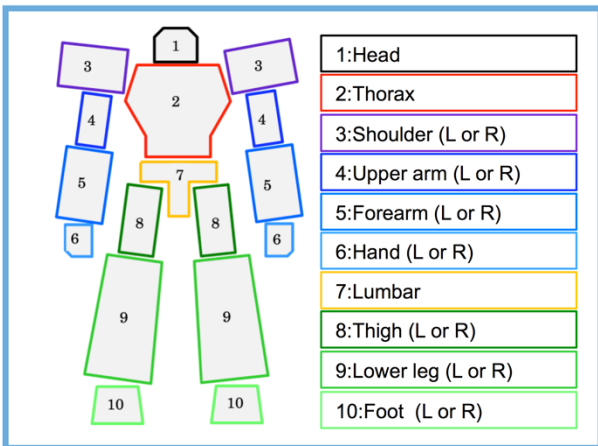


Figure 1 Robot Parts

Table 1 The Research List of Existing Robots

NO.	Title	Copyright	Robots
1	エウレカセブンAO Eureka Seven AO	©2013 BONES/Project EUREKA AO-MBS	3
2	機動戦士ガンダムAGE Mobile Suit Gundam AGE	©創通・サンライズ・MBS © SOTSU Sunrise・MBS	43
3	STAR DRIVER 輝きのタクト STAR DRIVER shine of tact	©BONES/STAR DRIVER制作委員会・MBS © BONES / STAR DRIVER Production Committee・MBS	6
4	ノブナガ・ザ・フール Nobunaga The Fool	©河森正治・サテライト/ALC/GP/ノブナガ・ザ・フール制作委員会・© Kawamori Shoji Satellite / ALC / GP / Nobunaga The Fool Production Committee	5
5	パディ・コンプレックス Buddy Complex	©SUNRISE/BUDDY COMPLEX COMMITTEE	11
6	革命機ヴァルヴレイヴ Valvrave The Liberator	© SUNRISE/VVV Committee, MBS	6
7	銀河機攻隊マジスティックプリンス Majestic Prince	©創通・フィールズ/MJP制作委員会 © SOTSU Fields / MJP Production Committee	10
8	翠星のガルガンティア Gargantia on the Verdurous Planet	©オケアノス/翠星のガルガンティア制作委員会 © Oceanus / "Gargantia on the Verdurous Planet" Production Committee	2
9	GEAR戦士電童 GEAR warrior 電童	©サンライズ © Sunrise	2
10	アイドルマスターゼノグラシア Idol Master Zeno Gracia	©サンライズ・バンダイビジュアル © Sunrise Bandai Visual	4
11	コードギアス反逆のルルーシュ Code Geass	©SUNRISE/PROJECT GEASS-MBS	9
12	コードギアス反逆のルルーシュR2 Code Geass R2	©SUNRISE/PROJECT GEASS-MBS	18
13	ゼーガペイン Zegapain	©サンライズ・プロジェクトゼーガ © Sunrise project Zega	3
14	ヒロイック・エイジ Heroic Age	©XEBEC・アルゴノートクルー © XEBEC・Argonaut crew	3
15	機動戦士ガンダム00 Mobile Suit Gundam 00	©創通・サンライズ・毎日放送 © SOTSU Sunrise Mainichi Broadcasting System	39
16	機動戦士ガンダムSEED Mobile Suit Gundam SEED	©創通・サンライズ © SOTSU Sunrise	21
17	機動戦士ガンダムSEEDDESTINY Mobile Suit Gundam SEED DESTINY	©創通・サンライズ © SOTSU Sunrise	22
18	交響詩篇エウレカセブン Eureka	©2005 BONES/PROJECT EUREKA-MBS	8
19	鋼鉄神ジージ Kotetsushin Jeeg	©永井豪/ダイナミック企画・ビルドベース © Go Nagai / Dynamic Planning and build base	1
20	創聖のアクエリオン Aquarion	©2004 河森正治・サテライト/Project AQUARION © 2004 Kawamori Shoji Satellite / Project AQUARION	3
21	蒼穹のファフナー Fafner	©XEBEC・竜宮島役場 © XEBEC・Ryugujima Yakuba	1
22	天元突破グレンラガン Gurren Lagann	©GAINAX・中島かずき/アニプレックス・KDE-J・テレビ東京・電通・© GAINAX・Kazuki Nakashima / Aniplex・KDE-J・TV Tokyo, Dentsu	6

First step of this analysis, we were collecting 226 robots image from 22 title of anime for modeling 3DCG robot parts. Table 1 is list of robot anime used in this analysis.

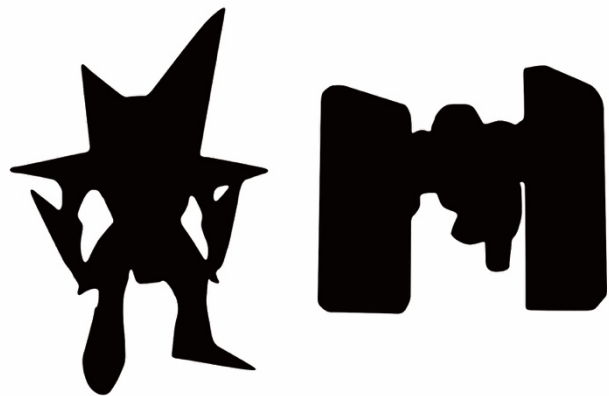


Figure 2 Example of Excluded Robots

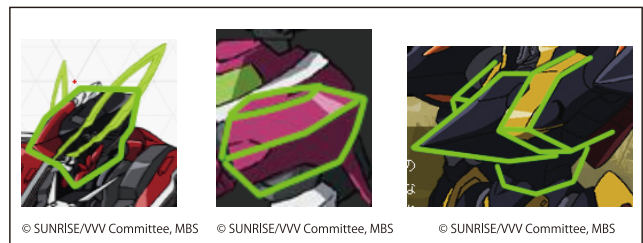


Figure 3 Analysis Methods of the Parts Shape

Second step in this analysis, we divide whole body of robot to each part, as shown in Figure 1. We divided the parts of robot to 10 body regions based on result of research.

"1: Head", "2: Thorax", "3: Shoulder", "4: Upper arm", "5: Forearm", "6: Hand", "7: Lumbar", "8: Thigh", "9: Lower leg (shin)", and "10: Foot".

In this paper, we focused on robots with these 10 body regions. We did not focus a robot that does not have all of these 10 body regions, as shown in Figure 2. The third step of this analysis, we investigated the shape of parts by drawing a line, as shown in Figure 3. In addition, we were detail classification using the common elements of the shape of the parts.

In this paper, we focused on the front and obliquely forward design of the robot. We did not focus on the rear-view design. Table 2 is the result of a detailed classification of shape of the robot parts.

The result of comparing the shape of the robot parts, we classified the shape of robot parts to 75 classifications. Because the upper arm is between the relatively large shoulder parts and forearm parts, any robot was a simple shape due to the range of motion. Therefore, the upper arm could be classified into two types. As shown in Table 2,

Table 2 2D Image Parts List

Parts name	1	2	3	4	5	6	7	8	9	10	11
Head											
Thorax											
Shoulder(L or R)											
Upper arm (L or R)											
Forearm (L or R)											
Hnad(L or R)											
Lumbar											
Thigh (L or R)											
Lower leg (L or R)											
Foot (L or R)											

Table 3 3D Image Parts List

Parts name	1	2	3	4	5	6	7	8	9	10	11
Head											
Thorax											
Shoulder (L or R)											
Upper arm (L or R)											
Forearm (L or R)											
Hnad(L or R)											
Lumbar											
Thigh (L or R)											
Lower leg (L or R)											
Foot (L or R)											

"Head" has 7 type shape classification, "Thorax" has 11 type shape classification, "Shoulder" has 11 type shape classification, "Upper arm" has 2 type shape classification, "Forearm" has 9 type shape classification, "Hand" has 6 type shape classification, "Lumber" has 8 type shape classification, "Thigh" has 5 type shape classification, "Lower leg" has 7 type shape classification, and "Foot" has 9 type shape classification. The first page must contain the paper's title, authors and their affiliations, the short

abstract and keywords.

Based on the analysis and classification results of existing robot parts described in Chapter 3, we have created a 3DCG model for simulation. We drew a three-view drawing of each part from images like Figure 3 or Table 2. As shown in Table 3, based on these three views drawing, we created 3DCG robot parts using 3DCG software.

Figure 5 is the execution interface of the system. The user of

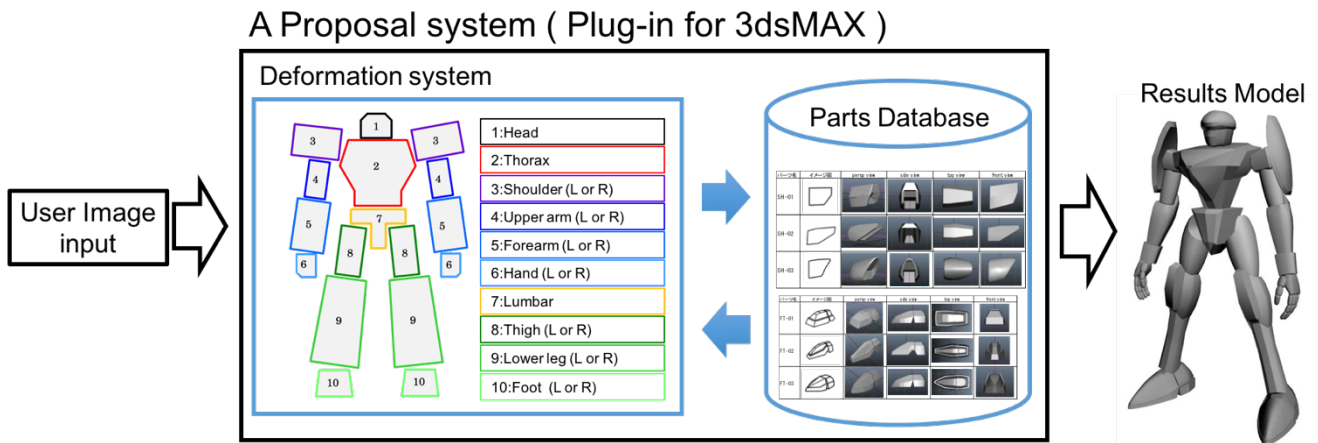


Figure 4 The System Summary

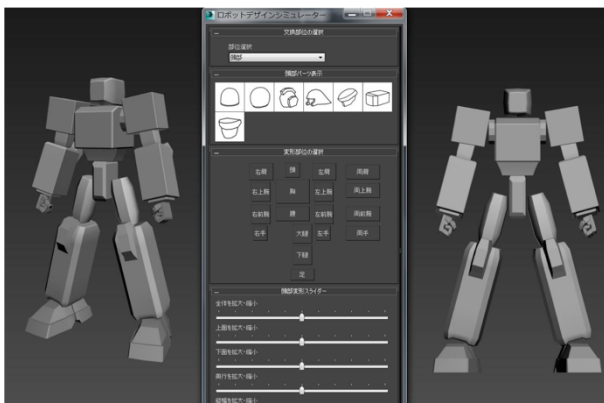


Figure 5 The Startup Screen

4 Proposal system

In this chapter, describe the simulation system that we propose. Our system is able to create draft of new robot design with robot parts replacement, transform, and change of the position. Our system was developed based on the system of the previous studies [5]. However, our system is possible to changing position of robot parts during deformation and reate asymmetry robot. In other words, our system is not having problems of existing research. Figure 4 is overview of our system. This system is a plug-in written in “Max Script” for 3dsmax. The user of this system can create any draft of robot design by repeating the simulation using this system.

Production procedures are as follows.

1. Select the parts of the robot.
2. Select a part of the body region of objective from the parts database.
3. Parts to transform into any shape.
4. To design the overall shape of the robot by using the 1-3 steps.
5. The output of the model that if the design has been determined.

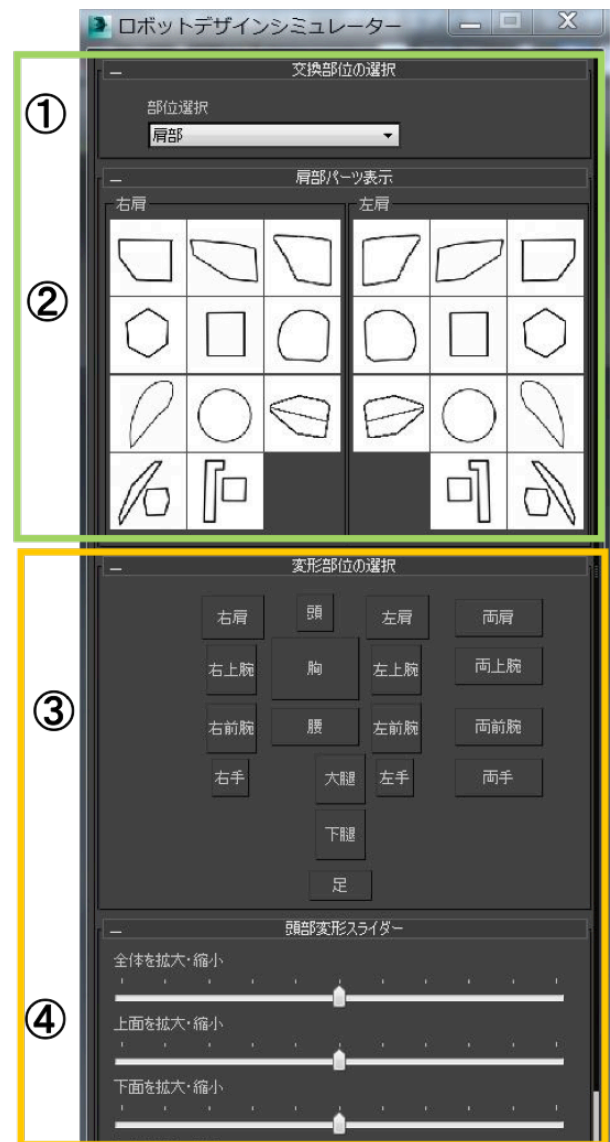


Figure 6 The Interface of Design Simulator

this system can manipulate replacement and deformation of robot parts using the buttons and sliders at the center of the Figure 5.

Figure 6 is the control panel of our simulation system. User operates the simulation in four steps using this control panel.

1. Selection of body region that the user wants to change parts
2. Selection of robot parts that the user wants to use

3. Selection of body region that the user wants to deform the shape of robot parts
4. Deforming the shape of the robot parts using the slider

By repeat these four steps, the user can create any draft of robot design.

5 Demonstration experiment

In this chapter, we describe the demonstration experiment.

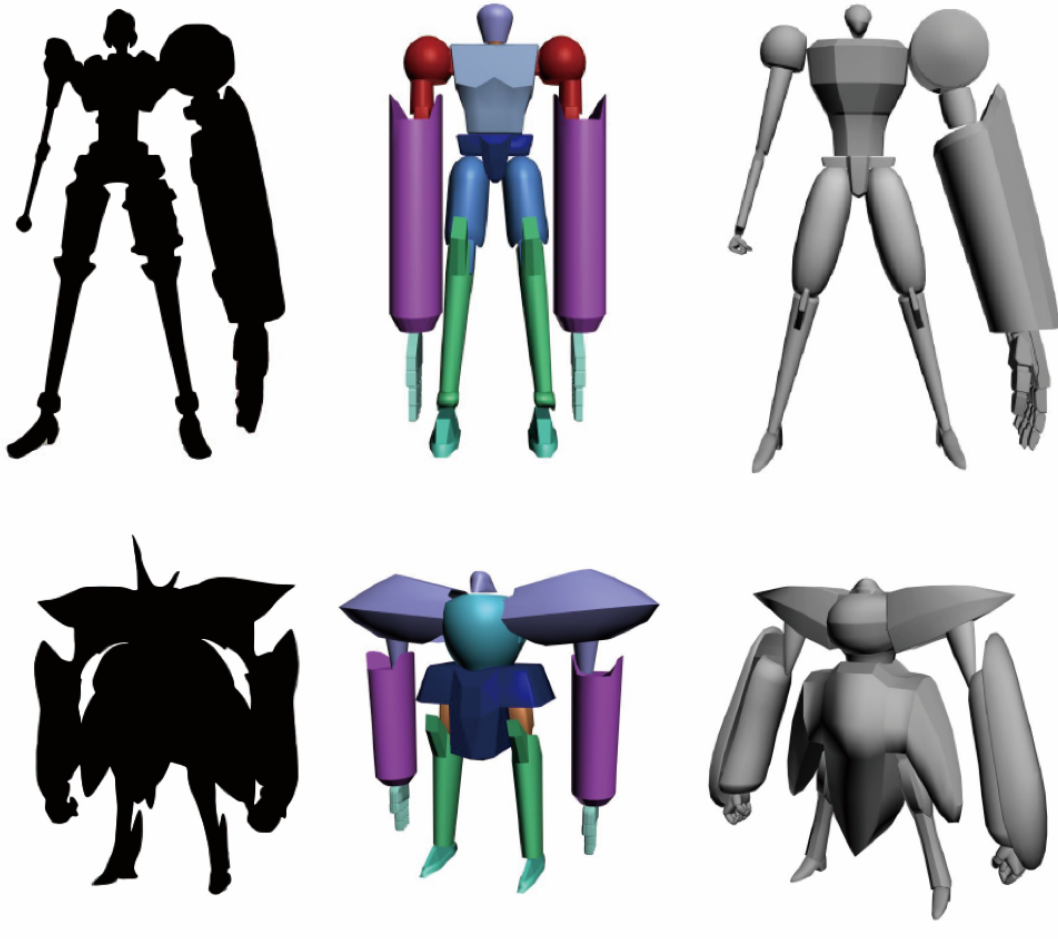


Figure 7 Result of the Experiment 1

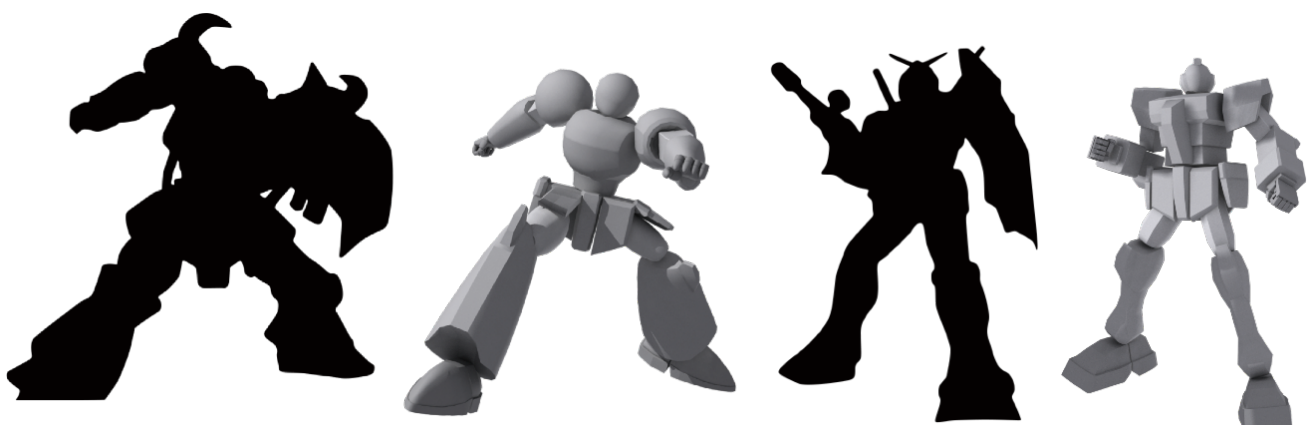


Figure 8 Result of the Experiment 2

We created the existing robot using our proposal system and system of previous research. In addition, we compared the image of a robot made with two systems.

Our system is a simulator for visualizing user's imagination about robot design. The most important thing for system of visualizing user's imagination is function that is able to create various shape robots. Therefore, we confirmed possibility of visualizing user's imagination by this experiment. Because, impossible to show the image that was imagined in user's head to others.

Figure 7 is an example of a simulation of an existing robot. We experimented with 10 robots using our system and system of previous research. Result of the experiment, our system is able to reproduce the existing robot with more short time and more high quality.

Figure 8 is another experimental result. We conducted a simulation experiment with poses of existing robot characters using our created system.

6 Conclusion

In this study, we found a common part for each part based on analysis of each part of the robot that appeared in the existing animation. Based on as a result, we were carrying out classification and pattern of the robot parts. Furthermore, we were creating the robot parts of 3DCG model. We have developed a simulation system that can to make a new robot design with a combine of the 3DCG robot parts and a deforming each part. We examined each body region of the robot that appeared in the existing animation. Furthermore, we classified shape of robot parts for find a common part of each body regions.

We were modeling the 3DCG robot parts based on the results of the analysis. In addition, we developed simulation system that is able to replacement, deformation, changing position of robot parts.

As a result, we have improved a problem of previous research. The main result of this system is four of the following.

1. System of previous research has a problem that too few of robot parts for simulation. We added robot parts. Robot parts increased from 45 types to 75 types.
2. Users intuitively become possible to select a robot parts because we made a button that icon of the image of the robot parts. As a result, efficiency has increased because the user does not need to see the robot parts list repeatedly.
3. In system of previous research, all body regions are independent. Therefore, after transforming the parent parts, it is necessary to adjust the position of the child parts. In our system, we have implemented a parent-child relationship of body regions. As a result, it is possible to eliminate unnecessary work.
4. Our system can create asymmetrical robot. Increased the type of combination of robot parts by increase in the

types of robot parts.

As a result, even if user is unskillful of drawing, our system can create robot design draft with more detail and short time.

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Garden Aqua: Tangible user interface study using levitation

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Abstract

Garden Aqua is a tangible user interface (TUI) that interacts with several balls floating over a water stream. Water is pumped up from the nozzles of several water pumps, and the ball floats above the water stream as a medium. The motion sensor at the top of the Garden Aqua detects the user's hand gesture, and the sensor allows the user to change the position of the ball and adjust the height of the water stream in real time. To apply Garden Aqua system to application works, we have created the Tone Matrix which composes a music of symphonious harmony using a user's hand position and motion. And it was exhibited at Siggraph Asia 2013. In addition, we analyzed the elements of TUI framework of two representative studies and Tone Matrix. Tone Matrix has most elements of TUI. The partially contained haptic direct manipulation element can be supplemented by an intuitive gesture control using motion sensors. It is expected that this study helps carry out further studies on TUI in practice and by analyzing TUI elements.

Keywords: Tangible user interface, TUI, Levitation, Ambient display, 3D interface, Image processing.

1 Introduction

In recent years, studies on Tangible User Interface (TUI) are constantly evolving. Different with the while existing Graphic User Interface (GUI) which deals with digital information such as a keyboard, a mouse and a monitor. TUI uses the abundant human sense of sight, hearing, touch, and body to connect the digital world with the physical world through actual interaction such as tactile manipulation and physical expression [1]. Users can interact with the digital world by combining with digital information through media of ordinary objects such like sound, light, air and water that are made up of atoms in the real world. It is considered as the main difference with the existing graphic interface [2].

Many studies on tangible interface have been carried out to embody its prototype and to develop the new system so far, however, their interactions with physical objects have been mostly performed on a two-dimensional surface. In the study by Jinha Lee and Tobias Alrøe, it was determined that the physical interaction with a user is feasible on a three-dimensional space through a levitation using various media as going beyond the boundary that the interaction is feasible only on a two-dimensional space [3,4].

In this study, the medium for the levitation of Garden Aqua system is water (Figure 1). Water is a substance that we interact frequently in our daily lives. Water fountains have been set up for public arts and entertainment from ancient times, and they have been created in various shapes from differences of the

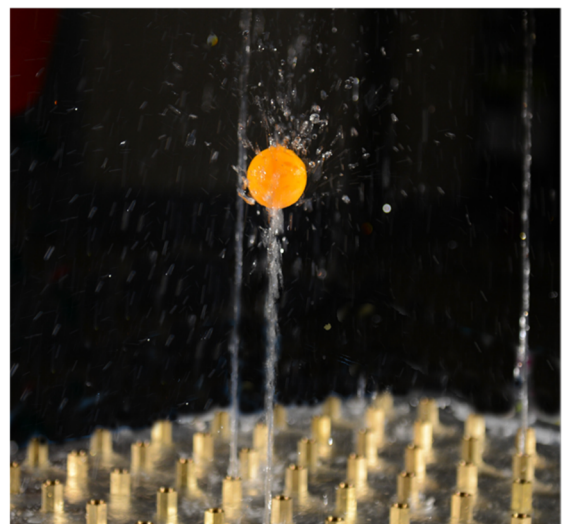


Figure 1 Levitation of Garden Aqua system using water as a medium

height or forms of the water streams. Garden Aqua system is a new type of TUI system that blends physical objects and digital virtual information in a 3-dimensional space. This system uses water stream to control the height of the water stream and the movement of levitating balls. In order to develop Garden Aqua system, it needs to design 5 elements as follows. Ball levitation using water, vertical height control, hand tracking, lighting system and 3-D calibration are essentially required. Accordingly, we present Garden Aqua system, which is a 3D TUI system using water levitation. And we produced a Tone

Matrix, which is a work designed by Garden Aqua system. The purpose of this study is to construct a research method of 3D TUI system through a series of processes for design, production and analysis by displaying the manufactured tone matrix and analyzing it according to TUI framework elements.

2 Background

2.1 Tangible user interface

Tangible User Interface (TUI) enables to embody an interface that is impossible for computer to express by itself as connecting digital environment to physical environment [5]. TUI provides an interface for specific application using a real physical form while Graphic User Interface (GUI) means an interface by a number of tools composed of pixels of a screen. That is, TUI can provide an interface that exactly match up with a user's physical environment while GUI should take unnecessary works to match to lots of interfaces [2].

Hornecker (2006) suggested the Framework of TUI [6]. As shown in (Table 1), the TUI Framework is classified into 4 categories; Tangible Manipulation, Spatial Interaction, Embodied Facilitation and Expressive Representation. The first category, Tangible Manipulation, is for smooth operability and reaction of the interface, i.e., how much a user express the tangible interaction physically. The second category, Spatial Interaction, is for applied tangible interaction in a real space and for movement of the interaction in the space. The third category, Embodied Facilitation, is for how much the material and spatial compositions of the product have an influence on users (or gallery)'s collective behavior. The last category, Expressive Representation, is for the expression and comprehension levels of elements and digital representation used in TUI. It was

Table 1 TUI framework

Category	Element	Contents
Tangible Manipulation	Haptic Direct Manipulation	Can users grab, feel and move the 'important elements'?
	Lightweight Interaction	Can users proceed in small, experimental steps? Is there rapid feedback during interacting?
	Isomorph Effects	How easy is it to understand the relation between actions and their effects?
Spatial Interaction	Inhabited Space	Do people and objects meet? Is it a meaningful place?
	Configurable Materials	Can we configure the space at all and appropriate it by doing so?
	Non-fragmented Visibility	Can everybody see what's happening and follow the visual references?
	Full Body Interaction	Can you use your whole body?
Embodied Facilitation	Performative Action	Can you communicate something through your body movement while doing what you do?
	Embodied Constraints	Does the physical set-up lead users to collaborate by subtly constraining their behavior?
	Multiple Access Points	Can all users see what is going on and get their hands on the central objects of interest?
Expressive representation	Tailored Representations	Does the representation build on users' experience?
	Representational Significance	Are representations meaningful and of long-lasting importance?
	Externalization	Can users think and talk with or through objects, using them as props to act with?
	Perceived Coupling	Is there a clear link between what you do and what happens?

emphasized that the representation results induced from actions applied in practice should be connected smoothly and definitely connect.

2.2 Levitation

A well-known work on levitation is the "ZeroN" (Figure2a). Using magnetic levitation, which has been studied for a long time, the object has been floated in the air, and the object has been further developed to change the magnitude of the magnetic field according to the position of the object. In addition, by reading the depth value of an object through an infrared camera, a user can read the position of the object in a three-dimensional space as well as a two-dimensional plane by moving the object within the magnetic field. Through this two technology, a natural moving in the air was enabled not influenced by gravity. ZeroN also can be applied in several ways. It changed the simulation of physical phenomenon that only possible in the virtual world to the type as possible in the real world. Or through ZeroN system, it can be provided physical layout of buildings at architectural field and manipulate the essential components such as lighting and camera at the same time. That was impossible in the existing real-type interface system.

Another study of aerial support is "Aerial Tunes" (Figure2b). As the author stated, "In Aerial Tunes we expect the magic of the floating balls to be intriguing as much as the people interacting with the installation for the people watching it". Aerial Tunes system is a more artistic and magical expression than technical expression.

Aerial Tunes consists of six cubes and bubble balls. Each cube includes a sensor that checks for distance and movement, and a

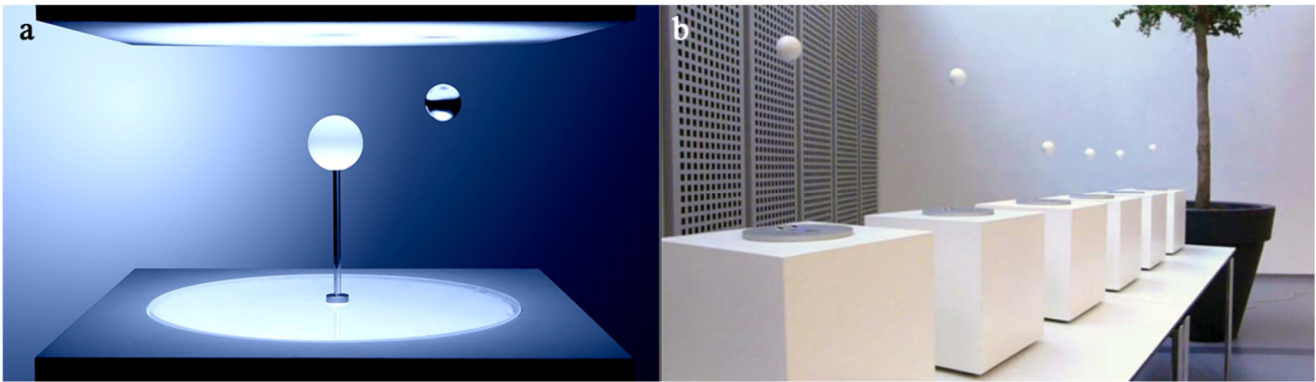


Figure 2 (a) ZeroN, (b) Aerial Tunes

blower that can wind vertically. The wind from the underlying blower caused the ball to float in the air. The sound is produced and reproduced according to the height and position of the ball. The six boxes used the same algorithm, but the sound being played is mixed into a stereo soundscape in accordance to the (in the audio software predefined) physical position of the cube in relation to the speakers. This makes the soundscape seem more spacious to the audience.) Aerial Tunes made abstract mood by using the inspired sound from a wind bell and Tibetan songs.

2.3 Tone matrix

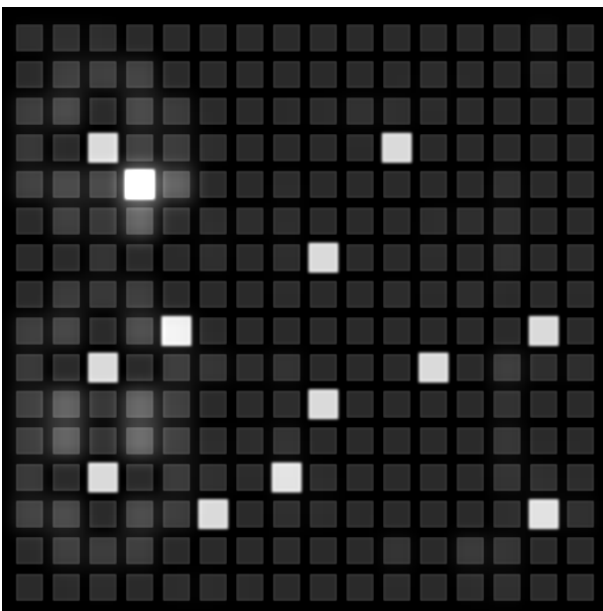


Figure 3 Tone Matrix

Tone Matrix is a tool for creating harmonious music with simple user interaction (Figure 3). There are 256 cells of 16 cells on X-axis for time and 16 cells on Y-axis for scale. Through a mouse, a user can produce music as turning each cell on or off. The music is played as follows; a cell focused on X-axis moves one cell from the left to the right. When arrived at the end of X-axis, the cell returns to the initial point and moves from the left to the right again. If the X value of the cell is focused on, and if the cell is turned on, the corresponding note is played. If a user selects several cells, the corresponding notes with the cells are

played repeatedly along the X-axis. If harmonious notes on Y-axis are arranged differently although the same cells on X-axis are selected, finally beautiful music can be produced.

3 Design

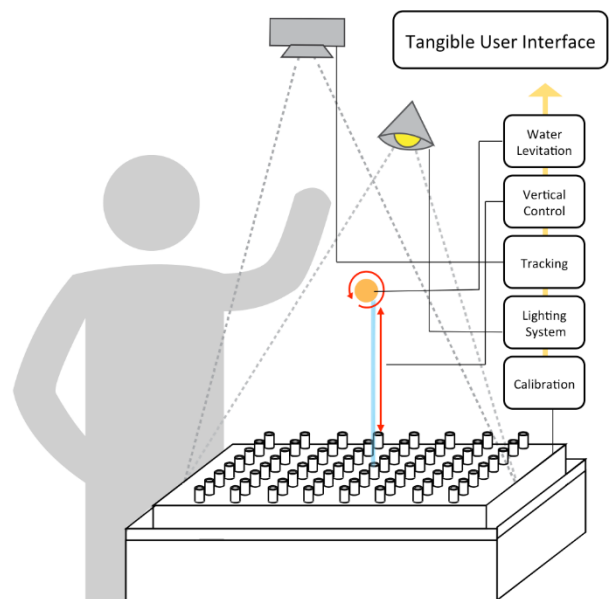


Figure 4 Design of Garden Aqua

Garden Aqua system uses water as a levitation medium, so it is necessary to put the lower section of the device in water. Each pump motor of the lower section sucks up water, and the sucked water takes the shape of each water streams, then be shoot up. A depth camera installed downward from the upper side of the Garden Aqua is installed to recognize the user's hand, thereby changing the height of the water stream. This allows the user to place the ball in any part of the space, recognize the hand with a depth camera, automatically draw the water, and place the ball on the water stream. The lighting system also illuminates each ball and stream to make them more visible. The design method is illustrated in (Figure 4).

3.1 Levitation

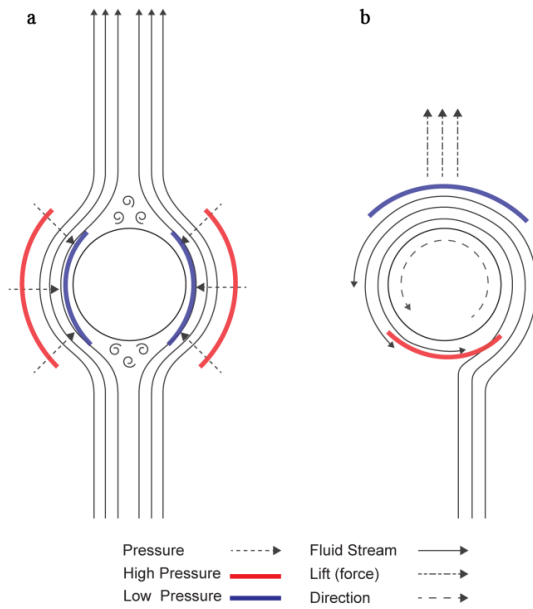


Figure 5 Principle of levitation

As shown in (Figure 5), when the user puts the ball on the water stream in the same direction, the ball keeps going up and down on the water stream, and does not fall down, and keeps its position continuously. This is because the pressure of the moving fluid (water) is greater than the pressure of the stationary gas (air). As you can see in (Figure 5a), the water is passing on both sides of the ball. This phenomenon is likewise because the pressure of the outer water moving forward is stronger than the pressure of the air between the ball and the water, so that the ball does not fall out and the ball stops moving inside the moving water.

The phenomenon shown in (Figure 5b) is a phenomenon applying the phenomenon shown in (Figure 5a). The levitation phenomenon is applied to a ball on a single stream. When the water rises up the ball, the outside air is applied with a weak pressure, and at the same time strong water pressure is applied to the water coming down the ball, causing the ball to continually circulate in one place due to the difference in pressure. In addition, due to the surface tension of the water, the sphere always rotates in the same direction, and the fluid velocity at the upper and lower sides is changed to generate lift.

$$L = \frac{1}{2} \rho V^2 AC$$

- L : Lift Force
- ρ : Fluid density
- V : Stream velocity
- A : Area of sphere
- C : Lift coefficient

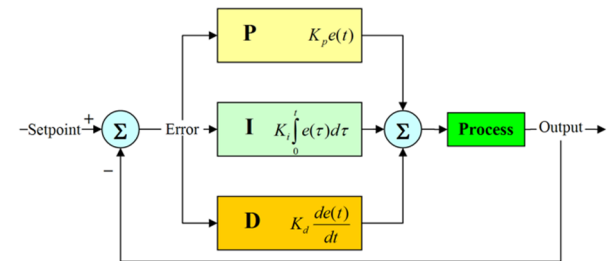
Figure 6 Formula of lift force

As shown in (Figure 5), lift becomes stronger as fluid density,

fluid velocity, and contact area increase.

3.2 Vertical height control

The ball should be used that has enough mass can be levitate. The mass is inversely proportional to acceleration when given the force ($F=ma$). In Garden Aqua, this formula is to be used also. In other words, when the ball receives levitate force(F) then receives acceleration(A) to float in the air. This acceleration(A) is inversely proportional to the mass of the ball, so, even if the pressures of the water stream are the same, the lighter mass can given the more acceleration caused by levitate force, the higher the height of the ball's floating.



$$u(t) = MV(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{d}{dt} e(t)$$

Defining $u(t)$ as the controller output, the final form of the PID algorithm is :

- K_p : Proportional gain, a tuning parameter
- K_i : Integral gain, a tuning parameter
- K_d : Derivative gain, a tuning parameter
- e : Error = SP - PV
- t : Time or instantaneous time (the present)
- τ : Variable of integration; takes on values from time 0 to the present t.

Figure 7 Formula of PID algorithm

The height of the water stream can be changed by control of water pressure that can be controlled directly by pump motor. At this time, the formula of PID Algorithm such as (Figure 7) is applied.

3.3 Hand tracking and light system

When a user tries to place a ball on a water stream coming from a nozzle installed at the bottom of the Garden Aqua, the water stream of the nozzle is automatically raised to a suitable position. Then the user can intuitively put the ball on the water stream of the desired height easily. It allows to recognize the position and the shape of the user's hand and to control the water stream by processing images using a depth camera installed on the top of Garden Aqua.

The processing images using a depth camera is the followings; as shown in (Figure 8), images are input into the camera in real time. In the image frame including the hand, objects except the hand are extracted in the image through Adjustment Threshold. The extracted hand shape is determined by Contour tracking, and then calculate to which nozzle is subject. And then, the spurting nozzle and the height and the pressure of the water stream are calculated from the height of the nozzle and the depth observed by the depth camera, and finally, the water stream is spouted from the nozzle.

A light system is installed on Garden Aqua. To let the user check user's hand position, the system plays a role to show the hand's position through light. By regulating colors and positions of the light differently, the light is projected upon different water streams to express various data on streams of water.

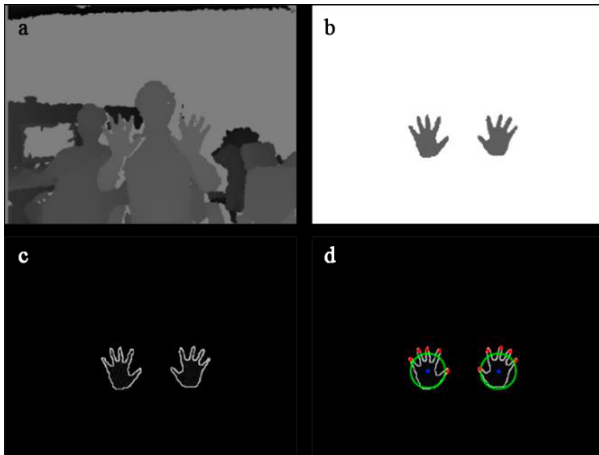


Figure 8 Hand tracking and light system (a) Gray-scale image of real world. (b) Extraction through adjustment threshold (c) Contour tracing (d) Segmentation of hands

3.4 3-Dimension calibration

Some problems on precision may be caused to apply to image data after calculating the data themselves from a lens of one depth camera. In particular, the errors are slightly different depending on the position of the lens. This phenomenon is able to be solved by calibration (Figure 9). Two points having exact distances (80cm, 150cm) are placed by arranging checked patterns of black and white colors on each position, and then the distances are measured. Calibrate the obtained values of x-, y- and z-axes by multiplying by the calibration value. And, calibrate the pump motors by height test for each pump because they have pressure difference by product.

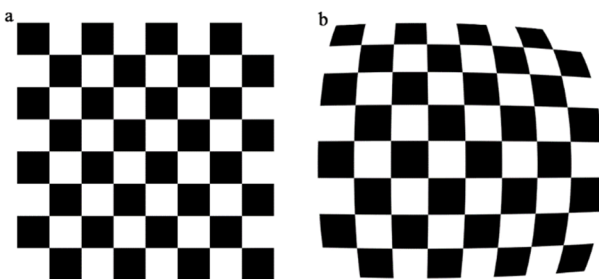


Figure 9 (a) Calibration completed (b) Calibration required

4 User interaction

4.1 Positioning of balls

For Garden Aqua, balls are put on jets of water. A user holds the ball above one of several nozzles after choosing the corresponding ball, and then a water stream is automatically shot slightly below to the height of the ball, and the user puts

the ball upon the water stream. Not only one ball but balls as many as the number of total nozzles can be put on water streams at the same time, and only one ball can be put on one cell. Balls should be placed as controlling it properly.

4.2 Controlling of height of water jet

A ball on a water stream is stopped in its place as levitating. In Garden Aqua, the pressure of the water streams is controlled by using this principle. The ball on the water stream can be moved vertically up and down by fine control of the pressure. The pressure of the water stream is regulated by height and position of the user's hand. The user puts his/her hand on the water stream on where a ball is levitating. Then, the distance between the user's hand and the water stream is calculated by a depth camera. When the user's hand is somewhat gone up higher than the height of the water stream, the height of the water stream gets higher as heightening the water pressure. On the contrary, when the user's hand is somewhat gone down lower than the height of the water stream, the height of the water jet gets lower as lowering the water pressure. Accordingly, the height of the ball levitating on the water stream can be naturally regulated as the height of the water stream is regulated.

5 Application of Garden aqua: Tone Matrix

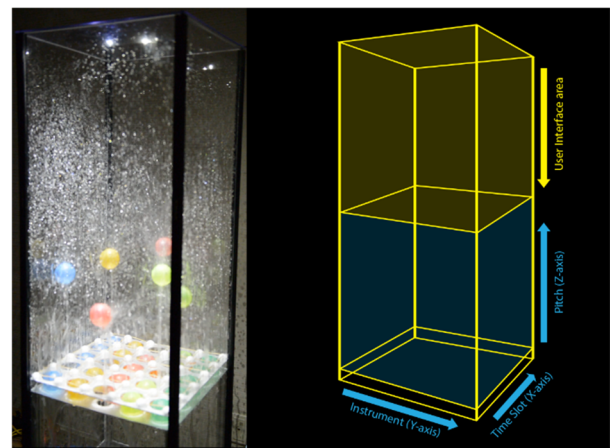


Figure 10 Tone Matrix structure

In this study, we make an application work applying the existing Garden Aqua system. In existing Tone matrix work, the music played changes as the X, Y positions of the cell change. As shown in (Figure 10), one more dimension was added to Tone Matrix applying Garden Aqua than the existing work. The X-axis is a time axis like the existing work. Repeatedly moving from left to right in the X-axis, plays the sound of the cells of the X positions being focused. On the other hand, the Y-axis and the Z-axis mean the type of instrument and the pitch of the sound, unlike existing works. When the Y position is changed, the musical instrument type of the music to be played is changed. Depending on the Y position, it is selected as one of a total of 8 instruments (flute, trumpet, violin, cello, harp, marimba, piano and organ). And, when the position in the Z axis

increases, the pitch of the sound of the corresponding cell increases. So, by using various instruments and various pitch, more variety of music can be made. The operation method of Garden Aqua Tone Matrix is as the following.

Tone Matrix has 36 cells, 6 for X-axis and 6 for Y-axis, and each cell has a motor pump and a nozzle. A ball is located on every cell. A user makes a motion recognition equipment (Kinect) read the user's hand motion. The equipment is installed on the top of Tone Matrix. A lighting system is also installed on the top of Tone Matrix. The light system illuminates corresponding cells to the position of the user's hand in real time whenever the user moves user's hand.

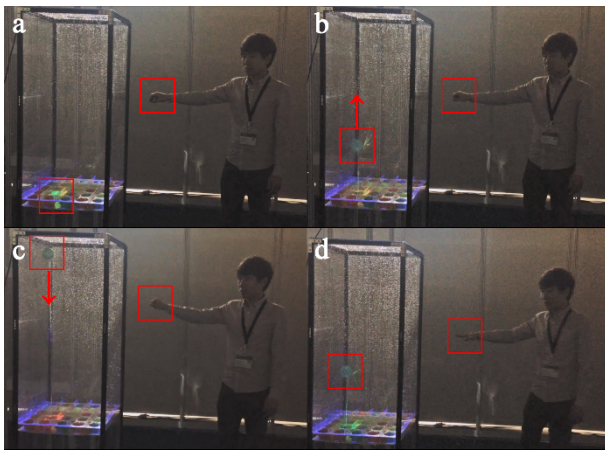


Figure 11 User input gestures for Tone Matrix (a) Select (b) Upward (c) Downward (d) Deselect

The user can use 4 gestures as Tone Matrix inputs. The first input is a gesture that selects a cell (Figure 11a). When the user motions to pick a ball with user's fingers on the corresponding cell, the cell is chosen, and the light system on the top illuminates the cell continuously. When the cell is chosen, the user can control the height of the water stream above the selected cell. Second input is a gesture to raise user's hand (Figure 11b). When the user put user's hand up on the chosen cell, the pressure of the water jet strengthens, and the ball is gone up to the height of the user's hand. As the ball height increases, the pitch of the sound of the cell increases. Third input is a hand gesture down (Figure 11c). When the user put user's hand down on the chosen cell, the pressure of the water jet weakens, and the ball is gone down to the height of the user's hand. Contrary to the second input gesture, the lower the height of the ball, the lower the pitch of the sound in that cell. The last input is a gesture that deselects the cell (Figure 11d). When the user motions to unpick a ball as unfolding user's fingers, the ball is stopped in the position. At the same time, music is produced by matching the corresponding sequences, notes and instruments through position values of X, Y and Z-axes of the ball depending on the method of producing music of the above mentioned Tone Matrix. The user can produce lots of music as controlling many balls.

6 Discussion

We produced Tone Matrix among application methods utilizing Garden Aqua system in practice. This product was selected for Emerging Technologies in Siggraph Asia 2013, and it was exhibited to let many users use for 3 days. We checked whether this product is accorded with TUI elements by using 4 elements of TUI Framework suggested by Hornecker (2006). In addition, we examined the difference between two representative studies using levitation by checking and comparing them. We marked ○ if the product exactly embodies TUI elements, △ if partially embodies them, or × if not embodies them. The following (Table 2) shows embodiment of TUI elements by product.

Table 2 Embodiment of TUI elements by product

Category	Element	Tone Matrix	ZeroN	Aerial Tunes
Tangible manipulation	Haptic Direct Manipulation	△	○	○
	Lightweight Interaction	○	○	○
	Isomorph Effects	○	○	○
Spatial interaction	Inhabited Space	○	○	○
	Configurable Materials	○	○	△
	Non-fragmented Visibility	○	○	○
	Full Body Interaction	△	△	△
	Performative Action	○	○	△
Embodied facilitation	Embodied Constraints	○	○	○
	Multiple Access Points	○	○	○
	Tailored Representations	○	○	○
Expressive representation	Representational Significance	○	○	○
	Externalization	○	○	○
	Perceived Coupling	○	○	○

All of three products embodied most elements, however, they partially embodied for several elements. In Haptic Direct Manipulation of Tangible Manipulation, Tone Matrix has limits that a user can control balls indirectly. But it's because the real working parts and the controlled parts were separated in order to agreeably control Garden Aqua using water. The motion sensor located at the top out of the product catches intuitive gestures of a user's hand, and balls located in the product move instantly. Therefore, it may be considered as a complement of the direct control elements. In Full Body Interaction of Spatial Interaction, all products are partially embodied. All of the three products are able to be controlled by hand and arm, but not by whole body. In particular, Zero N has more limits. In Performative Action, Tone Matrix is able to apply hand's

motion to the product by tracking the motion in real time, while the others partially apply to the systems.

7 Conclusion

Many studies on TUI have been carried out until recently, and lots of interfaces could be emerged by these studies. This study on the levitation by 3D TUI has been carried out by various media from the several existing studies. In this study, the levitation was realized by using water as the medium, and a 3D TUI, the Garden Aqua system, was produced.

To produce TUI of Garden Aqua, the levitation was designed using difference in water pressure by each height of balls floating on water jets. And, the vertical heights of the balls and the water jets were controlled by regulating pressures of the water jets spurting from nozzles of water pumps. In addition, we applied a user's commands as being input through the hand-tracking technique in real time in order to provide the feedback to the user in real time, and we showed the relevant feedback to the user through the lighting system. Finally, it enabled to exactly control without any distortion through a 3-D calibration process. By the above designs, the simple and intuitive TUI interaction was enabled so that Garden Aqua system and the user can select locations of the balls and control heights of the water jets.

In addition, we produced Tone Matrix, an application of Garden Aqua system, and exhibited it in Siggraph Asia. Accordingly, we analyzed elements by Framework of TUI together with two representative products embodying Tone Matrix and levitation TUI. As the result, most elements were embodied in three products, however, several elements were required to be filled up. Additional studies will be carried out on the elements necessary to be complemented as the result of the analysis of this study. And we try to contribute to the relevant TUI studies by producing and analyzing various products using Garden Aqua system.

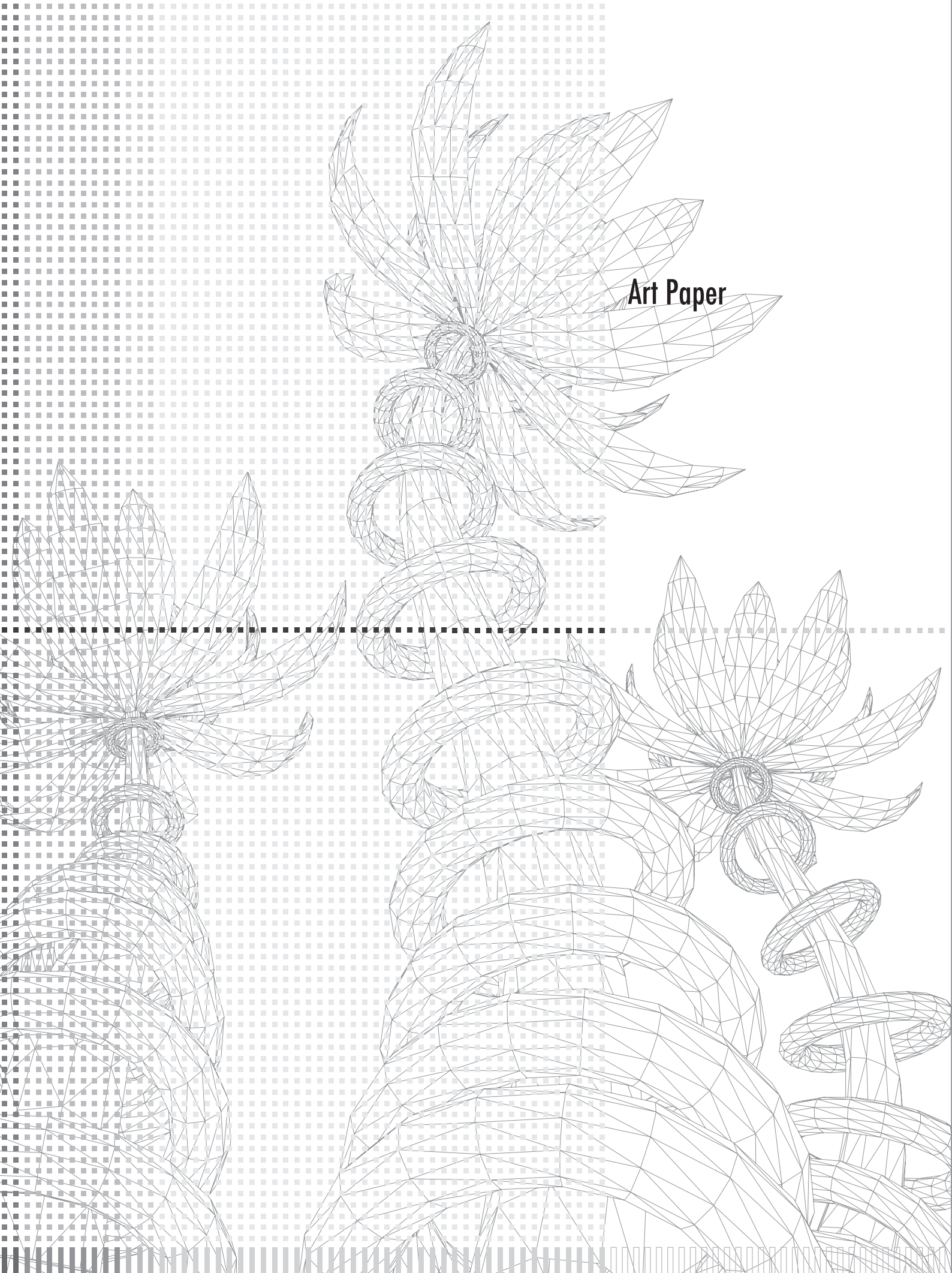
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Art Paper



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Gamification Experiment in Introduction to ICT Development Course Through Art and Design



Abstract

Introduction to Information and Communication Technology Development course is one of general courses for 1st year Faculty of Visual Art and Design students in Institut Teknologi Bandung, Indonesia. The aim of the course is to develop understandings among students of Institut Teknologi Bandung for their future professional reference and benchmarking. Although the course has basic educational presentation and materials, the lecturers are facing difficulties to elaborate the content in order to get the students' attention and participation in the class meetings. The author conducted gamification experiments for 3 consecutive academic years since 2014 through elaborating and combining gamification mechanics Art and Design activities. This paper depicts 3 gamification experiments which may become future reference for game studies or media studies, especially gamification activities in high educational institutions. The result showed that game mechanics in gamification are good in creating interaction and playful experiences. However, in order to get the participants' active engagement, especially participants with visual art and design discipline, it requires more than just applying gamification's game mechanics. The game administrators must provide enough room for participants to communicate freely, to create and actively innovate the game through compact background story, design templates and guidelines.

Keywords: gamification, game studies, media studies

1 Introduction

Introduction to Information and Communication Technology (ICT) Development Course is one of general course for first year students who study in Institut Teknologi Bandung, Indonesia since 2008. Institut Teknologi Bandung established in 1920 initially as Technische Hogesschool, one the oldest engineering high educations in Indonesia, and became Institut Teknologi Bandung in 1959 [1]. The purpose of Introduction to ICT Development course for Visual Art and Design Faculty

students is to give basic understanding on recent ICT development especially in socio-cultural and professional point of views. The subjects of the course are basic of ICT explanation, computer's application tools, networks, and problem solving practices, and implication of how ICT affects human lives, world, and interaction. All of them are based on Beekman's Tomorrow's Technology and You which published by Pearson Education as the main sourcebook [2].

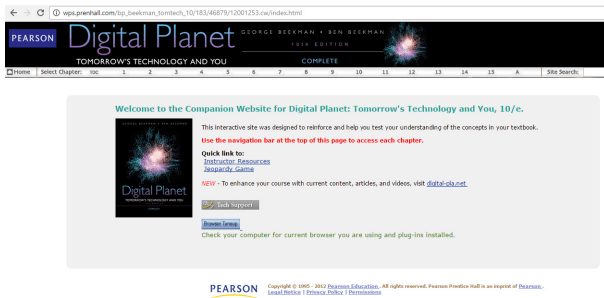


Figure 1: Beekman's Tomorrow's Technology and You 10th edition [3]

The book is supplied by continuously updated website and compact discs supplement consisted of digital content and basic presentation tools in Microsoft PowerPoint. Although the course content is constantly updated through the website, there is a problem that the lecturers in Faculty of Visual Art and Design ITB have to solve, which are updating audio visual teaching materials and socio-cultural and digital interaction in worldwide web as context materials. The first problem occurred when lecturers evaluated the teaching performance qualitatively and found significant depreciation of students' interest since 2010 and it is getting worse every year. The lecturers must update their audio visual teaching material databases at least every two years, but based on personal expertise and depth of understanding, it makes the audio video materials cannot be exchanged among them. The second problem occurred when updating the audio visual supporting materials is proven to be a matter of merely "cosmetics" communication. However in the other hand, updating socio-cultural and art & design conflicts happened in social media and worldwide web is the essence of taunting students' interests and understanding towards ICT Development and socio-cultural impacts.

2 Gamification Experiment

In the beginning of second semester in academic year 2013/2014, the author with the help of several post graduate students as assistant, set an experiment in order to create new

concept of delivering Introduction to ICT Development course through gamification. Gamification is applied game components and elements to create meaningful and playful achievement as well as experiences in social and or organizational interaction. According to Deterding et. Al. [4], gamification is using game design elements in non-game contexts. We developed a gamification simply by applying 7 game mechanics according to Bressington [5], which are Badges, Levels, Leaderboards, Progressbar, Virtual Currency, Awards, and Challenges among participant. The experiment was continuously elaborated for 3 consecutive years until academic year 2015/2016.

Techno-Gaia (2014)

The first gamification experiment on Introduction to ICT Development course titled Techno-Gaia. The basic concept of Techno-Gaia is the world setting where the students play the role of novice who climb up to be the top of significant profession in the end of the course. Meanwhile, lecturers and assistants are positioned as guild masters who deliver contents and mandatory mission in next class meeting or submitted online. The students are divided into 3 major professions or jobtype based on their answers on the initial questionnaire on the beginning of the course, and each job type is assigned a different emblem. As the consequences, each given mission must be designed specifically based on available job types.

The gameplay of Techno-Gaia applies the common Role Playing Game system such as Ragnarok Online MMORPG of Final Fantasy Tactics where the player can choose certain role which may affect the next assignments, missions, or activities. Overall, there are 17 job types which are based on 3 major professions. There are Bounty jobtype who pursuits highest achievement in ICT knowledge and understanding, Novizio jobtype who emphasizes aesthetic and state of the art in ICT projects, and Trader jobtype who is heavily based their decision on potential economic value. The students' performance in finishing personal or group mission will affect their position on the total scoreboard. Every students can see their score in leaderboard which is posted in facebook group weekly. When the students move on to the advance jobs or



Figure 2: Techno-Gaia (2014) Gamification Visual Elements. Badge of Various Job Type (from left to right upper row: Bounty, Trader Tycoon, and Trader Kingpin. From left to right lower row: Novizio Maestro and Novizio Whitesmith), and Players Avatar (from left to right: Bounty, Novizio, and Trader) [6]



Figure 3: The Imitator War (2015) Gamification Visual Elements. Game Logo and Title (upper left), Country Representation (bottom left, from left to right: US, Italy, German, Japan, and UK), Achievement Badge signified with number of stars (private, Major, Captain, Liutenant, and Colonel).

levelling up, their emblem will shift into a more detailed visual as their reward in form of screen printed scarfs as achievement badges (See figure 2).

Imitator War (2015)

In academic year 2014/2015, the author offers the participants to create their own gamification theme. They are making groups and presenting their proposal towards others. The winner is gamification concept voted by the most of participants through short message system (SMS) voting system. The winning group assists the author as game masters throughout the semester delivering course's content and missions. The concept of gamification in academic year 2014/2015 is a Rebel vs Empire in year 3058. The world setting is German (game masters) dominating the world as the winner of 3rd world war and there are 4 rebellious countries against them. The game participants are making groups which then enlist under one of four countries and they have to do the missions in order to protect their cities from German aggression which may affect their total hitpoints. Each country has significant characters which will affect their attitude and style in finishing the missions.

The participants must develop their clan's emblem as their signature. They have to crawl up from the lowest level of participant, which is private to colonel as the highest possible rank. In Imitator War, the participants are introduced to sabotage mission system and Clash of Clans. Sabotage mission is a task that is secretly given to a group by the game masters to do other's secret mission with better result. If they did better than assigned group, the saboteur group will get

double victory points in return. Clash of Clans is ICT quiz competition for groups. The name Clash of Clans is taken from the famous mobile game in 2016 [7]. The quiz system makes the member of the group collaborate to find answers and response the question as soon as possible. Those activities are supported by constantly updated leaderscore board, and eventually heat up the competition throughout the semester (see Figure 3).

Kala Isvara (2016)

Kala Isvara is the latest concept of gamification applied in academic year 2015/2016. The concept of Kala Isvara is similar with Techno-Gaia but has deeper root in local content and traditional atmosphere. The participants are people of Zeelata world divided into 5 countries origin with their own value, namely Virata the fire country with bravery with fire lizard emblem, Manesha the country of water with wisdom with sea dolphin emblem, Satyata country of earth with honesty with turtle emblem, Badhr country of wood with benevolence with horse emblem, Vasana country of steel with righteous with tiger emblem, and they must serve under Yaksha Technologia (the game masters) with elder dragon emblem. All the names are derived from sanskrit language while the elements are taken from five elements or five states of change from Chinese mythology [8]. Those 5 countries are underlings of Yaksha due to lack of high technology innovation and application. The story of the game is, the students are future generals of Yaksha who compete with each other to earn that position. At the end of the semester, their scores will determine whether they can claim their position or failed (see Figure 4).



Figure 4. Kala Isvara (2016) Gamification Visual Elements. One of Participant's Avatar (left), Kala Isvara logo and emblems of the countries in Kala Isvara (upper right: Yaksha Technologia, lower left to right: Virata, Manesha, Satyata, Badr, and Vasana) [9].

In Kala Isvara, the active participation of the students are more far-stretched than previous game. They have to make their own avatars, nicknames, its background stories, and print in a card as their presence item in every class meeting. They also need to make a group and design their clan's banner, and appreciate and vote presentation materials of the game masters through their facebook account. The interaction among participants such as Clash of Clans and sabotage missions as well as leaderboard system, various personal and clan's missions are still applied. At the end of their semester, the participants are required to develop a game which may become the basic gamification concept for the next gamification of ICT Development course in academic year

2016/2017.

Gamification Concept Review

Each gamification concept has their own uniqueness which engages different deep interactions. Techno-Gaia 2014 gamification concept gives the game masters full authority in delivering contents and options of choosing job type towards the participants based on their personal preferences, but the downside is, the game masters feel overwhelmed in every session because they have to develop various missions for every job type and calculating points. The real time scoring leaderboard system creates competition among participants. Achievement points depicted by additional markings on their

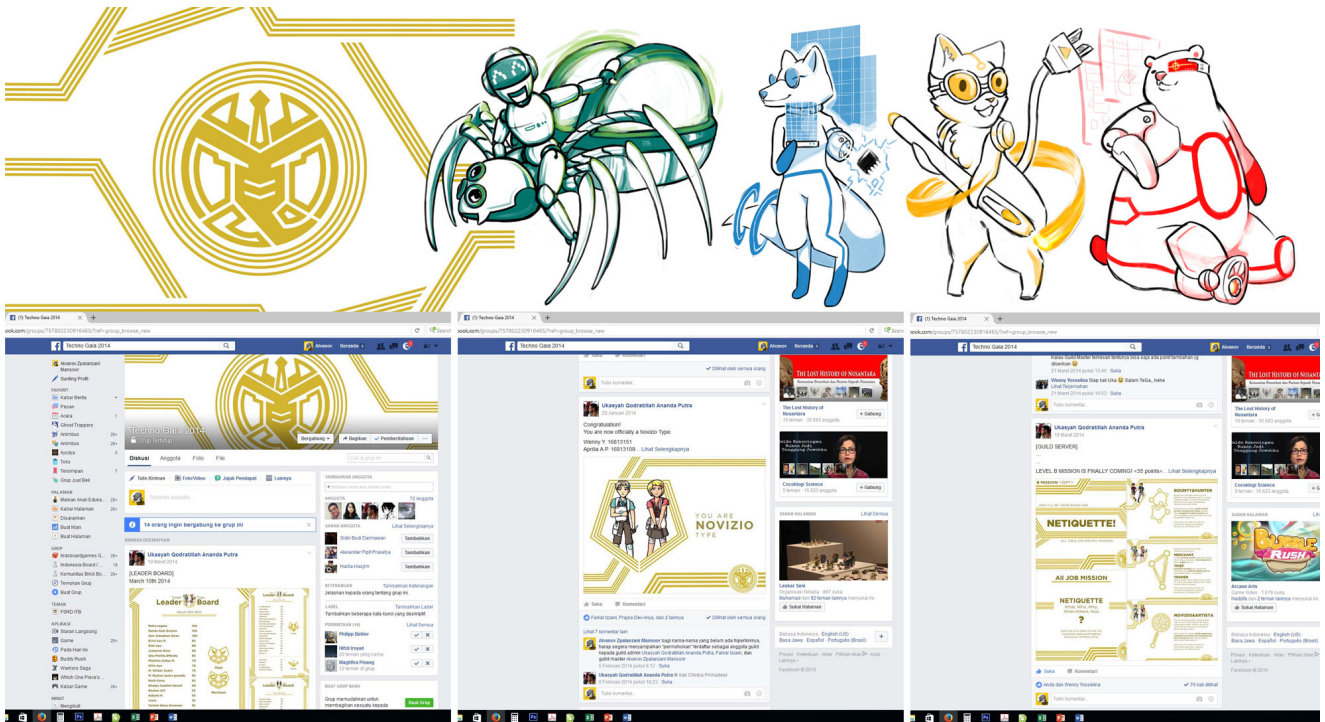


Figure 5. Techno-Gaia (2014) Game Master Logo and Avatar. From left to right (top images) Techno-Gaia Game Master logo and Game Master Avatars, (bottom images) facebook Group, Levelling Up announcement, and Mission announcement [10].

emblems also become their goals. The members of game masters are enthusiastic to develop game mechanics such as gamification logo, presentation templates, avatars and game master's uniform.

The participants are getting more perceptive at their expertise in the future, because the mission accomplishment is mainly in artwork form such as illustrated posters, comics, and audio visual materials, whether they make it themselves or modify it from several visual materials from internet with restricted precautions such as copy-pasting artworks required references.

Intense interaction among participants and game masters in class meeting happens when the talk is on socio-cultural interaction in digital world, such as manners in online corresponding with company representatives, social media usage, and broadcasting false information or hoaxes. The students are always fascinated with the showcase of technology advancements, but somehow neglecting the social impact. Meanwhile, in online interaction or facebook group interaction, the intense communication happens during launch mission. The game masters and participants can verify or clarify the mission or the output in order to do the job correctly. The above communication happens thanks to one secret mission that leaks to others and resulted mission cancellation in the end (see Figure 5).

One of special missions given to the participants is a mission to forecast the future technology and present in academic and illustrated posters. They have been given the audio-video materials that shows, recent technology are the result of "the dream of our forefathers." Therefore, despite of cherishing the recent technology, the students must forecast the form of future technology. They will be supervised by seniors invited by the game masters to help shaping up the ideas of the participants. The forecast mission results shows that the participants gains better insight and understandings on how they articulate ICT in their framework. Most of them can dig up certain technological knowledge which are still new in 2014 and embedded into their dream projects.

The 2nd gamification experiment or The Imitator War 2015 gamification concept is different from Techno-Gaia. The visual and game ideas are inspired by Command and Conquer: Red Alert 3, a Personal Computer game introduced in 2008 by Electronic Arts [11]. There is no job types variant but levelling up achievement instead. The sabotage mission and Clash of Clans or quiz competition activities are heating up the competition (distributing points through quiz session prior to mid semester test and end of semester final test). The facebook group communication system is not applied on this year because the game masters are constantly communicating with the participants. The missions are delivered through class meeting and done in form of artworks, illustrated posters, comics, and such. At the end of semester, the participants are rewarded an embroidered emblem which represent their latest position on the scoreboard.

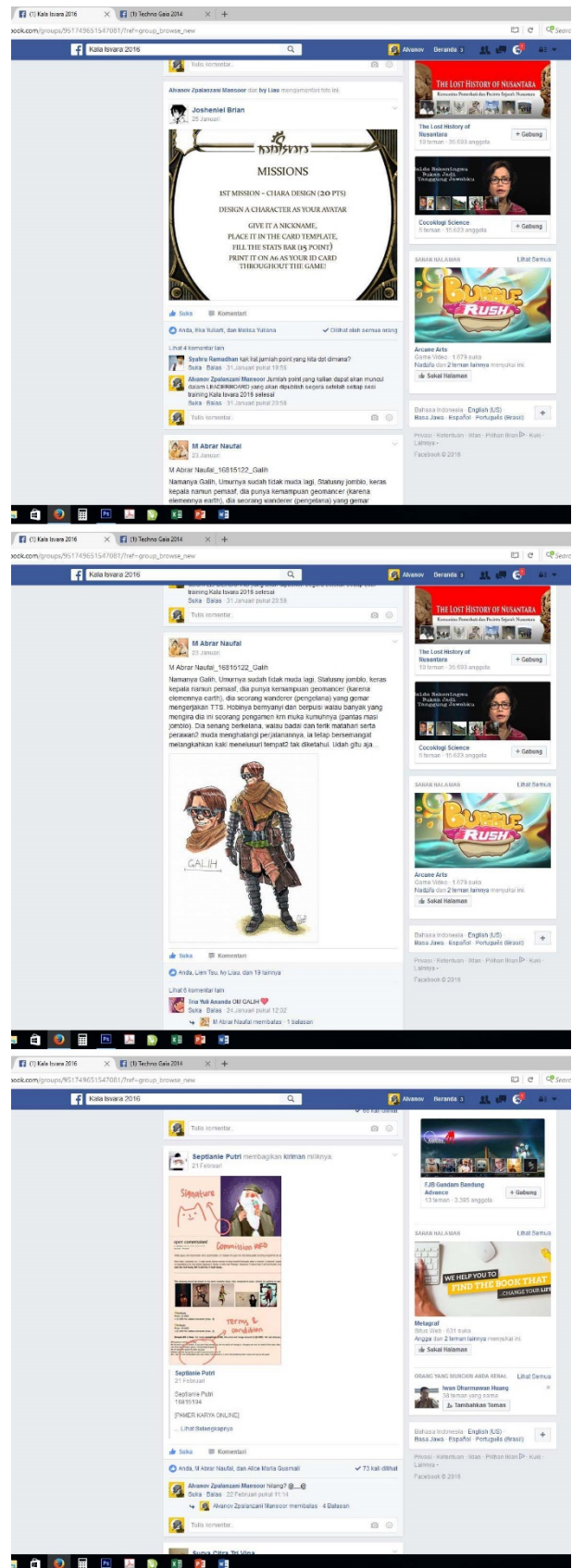


Figure 6. Participant's Avatar submission (top and middle figure) and Game Master's presentation reviewed by the participants [12].



Figure 7. Participant's (4 images on the left) and Game Master's avatar (4 images on the right within card template) showdown [13].

In 2016, the concept of active participants in re-creating avatars, clan's banner, appreciation and voting system on game master's presentation materials, Clash of Clans (quiz competition), and developing interactive content as the last group mission gain higher interaction from the participants more than previous gamification concepts. The participants are enthusiastic in creating avatars, background stories, and compete with other clans in Clash of Clans (quiz competition). The students eagerly share their avatars and background stories in facebook group that stimulates reviews and conversation among members (see Figure 6).

Similar treatment applied towards the member of game master assistants. In the previous Techno-Gaia 2014 Gamification Project, logo, identity and visual assets are elaborated by assigned person. Meanwhile, in Kala Isvara 2016 Gamification Project, the team designed a template or guidance for all participants included the game master team members. Instead of one person design, this experiment produces templates for all to use and elaborates as frame that unified everyone's design. The game master and group of participants compete with one another in sharing the contemporary contents that might bring advantage for their professional future (see Figure 7).

Overall, most of the content of ICT mandatories are developed through gamification contexts, especially in missions which needs their perspectives in game such as job or profession (Techno-Gaia), races (Imitation War), or elements they represents (Kala Isvara). Although the utility of gamification experiment in Introduction to ICT course is still done qualitatively, it may be measured quantitatively. Therefore, on the next gamification experiment which will be conducted in early 2018, several quantitative measurements are under development to be applied.

3 Conclusion

There are various results of gamification experiments in Introduction to ICT Development courses on 3 consecutive years, but several things need to be marked.

- There are significant understanding from participants on the role of information and communication technology (ICT) in art and design discipline based on the quality of question asked, how the participants present their works

on certain missions.

- Almost all gamification concepts are successfully creating interaction and playful experiences. The participants' interest, appreciation, and attention towards the course content increase significantly compared to pre-academic year 2013/2014.
- The engagement between participants and game masters are well built through gamification mechanics as Bressington mentioned.
- To make further interaction in gamification as a goal, applying game mechanics through rewarding the participants activities is not sufficient especially for students of Visual Art and Design studies. They need to be challenged through creative artworks and examples to create creative and explorative output.
- Quantitative measurements needs to be applied on the next gamification experiment to validate the previous qualitative gamification experiment results.

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