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Contents

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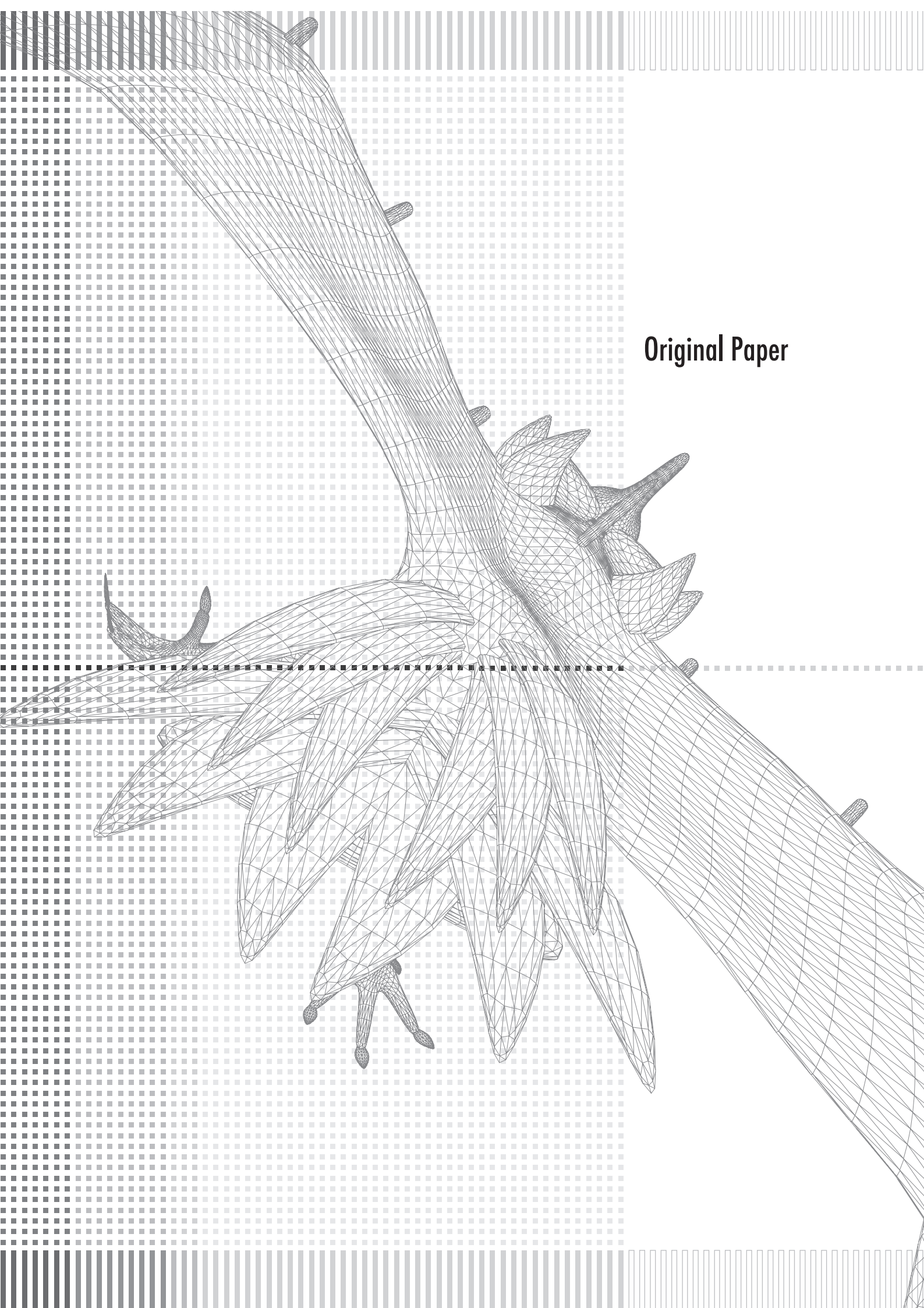

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Character creation and customization for Massively Multiplayer Online Games

Brazilian cultural analysis for Online Educational Games

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Abstract
The research here described represents the small starting point of a bigger research project which objective is to develop a Virtual Learning Environment based on the popular Massively Multiplayer Online Games for Brazilian students. Following the player's flow in the gameplay, the first step to be considered is the avatar creation and customization. The objective of this paper is to settle the initial parameters for the character's creation system based on the cultural aspects of Brazilian people. Using an exploratory and comparative methods, this work has analyzed three different online games in order to determine which avatar's characteristics should be customizable. Seven distinct Brazilian ethnic groups were found formed by five other groups, including international immigrants, like Japanese. Based on these groups and the games analyzed, the next steps for this work and a new research were established as results. From now on, the character's archetypes should be developed to set up the customizable body parts. Additionally some complex problems were found to be answered in future researches, as the player's class assignment in an educational game. It was considered important to assign some technical directions in this early stage of development, such as the Game Engine selection and software parameters that are not directly related to the culture, but to economic and social aspects of the target audience. Three Game Engine with free version available were analyzed and the results has pointed to Unity, for its low cost and flexibility and multi-platform as well. The Web Browser game deployment capability really suits the requirements of this project.

Keywords: Online Games, Culture, Education

1 Introduction

This work represents the first step of the first step in a research focused on to create and develop a Virtual Learning Environment based on the Massively Multiplayer Online Games known by the acronym MMOG.

For the first step is needed to understand what comes first in a so complex system. In despite of the traditional project methods, what of course will imply the production of a Game Design Document and other additional development documentations, for this research's purposes, this work is guided by the user's play flow itself.

This decision was taken because of the nature of the research and the complexity of the project, for the prototype development was segmented in different parts in order to make it possible to be executed with low resources.

This first step is, in fact, the character creation and customization by user. This is an important part of MMO games and defines a relevant aspect of interface: the avatar.

The objective of this paper is to establish the starting parameters for the avatar's creation and customization system for a Massively Online Educational Game for Brazilian students.

The results obtained through a bibliographic exploration method and a comparative method applied between three Massively Multiplayer Online Games has indicated seven Brazilian ethnic groups to be used as the basis of character conception and which properties could be customized.

2 Starting Concepts

Before going through the main goal of this work is necessary to set up some essential concepts. First of all, the MMOG itself, as one of the most popular genre of games nowadays.

The terms MMOG and MMORPG are commonly used to describe a subgenre of games that allows the user to play over the Internet with hundreds or thousands of other players [2]. As seen in the beginning of this paper, the acronym MMOG means Massively Multiplayer Online Game and RPG comes from Role-Playing Game, a board game that, along with the computer's technology is the very origin of such subgenre [2].

The ability to play the game and interact with other players makes this kind of digital world one of the best environments to promote education according to theories of cognitive interaction involving participation in a community in order to construct the knowledge [3]. Also, this same community is responsible in the process of culture generation through nature.

These special aspects of MMOG have triggered this research with the objective of develop an online game with the best parameters in accordance with education principles.

As said before, the first step in this colossal task resides in the creation and customization of the avatar by the user, what points to the next concept needed of some discussion.

The virtual representation of conscious beings in synthetic

environments, immersive or ubiquitous, is the so-called avatar [4]. The Hindu idea of a god among people through a physical manifestation is the origin of the word avatar and the concept behind this virtualization process.
The actions performed behind the avatar's mask reflects a new way to communicate, but also it is related to how people act differently behind different avatars. It gives freedom somehow to people enabling not only to "be" someone else but also to act as someone else.
These aspects implies an interpolation of culture, of what the individual takes to the virtual environment and what he will get from there and more important: the sum of all those experiences.
For consider this process of creation culturally important and because it is the first challenge the user faces inside the MMOG when entering for the very first time, this work aims to discuss more about how to develop a system for distance learning that allows the student to create and customize his own character.

3 Project Outline

The character creation system to be developed starting with the studies here discussed is part of a bigger project. The main research project have the objective of develop a Virtual Learning Environment for Distance Learning Education based on the MMOG. The target-audience in the first moment will be Brazilian students from the basic education.
The prototype should be developed in a modular structure and will be possible to adapt it to many other targets and countries.
The avatar creation involves some characteristics and it is important to define which of them will be present in the project and which will not.
The character creation usually begins with choosing a race. It will reflect in the character's background, its species, physiognomy, history, heritage, philosophy and so forth [1].
In the proposed educational game, there will be only one race: human. Thus, no race choosing will be necessary.
In the games, people want to play other races than human. Players prefer to be elves, dwarves, orcs, goblins and all sorts of fantastic creatures. However, this project intends to be a different type of class. Not for elves or Halflings, but for humans.
The purpose of this is to create a link between the player and character. It will be possible, probably, in the future to change the appearance of the avatar in a variety of ways, but in this first moment, the player is a student, just about to discover an entire new world of knowledge, but still a student.
The second feature to be chosen is the appearance. It will be discussed ahead and because the player will not be able to pick other race than human, it is important to give a special attention to this part of the system.
The third step on character creation is the definition of a class. Again, it is not applied to this game; however, the class represents an important element in the balance of the game affecting directly in the group's gameplay, essential in a MMOG [1]. This factor generates the first problem to solve: how to develop classes among students? It needs to be in the project but how is best way to represent it in a virtual learning environment?
Some games includes profession choosing in the creation process, but in this project the profession choosing will not be present during the avatar's creation but later in the game and maybe under a different term.
The last step in the avatar creation is usually give him a name.

4 Appearance Aspects

Among the concepts explored so far, the avatar's appearance is most complex to understand and apply in an interactive system. The reason is related to the psychological and sociological aspects involved.
One of these aspects relays in the body and conscious' relationship and how in the postmodern times this connection is not only restricted to a physical body [5].
Three different MMOG were analyzed in order to study the customization mechanics and appearance features. In the "World of Warcraft" and "Ragnarok Online II" the level of customization are limited to more general visual aspects while in the "Star Wars: The Old Republic" deepest changes are allowed, such as scars and make-ups, for instance.
The first difference realized was the design style direction [6]. The "World of Warcraft" shows a more stylized visual and "Star Wars" is directed to a more realistic graphic. Considering the project's target audience and the character design style defined by George Maestri [6], this research will follow an even more stylized visual approach, as seen in games like "Ragnarok Online II". The Figure 1 shows a visual comparison between these three games regarding the character's creation screen, from the left to the right: "World of Warcraft", "Star Wars: The Old Republic" and "Ragnarok Online II".

Figure 1 Character Design Styles

It was decided to keep less options of customization as for the target audience there is no need of scars or make-ups nor facial hair or horns. Therefore the options kept for the prototype development and based on the analysis of the three games will be: body type, height, hair style, hair color, skin color, eye type, eye color, nose and mouth.
A more accurate and deep study should be done for the concept creation of eye, nose and mouth types and for the hair style as well. For the body type, it should not provide a too fat or too thin character, but it must let some freedom for this represents one of the most important aspect of MMOG character concept: player's singularity.
These are characteristics more related to ethnicity than culture,

but both concepts are directly and strictly linked and have an important area of interpolation where the individual's subject exist. Not only eyes, nose and mouth are ethnicity studies dependent but more important: the skin shade.
In the case of Brazilian students, it is more difficult to establish customization parameters based on the ethnicity and culture because of the country's size and history.
It was found very difficult to establish some criteria on how to classify human visual characteristics through the complicated Brazilian categories based on skin shade for it does not reflect the common black-white paradigm [7]. Instead is possible to find four distinct ethnic groups in Brazil from many different origin and mixtures, as show in table 1.

Table 1 Ethnic Groups in Brazil

Group	Description
White	The major part of this population are European descendants, mainly from Portuguese, Spanish, French, Italian, Dutch and Slavic. Most of them lives in the south region of Brazil.
Black	Were forced to work in Brazil as slaves in a past time in the sugar and coffee production. After the end of slavery, they are still concentrated in areas where the work exploration were more intensive, as northeast and southeast regions.
Indian	The native population before the Portuguese colonization. They were almost totally exterminated during the colony period. Actually they live mainly in north and central region of Brazil.
Brown	Originated from the miscegenation between White, Black and Indian.

The Brown ethnic group on the other hand have originated three other distinct groups as shown in Table 2:

Table 2 Brown originated groups

Group	Description
Mulato	Comes from the union between White and Black. They represents 24% percent of Brazilian population and lives mostly in northeast and southeast regions.
Caboclo	Descends from the mixture between White and Indian groups. They represent 16% of Brazilians and lives mainly in the north and central regions.
Cafuzo	The minority group represents only 3% of population. Comes from the miscegenation between Black and Indian and lives mainly on Amazon, northeast and central regions.

Those groups were formed along the History through the combination of five original groups: Natives, Portuguese Colonizers, African Slaves, European Immigrants, Asia and Middle-East Immigrants.
Based on this, there is still one more aspect to consider in order to develop a Brazilian based character creation system: the immigrants. There are, for instance, a considerable number of Japanese immigrants in Brazil.
Started in 1908 with the Kasato Maru steamboat arriving at Santos Port, the Japanese migration to Brazil represents an important aspect of Brazilian development and culture, especially in the southeast and Amazon regions [8].
Considering that and the fact that today there are many children of Japanese immigrants and other cultures as well, it is possible to assume a student player should be frustrated for not be able to find their own ethnic characteristics in the system.

5 Costume

Evidently, costume is part of appearance, however it is a so complex field, specially associated with culture, the way it always should be, that it was necessary to put it in a separated section.
For now, it is not this work's objective go through aesthetical elements, as fashion design, for instance, but establish the cultural relations between the traditional wearing and the ethnics groups described before.
The main reason for this distinction lays in the fact the character's creation process in the MMOG usually do not show the avatar in the clothes it will use in the beginning of the game. The low-level characters commonly uses very simple equipment in order to acquire more advanced stuff during the game progress.
The problem found in the avatar creation screen is that is very frustrating to create and customize a character wearing too simple clothes. To see the character wearing advanced vestments helps the user to realize how the avatar will be in the future, according to the game progress.
In the game "World of Warcraft" in its latest expansion called Mists of Pandaria, the solution was to put both visions in the character creation screen, showing the future armor set (left) and the starting equipment (fig.2).

Figure 2 Mists of Pandaria Character Creation View

In this project, as a virtual simulation of a school, the initial wearing set should be a common school uniform. Of course, the students will be able to change it to a variety of sets during the game, including different school uniforms.

For a Brazilian student of Japanese origin, for example, it will be possible to change the uniform to a more Japanese style school uniform, what is very different from Brazil. In addition, for the same student, according to his progress, it will possible to unlock more traditional dressing, like kimonos.

The player's equipment to be shown in the avatar's creation screen in this virtual learning environment project should be based on the different traditional dressing according to the ethnics division found in this research.

The traditional wearing will not be restricted to one ethnic group, but in the character's customization process, this division should help different children to identify their own visual style, what can be freely changed in the game. Body parts' customization will also allow a free combination in a way the players could create a very singular avatar.

6 First Sketches and Visual Directions

Based on the seven Brazilian ethnic groups found and main immigrant's descendants, a character's creation and customization system should be, from now on developed.

The main characteristics of those groups should be turned into archetypes for a starting point of creation. The mixing of these characteristics and costume will give the needed singularity.

First step had taken following the three main groups found (fig. 3), considering that the fourth one is a result of the first three's miscegenation.

In order to develop these first white, black and native visual concept, some factors was taken in consideration. First of all, the drawing style.

As discussed before, the design direction will follow the stylized concept [6] for it would be more suitable to the target audience: Brazilian's junior high-school students (between the 6th and 9th years of school).

Among the many different drawing style around the world, the Manga style was chosen.

Manga is also known as Japanese comic books. A very rough definition though, as Manga still have many differences to its western counterpart [9]. With the popularization of Manga around in Japan and around the world, especially after the Second World War, this visual and narrative culture become a very distinctive style of art and representation.

In Brazil, during the 1990's, Manga and Anime become very popular, an event known as The Boom of Manga [10]. After this period, many children and young people become more interested in Japanese culture. Today, there are many Manga and Anime officially translated to Portuguese and a variety of fairs is placed over the country every year, with traditional Japanese food, games, manga and anime contents been shared and Cosplay competitions.

Due to this proximity with Japanese culture and the popularity of Manga in Brazil, the visual style for the characters will be based on Japanese Comics.

Some elements were established in order to compose different characters. Hair, eyes, nose and mouth represents a very ethnic visual representation of an individual. Similar characters in Manga were researched. The most difficult one was the Brazilian native. Although there are just a few black characters in Japanese comics, none was found of Brazilian natives.

The first three concepts, each of them representing one ethnic group found here can be seen on figure 3, left to right, black, white and native.

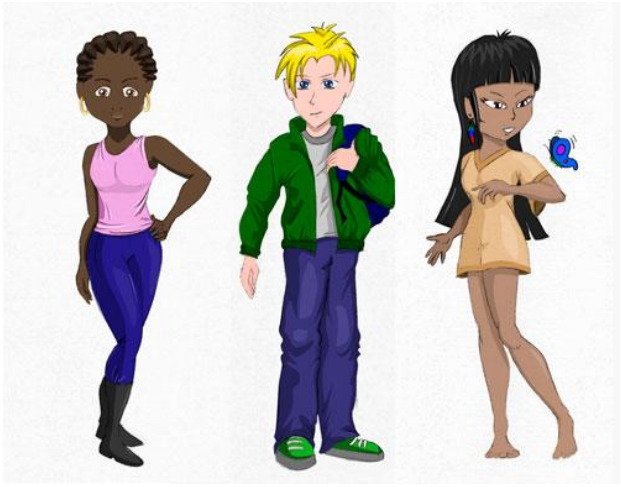

Figure 3 First three visual concepts

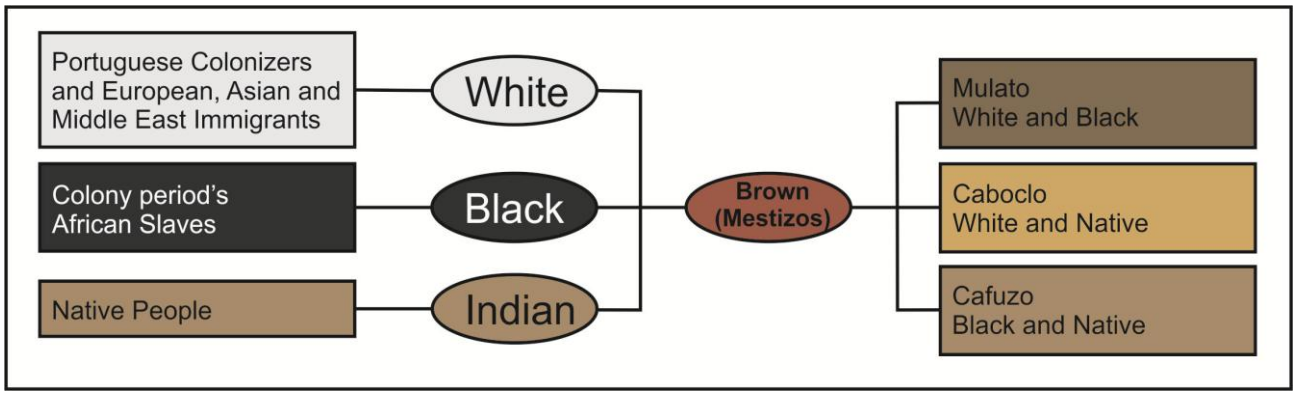

Figure 4 Brazilian Ethnic Groups Graphic

7 Avatar and Educational Process

The relation between humans and avatars in virtual worlds is in fact a very complex condition. Even the relation between the mind and the body has changed since Descartes and his modern philosophy.

After the Modernism, human began to think about body as a separate entity, a biological suit to be modeled according to social environment [11]. Later, with the down of postmodern paradigm, the mind has become a key to understand the very nature of human consciousness and how it is totally apart from physical body.

The consciousness fluidity between many social realities [12] also applies to virtual social realities. Nowadays is common for people to wear their avatar masks and for some time become part of an entire new universe where we can interact with other people and construct new societies.

With this context given, is possible to visualize the role of avatar in people's life. When playing games or discussing in social platforms, the avatars represents a different individual, not the physical subject anymore.

What it have to do with education? When speaking about online education is secure to say: everything. If the avatar represents the identity of a conscious mind, a virtual temporary body, it is, in fact, the interface of mind with the realities.

For a student, constructing its own identity and knowledge, it will represent the self in a virtual version, important to establish the relations with other students.

In the socio-constructivism theory of education, the relation or socio-interaction is the very basis of knowledge construction [12]. As virtual societies are still societies, is plausible to extend that concept to simulacra and its inhabitants: the avatars.

For this understanding, the avatar is the subject of interaction and the temporary representation of mind. Its social relations will construct knowledge, good or not, depending on the simulacra conditions, such as social environment and context learning approach.

A specific virtual world can offer an even more fertile ground for knowledge raising: the games. Play act can be placed as the leading source of development in a child [13].

Imaginary based games, such as RPG (Role Playing Games) and its variations such as the MMOG, are composed by rules of behavior and establishes a reality projection or simulation. Social development comes from these not formulated rules but implicit within the game itself.

Also, the semiotic structure of meaning and object is constructed by play. By dealing with things that carries a meaning, the child replaces the objects by word meanings and start to create a complex semantic sphere [13].

Evidently, all those concepts designated for physical societies must be tested in their virtual versions to confirm the practical appliance of theories. The simulacra is the digital counterpart of us and games comes with behavior rules to define these simulated communities.

Thus, more will be analyzed from this point. Assuming the socio-interactionist post-modern theories of education, the path to be followed is clear enough to start a journey with avatars into contextual learning field of research.

8 Technical Aspects and Design Tools

Besides this article's objective points to a more analytical and theoretical approach, it is important, as a first step in an applied research, establish also some technical aspects for the product development.

The main tool, the Game Engine, should attend for some important requirements, among them, modular development and low cost are the most important.

Other requirements as Online Game Capability (server and client communication), fluid and easy project pipeline, integration with the most popular software available, multi-platform capability and high level of customization were also taken in consideration.

Three of the most popular with a free version available Game Engines were analyzed: "Unity", "Unreal UDK" and "CryEngine" (table 3).

Table 3 Free Game Engines Comparison

Engine	Platform	Script Language	Version Control	Price
Unity	Windows Mac OSX Android iOS X360 PS3 Wii	C# JavaScript Boo	Yes	Limited Free or $1500 full
Unreal (UDK)	Windows iOS	Unreal Script	No	Limited Free or $95 + 25% Royalties
CryEngine 3	Windows X360 PS3	C++ Visual Script	No	Limited Free or $1.000.000 + ?

The table shows that "Unity" engine have many advantages in comparison with its competitors. First of all and based on the user tests also performed, the limited version and the free version of "Unity" does not carry a significant difference. In fact, most of the limitations presented are visual related and not really functional.

The cost is an important point of decision. In Brazil, in despite of a crescent economy, there's corruption and many social problems, including one of the world's worst wealth distribution [14], what results in a society where video games and other cultural entertainment are not the priority at all.

Also, schools usually does not have budget enough to invest in computers or digital laboratories. Unfortunately, is very common to see schools with very old computers or none.

For these reasons, the final product must be light enough to run on slow computers, maybe over the Internet through the Web Browser. The cost should be low, affordable to schools and other Brazilian educational institutions. Here, "Unity" took the advantage again.

"Unity" engine also offers the possibility to publish the game directly on Web Browsers as well, as its native format running under a player plugin ("Unity Player") or in "Adobe Flash" format, one of the most common Web content players available.
After this analysis it was found that "Unity" is the more suitable tool for this project.

9 Next Steps

This is just the beginning. A good one.
The challenge will be to create a simple system for the target audience but with all the features that reflects the complexity of Brazilian ethnic formation.
Another challenge resides in the modular aspect of the software architecture. The main research presumes a game that can be used by many different educational institutions. Therefore, the software should allow the addition of new characteristics and character`s archetypes in order to work for other countries as well.
It is clear "Unity" should be used as the game engine for this project. Cost and flexibility factors were strong factors and affects cultural and economic aspects of the proposed target audience.
In the end, the system must be submitted to user`s evaluation, in alpha and beta tests, for the final corrections, bug fixes and improvements. The target platform is Web Browsers, but tests with mobile devices such as cellphones and tables will be performed. A multi-platform system is been considered.
For the first sketches of visual concepts presented here, more should be done, of course. Male and female for each main ethnic group plus hair, face, eyes, costume and accessories must be designed to fulfill the conceptual phase of this project.
The variety of customizable parts will make possible to turn all the three main groups into others, according to the user's will. That should be verified later with the target players.
This Avatar Creation System will expanded to the Non-Player Character Creation System and for the Teacher's Avatar Creation System. The separated system should work as one in the modular and asset concept and will depend on the profile logged in.
Speaking in profile, the relation between Server and Client should be studied and developed alongside the Avatar's system design. Issues as security and user's account must be resolved before the tests. Database such as SQL is been considered but other options will be discussed furthermore, like the third party service called "SmartFox". Again, cost and flexibility will be taken in high consideration during the decision making process in order to develop an affordable and reliable software.
Finally, it was considered a very complex concept the character's class assignment. Another parallel research is needed to bring some light to the problem according to educational theories here discussed.
Education is a very complex field and is related not only to culture but human cognition and social relations. An applied research like this should have a theoretical twin by its side. In the near future, the integration between the system to be developed and the concepts found should result in an educational tool more suitable for students and professors around the world.
With this stated, from now on, this research should follow two paths. Research and development will become the guideline for the next steps that will be achieved starting with the findings here described.

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A Design Study for the Haptic Vest as a Navigation System

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Abstract
Along with the arrival of the information age, people have started to pay attention to user experience design based on the human sensory organs. Instead of traditional user experience design based on vision and hearing, the experience based on tactile feedback has gradually become the mainstream in the field of product design. With this paper, we're discussing the designing and production of the haptic vest, originating in our development of the haptic navigation system. We aim to actualize "symbolization" or "implication" of the haptic information. Haptic vest is a design of conveying electronic information using tactile feedback, with 60 actuators. Through these actuators, haptic vest provides users with navigational information. Thus, the vest not only serves as the medium for the actuators, the experience of tactility here comes from the vibrations of the actuators and the information it attempts to convey.

Keywords: Haptic Vest, Vibration, Navigation

1. Introduction

In the background of experience economy, tactile experience has been gradually replacing the visual and auditory sense in the design field based on the human sensory organs, becoming the new mainstream of design. The background of the electronic information age makes the experience of tactile design not only refer to the users touching the material texture, such as soft or hard, the information product technology also makes tactile design more widely and deeply used in various fields.

This paper mainly introduces our design of the Haptic Vest as a navigation system based on tactile feedback. The basic design idea is that users get the directional information through feeling the vibrations coming from the 60 actuators which are attached to the vest. We introduce from the design concept and prototype, to the experiments of user experience and the discussion, and we propose to actualize "symbolization" or "implication" of the haptic information and apply it into future design and works.

2. Related Works

As more and more researchers treat tactile sensation as a means of presenting information, there have been a lot of researches research about the tactile experiences in personality development and cultural patterning of tactile experiences and so on[1]. Also, there are researches about the conditions influencing tactile feedback [2] and how to control and enhance the tactile feedback with different methods [3] [4].

And there have been many application of tactile sensation in various fields. For example, there are researches that study the transmission of haptic information in the form of tele-presence by using sofa as the medium [5]. Other haptic examples also like touch screen operation of smartphones and tele-surgery in the medical field [6].

3. Design Concept

Going from the previous examples, we felt tactile sensation is important and promising and decided to research it more in-depth.

First, we discussed haptic actuation and brainstormed several ideas:

・Horror Theater Chair: Chairs with actuators stimulate spectators in tandem to the movie in order to generate scares.

・Human Darts: In this game, you are the target and you can experience darts sticking in your body.

・Breaking Watermelon: Through haptic information, the player is guided to a watermelon in order to break it.

In fact, there have been some applications of haptic technology in navigation fields, like the wearable haptic navigation guidance system [7], also application based on chair [8] .

And in order to bring these ideas to fruition, we considered it to be important to design a device that can stimulate the torso area. We therefore decided that a vest would be an appropriate device for the prototype. The vest's actuators are able to simulate 3 forms of output, which are "time", "strength" and the "mapping" of the actuators. In this research, we focused on the possibility of using haptic stimuli for navigation. This paper discusses the design of the wearable device "haptic vest".

4. Prototype Design

4-1 Material of the Vest

In our research, the important point is to convey direction by the means of vibratory stimulations to the user. We consider that it is important to stick the device to the body as tight as

possible when the user wears it. In addition, by taking account of the actuators attached in it, we also consider that it is necessary to prepare a material with an acceptable amount of strength and elasticity. As the best material for these conditions, we chose a wet suit.
The wet suit to be used in seawater is extremely elastic. It fits the body and is a very durable material that has a certain thickness to maintain body temperature. So, it can be easily processed, put on, and taken off, we adopted the "BREAKEROUT _DTSVEST_FZIP", which is a vest type wet suit with a frontal zipper.

4-2 Actuators Arrangement

As the main element in our device, we have to carefully select the actuator. As described in section 2-1, to add three elements to the haptic vest, it is necessary to make patterns of vibrations by using multiple actuators. Therefore, we used small disk-shaped vibration motor (FM34F) manufactured by TPC, seeing Figure 1, which is commonly used in mobile phones and so on, and we attached 60 of those to the vest.
With regard to the arrangement, we placed them in a 12×5 array to the entire torso so each vibrator has equal intervals, seeing Figure 2. By applying this arrangement, we assume that the interpolation effect such as apparent motion and phantom vibration can be obtained. This interpolation effect has been demonstrated experimentally in the research report "Surround Haptics" by Disney Research [10, 11], so additional performance would be expected in our research, as well.

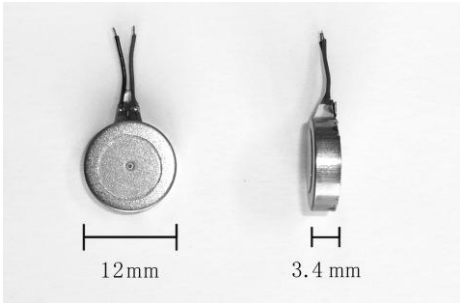


Figure 1 Small disk-shaped vibration motor FM34F

Figure 2 Placed actuators

4-3 Wiring and Implementation

We had to do the wiring to assemble the device. In order to connect each actuator to the vest, we needed a lot of conductive wires. On the other hand, to effectively convey the vibration, anything that could stimulate the body other than the actuators should be eliminated in the inner side of the vest. Therefore, we tried to use the conductive thread as conductive wire. However, the line did not conduct well because the resistance of the conductive thread was much higher than we thought. Therefore, we used conductive wires for all lines. Furthermore, to prevent uneven surface that is caused by overlapping conductive wires, we pull the wires ends of the actuators out of the vest and all wires were arranged on the outside to make it safe; the wires are not directly in contact with the skin.
Earlier we noted a point that the vest is elastic, however the wires are not. We checked on the level of expansion and contraction of the vest when it is worn. We confirmed that vertically fiber has little stretch, but horizontally it has considerable stretch when the user wore the vest. We referenced aforesaid data as well, and made the wiring as shown in the figure 3.

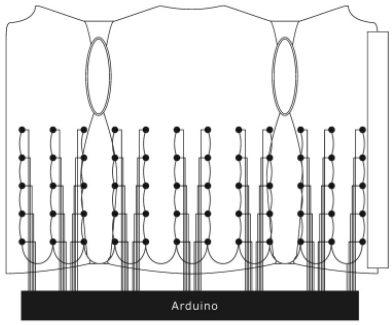


Figure 3 Wiring diagram

4-4 Controller and Operating Procedure

We utilized Arduino Uno as a controller to control all of the vibrations. Furthermore, we implemented the Arduino IDE as the coding environment. Due to Arduino's smooth communication with the processing software "Processing", it has brought about easy development of original applications for controlling hardwares. To make it possible to actuate 60 vibrations by a single Arduino, we arranged 16 connections to the channels of the LED driver which is shown in Figure 4.

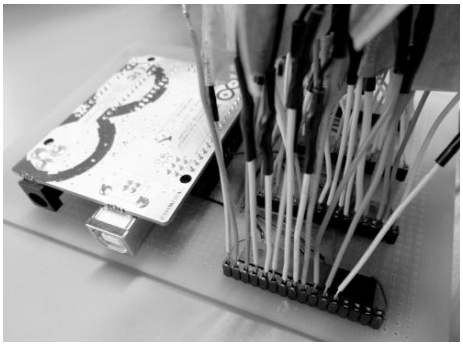


Figure 4 LED driver and Arduino

The interface design to control the actuators is quite simple with only threee basic functions, i.e.: to configure which actuator to control, to control the duration of the vibration, and how many voltage needs to be applied. We use the an array of

actuators on the vest as the controller screen to provide an intuitive mental model of how the hardware and software are connected. In addtion, we quantify the degree of voltage in 15 levels and express it by different color intensities. It makes us comprehend the entire posittion and level of voltage of the actuators intuitively, seeing Figure 5.

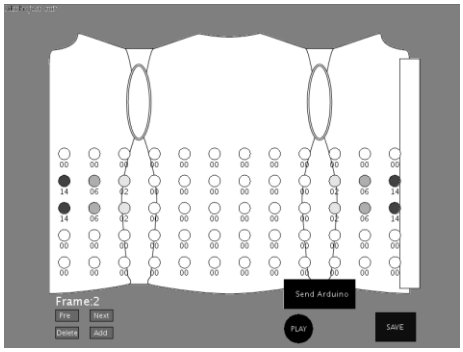


Figure 5 LED driver and Arduino

5. Experiments

Purpose

We made different vibration patterns for users to test how the users feel about the vibrations and what information they can get from feeling the vibrations. We hope to find out the better way to transfer the vibrations into navigation information, and to actualize “symbolization” or “implication” of the haptic information and apply it into future design and works.

Participants

We solicited 4 college students as participants, 1 male and 3 female.

Scene Settings

The participant doesn’t know the way to the destination he/she wants to go to. Fortunately he/she wears the haptic vest, which can tell the right direction and right way to go by vibrations. With the help of haptic vest, the participants are able to get to the destination.

Test Process

The participants wear the haptic vest and, while feeling the different vibration sets, answer the questions and write down the feeling. Wearing haptic vest is as Figure 6 shows.

Figure 6 haptic vest

Test Content

We have set 30 different vibration patterns telling which direction to go. These include 7 going frontal (shown in Figure 7), 7 going back (shown in Figure 8), 8 going left (shown in Figure 9), and 8 going right (shown in Figure 10).

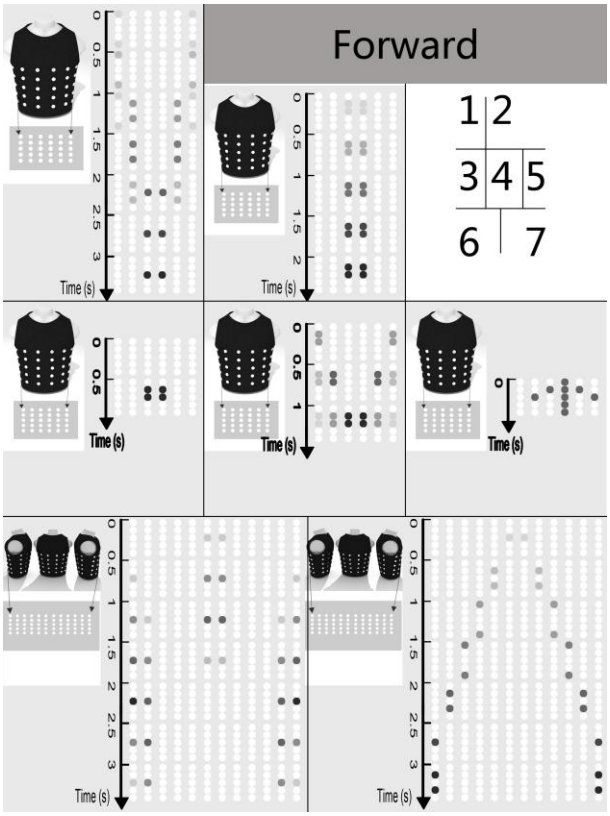


Figure 7 Patterns Going frontal (1~7)

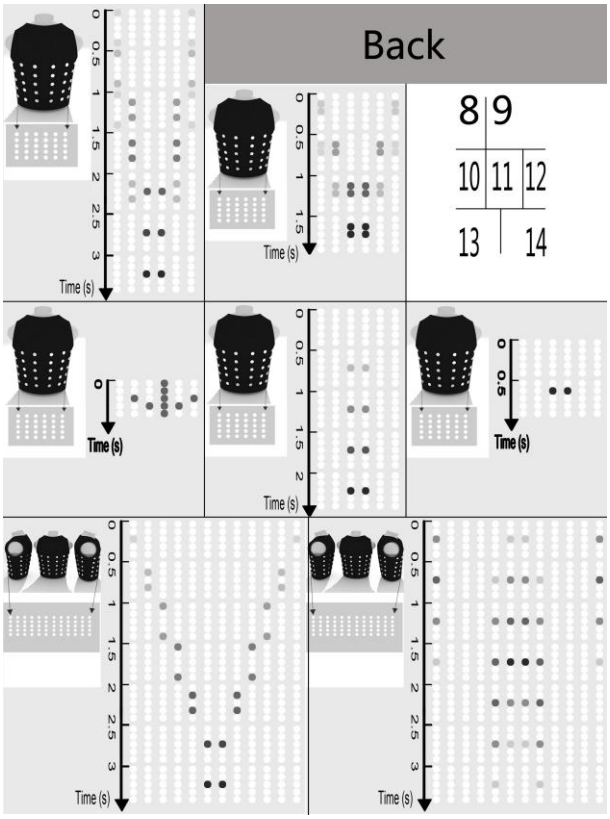


Figure 8 Patterns Going Back (8~14)

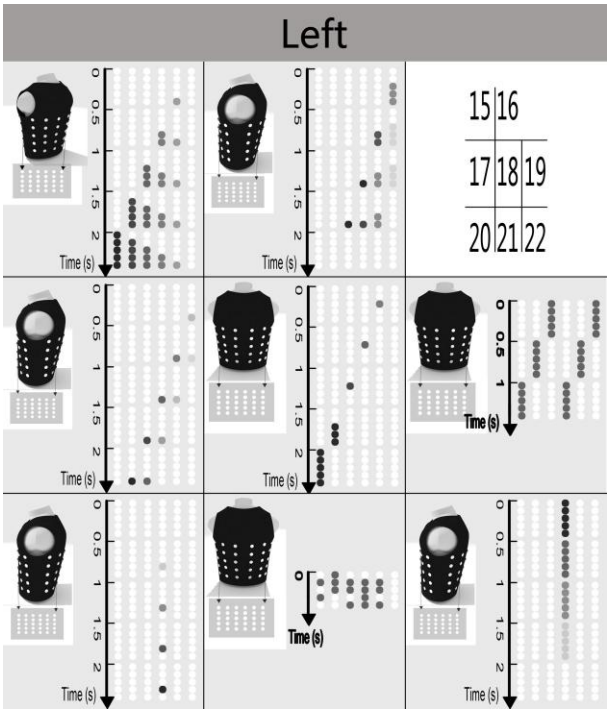


Figure 9 Patterns Going Left (15~22)

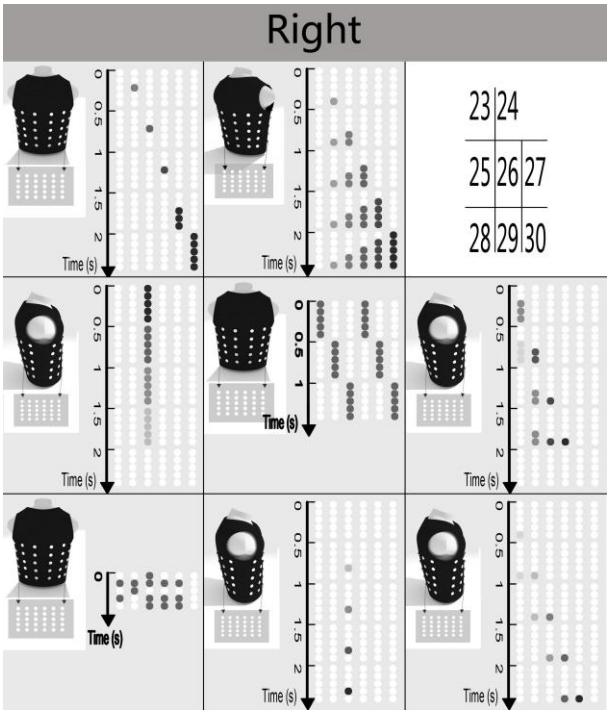


Figure 10 Patterns Going Right (23~30)

In every pattern, we set some actuators to vibrate at the same time or in order, and each of the vibrations has the same or different strength.

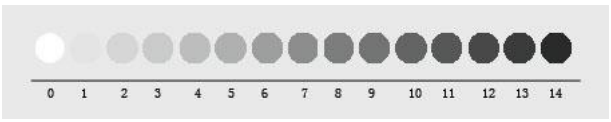


Figure 11 15 Kinds of Strength

The amount of strength is expressed by a value ranging from 0(weak) to 14(strong). Figure 11 shows the 15 kinds of strength expressed by different colors in this paper.

Tasks

While doing the test, the participants need to answer three questions:

a. Which direction does the sample want to convey?

b. Do you think it's easy to understand the meaning? Choose between 1(very difficult) to 5(very easy).

c. Do you feel comfortable while it vibrates? Choose between 1(very uncomfortable) to 5(very comfortable).

Results

We analyzed the results from the aspects based on the three questions mentioned above; the result is shown in Table 1. In Table 1, we show the pattern number, the intended direction of the pattern, the number of participants getting the right answer, the easiness and the comfort level of each pattern.

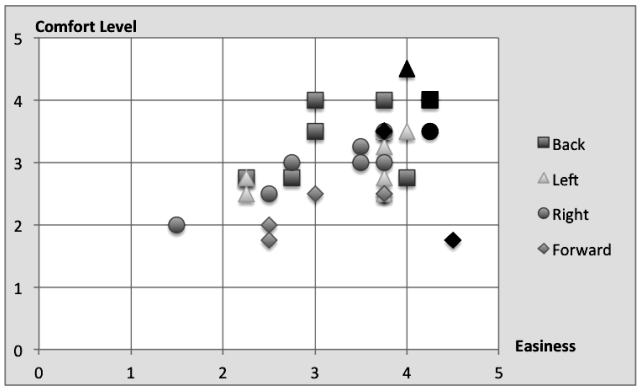
Table1 Results

Pattern	Direction	The number of participants getting right answer	Easiness	Comfort Level
1	Frontal	3	3.75	3.5
2	Frontal	2	2.5	1.75
3	Frontal	3	3.75	2.5
4	Frontal	4	4.5	1.75
5	Frontal	4	3.75	2.5
6	Frontal	4	2.5	2
7	Frontal	4	3	2.5
8	Back	4	3	4
9	Back	4	4.25	4
10	Back	3	2.75	2.75
11	Back	3	3	3.5
12	Back	2	3.75	4
13	Back	4	4	2.75
14	Back	3	2.25	2.75
15	Left	4	3.75	2.75
16	Left	4	4	3.5
17	Left	4	3.75	3.5
18	Left	4	3.75	3.25
19	Left	2	2.25	2.75
20	Left	4	4	4.5
21	Left	2	2.25	2.5
22	Left	4	3.75	2.5
23	Right	4	3.5	3
24	Right	4	3.75	3
25	Right	4	4.25	3.5
26	Right	2	1.5	2
27	Right	4	3.5	3.25
28	Right	1	2.75	3
29	Right	4	3.75	3.5
30	Right	2	2.5	2.5

Discussion

The result using graph type in Table 2 shows the best pattern in each group (i.e. going frontal, going back, going left and going right), which are highlighted in table 1.

Table 2 The Analysis of Total Data



a. Frontal and Back

Depending on the level of easiness, the best vibration pattern of the group "going frontal" is pattern 4. However, while depending on the level of comfort, the best pattern of the group "going frontal" is pattern 1. Among the group going frontal, pattern 1 and pattern 4 have similar order, strength and moving actuators. The best vibration pattern of the group "going back" is pattern 9, which also almost the same. Both pattern 4 and pattern 9 change from weak to strong and have two rows of actuators vibrating at the same time. Also, in these patterns, the moving actuators are only in the front or in the back of the vest.

We also set three other types in the two groups. One has all the set actuators moving at the same time, at different strengths. The second type also has the actuators moving at the same time, but their strength remains constant. The last type has both the actuators in the front and the back moving in the same pattern. We found that type 1, 4 and 9, having a better user experience.

However, from Table 1 we can see that pattern 4 is especially difficult to understand. Also taking into account the comments of the users, it's difficult to understand the going frontal information, and some of the uses even think it means to stop. In turns out it's really hard to distinguish between them. Especially, regarding the pattern "going frontal", we need more research and testing.

b. Left and Right

The best vibration pattern of the group going left is pattern 20, while the best vibration pattern of the group going right is pattern 25.

Among the groups left and right, the following types employ similar patterns; pattern 15 and pattern 24, pattern 16 and pattern 27, pattern 17 and pattern 30, pattern 18 and pattern 23, pattern 19 and pattern 26, pattern 20 and pattern 29, pattern 21 and pattern 28, pattern 22 and pattern 25. Among all the patterns, we set one type in which all the moving actuators were moving in order at different strengths. Another type has the actuators moving at the same time, while their strength remains constant.

However, according to Table 1, regarding the pattern with the best user experience, we get different results. Comparing the two types, we can see the right one is much easier to be understood, while the left one has a higher comfort level. The differences between them is that the left one has only one actuator vibrating, while the right one has an array of five actuators vibrating at the same time. One other difference is that the actuator's strength of the left one changes from weak to strong, while the actuators' strength of the right one changes from strong to weak.

From the patterns analyzed before, we can see that the changing of the vibration's strength is a very important and useful method to give out direction information as a navigation system using actuators.

Furthermore, there are some differences between indicating different directions. The left direction and right direction can use the same vibration type, while the frontal and back directions have to use different vibration types. Especially, when designing the vibration type of going frontal, it's important to pay attention to the differences between stopping and going frontal.

Also, as the users commented, the different parts of the body experience the vibrations in different ways. For example, when given the same strength of vibration, the frontal one is experienced to be weaker. Therefore, the easier the vibration type is, the easier it is to be understood. In this aspect, there is a further need for testing the vest's user experience, rather than relying on theory.

5-2 User Testing on Vibrotactile Navigation

Based on the results of experiment 5-1, we continued the research with experiment 5-2,testing the vibrotactile navigation.

Purpose

・make sure if it is possible to navigate people using only vibrotactile stimuli through the haptic vest.
・measure how precise it can navigate.
・analyze if we can convey haptic information correctly.

Participants

All of the Participants are 21 or 22 years old and healthy university students (two males and one female.)

Environment

At first, we prepared a field like Figure 12 and 13 with the following conditions;
・a 50m by 50m space.
・put 10x10 markers 5 meters apart.
・markers' role: to mark routes and corners.

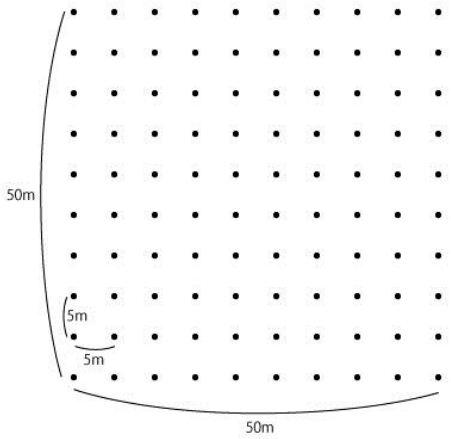


Figure12: "Setting the field"

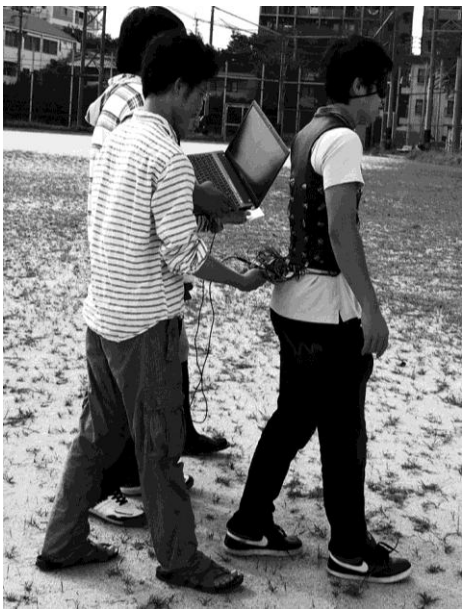


Figure 13: Scene of the experiment

In the future, we'll extend the experiment to a larger field than that of the preliminary experiment and we aim to test the device in the streets.

Furthermore, we also set up two cases: one using a blindfold and one without. In the latter case, we made sure of the usability for blind people by using the following method.

Setting the route

Next, we set the routes on the field. Subjects wore the haptic vest and walked along the routes following vibration patterns sent by the vest. We analyzed whether users can correctly understand directional patterns and walk according to those. Furthermore, we measured how precise our navigation system using vibration patterns is able to lead users.

Then, we set up two routes like Figure 14. In route 1, users walked without a blindfold. Its course, consisting out of the directions right, left, right, left, right respectively, consists out of five turning points and the total distance is 55m. In route 2, by making users put on a blindfold, we tested the haptic vest's validity for visually handicapped people. Route 2's course is left, right, right, left respectively, consisting out of four turning points and the total distance is 50m.

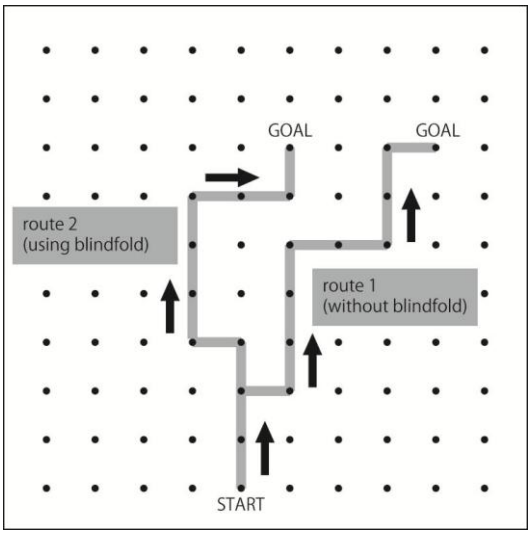


Figure14: "Setting navigation routes"

Directional vibration patterns

We sent users the four vibration patterns (frontal, back, left and right) and indicated directions by the result of experiment 5-1.

Each vibration pattern is as follows:

・Frontal (pattern 4, as we think the easiness of a pattern is important than the Comfort Level, so we choose pattern 4 to do the next experiment, instead of pattern 1)

Vibrations given by the actuators are moving from the underarm to the chest area and its power becomes stronger over time. By repeating this motion, the haptic vest gives users the illusion as if they were pulled forward.

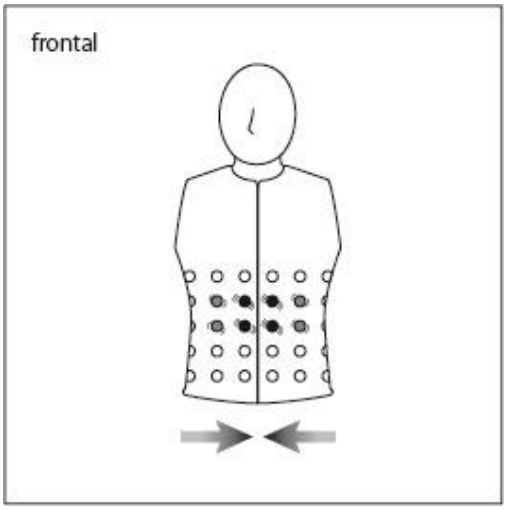


Figure15: "Frontal vibration"

・Back (pattern 9)

As opposed to the 'frontal' pattern, the vibrations are moving

from the underarm to the back area. Its power becomes stronger over time and this motion is continuously repeated. By this, users will feel as if they were pulled backward.

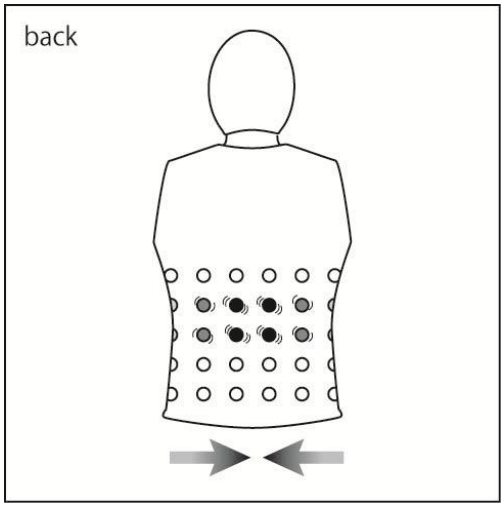


Figure16: "Back vibration"

・Left (Based on the result of experiment 5-1, the best pattern of group going left and going right is pattern 20 and pattern 25, and based on the two patterns we made new patterns to do the next experiment as follows)
Actuators vibrate below the stomach area in the left, becoming weaker over time. The pattern itself remains static and continues repeatedly.

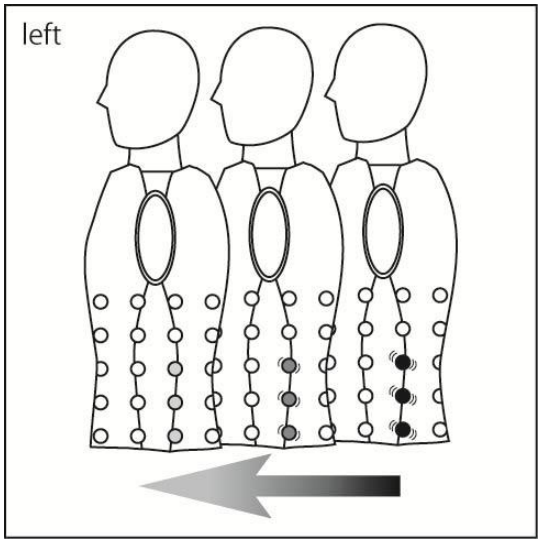


Figure17: "Left vibration"

・Right
As opposed to the 'left' pattern, actuators vibrate below the stomach in the right, becoming weaker over time. Just like the 'left' pattern, it remains static and repeats continuously.

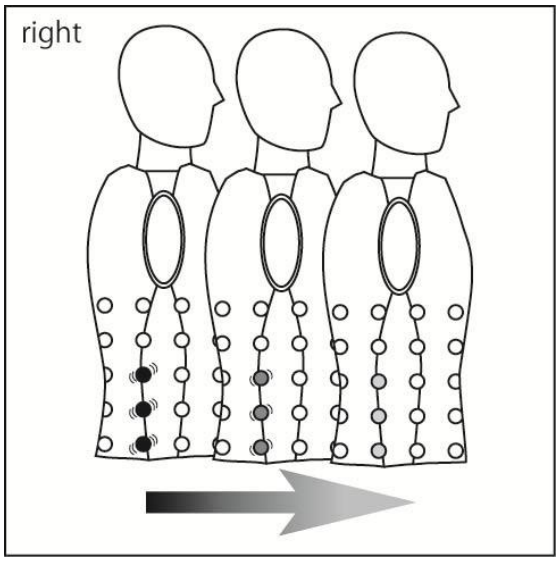


Figure18: "Right vibration"

Furthermore, while users are going straight on a straight route, we continuously send them the 'frontal' vibration pattern through the haptic vest. If they need to turn a corner, it sends them the 'left' or 'right' vibration pattern until users finish turning. We gave them the information of which way to go, by controlling Arduino and Processing manually. In addition, if users go the wrong way, we corrected them without telling them anything. In order to do this, we would send the correct directional vibration each time and lead them to the goal. Through the means described above, we investigated the accuracy of this navigation method, the rate of users' misunderstanding and the difference from visual or auditory navigation in the 50m by 50m field.

Test Process

Before starting this experiment, we explained two things to the users; the navigation is only through vibrotactile feedback and corners are marked through markers. First we made them take route 1. After that, we had users put on the blindfold and made them take route 2. In either route, we didn't teach them which direction the vibration pattern stood for, for the purpose of investigating whether they can correctly understand the meaning of the vibration pattern.

Results and Discussion

Figure 19 is a result of the non-blindfold navigation, where the users could see the markers on the field. A heavy gray line is the set route, other lines are the paths traced by the three subjects. In this route, no one needed to be corrected due to stray off the set route. We concluded that all of the users understood the meaning of the directional stimulation by vibration correctly. As shown in Figure 19, users sometimes slightly went off-route. This is caused by a time lag on the data sent between Processing and Arduino or a response time of users recognizing the directional vibration patterns. These problems can be solved by sending vibration patterns earlier. In conclusions, we found that the navigation system using the

haptic vest can guide users accurately enough under these conditions.

Figure 20 is a result of navigating using a blindfold. Users walked depending only on vibrotactile feedback from the haptic vest. Like in figure 8, the set route is marked by a thick gray line, whereas the users' routes are marked with the other lines. In route 2, due to the blindfold, users sometimes went off-course. It was difficult for users to go straight or make angled turns with the blindfold. Though, through correcting their course each and every time, they could arrive at the goal easily. According this experiment, even if the vision is shut off, through vibrotactile feedback people were able to navigate correctly. Moreover, we confirmed the effectiveness of the haptic vest when used with visually impaired users.

Through a survey, users mentioned that arriving at the goal was not difficult. They commented they can use the haptic vest to pay attention to other visual or auditory information.

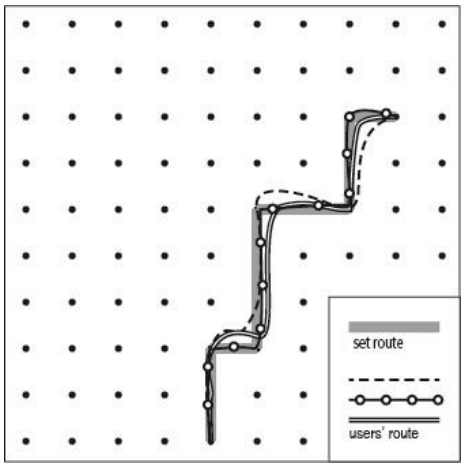


Figure19: "Result of route 1"

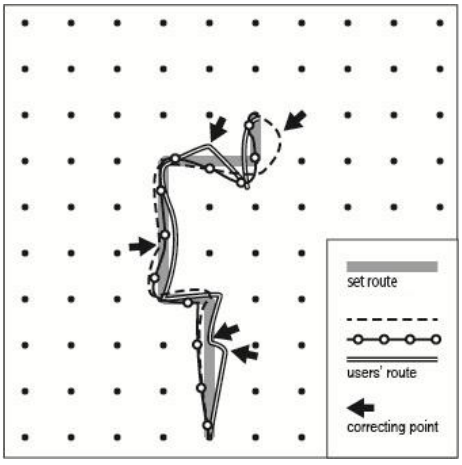


Figure20: "Result of route 2 with a blindfold"

6. Evaluation

Based on the two experiments, we can see that the tactile information by the haptic vest is useful as a navigation system and it succeeded to convey the vibrotactile information to users effectively. It shows the possibility of "symbolization" and "implication" of haptic information, which was our initial goal.

At the same time, there are also many problems need to been solved. As in experiment 5-1, based on the 30 patterns we've made and the user's comments and experience in the experiment, we'd like to improve new patterns to try to get better user experience. And also we will invite more subjects to take part in the experiment in order to get better results. And then get the best patterns of each group to apply them into experiment 5-2. And in experiment 5-2, we'll experiment in larger fields or streets and improve the precision of the navigation system, not only will it be possible to have hands-free navigation and invite more subjects. We'll also think about to convey the directional information more accurately.

7. Future Works

Next, we aim to do more user testing to make the research more in-depth. Also, in order to apply it better into various fields, we are surviving to add GPS mode and wireless mode into this system. Furthermore, we aim to apply this technology to other products as well, rather than just the vest. And in the future, we hope this system can be applied into many fields, such as game design, products for disability people, and also navigation system.

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Study in Patent Risk and Countermeasures Related to Open Management in Interaction Design

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Abstract
Interaction Design (IxD), which is the design process that considers how users communicate or interact with computers, has been growing in importance in recent years. Of particular note are new interface methods that go beyond the capabilities of legacy devices, such as the standard mouse and keyboard. In this study, we focus on such IxD innovations. However, it should be noted that, even though research into intellectual property (IP) management issues pertaining to IxD is important, there are currently no established precedents. Therefore, to explore the IP risks faced by IxD practitioners who engage in open management practices, we will begin by researching patent risks and the countermeasures for open management practitioners, and then explore proper countermeasures that relate specifically to IxD.

Keywords: interaction design, intellectual property, open source

1 Background and Goal

1.1Importance of Interaction Design

Interaction Design (IxD), which is the design process that focuses on human communication and interaction with computers, (restated as communication design between humans and contents, computer systems, or other humans via computers) is gathering increased importance with advances in the development of the computing engineering field in recent years[i]. Furthermore, the IxD field itself can be expected to gather significantly more attention with the development of digital signage and the rise of ubiquitous computing.

Of particular note is the development and practical realization of new interfaces, called Post GUI, which are different from the traditionally used mouse and keyboard interfaces. Furthermore, IxD developments are being strongly emphasized in government policies[ii]. In this study, we will focus on this kind of IxD.

Figure 1 Example of IxD
(left)Catchyoo graffiti (right)Freqtric Drams

1.2 Problems and Goals

As mentioned above, IxD is an important field, so it is logical to assume that the management of intellectual property (IP) rights related to that field would be of equal importance. However, when exploring such issues, a number of problems present themselves, which will be discussed below.

First, because there has been so little previous study of IP management as it directly pertains to IxD, there are currently no well-edited basic information resources, such as practical texts and/or case studies, that IxD researchers and/or production engineers (hereinafter referred to as IxD practitioners) can turn to for guidance.

Second, it is difficult for most IxD practitioners to devote sufficient resources to the aggressive pursuit of IP management strategies because, in most cases, they are researchers and sole proprietors engaged in small production operations.

Third, there is a general sense of uncertainty as to whether it would even be possible to apply previous and existing IP methods and strategies to IxD. This is because the field has its foundations in an open culture based on information sharing that has actively flourished since the beginning of the so-called informatization era.

As previously mentioned, research into the types of IP management practices that are best suited to IxD is important, so in this study we will attempt to provide well-edited basic information that is based on practical texts for use by IxD practitioners who are engaged in research or small production efforts[iii]. To accomplish this, we surveyed the composition elements of IP as they relate to IxD, and then researched the relationships between those composition elements and the current legal system. We then focused on prior and existing

exclusive IP operations (hereinafter exclusive operations), after which we conducted a case study to determine how exclusive operations are handled in the IxD field[iv].

We determined that there are problems with exclusive operations as they are applied to patents and other IP issues. In the discussion, it indicates that open operations, management including distribution with open licenses to all interested parties (hereinafter open operations) would be more effective in the IxD field.

Next, we conducted a case study into the application of open operations as applied to IxD and looked for ways they could solve the types of problems that are often encountered when exclusive operation practices are utilized while simultaneously attempting to ascertain which open operation elements would be most useful when pursuing an IxD project[v]. The results of this investigation showed that a study specifically targeting IxD open operation risk assessment is needed due to the serious nature of the risks involved, which can include forced termination of operations if IP right infringements are suspected.

However, there are no prior or existing studies that specifically target IxD risk management.Accordingly, in this study, we will focus specifically on risk assessments for practitioner engaged in open operation IxD research.

1.3 Process of Open Management

In this study, open operation is defined as the act of placing IP in a state that allows third parties to use it under certain conditions, and even encourages the creation of additional properties related or or based on the original. It is different from exclusive operation in that operation is governed under the licence issued by the originator or owner, not by a government agency. However, the licenses used in open source software (OSS), open source hardware (OSHW), or the open content (OC) that is used in IxD are still based on copyright law, thus treating the related products as copyrighted work[vi].

2 Research methods

2.1 Outline

In this study, we will focus specifically on risk assessments for practitioners engaged in open operation IxD research. While there have been a number of risk management studies on open source production efforts from the corporate point of view[vii][viii], little prior and existing research into risk management[ix] for open operation practitioners in general, or IxD field practitioners specifically, could be identified.

Accordingly, it is reasonable to discuss these topics using the process described below:

a. discuss risks and countermeasures in general open operation (not only IxD open operation),
b. discuss the requirements of the IxD countermeasures though an examination of the background of that field, and
c. based on the resulting countermeasures defined via "a", select those best suited to IxD open operations filtering them through the requirements in the result of "b".

2.2 Risk of Open Operation

Open Operation risk assessments cover a wide range of topics including administrative strategy, so we will initially focus on risks related to IP laws (hereinafter IP risks) that might possibly result in severe sanctions such as legal injunctions and/or demands for damage compensation.

The production of IxD includes several IP elements that could be subject to a variety of IP rights[x]. Therefore, we began our investigation by examining patent rights because the consequences of infractions in that area pose more serious risks than in others. Furthermore, because patent concerns lead straight to the core of most projects, and because other industrial property right laws, such as the Utility Model Act, the Design Act, and the Trademark Act, all refer directly to the Patent Act in many places, countermeasures to the risks related to those laws can be expected to follow Patent Law countermeasures. Therefore, in this study, we will examine the patent risk in the process described in 2.1 (a, b, and c).

Patent risks that result from infringement exist when somebody without title ownership executes patented third-party technology as a business activity (Article 68, Patent Act) or infringes by preliminary actions (Article 101, Patent Act). Publishing the technological information of a product (such as an engineering draft or source code) via a website is one of the common features in current open operation, including the IxD field. If such information includes patented third-party technology, infringement may result[xi]. In these cases, "the title" means patent right or its license, and "as a business activity" includes offering the product free of charge. Therefore, publishing technological information about such products could result in patent right infringement.

For example, when an engineer develops an electronic device and publishes the engineering draft and software source code for operating the device, an infringement may result if the published information includes patent technology belonging to a third party[xii].

The two primary aspects of patent risk that pertain to open operation are as follows:

1) those that pertain to a practitioners infringement on a third party's patent rights, and
2) those that pertain to a third party securing patent rights for technology produced by a practitioner who has put forth the effort resulting in the production of a new technology.

In both cases, there is a risk that a third party could execute their patent rights to restrain practitioner actions. In the next section, we will study the circumstances and countermeasures relating to both aspects of patent risk.

3 Result and Discussion

3.1 Risks and countermeasures in general open operation (not solely in IxD open operation) (process a)

3.1.1 Expected risk, circumstances, and countermeasures

Table 1 shows an overview of the circumstances and countermeasures related to the two patent risk aspects mentioned above.

Table 1 Expected risk, circumstances, and countermeasures

Expected risk	Circumstances	Countermeasures
1 Practitioner infringes on a third party's patent rights (application before being common awareness or public use)	1.1 Failure to confirm the existence of patent prior to infringement	1.1.1 Patent search >> Patent search, making patent map >> Securing an expert opinion
		1.1.2 Application for patent and examination request >> Application of patent and examination request
	1.2 Patent infringement exists	1.2.1 Rights handling >> Licensing, transfer of rights
		1.2.2 Request for invalidation trial >> Request for invalidation trial
		1.2.3 Redesign
		1.2.4 No countermeasure
2 Third party acquires patent rights for technology produced by the practitioner (after being common awareness or public use)	2.1 No patent application submission	2.1.1 Publication and proof of common awareness or public use >> Publication >> Proof of common awareness or public use
		2.1.2 Application of patent >> Application of patent
	2.2 Application for patent (after being common awareness or public use of the production) was submitted but has not been issued as patent.	2.2.1 provision of information to patent office >> Provision of information to patent office (>> Publication and proof of common awareness or public use)
	2.3 Application for patent (after being common awareness or public use of the production) was submitted and has been issued as patent.	2.3.1 Request for invalidation trial >> Publication and proof of common awareness or public use
		2.3.2 Right of prior use >> Publication and proof of common awareness or public use
		2.3.3 Rights handling >> Licensing, transfer of rights (>> Publication and proof of common awareness or public use)
		2.3. No countermeasure

(Table 1 notes)

<1> This means that the practitioner has infringed on the patent rights of a third party. In other words, it refers to a case where a third party has applied for a patent that covers the same technology produced by the practitioner, prior to his or her production of the technology. In such cases, if the practitioner executes the production, he or she is infringing on the third party's patent rights, and the third party can ask for an injunction and/or damage compensation.

<1.1> This means that no patent infringement by practitioner can be confirmed to exist, and that a patent infringement check is not done, so the check is needed. If infringement is found, the process moves to 1.2.

<1.1.1> Patent searches and the creation of a patent map are two methods that can be used to investigate potential infringement[xiii].

The primary purpose of obtaining an expert opinion by a patent attorney is the prerequisite survey he or she conducts to determine the possibility of patent right acquisition, which involves a survey of related technology patents that have been previously issued. Such opinions cost a minimum of 200,000 yen, and can sometimes exceed 800,000 yen.

For infringement by a practitioner to exist, a third party needs not only to have applied for a patent, he or she must have also obtained the patent rights. However, the Japanese patent system follows the “first-to-file” principle, which means that there is a time lag between the application and acquisition of patent rights. Therefore, it is necessary to search applications that were tendered before the publication of the production (common awareness or public use) to ensure there are no overlapping applications where patent rights have not yet been awarded.

<1.1.2> Under normal circumstances, the goal of such an examination request is acquisition of patent rights. On the other hand, the acquisition of patent rights means that no third party has previously obtained the patent rights for the technology itself. Additionally it has the additional effect of preventing a third party's acquisition of those patent rights (see 2.1.2).

<1.2> This means that an infringement of a third party's patent rights, by the practitioner, exists at this time. In such cases, if the practitioner proceeds to execute production, infringement results, and the third

party can ask for an injunction and/or damage compensation. For information on the “first-to-file” system, see 1.1.1.

<1.2.1> In situations where the practitioner desires to execute production of technology that is covered by a third party’s patent rights, the practitioner needs to obtain a license or receive a legal transfer of the related patent rights. In situations where such transfers are granted, the third party patent right holder normally demands a certain amount of fee.

<1.2.2> An invalidation trial is a legal proceeding that aims at stripping the patent rights from a third party based on the claim that the patent holder does not meet the legal requirements for patent ownership. If there is sufficient evidence to invalidate a third party’s patent rights, a request for an invalidation trial can be considered a valid option.

<1.2.3> Redesigning not to infringe a third party’s patent rights, if it is possible, removes the risk[xiv].

<1.2.4> No countermeasure is available. In a way, this choice is reasonable because the third party is not necessarily asking for an injunction and/or damage compensation, primarily because the legal expenses related to requesting an injunction and/or damage compensation are high. This is also applicable to other circumstance, such as 1.1.

<2> This means that the third party applied for the practitioner's technology after it became common awareness and public use produced and acquired patent rights. Based on the novelty requirement, such applications should be rejected, but successful cases have been known to occur. In such situations, if the practitioner executes production, infringement results and the third party can ask for an injunction and/or damage compensation.

<2.1> This means that no third-party application for a patent that covers the practitioner’s technology exists at this time. In such circumstances, it is necessary to prevent such third parties from submitting applications to patent the technology.

<2.1.1> In situations where a third party applies for a patent covering the practitioner’s technology, if the practitioner’s achievement is well publicized and proven, the examination officer can evaluate the situation correctly and reject the application during the patent examination process. Furthermore, even if the third-party application is initially approved and patent rights are awarded (see 2.3), proof of common awareness or public use of the production can be used as evidence to support the practitioner’s claim during an invalidation trial. It is possible to substantiate that technological production exists or that it is common awareness or public use at the time, by notarization. Notarization provides clearer and stronger proof than is possible without it[xv]. Additionally, production can be published through websites, brochures, academic publications, and similar venues.

<2.1.2> When a practitioner applies for a patent that covers a technological production and acquires the related patent rights, third parties cannot duplicate the patent acquisition. However, even if the practitioner’s application is rejected, the application could be used as evidence for rejecting the third party's application by the “first-to-file” principle. Additionally, the document attached to the application form (description, scope of claims, drawings) could be used as evidence for rejecting separate applications when they are announced in "the laying open of a patent application" made by Japanese Patent Office. Furthermore, such announcements work as official publications in an open operation process.

<2.2> This means that a third party has applied for a patent covering the technology of a practitioner production, but has not yet acquired the patent rights. If patent rights have been acquired, the third party can ask for an injunction and/or damage compensation to restrain the practitioner's actions concerning the product.

<2.2.1> If a practitioner provides information that confirms the existence of his or her product to the patent office, the examination officer can reject third-party applications based on such information (the adduce ratio was 72% in Dec 2011[xvi]). This means it is highly likely that provision of such information to the patent office will result in the application’s rejection. As mentioned above (2.1.1), if the evidence has been substantiated, the proof is stronger.

<2.3> This means that a third party has applied for and acquired a patent that covers the practitioner's technology after it became common awareness or public use of the production. If this situation is allowed to stand, the third party can ask for an injunction and/or damage compensation to prevent the practitioner from utilizing the technology.

<2.3.1> Practitioners can invalidate patent rights though invalidation trials. In such cases, proof of prior existence of the technology can provide an effective rationale for the trial examiner to reject or revoke the application. Thus, publication and proof are effective tools in this stage, just as they are in patent examinations (see 2.1.1).

<2.3.2> A practitioner can demand his/her right of prior use, which allows the practitioner to continue use of the technology. In such cases, prior publication and proof (see 2.1.1) will facilitate such arguments.

<2.3.3> To execute production of technology that is covered by the patent rights of a third party, it is normally necessary for a practitioner to obtain a license or receive a transfer of the applicable patent rights (see 1.2.1). In some cases, where the third party's rights are valuable to the practitioner (ex. transfer of rights), it is possible that the third party will not initially agree to a license or rights transfer. During such negotiations, it can sometimes be effective to state that the practitioner has the option of requesting an invalidation trial. In such cases, publication and proof of prior usage (see 2.1.1) can also be effective.

<2.3.4> (see 1.2.4) When a practitioner has been issued a warning regarding patent right infringement by a third party, publication and proof (see 2.1.1) can provide highly effective counter evidence.

3.1.2 Discussion about each countermeasure

Application for and acquisition of patent rights is effective for both primary aspects 1) and 2), and provide very strong protection. Furthermore, acquisition does not preclude open management from the viewpoints of culture or background. In other words, it is possible to allow open production while retaining the patent rights. This choice can reduce risks significantly. However, the costs related to the acquisition and maintenance of patent rights are generally too high for IxD practitioners[xvii].

Additionally, even if a patent acquisition attempt is unsuccessful, the application itself can increase common awareness of the technology through "the laying open of a patent application". Furthermore, in situations where a patent has been acquired, but is allowed to expire after its initial term, the lapsed patent can be used to block the acquisition of patent rights by a third party. These costs are lower than regular patent management which includes application, acquisition and maintenance. Therefore, it is clear that the patent system can be utilized as a gradual countermeasure in aspects of cost and effectiveness against patent risk in open management.

While publication and proof of common awareness or public use has a certain amount of effect in all situations described in aspect 2), notarization, the system whereby legal existence is established as a matter of official record, can be irrefutable[xviii]. Notarization involves a "fixed date", "certification", "notarized document", and/or a "notarized document of experimental fact".

With such "fixed date", it is possible to prove the existence of the technology in question on the day a related proceeding is done. Furthermore, notarization is inexpensive (700 yen) and easy to obtain. Normally, publication can be executed through documentation or community[xix] that announces the technology, outlines its details, and otherwise assists in the introduction.

When conducting a patent search, the provision of an expert opinion based on the investigation and analysis of a patent attorney is relatively reliable. However, it can be expensive for a practitioner. On the other hand, it is possible to conduct patent searches and create patent maps after a short period of training[xx] as the related database can be accessed free of charge[xxi]. This makes it relatively easy for practitioners to conduct their own patent searches, even if such searches are not quite as reliable as a professional effort.

Furthermore, in cases where infringement is alleged, the matter is often handled based on the presumption of negligence, and the consequences of proven infringement will be calculated lower if the practitioner can prove he or she took action to avoid violations.

3.2 IxD countermeasure requirements based on an examination of the background of that field (process b)

3.2.1 Solvency

The practitioners focused on in this study are presumed to be unable to afford incurring significant IP management costs[xxii]. Therefore, low cost countermeasures are needed.

3.2.2 Market and court cases

(Risks)

- **Market**

The market is small[xxiii] and there is little competition. The background includes open culture [xxiv].

- **Court cases**

Since it is very expensive to take action through the legal system, normally only major companies or "patent trolls" follow this route, and their objectives are normally limited to those with adequate capital to pay sufficient compensation.

Damage compensation amounts are normally calculated based on infringer's gain or the transfer of a certain amount of the production (Article 102, Patent Act). In a case involving open production, where the product is usually available freely via the Internet, both are normally impossible to establish as a matter of practice, and there is only one approved way for the court to calculate it (Patent Act Article 105-3)[xxv]. Therefore, in the case of damage suits, it is often impossible for a plaintiff to confirm definite benefit. Plaintiffs must always consider the disadvantages of pursuing court cases. When a major company brings a suit against a researcher, or when the objective is an open product, this can result in damage to its own image. Thus, even if the objective is the fruit of a charitable activity, the damage can be much more significant[xxvi].

As discussed above, patent risks do exist in IxD, but the amounts and possibilities are not excessive.

3.2.3 Required IxD countermeasure

It is needed to be low cost countermeasure and necessary and sufficient countermeasure in the case of open operation in IxD.

3.3 Best suited countermeasure to IxD open operations (process c)

Based on the countermeasures discussed in 3.1, we picked out the countermeasures best suited to IxD open operations by filtering them through the requirements in the result of 3.2.

3.3.1 Prevention countermeasure

- **Patent search and patent map**

Patent searching and mapping can be conducted at low cost after a short period of training because the related database can be accessed free of charge. This countermeasure is effective from aspect 1) for reducing the presumption of negligence and avoiding patent infringement.

- **Notarization "Fixed date"**

This countermeasure, which only costs 700 yen, can be used to prove the existence of the technology in question on the day a related proceeding is done (or when it was invented), as discussed in aspect 2).

- **Utilization of patent system (application, acquisition, maintenance)**

The patent system can be utilized as a gradual countermeasure in relation to the aspects of cost and effectiveness against open management patent risks. Therefore, this is an optional countermeasure. It is effective for both primary aspects 1) and 2).

3.3.2 After-the case countermeasure

- **Licensing, rights transfer, request for invalidation trial**

Other actions, such as licensing, rights transfer, or requests for invalidation trials, should also be taken on a case-by-case basis, after due consideration of the particular individual circumstances. Additionally, it should be noted that the use of notarization "fixed date" is effective for licensing, patent rights transfers, and invalidation trial requests, as discussed in 2).

4 Conclusion and Future subjects

This paper began with a discussion of the risks and countermeasures related to open operation as a whole (not solely to IxD open operation). We then discussed IxD-related countermeasures through an examination of that field's background. Finally, based on the countermeasures identified in the results of the first step, we selected those countermeasures best suited to IxD open operations based on the requirements contained in the results of the second step.

Future topics of study that are related to risk assessment in open management of IxD research include the following:

1) identification of ways to execute open operation, the effectiveness of open licensing (including patent-related article and defect liability risks, applicable (proper) licensing)
   and
2) other risks (IP risks (design rights, trademarks, copyrights, etc.), management), correspondence in cases where a market grows substantially)

Future subjects that are not related to risk assessment include the following:

1) conducting case studies into open management of other fields, introducing open innovation, exploring the advantages of exclusive management over open management,
2) building open management models in IxD and media art, and
3) building an IP creation cycle model that incorporates open management.

It should be noted that IP management, including open management in media art, is currently being researched and practiced in Yamaguchi Center for Arts and Media [YCAM].

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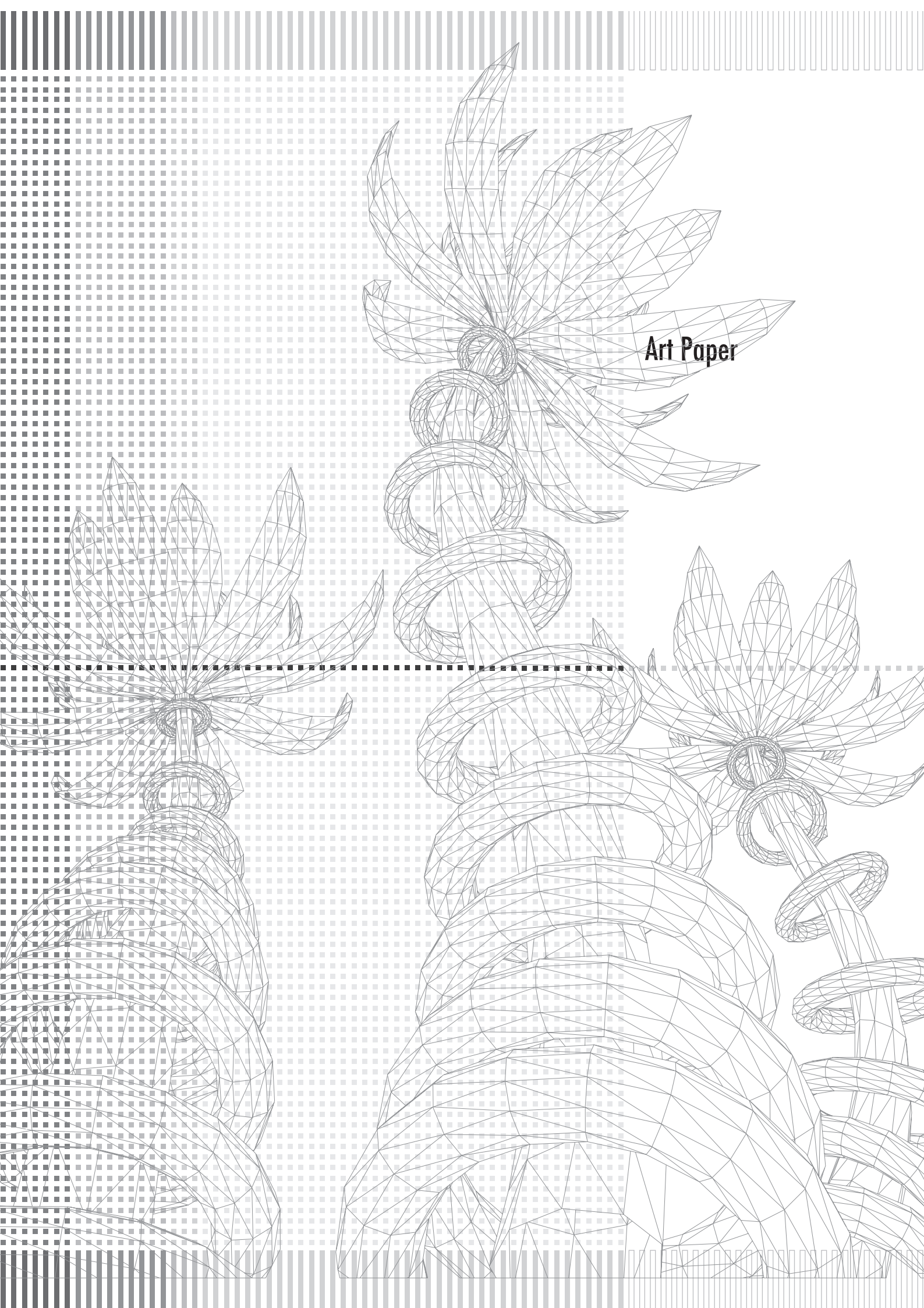
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A design process of musical interface “PocoPoco”: An interactive artwork case study

Abstract
We developed original solenoid actuator units with several built-in sensors, and produced a box-shaped musical interface named “PocoPoco”, using 16 units of them as a universal input / output. From the beginning to the time when a professional artist used it for live performance, we were confronted with many problems and had to solve them. In this paper we present a design process of PocoPoco, explaining actual problems and solutions. Then we discuss the process to design a artistic and practical interface.

Keywords: Musical interface; Tangible user interface; Shape-changing interface.

1 INTRODUCTION

In this paper, we describe a design process of PocoPoco, an interface we researched and developed. It was developed as an interface to provide dynamic affordance with movable parts. Through various processes, now it is being used in a live performance of a professional artist.

The authors have conducted a study that focused on the tactile-visual interaction design. At the beginning this research started as an investigation of possibility of kinetic interface. We experienced various tri al and error to implement this interface. At the same time we received so much feedbacks thorough demonstrations and live performances.

Hardware and software configurations and mechanisms for input and output processing of PocoPoco are described in detail in [3]. On the other hand, improvements in collaboration with a professional musician were made since [3] have been reported. And in [3], artistic issues such as a history of ideas that led to the creation of this interface, consideration about what kind of musical performance can be enabled by this interface, and what kind of musical performances were played actually were not reported. In this paper, we report performances by a professional artist and ourselves, and describe the design process from idea to practical use.

1.1 Abstract of PocoPoco

PocoPoco is an interface that can provide dynamic tangible information using movement of its movable parts. It has original solenoid devices for output and several optical sensors for input. The original solenoid unit consists of a base-parts and movable-parts, and they can move up and down by control from a build-in computer.

The units have built-in tactile switches to detect user’s push and built-in optical sensors to detect each unit’s height and rotations. Then this system can detect user’s “pushing”,

"catching" and "turning" actions.

At the same time, there are two full color LEDs in each unit. The computer controls the switching and the color of light.

This device has one set of MIDI IN / MIDI OUT terminal. It sends MIDI note messages to the outside sound source. At the same time other MIDI devices can control PocoPoco via MIDI control change messages.

Users can (1) edit sound loops, (2) play notes like keyboards and (3) manipulate sound effects by intuitive actions such as "pushing", "catching" and "turning" with PocoPoco.

1.2 Background

Today, there are various types of displays as interfaces that transmit information in the computers to a user. The development of displays is not limited to the improvement of the resolution, various products have been realized such as touch displays, 3D displays and flexible displays. The background of this seems to be that we are needed to manage more and more complex information with computers, so their interfaces are needed to be user friendly. Displays that can change GUI dynamically can work as an IO interface for various contents. But the information users receive is still limited to visual and audio. On the other hand, there are some reports about shape-changing interface.

Physical movement of real object provides impression to audience that could not be expressed by pictures. G. Michelitsch et al. developed Haptic Chameleon[4] and they tried to control affordance that an interface provides to users dynamically. Physical movement of interface can provide dynamic affordance to a user.

In the field of art, movable works represented by kinetic sculpture have attracted audience for a long time. Early experiments with movement in art began in the 1910s, led by artists of the Dadaist and Constructivist traditions represented by Marcel Duchamp. In 1920, Constructivist artists Naum Gabo and Antoine Pevsner used the term "kinetic art" in their Realistic Manifesto. Most of kinetic art works early in the twenty century were put into action by the force of wind or water. On the other hand, in these days modern art works controlled by computer systems are increasingly being published. For example "MorphoTower" by Sachiko Kodama [5], a magnetic fluid composed of micro magnetic particles carried in a water or oil based fluid are controlled by dynamic magnetic fields manipulated by a computer. On the other hand Parkes, et al. argued about kinetic interaction, as they called "Kinetic Organic Interface"[6]. They mentioned its specification and possibility for Human Computer Interaction.

Physical movement of an object may express information that visual and audio approach can't express. And kinetic interface itself can be art. From such a background we proposed attempts intended to integrate physical information such as movement and tactile information, with image expression, such as displays that integrate magnets or feather with displays [1][2]. At the same time we started a research of an interface that uses physical movement of itself as a media to transmit information.

1.3 Abstract of a design process of PocoPoco

Here we show our PocoPoco's development process at figure 1.

2 RELATED WORKS

Here we introduce related works we studied for PocoPoco's development.

2.1 Shape changing displays

In the field of shape changing displays, various structures for kinetic movement are being proposed.

Hoggan et al. [7] showed that input on a touch screen can be improved by adding haptic feedback for typing tasks.

Iwata et al. made FEELEX[8], a kinetic display consisting of movable pin actuators using DC motors and Piston-crank mechanism. Relief [9] by Leithinger et al. and Recompose[10] by Blackshaw et al. are also kinetic displays using DC motors and faders. A kinetic display with a DC motor has speed and power, but it is noisy.

On the other hand kinetic displays powered by a shape memory alloy can move quietly. Poupyrev et al. proposed RGBH display, where RGB is a color components and H is a height of a pixel. Lumen [11]. is an implementation of such RGBH display. This box shape black display has a matrix of LEDs and thin shape memory alloy (SMA) wires built-in. 13 by 13 pixel bitmap can express 2D image by LEDs and each pixel can also physically move up and down by SMA wires. It allows users to feel shapes of virtual images through touch. PopUp! [12] by Nakatani et al. are kinetic displays using a shape memory alloy too. A shape memory alloy can move very quietly, but on the other hand, it's not so powerful. And it takes relatively long time to transform, so it is not convenient to materialize rhythmical movements.

2.2 Tabletop type musical interfaces

In the field of interaction design, various types of tabletop interfaces have been developed and proposed. PocoPoco is one of the tabletop interfaces for musical expression.

Iwai et al. published "musical chess"[13], one of the tabletop device inspired by chessboard. In this work users can play music by arranging balls on the board.

"Notes on Small Fish" [14]is a table top device developed to support musical education.

In this work multiple users play music on the round table at the same time. This seems to be good example of tabletop device that used an advantage of tabletop device.

Pompeu Fabra University Music Technology Group developed reactable [15]. This system captures objects on a table and generates electronic music. Sequence music is played corresponding to moving and turning objects. Compered to other musical interfaces to play live electronic music, because reactable has tangible object as a music controller, it is easier to understand for audience how the player is controlling the music. Being used many professional artists for live

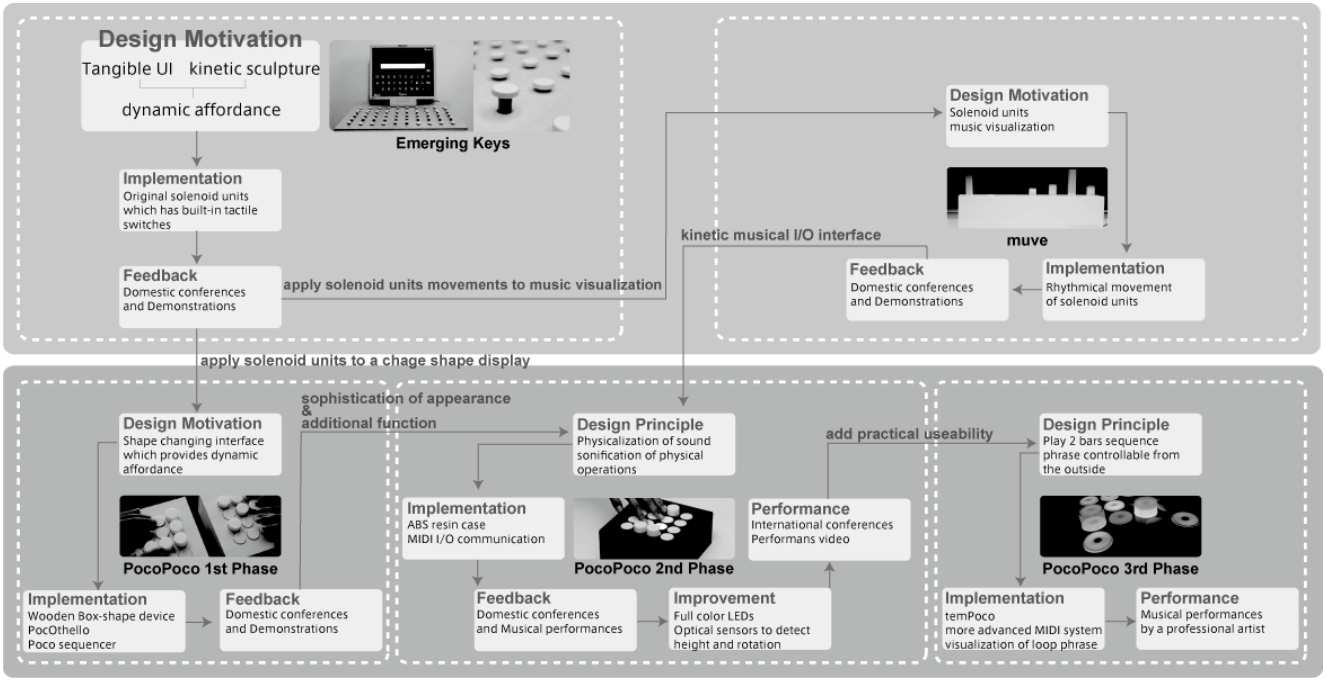

Figure1 Abstract of a design process of PocoPoco

performances this interface proved tangible musical interface is attractive for musicians and audience. And the developer team is commercializing reactable.

2.3 Sequencer type musical interfaces

This interface is kind of a music sequencer type electric instrument. Music sequencer is one of a device that plays various rhythms automatically. Some step sequencers, such as Roland MC-808 [16], can arrange rhythm patterns dynamically, and are being used by many artists for live performance.

Tenori-on [17], a Product of Yamaha, is an instrument that enables users to play music visually. With this instrument users can play music like drawing. As a salient characteristic of this instrument, Tenori-on has reversible displays, at the front and the rear. This means one display is for a player and another is for audience. Here the interface for musical expression seems to be regarded not only for players, but also audience. Its intuitive and visual-based interaction so was attractive that actually it seems to have provided many people who are not get used to manipulate rhythm sequencers an opportunity begin to use this type of machines.

We were inspired by Tenori-on's interaction design and playing method as a musical interface. On the other hand PocoPoco is kinetic interface and its physical affordance can provide information that cannot be expressed by visual and audio approaches. We applied physical interactions like "catching object" and "turning object" to musical performance, to differentiate our device from others.

3 PRE IMPLEMENTATION

Before starting the production of PocoPoco, we have made the production of two proactive works. "Emerging Keys" became basis of PocoPoco I/O system. "muve" showed a possibility of visualization of sound by up-and-down movements of solenoid units.

3.1 Emerging Keys

Emerging keys is a device that changes their interface in accordance with the purpose of use [18]. For the purpose of typing, they transfer to a keyboard, for the purpose of game, they float and user can use it as a controller.

3.2 Muve

Muve is a tangible music visualizer with seven original solenoid units [19]. It decomposes audio data to seven frequency ranges using Fast Fourier transform. And seven solenoid units move up-and-down corresponding to the sound level of each frequency level.

4 PROTOTYPE IMPLEMENTATION

In this chapter, we describe a development process and two applications we made in the first phase.

4.1 Conception

When we investigated previous studies of haptic interfaces, we discovered that most of games or electronic musical instruments are hard for users to control without visual information. Study of interfaces that can be used without visual information would lead to a development of universal interfaces useful for visually impaired people.

In the case of Emerging keys, our previous work, our concept was making an interface that can change the shape of a controller dynamically. Then the role of solenoid units was just forming various shapes, so the movements of them were not being focused seriously. Emerging keys was designed as a device that outputs image and sound. Accordingly, it had a display and a set of speakers.

We turned attention to movement of solenoid units itself and started considering a new interface that can provide visual and haptic effect for interactive system. The interface provides advanced interactions by integration of input parts and output parts. To present the tactile sensations of all solenoid units, the device was considered to be large enough to fit both hands of the user. Then we changed the number of solenoid units, from vertical and horizontal 6×10 of Emerging keys to 4×4, and designed the size of device vertical and horizontal 205 × 205mm, it is suitable to feel all of the solenoid units' movements when a user covers the device with both hands.

4.2 Hardware

The prototype was designed as shape changing display, to be used for a multiplicity of uses such as a communication tool, game and musical instrument.

Original cylindrical units (Figure 2) that can move up-and-down by solenoid actuators, named "Poco", are mapped into a 4x4 matrix. A tactile switch is embedded in each of the unit. So this unit can work as button input device.

A micro controller board, Arduino Mega, processes all the input-output control system.

In addition, we installed two speakers and a sound generation module, to realize sound output. And we installed one USB terminal to communicate with the outside computers. The casing consists of plywood.

4.3 PocOthello

PocOthello is a game application of PocoPoco whose motif is famous board game "Othello". PocOthello uses concavo-convex shape of Solenoid units to tell the condition of pieces meanwhile ordinary Othello uses black and white color of the surface (Figure 3). When user pushes Solenoid units, PocOthello builds the concavo-convex shape by computerized control in each case and PocOthello expresses a passage of pieces by the motion of Solenoid units. The feature of this application is that users can recognize the condition of the game haptically by putting their hand on the device. Therefore, even visually impaired people who cannot play ordinary Othello can play this game. At the same time dynamic movements of the device is impressive as a visual expression.

4.4 Poco Sequencer

Poco sequencer is an application developed to use PocoPoco as a musical interface. Using this application, users can make loop music easily. Through the survey of sequencer type musical interfaces, we found most of them are making music

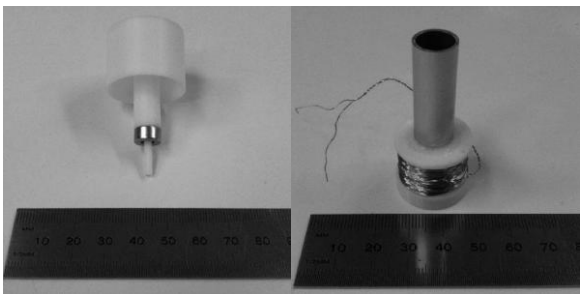

Figure2 a set of solenoid unit for the prototype
Left: movable parts, Right: base parts

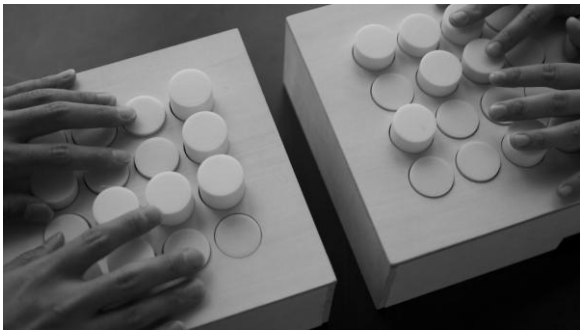

Figure3 playing appearance of pocOthello

by playing some musical phrases every bar or multiple bars. As seen in most of rhythm machines and music sequencers like Tenori-on, time progress in the sequence is expressed by a shift of timeline from left to right.

This system seems to be attributed by the fact that in general musical score time progress is expressed by a shift of timeline from left to right. In the case of Tenori-on, the device has 16×16 IO units and each row means one bar of a musical instrument. In the case of PocoPoco, to express sequence by 4×4 units, we applied a method to shift left top to right bottom, 16 units expresses one bar of a rhythm sequence (Figure 4). In the general musical score, time progress is expressed by a shift of timeline from one row to lower row, so this method seems to be easy to understand.

When a user pushes the top of a cylinder, its switch is flipped to the "on" position causing the cylinder to rise and a sound to play at regular intervals. When a Poco turned on is pushed down, its switch is moved to the "off" position and movements and the sound stops. Each Poco means a sixteenth notes, users can make loop phrase by selecting and pushing them freely. These tones are arranged so that a pleasant harmony results no matter which combination of notes is used.

Layers

PocoPoco has relatively few IO units and it can't express loops for multiple instruments at the same time. So we applied layers. Poco sequencer manages multiple layers in the program. Each layer keeps the sequence of one instrument. So users can pile up different musical phrases by changing layers. And each layer has a characteristic sound tone. Users can

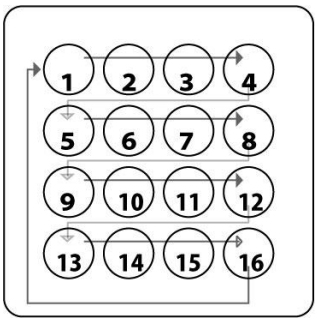

Figure4 order of the timeline shift

change layers by pushing specific 4 units at the same time.

4.5 Exhibitions and feedbacks

After the prototype implementation, we presented PocoPoco to some domestic study groups and displayed to some exhibitions.

The automatic movements of cylindrical units seemed to attract audience, from children to researchers.

Poco sequencer was praised in particular. The rhythmical movements of units seemed to attract audience. Thus we decided to concentrate to developing a musical interface using this device.

5 IMPROVEMENT FOR MUSICAL PERFORMANCE

In this section, we describe about the phase when we improved PocoPoco as an interface suitable for musical performance from the prototype. Below we detail changes in hardware and software, and feedbacks from the audience of exhibitions and music performances. In the prototyping phase, the shape changing display formed by solenoid actuators seemed to have some potential. Especially, Poco Sequencer, a musical application we made got positive feedbacks in some demonstrations and presentations. Therefore we decided to optimize PocoPoco as an interface for music performance. Then we improved design, hardware, and software.

5.1 Design goal

Poupyrev and et al. [20] mentioned design issues for musical controller for good design of musical interface on workshops, in CHI2001. Considering those issues, to apply this shape-changing interface to musical expression, we set following design goals:

Easy to play

Even children and musical beginners can play it in a short time. Without any special practices, users can enjoy playing it in a day. To realize it, we designed a simple and easy playing method as much as possible, for example users can play sequence music just by pushing each units and change sound tone by pushing four units at the same time.

Intuitive interactions

We aim to design intuitive interactions by mapping natural gestures to suitable musical elements, like “catching a moving object” “turning a knob”.

By unit’s movements and light expression, users should receive some suitable affordance. Movements of the units are well designed to present affordance to users, so as users can understand the playing method without any explanations.

Fine growth curve

According to the survey by Magnusson and Mendieta [21], though the longer people had played an acoustic instrument, the more they stressed the importance of embodiment in their musical practice, playing digital instruments seems to be less of an embodied practice. By introducing analog operations like "catching" and “turning”, we aimed at the design of the instrument to achieve precise operability, which has a good growth curve.

Aesthetically pleasing

Sophisticated instruments have sophisticated outward appearances. To motivate users to play music and to fascinate audience, we aim to design an aesthetically pleasing interface. Though in the case of the prototype we used plywood for the casing, since this improvement we have used the casing consists from ABS resin. We designed 3D models and made them using a 3D printer. We coated the base with surfacer, after that painted it. An ABS resin 3D printer that is currently popular has 0.25mm pitch. Because of surface bumps and light reflection, to make an aesthetic interface, we could not use the ABS resin directly. To make aesthetic interface using the 3D printer, we took below steps.

1. Filing by hands
2. Coating with surfacer (3 times)
3. Coating with paint
4. Filing by hands

After such steps, we implemented the black and white colored interface like an acoustic piano.

5.3 Implementation of MIDI system

Though the prototype could work rhythmically by measuring internal execution time, it did not have any communication functions and could not synchronize with other devices. On the other hand, depending on the small built-in sound module was limiting the variation of the sound tone. When we assume the use for full-fledged musical performance, it seems more reasonable that PocoPoco sends just trigger messages and an external application synthesizes sound. This method may be more flexible and expandable. Then we took away built-in speakers and a sound module, and installed MIDI IN / MIDI OUT terminals, then added MIDI communication functions.

By using general MIDI communication, users can use any

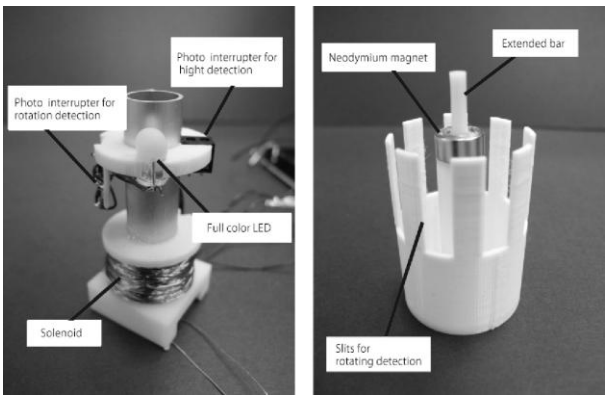

Figure5 a set of improved solenoid unit
Left: Base parts, Right: Movable parts

sound generators, workstations and speakers with PocoPoco, easily.

MIDI OUT

PocoPoco sends MIDI note messages from MIDI OUT, to play sound in the sound source. MIDI messages are sent to DAW (Digital Audio Workstation) software, Logic Pro in the computer, through a MIDI interface. Logic Pro play sounds, corresponding to the MIDI note messages.

MIDI IN

PocoPoco can be controlled by MIDI messages sent to MIDI IN. START, STOP, RESTART of sequence is controlled by general MIDI control messages. Users can send the control messages using DAW or MIDI controllers.

And users can control PocoPoco's rhythm by sending MIDI clock messages.

Users can synchronize multiple devices by sending same MIDI clock message to them.

We are using MAX / MSP application to synchronize 3 devices for 3 performers' ensemble.

5.3 Implementation of "catching" and "turning" functions

We witnessed many user tried to catch the popping units, or rotate or press cylindrical units. From the feedbacks we got by exhibitions of the prototype, some new ideas for more intuitive interactions occurred to us. Despite they didn't receive any explanations about playing methods, but they tried "catching" or "turning" actions to the moving units, as if they were granted actions. Then we considered these actions were quite intuitive for users, and we redesigned interactions and tried to map these actions to musical manipulations. To realize it, we implemented additional sensing system using multiple optical sensors. We installed three photo-interrupters in each solenoid unit, to detect units' rotation and up-and-down movements. To detect the height of movable parts, we fixed a photo-interrupter on the base parts (figure 5). This sensor tells the distance between base parts and the top of movable parts.

In addition, we installed two photo-interrupters to detect the rotation of the unit. The movable parts were rotatable around the axle of the unit. We made slits in the movable parts. Using these two photo-interrupters' data, the program detects rotation like rotary encoder (About these sensing system, please see [3] for details.).

Catching

PocoPoco's up-and-down movements are often compared to a certain arcade game, Whac-A-Mole.

A user who watched a rhythmically jumping or falling cylindrical unit, he or she can't stop to gaze it and try to catch it. We likened this operation to catching sound, and mapped it to sound sustain. During a user is holding the unit above, the sound tone doesn't attenuate.

Turning

Possibly because the cylindrical movable parts looks like some knob, many users try to turn the solenoid unit. Then we mapped the turning operation to the operation to control sound color. For example audio mixers and compact effectors for electric guitar, in general knobs are widely used to control sound color. Specifically, we mapped "turning" to volume and amount of modulation effect.

5.4 Implementation of full color LEDs

Through some demonstrations and live performances, the idea to install full color LEDs in solenoid units was occurred to us. The computer controls this full color light, so its color and timing can be corresponding to up-and-down movements. After this implementation, up-and-down movements with flash became more impressive and attractive for audience. At the same time, by changing light color corresponding to the editing layer, user can see the editing layer more clearly.

5.4 Implementation of Real-time mode

Through demonstrations in study groups and exhibitions, we found that most of musical beginners were supposing all the instruments generate sound after input gesture immediately.

In addition, PocoPoco's sequence function is suitable to compose some rhythm sequences like a drum set, but it is not suitable to play a melody. Then we implemented "Real-time mode" additionally. In this mode a sound note is played once the unit is pushed immediately.

5.4 Designing original score

As mentioned previously, this interface is optimized to play sequence phrases, and the playing method is not similar to the one of acoustic instruments like piano and guitar.

During making performance systems, we found ordinary musical score is not suitable for PocoPoco's play. So we designed original musical score (figure 6,7). In this score, the timeline moves left to right, and the units to be pushed is expressed visually.

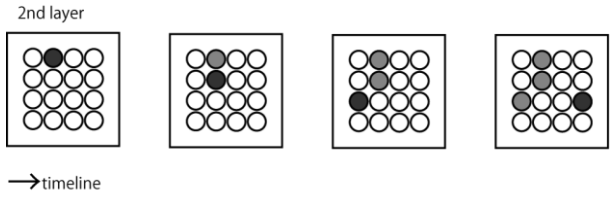

Figure6 example of the original scoring for PocoPoco

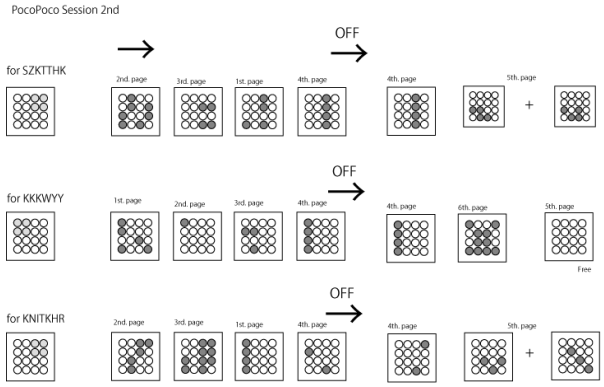

Figure7 score we used for the performance

5.5 Performance and feedback

Until now, we performed 8 musical performances and 11 demonstrations including ACM SIGGRAPH 2011 Emerging Technologies, and we estimate thousands of visitors played PocoPoco and watched our musical performances. Every time we get some feedbacks from visitors, we have been making many improvements to PocoPoco. Below we introduce some actual performances and feedbacks.

At the intercollege computer music concert 2010 on December 5, 2010, three of us performed the first ensemble concert. In this performance the synchronization of multiple PocoPoco with MIDI communication, the sound synthesis using external sound source, the Real-time mode to play the melodies, and an original score for the original composition were realized. From the fact that this performance has gained the support of audience and researchers, an ensemble format for three performers has been the basic form of our musical performances. Also, at that time we got the first idea of "catching" and "turning" operations, from the feedbacks of other researchers.

At the 89th IPSJ Special Interest Group on music and computer (SIGMUS) conference on February 11, 2011, we added one microphone to three PocoPoco, and we played songs including vocal performance. The vocal sound was processed like robot voice, and at that time one PocoPoco was working as a vocoder. The player could decide the vocoder's pitch by pushing PocoPoco's solenoid units, like real-time mode. This playing method was developed to expand PocoPoco's playability, but from the feedbacks we found the interaction between actions and sound was not clear for audience, then we abandoned this method as a result.

In June 2012 we published a movie of 3 performers' ensemble on the web. As of February 2013, this movie has been played more than 30 thousands times, and commented more than 35 times. Possibly this fact prove the potential of the musical performance with PoccoPoco.

Figure8 performance using PocoPoco as a vocoder

Figure9 a screen shot of the published movie

6 COLLABORATION WITH A PROFESSIONAL ARTIST

In this capture we describe a development process of PocoPoco's third implementation. In this phase we did a collaborative research with a professional artist Little boots, based in London. Through this collaboration, we improved PocoPoco to achieve her requests, and then this interface became more practically useful and attractive. We explain the process from the beginning of this collaboration to the live performance she used PocoPoco in public.

6.1 Little boots

Victoria Christina Hesketh, well known as Little boots, is electro pop singer songwriter born in U.K. She is a versatile player and she plays piano, keyboard, synthesizer, Tenori-on,

and etc. on the stage. She performed in Japan SUMMER SONIC 2009 at first. Including solo performance in Japan, she continues to perform actively at home and abroad.

She found our research through the Internet, and offered the collaboration with us. At that time PocoPoco had never been played on commercial music stages.

By complying request from a professional artist, we could improve the interface efficiently. Thus we decided to collaborate with her. For this collaboration we had one meeting and exchanged emails about 150 times so far.

6.2 Process of the collaboration

This collaboration started from a meeting at Tokyo. As her artistic characteristic, he takes a lot of electronic instruments and synthesizers in musical performance. She says she demands for her musical interface to be as visual as possible for a live performance so the audience can see what is happening and understand how the sound is created. And she says if the audience can make a connection between what they are seeing and what they are hearing then that is the ultimate achievement for her for a live show. From this point of view, PocoPoco, an interface that physicalizes sound by object's movements and light, seems to be suitable interface for her live show. Also, because she mainly plays dance music, she often plays on the dark stage and light of PocoPoco fits to the music. Through meetings and exchanges of e-mail, we reached one conclusion that the new PocoPoco she would use should be able to play two bars long phrases, to play a motif phrase of her representative song "Shake". At the same time, the sequencer had to be controlled by an outside interface (For example other instrument players can stop and restart the sequence using a MIDI interface). To achieve this we had to develop a more advanced MIDI system. In addition, for the audience, she hoped more impressive visualization of sound.

6.3 TEMPoco

PocoPoco's 4x4 matrix units are suitable to express 16 beats phrases. On the other hand it is not good at expressing long bars phrases. To enable PocoPoco to play 2 bars phrases, we had to remedy a defect. Then we developed a new gadget named "TEMPoco". This device relays MIDI messages between the outside interfaces and PocoPoco.

It has 3 sets of MIDI I/O terminals. One is connected to the outside interface and others are connected to two PocoPoco (Figure 10, 11). TEMPoco receives MIDI clock messages from the outside, and sends one bar's MIDI clock messages to one PocoPoco alternately. Each PocoPoco play one bar phrase one by one, then two of them can consist 2 bars loop phrases.

TEMPoco bypasses all MIDI note messages from two PocoPoco to the outside interface. In addition, control messages such as "stop", "restart" and "reset" are sent from the outside interface and relayed to two PocoPoco at a time. A program in PocoPoco receives these control messages and controls its sequence. Using TEMPoco, we could enable PocoPoco to "play 2 bars long phrases" and make it "controllable from the outside".

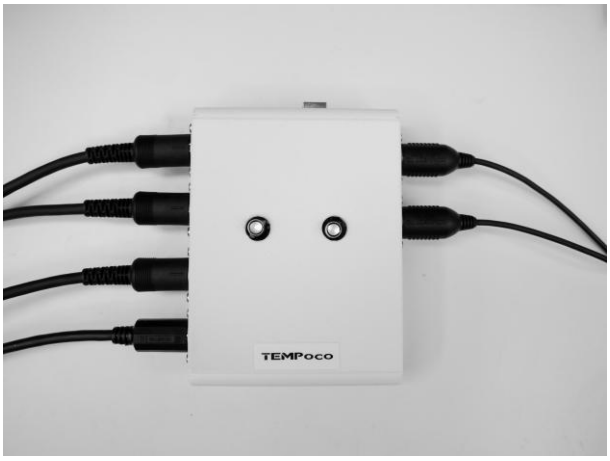

Figure10 appearance of TEMPoco

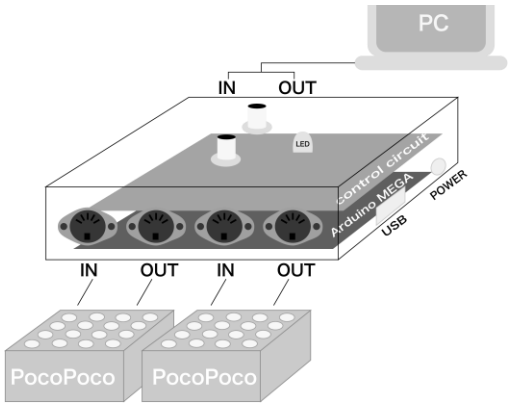

Figure11 communication system of TEMPoco

6.4 Visualization of the timeline

For more impressive interaction, we visualized sequence timeline by LEDs' flash. The flash pointed the timing of 16 beats. In addition, we set up respective light color for each layer. When some unit's switch is turned on, the unit continues to turn on the light. Using this system, users could compose rhythm sequence like drawing (figure 12).

6.5 Performance and feedback

May 4, 2012, at XOYO London, Little boots used PocoPoco for her public live performance at first. In this performance two PocoPoco were connected to TEMPoco, and could play her song "shake" without mishap.

After that we performed a questionnaire by e-mail to her about evaluation of PocoPoco as a musical interface. As good points, she mentioned

·a music novice or beginner could easily play with PocoPoco and start making music and begin to understand the connection between what they are playing and how the sound is reacting.

·a trained musician like herself can use it and get to a very

advanced level of programming and performing with it quickly

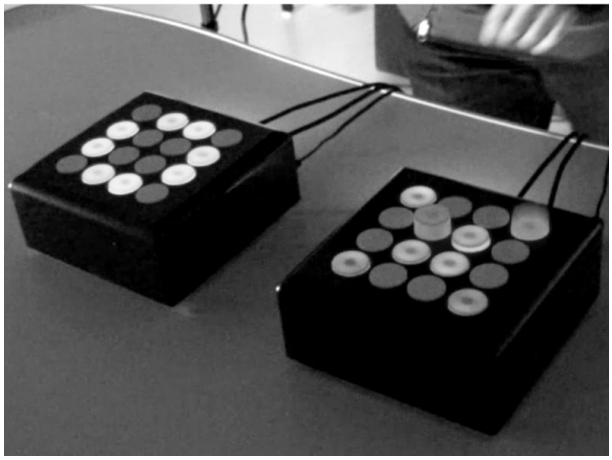

Figure12 Playing appearance of PocoPoco, the third phase

In fact she says that she witnessed large audience was gazing on and fascinated by PocoPoco's movements.
On the other hand, she mentioned bad points below

·The main difficulty for her with PocoPoco is it is not stable enough to be moved around for live performance and touring travel

·She had many problems with the solenoid units not reacting or getting stuck and having to open up the inside but repairing them was too hard for herself.

We consider that these problems are due to the fact that many of the current manufacturing steps of PocoPoco is dependent on the handwork. Changing the course of production, such as outsourcing some modules, may solve these problems.
Even though it has a difficult point about stability, she is highly approving the potential of PocoPoco as a musical interface for full-fledged musical performances. This collaboration will continue and additional improvements will be implemented. PocoPoco will be more stable and practical to be used for various performances.

7 CONCLUSIONS

In this paper we described a design process of PocoPoco. Through various design processes such as planning, implementation and evaluation, PocoPoco made refined as a practical interface. Especially, collaboration with a professional artist seemed to be an efficient process to improve the interface. PocoPoco can provide advanced interactions by integration of input parts, such as a tactile switch and photo-interrupters, and output parts, such as a solenoid actuator and full color LEDs into a small unit. This unit is just a cylinder as long as it has stopped, but once it starts to move and flash, it can provide various impressions such as Whac-A-Mole or a knob. More precise control of these movement and light may create other impressions. We will keep studying affordance that an interface provides to a user, and pursuing intuitive interactions with that a user can control the interface without any explanations. While we abandoned some applications such as "pocOthello" in the design process, shape-changing interface has possibility to be used for various applications. We would like to continue designing new interfaces, referring to PocoPoco's design process. PocoPoco is a so simple and intuitive interface that music novice or beginner could easily play with it. At the same time its physicalization of sound is valuable for full-fledged musical performances. But this interface is immature, for example about the stability or preciseness of control. We will keep refining them and pursuing artistic value, for example original sound or playing methods that only this interface can realize.

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