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“Penguin Hockey”: A Tangible Playroom for Children

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We have developed an interactive installation called "Penguin Hockey". It is a demonstration content of "Tangible Playroom" for children. Tangible playroom looks an empty children's room but it has large tangible image space with projector and big spatial force feedback display. Children can interact with not only computer-generated objects but also their friends and real physical objects. Penguin Hockey is a simple 3D hockey game playing with A.I. penguins. Players can interact with computer-generated objects and their friend. It is targeted to players as young children, elementary school age (6-12). This system provides not only application of Mixed Reality, but also a tangible life space installation naturally.

1. Introduction: "Humanistic Reality"

“Humanistic Reality” is the most important element for interaction in the future. We also believe this is an important element in the future of computer entertainment.

Graphics, network and force display technologies have greatly expanded the possibility of computer entertainment and the market of video game industry in recent years. However, it is causing a serious issue to children who are main target user of computer entertainment. The amount of time they spend playing games reduces the occasions to interact with other people as well as being physically active.

The philosophy of most computer entertainment worlds focus on violence and exclusivity. And they train their players to single players in the sprint of “Winner is good, winner is one." However, computer entertainments main target isn't essentially negative education and/or non-moral, is it? If the main reason for this problem is only a request of incentive from market, what is the forgotten element of current computer entertainment history?

Virtual Reality (VR), Mixed Reality (MR) and Augmented Reality (AR) technologies are deeply related to the computer entertainment technologies. Both of them are interactive, though VR/MR/AR technologies don't only aim at the amusement. In the standing from these researches, we noticed that human specific real feelings are important rather than device/sensor specific realistic stimulus through understanding about human information processing such as

perception, sensation and representation. Human specific real feeling includes a lot of information not only physical but also unphysical like senses or images. And now, we have no measure for this unphysical information. In addition, it's nonsense to clear them all. Then we defined these to integrate as “humanistic reality" in this paper.

If the forgotten piece of current computer entertainment is humanistic reality, how can we solve the problems that we said above?

2. Motivation

Computer entertainment has great influence power to children. It can give a lot of unphysical stimulus to players via computer monitor. For example, affective Role Playing Games can show a supposed world, social system and artificial mentality. “The Sims" can praise an importance of human relation using its game system. “Ultima Online" realizes explorations, communications and life with someone in another country. They look interesting and we can spend time to get some amusing.

Our main motivation is we would like to realization of some possibility to solve a problem. The problem is simultaneity between amusing of computer entertainment and losing of humanistic reality. Impressive computer entertainments deprive children of time to be spent with family and/or school friends because of the attraction to them. The time to be spent includes naturally important humanistic reality. The idea of humanistic reality can be represented by some examples such as, “Beating something causes painful fist", “No experience can be copied", “Relations of friend cannot be reset", or “Another person doesn't understand my eyes' view in directly". Each example is very simple but we cannot program all of them into a computer entertainment. If we realize something that solves them using interactive techniques, people will notice the important forgotten piece in the history of computer entertainment. This is our main motivation.

3. Related works

If we plan to realize our motivation as making an entertainment application of MR/AR technologies such as “RV-Border Guards: A multi-player entertainment in Mixed Reality Space"[1], will be very excitable and impressive for visitor. However, it cannot solve our motivation. These systems have different orientation from us. Because it needs different installation in different entertainment space, its contents cannot be replaceable. We have to execute our system on usual life space naturally for realizing Humanistic Reality.

To realize our concept, “Tangible" is a good keyword. The word Tangible means “material, palpable, perceptible, physical plain". Especially, MIT Media Lab has a research group for tangible (http://tangible.media.mit.edu/). Their works such as “TellTale" [2], "PingPongPlus" [3] or "KidsRoom" [4] can show us a possibility of Humanistic Reality. However most users of these tangible interfaces are supposed as divided people by computer or networks. Our targeted people are children who play a future computer entertainment. And we would like to solve a problem that children are divided from their family. Then players' time and

space should be shared with other people. Our previous works provide some hints. “Foot Interface: Fantastic Phantom Slipper" [5] realized naturally an installation that has an immersive half dome shape floor screen and slipper style interface with a real-time optical motion capture system. Its player can feel physical activation using their whole body movement. For children, projected floor screen is intuitive and tangible, but it is a weak point that the players have to wear the wired slipper interface.

“SPIDAR" [6] is a space input device with force feedback. It is a useful device that has a long history and applications in force feedback display researches. “Virtual Basketball" [7] is a real-time basketball simulator with a large back projected screen and big SPIDAR as large as a room. In this system a player can feel and throw an invisible basketball. The content for this system will be able to be replaced, but its large screen matches only to an entertainment location such as a game center or inside of CAVE rather than home computer entertainment [8].

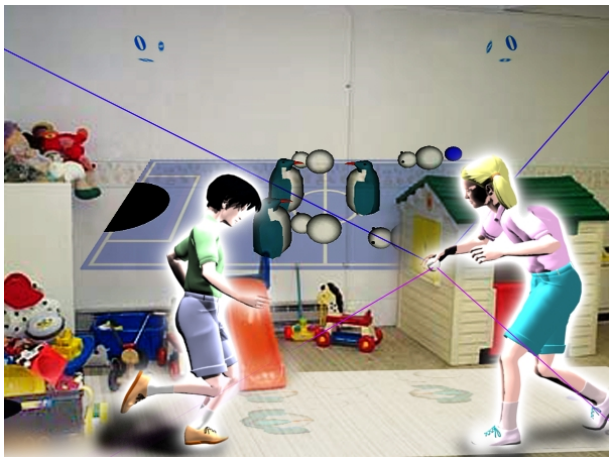

Figure 1. Supposed Image of Tangible Installation. Children can interact with computer-generated characters in usual living space. Strings for Force Feedback are built in corners of the room. It can remove from a grip with in a short time.

4. Development

4-1 Design Philosophy of Tangible Playroom

Because of above backgrounds, we have targeted our new system for the future computer entertainment as below:

-We have to install it to daily living space.

The future of computer entertainment, which we think, shouldn't divide children from their family.

-Our system should be able to restore the room to normal state as soon as possible.

If our system needs a special room for installation, no one will use it except rich people.

-Our system has to display a force feedback with simple devices.

Humanistic Reality cannot realize only visual stimulus.

We named these concepts “Tangible Installation" like “Tangible Interface”. Traditionally, the “interface" sounds the medium surface between the user and the computer. In our concept, it looks a medium between players as well as a mirror like reflection for each player.

Additionally, the home is the best space for education and learning society. Especially, a

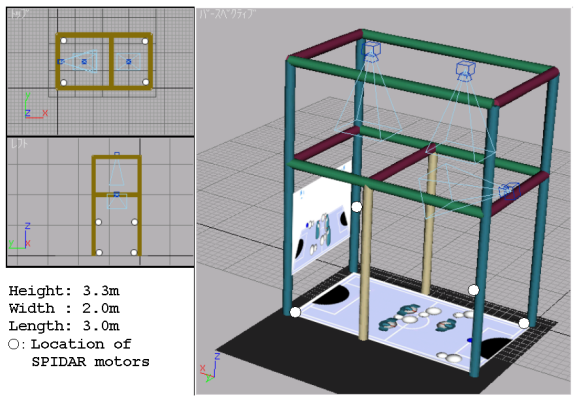

Figure 2. Prototype of Tangible Playroom system. It has 3 projectors and 4 force feedback motors with a tough steel frame. Projectors illuminate 2 screens made of vinyl for easy maintenance.

nursery (children's room) or a playroom sounds good for entertainment. If we plan an exclusive room for our system, it will be only an extended concept with current computer entertainment. So we call the new system “Tangible Playroom".

4-2 Hardware

We describe our prototype here. The framework of our system is built of steel poles, which are 5.5cm in diameter. These form a structure, 2m wide, 3.3m high, and 3m in lengths. It has 3 projectors, each connected to a PC. These illuminate the floor and the front. The floor screen is the main screen for playing, with the front screen being subsidiary. In the center of the system, we set a grip sphere (4.0cm in diameter) for the force feedback system, “SPIDAR". It can input 3D location and generate force feedback using wire tension from 4 encoder motors.

Ideally, these motors should build into a room structure like corner column. And the grip sphere of SPIDAR can change other grip like dodge ball or a toy plane for contents flexibility.

4-3 Flexible Multi Projection

To make immersive image space to usual living space, we have to generate large image space. The prototype has 3 sets of projector and PCs. Then we have developed flexible multi-projection image generating system. Network-connected computers make it and each client computer performs rendering 3D characters in real-time. All clients are completely separated each other so it can generate image as large as system need. For adjusting their projected images, we prepare an easy adjusting software system, too.

This is very important system to realize our tangible playroom. It can enlarge a play field as number of projectors as environment need. And if people need to render a subsidiary screen or animated cute wallpaper for playroom, it can do it too.

It is the most important point that Flexible Multi Projection system is great cheaper and transportable than previous multi-projection system like CAVE.

4-4 Game Design of “Penguin Hockey"

We decided our game design of the first contents for “Tangible Playroom" as shown below:

Feel Humanistic Reality

It's immersive, tangible but un-exclusive. No one kills someone. Instead, children can learn important physical/unphysical experiences here.

Cooperative and Collaborative

In our system, a few players can play at the same time. And the computer is a companion, not an enemy. Our system should be used collaboratively. If our A.I. character is a target for violence or destruction, it doesn't match our concept.

Activate and Intuitive

This isn't only an experimental system but also game for children. The look and feel of our system should be amusing and joyful. Players should be able to walk, run or roll without constraints. Our system should not require the players to adapt to arbitrary rules.

These design concepts created the first game contents, “Penguin Hockey". The “Penguin hockey system" is based on a simple Ice-Hockey style game. Characters, the 3 “A.I. penguins" in 2 teams, move on the iced field freely. There are 4 pucks,

which are shaped like “Snowmen", and both of the sides have a goal.

Each penguin moves to take the pucks to the rival side's goal. The player joins to fields as one of the penguins. To win the game, the player needs to collaborate with the teammate penguin on the same team. For example, when the rival penguins shoot the puck at the player's goal, if a teammate guards the goal, the player can block rival attacks in front line. Similarly, if the teammate attacks in the front line, the player should guard in front of the goal (Fig.3).

A typical play style is collaborating with A.I. penguin of same team and throwing in pucks shaped like a snowman to goal hole. Subsidiary players can join together, because the floor screen is too large to see whole screen at once, and the main player needs help from subsidiary players. Sometime penguins of rival groups defend their goal then player can push penguins by own hand with some heavy feel and its voice.

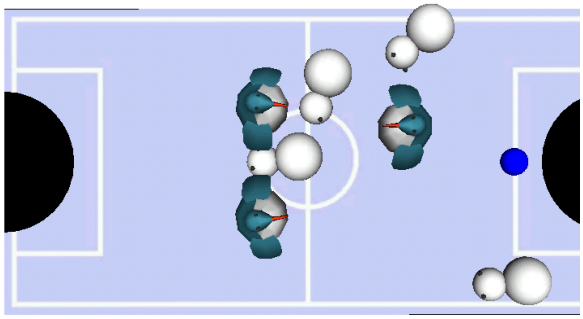

Figure 3. Top view of the game image projection. This image was projected to the floor screen. Right is the player’s side. The blue sphere means the 3D location of player. It is overlaid on the player in real space. Now the enemies attack at same time, and the teammate is going to the front, so the player guards the front of the goal.

4-5 System Diagrams

The 3D location of players is calculated on a server PC by using input from 4 encoder motors. Player's location acts on the “Real-time rigid body dynamics engine". It has all the information of locations and behaviors in our Virtual World. If it detects any collision with the floor or other characters, it generates reaction force using penalty method. All of characters in this world are driven by Rigid Body dynamics. Only 3 penguin characters can move themselves by force vector from “A.I. engine" autonomously. “Game Judge" watches the hockey game applying rules such as awarding points. The “Sound System" plays sound effects driven by the real-time physics simulator depend on the output of the penalty method. The “Flexible multi-projection" performs 3D drawings for 3 projectors by 3 PCs connected to a network (Fig.4).

4-6 Real-time rigid body dynamics engine

All of the characters in this system obey the rule of

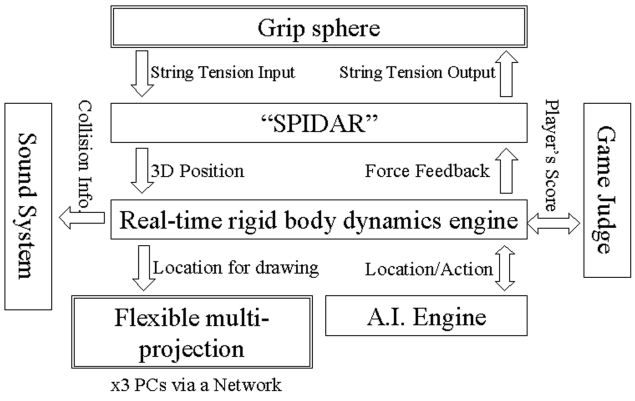

Figure 4. System Diagram. The player grasps the “Grip sphere” of SPIDAR. It tells the player’s 3D position to the ‘Real-time rigid body dynamics engine’. It acts the behavior of characters in this world and tells information to other systems.

Rigid Body dynamics.

$$\begin{cases} \mathbf{F} = m\dot{\mathbf{v}} \\ \mathbf{N} = \mathbf{I}\,\dot{\omega} \end{cases} \quad (1)$$

Pucks and Penguins are all shaped like a “Snowman", which are two connected spheres with different diameters (Fig.5). Each object has a center of gravity (G1, G2). When both objects are in collision, C1and C2 is most penetrating point of each object. P1, P2 is vectors from the center of gravity to the most penetrate point.

$$\begin{cases} \mathbf{F}_1 = (\mathbf{C}_2 - \mathbf{C}_1)\cdot k \\ \mathbf{F}_2 = (\mathbf{C}_1 - \mathbf{C}_2)\cdot k \end{cases} \quad (2)$$

As illustrated in Exp. 2, given the most penetrating points C1, C2 and spring constant k, the reaction force F1, F2 can be calculated.

As a result, difference equation (Exp. 3) can produce velocity vector $\mathbf{V}_i$ and angular velocity vector $\boldsymbol{\omega}_i$ at Δt seconds later.

$$\begin{cases} m_i\mathbf{V}_\mathbf{i}(t+\Delta t) = m_i\mathbf{V}_\mathbf{i}(t) + \mathbf{F}_\mathbf{i}\cdot\Delta t \\ \mathbf{I}_\mathbf{i}(t+\Delta t)\boldsymbol{\omega}_\mathbf{i}(t+\Delta t) = \mathbf{I}_\mathbf{i}(t)\boldsymbol{\omega}_\mathbf{i}(t) + \mathbf{P}_\mathbf{i}\times\mathbf{F}_\mathbf{i}\cdot\Delta t \end{cases} \quad (3)$$

Representation using rigid body dynamics causes a higher quality of reality to visual and force feedback in VR worlds. So our system can realize a tangible interface in the real world.

5. Results of prototype system

We installed our prototype system at an event that was prepared for children including handicapped individuals (August 1-7th, 2001 in Osaka Japan). From all experimental players, we got their impressions via questionnaire. There were 361 persons who had played in 7 days. Numbers of players in the age of 12 or below was 336 (93%). Average age in this group was 7.53. The youngest was aged 1. The ratio of gender is 57/42 (boys/girls). 97% of players answered [Joyful/Amused]. 93% of players could touch the virtual objects. In answer to the question, “How are you when you touch these Invisible objects?" 45% replied with [wonder/mysterious] and 29% replied with [Amused]. At the end of questionnaire, we asked for the player's favorite TV game title in advance, and we asked that, “In addition, do you like our “penguin hockey" rather than your favorite?" then 59% said [Yes].

We took some snapshots while they are playing (Fig. 6-8).

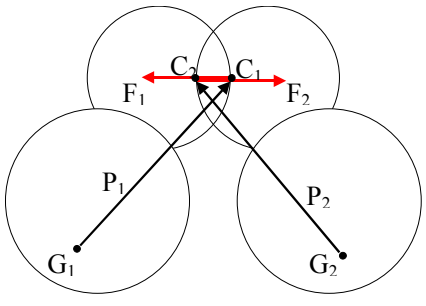

Figure 5. Penalty method. The output force can calculate from the distance between most penetrate point.

6. Discussions

In Figure 7, a girl (age 9) is playing energetically. The boy on the left is watching the subsidiary screen. The boy in the center is holding the frame pole. In Figure 8, they are a little sister (age 4) and big brother (age 6). They had sat down on the floor screen directly and touch the images.

Some of handicapped children who use a wheelchair or have limited arm motion tried our system and were able to enjoy it. If a player has limitation of arm, player can use this system with walking and holding our sphere grip.