“PENGUIN HOCKEY”: *A VIRTUAL REALITY GAME SYSTEM FOR CHILDREN*

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Abstract: We have developed a Virtual Reality amusement system called “Penguin Hockey”. Most previous work on virtual reality amusement systems has targeted the players aged approximately 10-15. However, our system targets younger children, of elementary school age (6-12). We believe that Virtual Reality systems for a younger age group require robustness and simplicity, rather than general Virtual Reality. Therefore, the Penguin Hockey System has been designed as simple 3D hockey game using a large floor screen, wire based 3D force display, rigid body dynamics and A.I. algorithms to provide a companion to play with children. More than 300 children have played with the system. We got the players’ impression via questionnaire after they tried the system. In this paper, we report details of the development and analyze the players’ impressions.

Key words: penguin hockey, virtual reality, SPIDAR

1. Introduction and Motivation

Recently, there have been many Virtual Reality (VR) amusement application systems such as theme park attraction or interactive game systems using motion capture. However, most VR game applications do not target younger children, such as those of elementary school age. For example, children, who have not played any games yet, cannot understand that a moving a character on the screen represents them without instructions. Additionally, most games are violent, involving fighting, killing or destruction. The game producers expect their users will be in the 10-15 age group, or older. Thus, there are only a very small number of VR Edutainment applications for young children, with the exception of walkthrough applications.

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We were therefore motivated to create a system that could be played by younger and/or handicapped children. Ideally, we wished to create a system that could be used easily and immediately, and would help with learning of physical behaviors.

2. Design Philosophy

We decided our system concept as shown below:

[Active]

Our players are children, so we shouldn't present our system like technical experiment using a chair or electronic devices. Players should be able to walk or run without constraints.

[Intuitive]

Our system should not require the players to adapt to arbitrary rules. We use a realistic physics system so that the VR experience will be as similar to the real world as possible.

[Amusing]

This isn't only an experimental system but also game for children. The look and feel of our system should be amusing and joyful.

[Collaborative]

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 Edutainment policy.

[Cooperative]

Our system can play with a few players at same time. Playing with another person like their friends or parents is good for human communication and education. Exclusive play is also available.

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.

3. Development

3.1 Hardware

The framework of our system is built of steel pole 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 to the floor and the

front. The floor screen is the main screen for play, 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". SPIDAR is "SPace Interface Device for Artificial Reality". It can input 3D location and generate force feedback using wire tension from 4 encoder motors.

Figure 1. Design of Penguin Hockey 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.

3.2 System Diagrams

The 3D location of players is calculated on a server PC using input from 4 encoder motors. Player's location acts on the "real-time physics simulator". 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 our Virtual World are controlled 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 "3D Graphics Engine" performs 3D drawing for 3 projectors by 3 PCs via a network (Fig.2).

Figure 2. 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 behaviors of characters in this world and tells information to other systems.

3.3 Game System

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 to defined. Each penguin moves to take the pucks to the enemy 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 controlling the penguin on the same team. For example, when the enemy penguins shoot the puck at the player’s goal, if a teammate guards the goal, the player can block enemy attacks in front line. Similarly, if the teammate attacks in the front line, the player should keep guard in front of the goal (Fig.3).

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.

All of the characters in this system obey the rule of Rigid Body dynamics.

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

Pucks and Penguins are all shaped like a "Snowman", which are two connected spheres with different diameters (Fig.4). Each object has a center of gravity (G_1, G_2). When both objects are in collision, C_1 and C_2 is most penetrating point of each object. P_1, P_2 is vectors from the center of gravity to the most penetrate point.

Figure 4. Penalty method. The output force can calculate from the distance between 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 $\mathbf{C}_1$, $\mathbf{C}_2$ and spring constant k , the reaction force $\mathbf{F}_1$, $\mathbf{F}_2$ 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.

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

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

4. Results

We installed our 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 person had been played over 7 days. Numbers of players in the 12 and below age group 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. 5).

Figure 5. Pictures of players' behavior.

5. Discussions and Conclusion

In the left picture (Fig. 5), 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 right picture, 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.

Especially, SPIDAR has thin strings however no injured are good results for us. Our staff in charge had taken care to strings. Most of players grasp the grip sphere from not only the front but also side and back. And they often hide the thin string by themselves.

In conclusion, we have developed a new VR amusement system targeted at younger children. It can provide tangible environment using the floor screen, the rigid body dynamics, A.I. algorithms and SPIDAR.

As an application of this system for the future, the home is the best installation space for education contents. Especially, a nursery (children's room) or a playroom sounds good for natural entertainment space. Therefore, we call this system as "Tangible Playroom". It should be a type of future computer entertainment systems (Fig. 6).

Figure 6. A future snapshot 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.

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