Multiplayer Game System for Therapeutic Exercise in Which Players with Different Athletic Abilities Can Participate on an Even Competitive Footing

Kazumoto Tanaka, Takayuki Fujino

Abstract—Sports games conducted as a group are a form of therapeutic exercise for aged people with decreased strength and for people suffering from permanent damage of stroke and other conditions. However, it is difficult for patients with different athletic abilities to play a game on an equal footing. This study specifically examines a computer video game designed for therapeutic exercise, and a game system with support given depending on athletic ability. Thereby, anyone playing the game can participate equally. This video-game, to be specific, is a popular variant of balloon volleyball, in which players hit a balloon by hand before it falls to the floor. In this game system, each player plays the game watching a monitor on which the system displays tailor-made video-game images adjusted to the person's athletic ability, providing players with player-adaptive assist support. We have developed a multiplayer game system with an image generation technique for the tailor-made video-game and conducted tests to evaluate it.

Keywords—Therapeutic exercise, computer video game, disability-adaptive assist, tailor-made video-game image.

I. INTRODUCTION

STUDIES of computer video games for support of therapeutic exercise have been promoted extensively [1]. Such games are played by moving the hands and feet. These physical exertions are helpful for obesity control and treatment of functional disorders. Using game machines that are available on the market, many assessments of therapeutic performance have been conducted in a case study manner (e.g. [2]).

Multiplayer games can accommodate more than one player and can therefore improve motivation for exercise [3]. However, it is not often the case that players having different athletic abilities can enjoy a game while mutually competing. Currently, studies are being undertaken to find methods to support players so that they can mutually compete on even terms [4]-[6]. Studies [4], [5] that support differences of visual contact skill examined a method by which players might not notice the support itself because, if players were able to notice the existence of support, their motivation would be impaired. However, these studies support visual contact skills in shooting games, not therapeutic exercise games.

In *Heart Burn* [6], players pedal to perform a car race in a virtual space. It is a therapeutic exercise game for improvement of cardiopulmonary function, where the propulsion force depends on an individual's physical power applied to a race car. The actual motion of each player is not observed in game images of *Heart Burn*. Therefore, designing a disability-adaptive support for such a game is simple. Moreover, the assist is not readily apparent because, even performance that is unsuitable for kinetic momentum of the player being supported is shown.

An avatar can accurately reflect player movements, which is beneficial for improving the game reality. In fact, many research projects have developed computer video games utilizing motion capture devices such as the Kinect [7]. However, disability-adaptive assistance in an exercise game using an Avatar that presents real movements has rarely been proposed to date. An earlier report [8] describes one study dealing with such an attempt, but it is not a multiplayer game. This is true because Avatar movements exactly reflect a player's movements, and artificiality becomes distinct if performance of an exercise is improved on the computer side. This paper presents a proposal of a method for disability-adaptive assist in a multiplayer game using a real avatar. Fig. 1 presents the status of this study.
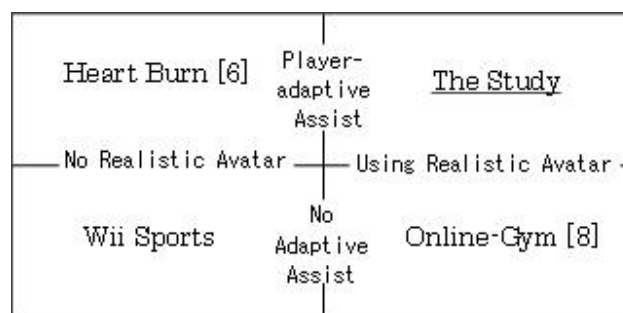

Fig. 1 Placement of the study in the field of competitive multiplayer games for exercising

The video game to be developed is balloon volleyball, which is a popular group sports game enjoyed at elderly facilities and the like (a balloon is sent up by more than one person using their hands so that it might not fall onto the floor). In an actual balloon volleyball game, a certain technique is used in some cases to change the balloon weight (percentage of helium gas) depending on the degree of exercise capability. This technique is regulation of the balloon speed. However, this means that the actual balloon volleyball game can be performed by players with similar exercise capabilities. This inconvenience is

K. Tanaka is with the Faculty of Engineering, Kinki University, 1, Umenobe, Takaya, Higashi-hiroshima, 7392116, Japan (phone: +81-(0)82-434-7000; fax: +81-(0)82-434-7011; e-mail: kazumoto@hiro.kindai.ac.jp).

T. Fujino is with the Faculty of Engineering, Kinki University, 1, Umenobe, Takaya, Higashi-hiroshima, 7392116, Japan (e-mail: fujino@hiro.kindai.ac.jp).

World Academy of Science, Engineering and Technology
International Journal of Humanities and Social Sciences
Vol:9, No:1, 2015

specific to a game using common objects, such as balls. With the game system of this study, each player executes play while observing an individual game monitor. Disability-adaptive assist is realized such that game images, which are processed such that the game player might not feel artificiality and might play with ease depending on the player's exercise capability, are displayed on the monitor for each game player. The game image presented to each player is designated as a 'tailor-made video game image'.

With a video game involving more than one player, they normally share equal status. One feature of this study is the tailor-made video game image. Each player performs interaction with other players based on actual motions under a competitive situation created to meet one's own exercise capability. Consequently, all players, each having different exercise capabilities, can participate in a game together. Yet everyone performs exercises suited to the player's exercise capability. In other words, using tailor-made video game images, mass games and therapeutic exercises of individuals can become mutually compatible.

To date, we have developed a balloon volleyball game system by which players with different muscle force and eyesight were able to compete on an equal basis. This paper explains this system and its related assessment experiments.

II. THE GAME SYSTEM

The system has as many "units" as the number of players. One unit consists of a personal computer, depth sensors, and a display device. Computers are mutually connected by communication cables. Fig. 2 portrays the system concept for a two player (A, B) case.

Fig. 2 also shows a case of support where the muscle force of player A is inferior to that of player B. Avatar B is placed nearby in the image presented to A; avatar A is placed more distant in the image presented to B. The time before a ball arrives at A or B is identical in both images shown. Therefore, the ball can be moved slowly in the image presented to A and can be moved quickly in the image presented to B.

When the players' clarity of eyesight differs, considerations are given so that the ball can be identified easily. In the images presented to the player with poor eyesight, the brightness of the ball is increased. Also, its size is larger.

A virtual balloon volleyball game is realized as follows: Using depth sensors, the position and orientation of a player are recognized on the computer. Then an avatar of the player is displayed based on this information. Furthermore, avatars of other players are displayed based on information of the other player sent from the other computer. Regarding the virtual ball, information of collision with the players is shared by each computer. Then its position is calculated based on a motion equation in each virtual space, and rendering is made.

The system being developed uses a depth sensor (Kinect; Microsoft Corp.) and a sensor (Kinect for Windows SDK; Microsoft Corp.) for recognition of the position and posture of the player. The computer has a Core i7 3820 (Intel Corp.) as the CPU, 16 GB memory, and a video chip GeForce GTX 660 (NVIDIA Corp.).
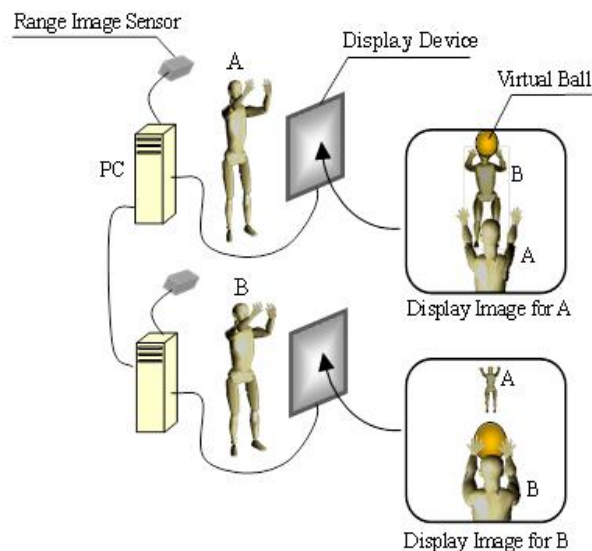

Fig. 2 Scheme of the game system and an example of a tailor-made video-game image

III. EXPERIMENT

Whether players with different muscle force and eyesight can compete fairly is checked through experimentation using tailor-made video game images.

In all, 21 healthy university students (ages 20–22) with normal eyesight (including corrected vision) participated in the experiments. They were divided into 7 groups (3 students in 1 group), each of which consisted of a player with limited visual function, a player with limited muscle force, and a player with no physical limitation. Limited visual function is a limitation caused by cataracts or a narrowed visual field. The participants wore goggles for a vision disorder experience to undergo the simulated experience. Regarding the limited muscle force, mounting of weights on their hands and feet was attempted initially, which came into question because of the increased burden on experiment participants. Such a limitation was provided at the game system side that fast movements of a player with limited muscle force were not recognized. In other words, the player was requested not to move quickly. Simulated muscle force limitation was provided. The upper limit of the movement speed was set as 400 mm/s.

For a tailor-made video game image in which visual function is limited, the ball size was increased by half. The ball brightness was doubled. These were determined experimentally by examination of participants wearing goggles. In the image for a player with limited muscle force, the distance to an avatar of another player (2 people) was determined appropriately through numerical simulation and results of preliminary experiments.

IV. RESULTS AND DISCUSSION

In the experimental game, the number of times a player failed to return the ball (points lost) was used for scoring. A game using a tailored-made video game image is designated as "with support." A game without using it (distance between players, size and brightness of the ball are identical to those of

World Academy of Science, Engineering and Technology
International Journal of Humanities and Social Sciences
Vol:9, No:1, 2015

the image of the player with no physical limitation) is designated as "without support."

In the experiment, participants of seven groups were requested to practice while taking a break properly until they became sufficiently accustomed to the balloon volleyball game. Particularly, players acting as the limited muscle force player continued to practice until they realized the motion speed. Subsequently, they each performed once in a *without support* game and in a *with support* game. Completion of the game was set to such a point when chances to return the ball to all the players reached 20 times.

The average rate of loss ($n = 7$) of the player with each physical condition in the game performed *without support* is portrayed in Fig. 3. The average of the rate of loss ($n = 7$) for *with support* is presented in Fig. 4. It is readily apparent from Fig. 3 that for the *without support* case, although the average rate of loss of the player without physical limitation is lower than that of the player with limited muscle force, for the *with support* case, the average rate of loss was reversed (Fig. 4). Furthermore, although the average rate of loss of the player with limited visual function is moderate for the *without support* case, it is lowest for the *with support* case.

To ascertain whether the difference of the average of the rate of loss is significant or not for the *without support* case and the *with support* case, dispersion analysis of one factor (without physical limitation, with limited visual function, with limited muscle force) was conducted for the without correspondence case. A significance level of 0.05 was used. Homoscedasticity was hypothesized with $p = 0.40$ for the *without support* case and $p = 0.08$ for the *with support* case by a Levene test. Results of the dispersion analysis are such that the main effect is $p = 0.01$ for the *without support* case and $p = 0.02$ for the *with support* case, which indicates that the main effect is significant in both cases.

Next, Bonferroni's multiple comparison was conducted. Results show that the difference of averages was significant ($p = 0.01$) between that for without physical limitation and with limited muscular force for the *without support* case. The difference was significant ($p = 0.01$) between results without physical limitations and with limited visual function for the *with support* case. No significant difference was found between results obtained without physical limitations and with limited muscular force.

By multiple comparison of results obtained in *with support* and *without support* games, a player with no physical limitations was found to be superior to a player with limited muscle force. However, for the *with support* game, no difference was found in the rates of loss. In other words, it might be said that a player with no physical limitation and a player with limited muscle force played an evenly matched game because of the tailor-made video game images.

A player with limited visual function is nearly equal to a player without physical limitations for the *without support* case and became superior if support was provided. Although the simulated experience of cataracts and a narrowed visual field was regarded as limited visual function in the experiment, players caught a display area (42-inch television) of the game at around the center of the visual field. A narrowed visual field did not affect game play. In the simulated experience of cataracts, eyesight was glazed, but it was not so remarkably influential on game performance. The player was able to distinguish the ball. It was therefore considered that the ball hit rate of the player with limited visual function was improved and that the player had an advantage in the *with support* case, brightness was improved to magnify the ball.
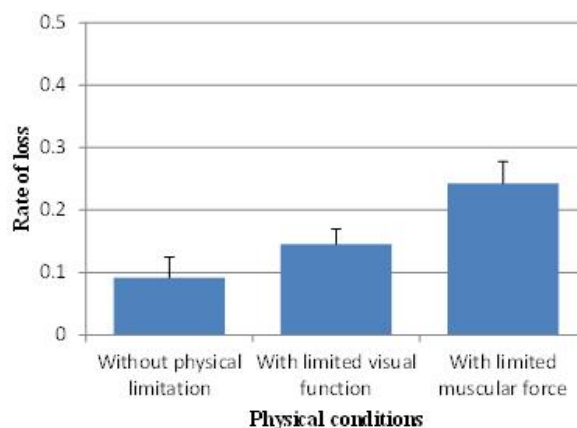

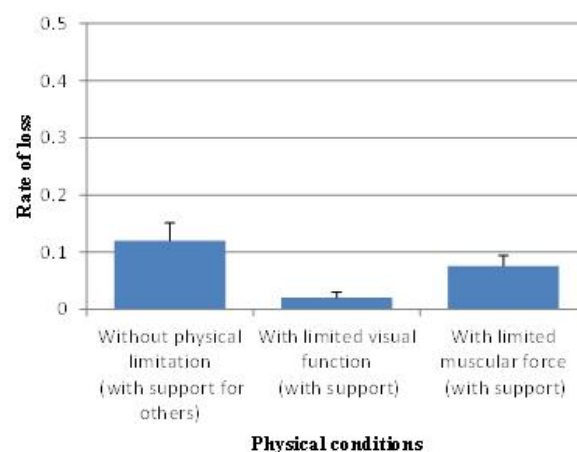Fig. 3 Result of the *without support* case

Fig. 4 Result of the *with support* case

REFERENCES

[1] J. Wiemeyer, "Serious Games - The Challenges for Computer Science in Sport," International Journal of Computer Science in Sport, vol.9, no.2, pp.65-74, 2010.
[2] Plow, M., et al., "A Qualitative Study Exploring the Usability of Nintendo Wii Fit among Persons with Multiple Sclerosis," Occupational Therapy International: Special Issue: Clinical Research in Occupational Therapy, vol.21, no.1, pp.21–32, 2014.
[3] Göbel, S., et al., "Serious Games for Health – Personalized Exergames," Proc. ACM Multimedia 2010, pp.1663-1666, Firenze, Italy, October 2010.
[4] Bateman, S. et al., "Target assistance for subtly balancing competitive play," in proc. of SIGCHI Conference on Human Factors in Computing Systems 2011, 2355-2364, Vancouver, Canada, May, 2011.

[5] Vicencio-Moreira, R., et al, "The effectiveness (or Lack Thereof) of Aim-assist Techniques in First-person Shooter Games," in proc. of SIGCHI Conference on Human Factors in Computing Systems 2014, 937-946, Tronto, Canada, April-May, 2014.
[6] Stach, T., et al., "Heart Rate Control of Exercise Video Games," in proc. of Graphics Interface, Kelowna, Canada, 2009.
[7] Cassola, F. et al., "Online-Gym: A 3D Virtual Gymnasium Using Kinect Interaction," Procedia Technology, 13, 130–138, 2014.
[8] Eichhorn, S., et al., "Development of an Exergame for individual rehabilitation of patients with cardiovascular diseases," Australasian Physical & Engineering Sciences in Medicine, 36(4), 441-447, 2013.

Kazumoto Tanaka is a professor of Department of Informatics, Faculty of Engineering, Kinki University, Japan. He received Ph.D. degree from Tokushima University in 2002. His research interests are image processing, virtual reality, sport performance analysis, and computer assisted sport training. He is a member of IACSS.

Takayuki. Fujino is an associate professor of Department of Electronic Engineering and Computer Sciences, Kinki University, Japan. He received Ph.D. degree from Meiji University in 1994. His research interests include network computing, network resource management, and network security. He is a member of IEEE.