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SPECIAL SECTION ON HEALTHCARE INFORMATION TECHNOLOGY FOR THE EXTREME AND REMOTE ENVIRONMENTS

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Dance Exergame System for Health Using Wearable Devices

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ABSTRACT This paper proposed a dance training game applied using game theory by using wearable devices. The system extracts the teacher's motions by using motion capture sensor technology. The pressure on the foot was sensed while dancing, and the motions of the ankle were extracted. The exergame enables students to watch the teacher's dance in all directions by using an avatar and gaining the effects of both exercise and education by repeatedly practicing avatar's dancing. To overcome the space constraints of the special equipment in the course of acquiring and measuring the students' movements and to allow students to practice at any place, the movements of the user's foot were measured by using a sock type wearable device that the user wears in their lives normally.

INDEX TERMS Virtual reality, wearable sensors, computer aided instruction.

I. INTRODUCTION

Exergaming is a combination of 'exercise' and 'gaming', which represents the system or content in which the effects of exercise can be seen in the process of playing a game. This is an old idea that began in the 1980s, but, since 2006, a lot of attention has been focused on it with a significant amount of content being developed, including game consoles and controllers that can easily support it [1]. Due to the recent technological development of hardware and software associated with virtual environment technology, virtual reality and game theory have been used for various forms of education and practice. They are also being effectively used for some functional games that target health. Adding interesting elements to a monotonous exercise program by applying game theory to the program helps users actively participate in the game while also adjusting the difficulty level of the exercise according to the participant's physical ability, allowing him or her to be absorbed in the game and increase persistence and concentration on the exercise. For sports, particularly those such as golf in which one repeats certain specific motions or a dance that requires one to memorize a dance routine, educational effects can be increased through the development of effective exergames by applying virtual reality technology [2].

In this paper, a study has been conducted that combines dance education with game theory and virtual reality technology. Traditional dance education consists of a teaching and learning process in which students learn the dance routine by watching their teacher and are advised and corrected through communication while dancing together with the teacher. Since this process is under constraints (the teacher and the students must meet in the same space at the same time), some research is being carried out to remove these time and space constraints by using virtual reality and game technology. The previous conventional user interface method of teaching with a mouse and a keyboard would be said to have not advanced past the stage of checking and memorizing the teacher's motions, whereas the user's motions can now be detected by measuring those of the Wii and PlayStation Move controllers. The Microsoft Kinect sensor is a motion sensor used for the game console Xbox 360, which can recognize the user's motions by using a depth sensor. Many exergames have been released for the Xbox 360, and they are being used to study exergames in which you can actually move and experience the physical movements due to the release of Kinect sensor for PC [3]. In addition, an attempt has been made to practice dancing with an HMD while watching a dancing avatar in a mixed reality environment [4].

Since the development of game controllers makes it possible to acquire relatively precise motions of the user, the controllers can be functionally used. However, the exergames have space constraints that force users to play the games only

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in the place where the exergame system is installed. Recently, various wearable devices have been released to acquire users' healthcare information. They are updated with users' health data by interlocking with the mobile devices while also measuring approximately how much exercise the user does. Those wearable devices can also be used for exergames since they can be used in users' daily life with no space restrictions. In this paper, an exergame system has been proposed that can check how much exercise the user does through extracting the user's physical information by using a wearable device that can extract foot motions. Most of the existing dance-based studies have applied game theory in order to score based on the difference between the skeletal information of the lecturer and that of the student by either letting them wear a motion capture device or using an external image sensor. In order to measure the user's motions, a special machine or game controller is being used and this causes the space constraints. This study has suggested an exergame system that enables users to practice dancing on the move or in a free space by using wearable equipment that can measure the movements and pressure of the foot so as to solve the space constraints caused by using an installed controller.

The rest of this paper is organized as follows: In the next chapter, the studies related to dance exergame system are analyzed and, in Chapter 3, the design and implementation of the system that uses a wearable device are described. Finally, the system proposed in this study is also analyzed.

II. RELATED WORKS

Various studies have been done on dance training systems for a long time. Most dance training courses are taught by a teacher for theoretical and practical training, and the student practices repeatedly. The teacher checks the student's learning outcomes and corrects the student's mistakes via feedback or suggests what to learn in the next stage. In educational environments with space constraints where teachers and students can hardly meet, the teacher has used the traditional method of verifying and evaluating the students' practice results recorded on video [5]. This method may have some aspects that the teacher may be unable to recognize video that has been recorded in a unidirectional way. A system has been developed to measure accuracy in real time while the user wears motion capture equipment and dances with virtual avatars in it [6]. The motion capture system is the most accurate way to acquire human movements and is widely used in animation, movies, and games. It is also used in art performance with visualized motions in real time [7]. The motion capture technology enables students to accurately acquire the teacher's movements by saving the movements in the form of three-dimensional data and visualizing them in various angles. When a student wearing motion capture equipment practices, the difference between the target movements and the practice movements can be detected in real time, providing an effective learning method while also allowing the learning results to be measured in real time [8].

Educational content to meet users' education levels can maximize the effectiveness of education by absorbing users through keeping them entertained while providing a sense of accomplishment [14], [15]. In order to provide the user with suitable content for their education level, an interactive training system must be used. The system should measure the education results of the user and provide a real-time reorganizational curriculum according to their education level. Games go well with exercise practice because they can immerse users in the physical activities at the target level by being fun and applying game technology to the education that includes physical movements [16]. In analyzing the studies on combining health and games, the amount of papers published through related research continues to increase. Moreover, when analyzing the themes of the thesis, there have been plenty of papers written from the educational and cognitive viewpoint originally, however, research using games from the viewpoint of exercise and rehabilitation is on the rise these days [17]. In particular, one bit of research has been carried out to attract students to physical education classes by using entertainment and game systems as dancing is an effective physical education method that can enhance students' physical exercise and increase balance [18]. Dance Dance Revolution (DDR) was released by a game company and used to conduct a study on the elderly to practice walking with visual information like the game. Such research has shown the possibility of being used as a remote health device [19]. In this paper, a dance training system is combined with the game technology and research on dance training, which can make users interested and immersed through movements, has been done.

Motion capture technology can acquire human motion data, has been widely used in industries such as movies and games, and has been improved to a significant extent. Recently, low-cost motion capture devices have also been released as the technology is used in the field of virtual reality. The motion capture equipment can be largely divided into visual tracking and non-visual tracking methods [9]. A visual tracking method involves using a camera-based tracking device - mainly an infrared camera. The infrared camera method involves extracting the infrared images generated from the IR marker by attaching it to the user's body. It is divided again into an active marker method, which extracts infrared images from the IR LED attached to the user's body, and a passive marker method, which extracts infrared images generated by reflective materials reflecting the external IR LED. The optical motion capture method requires an expensive system, but it is mostly used to acquire human motions in fields such as movies and games because the method can acquire accurate human motion data. Research on dance education was also carried out by using a Kinect sensor, one of the Depth Cameras, which acquired the teacher's movements and extracted skeletal information without having the student wear the equipment [10]. The motion capture system that uses the Depth Camera is used frequently due to two advantages: the user doesn't need to wear the equipment, and it is inexpensive. However, it has certain problems such as low resolution, limited distance measurement, and overlapping [11]. In order to overcome these limitations, research is being conducted in which many Depth Cameras are used to acquire human motions in real time [12]. The non-visual tracking method includes the following systems: an acoustic system consisting of an ultrasonic generator and a receiver, a mechanical system to acquire human movements using a jointed mechanical device, and a magnetic system with magnetic sensors attached to each joint to measure the positions and angles of the joints. In recent years, the sensor-attached motion capture system, which recognizes the IMU sensor attached to the human body, has been made smaller (miniature) due to technological developments. This system is being used more due to its capability to build up a motion capture system at a relatively lower cost than that of the marker method by complementing the drift problems of the gyro sensor. In addition, by attaching a wearable device that can easily transmit vibrations, users can effectively practice dancing by being provided with proper timing [13]. Recently, various wearable devices have been available to measure the user's vital signs and are also expected to be applied significantly in daily education due to users being able to wear them in their daily lives. In this study, the user's movements are measured and applied to dance training by using wearable equipment that can extract the user's foot motions.

III. EXERGAMING SYSTEM USING WEARABLE DEVICE

In this study, an exergame system has been proposed that enables students to watch the teacher's dance in all directions by using an avatar and gaining the effects of both exercise and education by repeatedly practicing the movements of the avatar's dancing. To overcome the space constraints of the special equipment in the course of acquiring and measuring the students' movements and to allow students to practice at any place, the movements of the user's foot were measured by using a wearable device that the user wears in their lives normally. An exergame system has been proposed to be able to measure the scores by collecting the user's foot motion data and comparing them with that of the teacher and to adjust the difficulty of the education contents by applying game theory. The proposed system is composed of four processes as shown in Figure 1.

The first process is the creation of dance motions that the user can repeat. Reflective marker motion capture equipment was used to create natural dance motions. When a teacher dances wearing a costume with reflective markers, the animated information of the skeleton is collected through the positioning information of the reflective markers. In addition, by receiving data input from the wearable sensors on the socks and the ankles, the parts of the foot landing on the floor first, as well as the degrees of landing while the teacher was dancing, are also measured. The second process is the development of an application that allows the user to animate the dance by setting avatars of various types to the captured actions. The user can check the dance motions performed

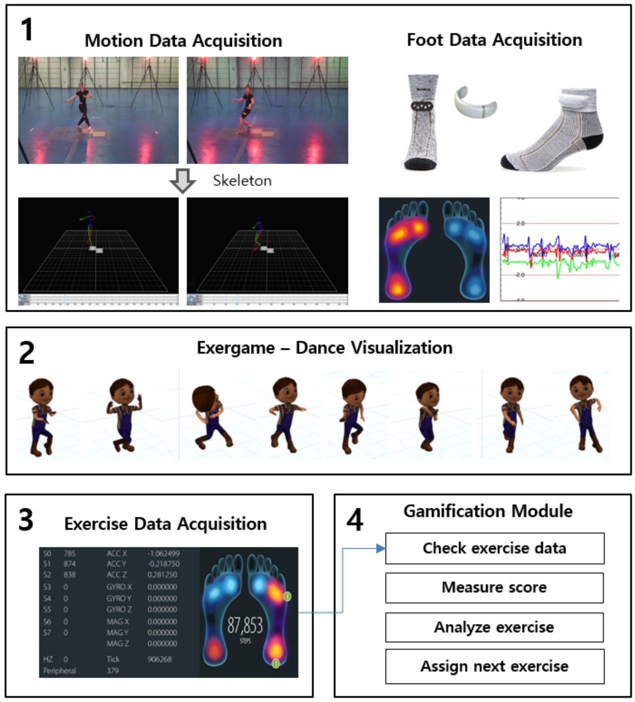

FIGURE 1. The Design of the dance exergame system.

by the teacher from various angles in three dimensions in the system equipped with the HMD. The third process is the development of a module that obtains the motion and health information data from a wearable device worn by the user. Lastly, this consists of a gamification module that immerses the user by checking the avatar's visual movements and the user's motion data, scoring them and providing a dance that is suitable for the user's ability.

A. DANCE MOTION ACQUISITION

In this study, an optical motion capture device was used to acquire the dance motions. Socks called Sensoria Fitness were used to extract the accurate steps of the dancer. Since the movements can be fast and dynamic depending on the types of dance, the optical motion capture equipment was used in order for the dancer to avoid wearing heavy equipment. To use the optical motion capture, a number of infrared cameras were set up and a camera calibration process was performed to collect information on the positional relations between the cameras. When the dancer was dancing with the IR markers attached to the costume as shown in Figure 2, the IR markers can calculate the three-dimensional positional information during the dance. When the dancer danced with 35 reflective markers, the two-dimensional positions of the IR marker in the images from each IR camera per 0.01 second were analyzed, and the three-dimensional X, Y and Z values of 35 reflective markers were calculated and stored using the calibration data.

The stored 3D data of the reflective markers are used not directly but in another format in which they are converted

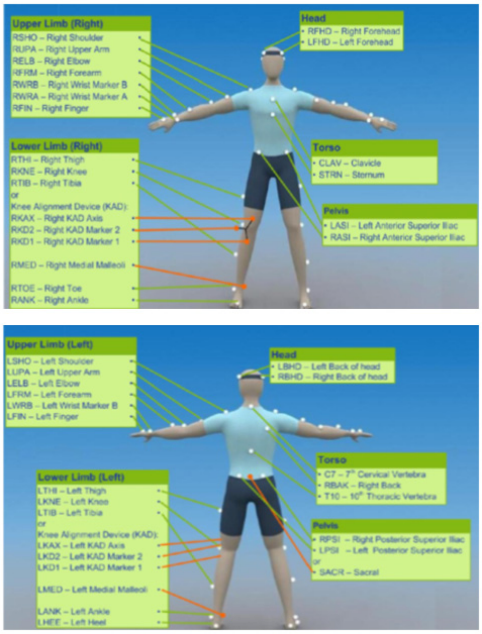

FIGURE 2. **The position of the reflective IR markers for the optical motion capture system.**

into a hierarchical file with human skeletal information (ex: Biovision Hierarchy (BVH) format) through post processing. Most game engines use a human (avatar) model with a skeletal structure so the dancer's movements can be visualized if the converted BVH data are transferred to the avatar of the game engine. Using a game engine to visualize the movements of the dancer allows the user to observe them at various different positions while sensing the full three dimensions by using a device such as an HMD. The user can have the advantage of observing the movements in a mobile environment. This study acquired the motion data of two dances. As shown in Figure 3, Korean dance data with gentle motions is obtained and the break dance data with fast and dynamic movements was also obtained as shown in Figure 4. In Figure 3 and 4, the above photos were taken while the dancer was actually dancing with the IR markers and the below pictures show the visualization of the BVH converted data.

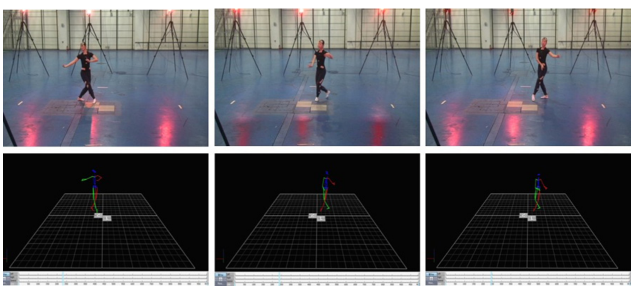

FIGURE 3. **The motion capture data acquisition from a traditional Korean dance.**

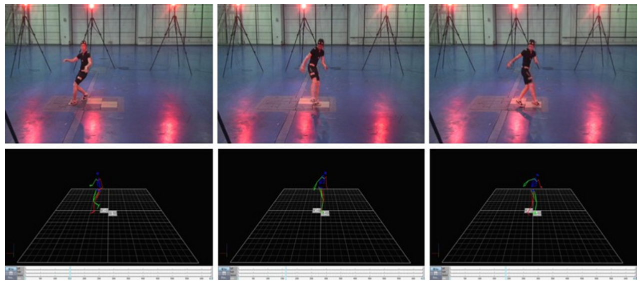

FIGURE 4. **The motion capture data acquisition from a breakdance.**

B. FOOT STEP DATA ACQUISITION

One of the important factors in the process of dance education is the movement of the feet. In this study, the Sensoria Socks Developer Kit was used as shown in Figure 5 to measure the feet movements and pressure because it is difficult to know exactly when the user's foot landed on the floor using only the avatar motion visualization. The teacher's movement is captured with motion capture data simultaneously while teacher are dancing. The user's scores on the dancing steps can be measured when a student is dancing using sensors when the students wear the Sensoria Socks.

FIGURE 5. **Sensoria Fitness Socks and anklet.**

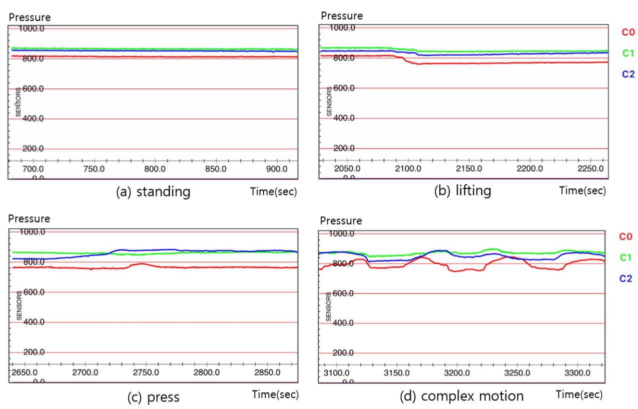

FIGURE 6. **Pressure sensor of left foot based on movement.**

The Sensoria Sock while dancing can measure and collect the pressure data of the foot as shown in Figure 6 and 7. The pressure of three areas in the sole of the feet can be captured as shown Figure 5. The stable condition (standing) of pressure are different depending on the shape of the foot and the shoe.

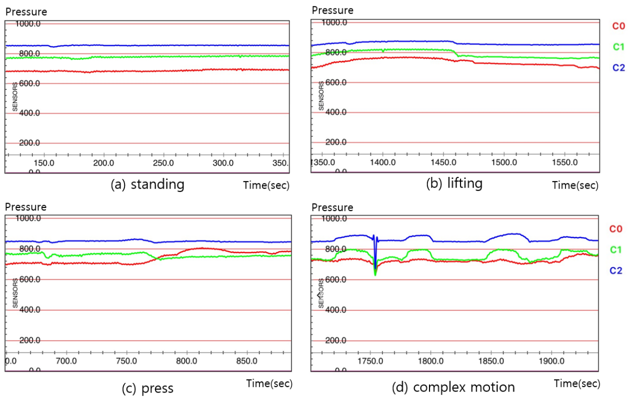

FIGURE 7. **Pressure sensor of right foot based on movement.**

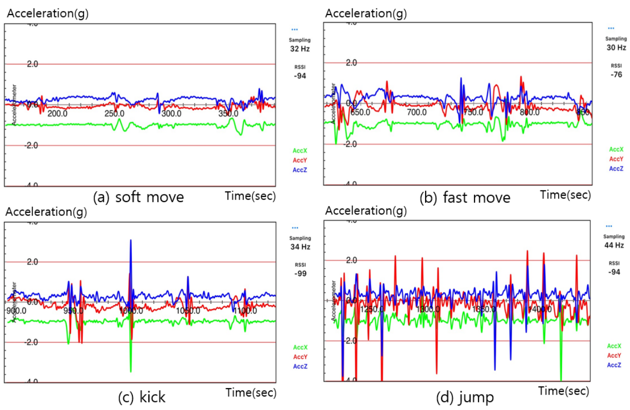

FIGURE 8. **Acceleration of foot based on movement.**

The human's foot motions can be predicted by calculating the relative pressure value.

The user's acceleration of foot motions can also be measured by receiving the data from sensoria anklets on the human ankles as shown in Figure 8. Dance motion is predicted by analyzing acceleration data.

C. DANCE MOTION VISUALIZATION

Traditional dance training systems use a direct learning method and involve acquiring movements by either watching the teacher dancing or repeatedly watching a video clip of the teacher. Methods such as this can convey the atmosphere of dance with a realistic costume and background, but they have limits such as not being able to know the dancer's movements in all directions. This system is designed to watch the dancer's movements on two platforms. This also allows the student to check the movements at various positions and angles by wearing the HMD in the space with the HMD installed. Moreover, the system is designed for the student to be able to check the teacher's movements on their smartphone in the space where the VR equipment is not installed. Students can repeatedly check the teacher's movements from all angles through playback of the avatar by using smart phone. This study obtained and visualized the motion data of two dances done by a man and a woman. Figure 9 show a male avatar and a female avatar to visualize a dancer in the process of dancing. The application applied visual and sound effects to represent the timing of the stepping on the stage of avatar in virtual environments.

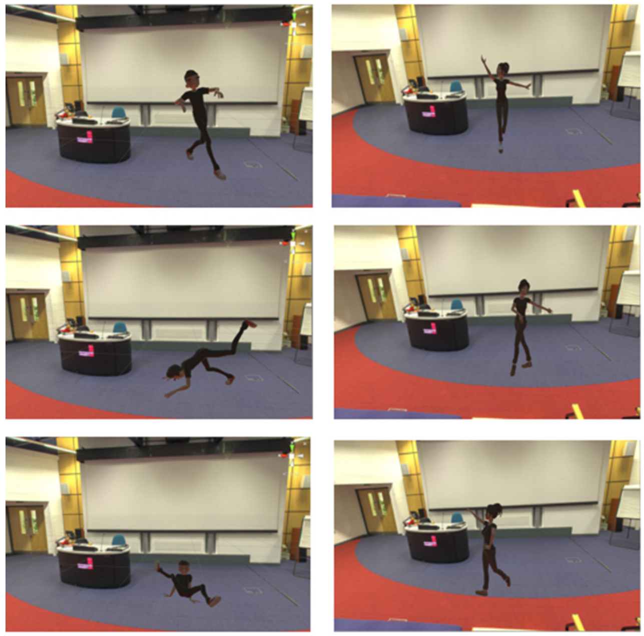

FIGURE 9. **The application of avatar dance.**

D. WEARABLE INFORMATION ACQUISITION AND EVALUATION

Special devices capable of measuring users' motions such as DDR are required to extract the motion information or the health information from users [20]. Users had to visit a place where the equipment was installed to enjoy an exergame. Thanks to the development of sensor technology, devices that extract users' movements can be used in game consoles for family use and are also provided at a low cost. Although the motion extraction system has been simplified, it still has space restraints. This study proposed a method of extracting users' motion information and using it for an exergame through using wearable devices that can be worn by the user in their normal social life. Users' motion information can be divided into two types according to the accuracy of the measured movements. The first type of information is rough judgements on the user's movements. Recently released smartphones have a built-in IMU sensor that allows extraction of information pertaining to things such as walking. Band-type sensors are used in order to use more accurate data. Using wearable equipment such as a Fitbit, you can acquire comparatively accurate information such as the number of the steps you've made and energy you've used [21]. Most exergames use pedometer controller and a gyro sensor together. Pedometer controller is good to measure walking steps. In the pedometer controller, a sensor provides information on the number of the steps made and uses the callback function whenever the sensor detects the user's walking steps. It can extract step timing from the user by referring to the previous events. It is good for measuring number of steps and total exercise, but it is difficult to use for direction of steps. Thus, a pedometer controller and a gyro sensor were used together. Besides, it sets the approximate scores through measuring the process and direction of the steps by using a gyro sensor to measure the time and movement of the feet. Another approach is the use of a professional wearable device. Various kinds of sensors are attached to the shoes in order to extract accurate stepping information, and these can extract the exact timing of the steps or the foot positions [20]. Our solution is sock type wearable device in the previous section. Several sensors are attached inside the socks, it is possible to extract data pertaining to which part of the user's foot touches the floor first, how much physical power he or she uses, and motion of foot.

Evaluation module uses three factors such as foot touch timing, the position of touching area of foot and the movement of foot. The module changes the pressure and acceleration data as shown in Figure 6-8 to three factors. The scores can be measured by checking comparative three factors between teacher's data and student's data. After analyzing the evaluation data, the system suggests next dance for the student's practice.

IV. CONCLUSION

This study proposed a dance training game applied using game theory by using wearable devices. Dance is an exercise that attracts plenty of attention in the media, where many people have actively participated in many classes organized in fitness centers and schools. Dance lessons are done using the traditional teaching and learning method, where students watch a skilled teacher while dancing. Because of the time and space constraints in learning, various dance education systems have been studied recently to apply virtual reality technology, and the educational effects have been recognized.

The proposed system extracts the teacher's motions by using motion capture sensor. It allows students to accurately understand the movements of the teacher by observing the virtual avatar dancing in all directions after applying the teacher's motion data to the avatar. Especially, pressure on the foot and the motions of the ankle of the teacher were extracted. The foot motion data were used in dance education in order to accurately recognize the steps, one of the more important elements in dancing.

With game theory being applied to the dance training system, a dance exergame has been created that maximizes factors to attract interests and while increasing the level of immersion by applying the appropriate level of dance to the user's ability. Through using the motion data of the mobile devices and wearable devices to measure scores for the level system, the exergame allows the user to be able to do the exergame naturally in daily life with no space constraints. In this paper, the method of measuring both the landing on the floor and the motion of the foot was applied for scoring. Of course, there is a weak point regarding not being able to calculate the accurate scores of whole-body movements if the motion sensor is not used and the overall movements cannot be measured. However, the strong point is that it allows practice in every space since the wearable device that are not inconvenient for living is connected to the smartphone. What is much better is that it never bothers the user while wearing it when he or she doesn't practice. In the future, research will be conducted on an exergame that can measure the overall physical movements of the whole body by measuring the motions of the arms and hands by using a wearable device.

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