J Inf Process Syst, Vol.13, No.4, pp.876~892, August 2017
https://doi.org/10.3745/JIPS.02.0068

ISSN 1976-913X (Print)
ISSN 2092-805X (Electronic)

JOURNAL OF INFORMATION PROCESSING SYSTEMS JIPS

Interactive Experience Room Using Infrared Sensors and User's Poses

Green Bang*, Jinsuk Yang**, Kyoungsu Oh**, and Ilju Ko*

Abstract
A virtual reality is a virtual space constructed by a computer that provides users the opportunity to indirectly experience a situation they have not experienced in real life through the realization of information for virtual environments. Various studies have been conducted to realize virtual reality, in which the user interface is a major factor in maximizing the sense of immersion and usability. However, most existing methods have disadvantages, such as costliness or being limited to the physical activity of the user due to the use of special devices attached to the user's body. This paper proposes a new type of interface that enables the user to apply their intentions and actions to the virtual space directly without special devices, and test content is introduced using the new system. Users can interact with the virtual space by throwing an object in the space; to do this, moving object detectors are produced using infrared sensors. In addition, the users can control the virtual space with their own postures. The method can heighten interest and concentration, increasing the sense of reality and immersion and maximizing user's physical experiences.

Keywords
Human Pose Recognition, Infrared Sensor, Interactive Experience Room, Virtual Reality

1. Introduction

The living spaces of users have undergone revolutionary changes due to the development of information and communication technology. The space paradigm has rapidly progressed through the combination of real and virtual spaces, thus increasing the need for new virtual reality services. Virtual reality is a technology that enables users to indirectly experience situations that they cannot experience in real life by using various sensory systems, such as touch, in a virtual space constructed by computers [1-3]. To date, virtual reality has been applied to various fields to develop hardware and software process performances, such as sensors and displays and computer vision and computer graphics, respectively. In particular, it has been used actively in the fields of broadcasting, games, defense, and tourism, and smartphones are widely used for entertainment and e-learning [4-8]. The major research area of virtual reality is mixed reality [9], which is a technology aimed at increasing the sense of reality by combining real and virtual spaces; it can be divided into augmented reality and augmented rituality, which are based on real space with virtual objects and virtual space with real objects, respectively.

Manuscript received March 17, 2017; first revision May 16, 2017; accepted May 29, 2017.
Corresponding Author: Ilju Ko (andy1026@gmail.com)
* Dept. of ICMC convergence technology, Soongsil University, Seoul, Korea ({banglgreen, andy1026}@gmail.com)
**Dept. of Digital Media, Soongsil University, Seoul, Korea ({ispio, oks}@ssu.ac.kr)

Users recognize the information made by a computer in real space and interact with virtual objects. Studies have focused on minimizing the awkwardness of the combination of the two spaces. This is referred to as registration, a process of mixing real and virtual spaces, and there is a geometric (to match the geometric coordinates), photometric, and temporal time gap between users' viewing points in registration [10-12]. The existing methods used various devices, such as head-mounted displays, stereo monitors, motion trackers, and position sensors in order to perform registration correctly, and they made strive to increase measurement times and sensor precision. Additionally, the methods used algorithms for image processing, computer vision, and sensor data correction to solve problems that cannot be solved by hardware.

The methods have limitations related to user activity, because special devices, such as markers or tablets, are usually attached to the users' bodies or gripped by their hands, reducing the naturalness of expression, usability, and sense of immersion. More specifically, first-person virtual reality, which provides the highest sense of immersion, has an interface related restriction due to the necessity of wearing a head-mounted display, and the number of simultaneous users is also fixed. Dome-type virtual reality has the advantage of being able to used simultaneously by many users, but the construction costs are high, and its touchscreen or button-type display can usually only locate virtual objects inside the display area. The following four characteristics should be present for the virtual reality system interface to support naturalness, usability, and a sensor of immersion simultaneously. First, it needs to support a high sense of immersion when controlling real objects that users interact with in the virtual space. Secondly, it should offer natural control methods that do not provide a limited interface, but controls similar to real life. Third, users should feel a sense of reality when using the interface through visual and audio feedback. Fourth, users should be able to easily and intuitively understand how to use the interface without complex guidelines. A though these characteristics have been researched separately, interfaces with all four characteristics are rare.

This paper proposes interactive experience spaces that can expand real-life experience to virtual life using interaction technology based on infrared sensors and user postures, and it also tests content with technology. Our purpose is to construct an expandable new real-life space and to increase user interest and the sense of immersion while minimizing limitations. To minimize the restrictions of existing interfaces, we detect objects thrown in the virtual space by users using infrared sensors, and they construct interactive experience spaces by controlling the virtual space using their posture. Users can experience a sense of spatiality and reality by interacting with the virtual space naturally in real space. Similar to the proposed method, we can find through experience-based display using media art. In general, their work uses equipment such as Kinect or lasers as a single unit because of the limited space. However, we propose a method to expand the limited space and to increase user immersion by verifying the infrared sensor, 3D projector and fabric screen.

The proposed method makes the following main contributions.

- The Interactive Experience Room was constructed for users to experience a virtual space without any special devices attached to their bodies. The Interactive Experience Room is a new space that expands real life to virtual space, and it also maximizes the sense of immersion and reality compared to a virtual space with a free interface.
- To expand the real experience from the real to the virtual space, an interface that makes it possible to move between the real and virtual spaces was made. If users throw balls toward the virtual space, the balls are represented and depicted as flying in the virtual space. The balls in the

virtual space interact with other virtual objects in the space, so users can receive feedback on their activities. Additionally, user's postures can be recognized by Kinect sensors, and used to control the virtual space.

- The test content was developed to maximize the new interface. The test content is a game in which users throw balls into the virtual spaces, and they need to consider how to throw the balls at each stage to complete the given mission.

This paper is organized as follows. It presents related works, the system structure of the interactive experience space, the play method of the test contents, and the test results, in Sections 2, 3, 4, and 5, respectively. Finally, in Section 6 presents, the conclusion.

2. Related Works

Virtual reality builds a virtual space that feels similar to real life, and it is a technology that gives various inputs and outputs to interfaces. The interaction in virtual reality makes it possible to access artificial virtual space naturally. The display devices, which show the virtual space, and the interface, which enables interactions with the virtual spaces, are very important factors in virtual reality. The following display and interface technologies are used in virtual reality: display devices, recognition technology, registration technology, and information generation technology.

2.1 Display Devices

Virtual reality can be realized using various devices with cameras and displays, from head-mounted displays (which users directly wear depending on the purpose to smartphones, tablets, and PCs [13]. In the case of head-mounted displays, users wear the glass-type display, and when using a PC, the virtual space is shown on the monitor with webcams and camcorders. Smartphones or tablets are equipped with both cameras and display devices, and relevant research has been conducted actively. Recently, virtual reality for vehicles has been developed using head-up displays (HUDs) [14].

2.2 Recognition Technology

Virtual reality is based on various recognition technologies. To give users information that is not recognized, the system should have various types of environmental information. For this, it uses object and location tracking technology based on images and sensors, respectively. A widely used technology for object tracking based on images is the method of using square markers. Square markers are used in many studies, and there are various types, including ArToolKit [15], ARVIKA [16], and ArLoc [17]. The square marker tracking system tracks the square in the image and creates templates to match given patterns with tracked square markers. The matched template assigns a marker ID with the highest similarity. The tracked marker ID determines the virtual model that is shown to the users, and the basic coordinates and direction of the virtual model are determined depending on the position and direction of the tracked markers. Markerless methods [18] are also used based on the characteristic points of images or faces without using square markers. Markerless methods also have various types of recognition methods, but the virtual model is represented based on the recognized position and direction of particular patterns inside the images.

2.3 Registration Technology

Registration [19] is a technology that combines virtual models with real images when virtual spaces are constructed. If the square marker method is used, the virtual model is represented in the virtual space relative to the direction and position of the markers by generating the designated model in advance based on the marker ID. In the case of GPS and geo-magnetic sensors, the virtual objects are shown in the virtual space by selecting the objects based on the sensor information.

2.4 Information Generation Technology

Virtual reality makes virtual models based on recognition technology, and augmented reality environments are constructed by registration with input images. Firstly, for the square markers, the information and virtual models represented in the virtual spaces are determined depending on the recognized marker ID. In the case of the augmented reality (AR) maintenance tool, it makes the operators follow the animation with representations of 3D animation for each step of the maintenance based on the maintenance process scenarios, and manufacturing planning can help the factory designer design the production factory by constructing the virtual model for the action radius of the operators. For indoor and outdoor user interfaces [20,21] or AR navigation using GPS, the virtual objects are selected and the current position and direction information, which are needed to visualize the map, are displayed for users. This also shows the paths or the building, which emerge from the viewpoint of users from their current position to their destination and are given to the users by generating virtual models.

3. Interactive Experience Room System

Most existing methods have tried to achieve a new space that can match the real and virtual spaces. However, existing methods have disadvantages, such as using head-mounted displays or attaching devices to the user's body, which can limit user's physical behavior and disrupt their immersion in the virtual space. We overcome the disadvantages of existing methods and propose new ways to increase immersion in virtual space. The new method we propose does not try to combine the real and virtual spaces, but maintains them. The spaces are connected with equipment; Fig.1 shows the concept of the new method. The user faces each divided space. One is the real space in which the user actually stands, and the other is the virtual space shown through the display wall. The display wall is a boundary between the two spaces, and we created a new system that connects these two spaces. This system is called the Interactive Experience Room, and we provide an overview and explanation of its components in this section.

3.1 System Overview

This section summarize the Interactive Experience Room system, which connects the virtual space and real space to increases the reality of virtual actions.

Fig. 2 depicts the overall system of the proposed Interactive Experience Room. In the new system, the user no longer needs to be equipped with exclusive devices like head-mounted displays as in existing methods. The user simply enters the Interactive Experience Room and throws the ball or controls the virtual space with simple poses. The ball the user throws flies in the virtual space and interacts with the virtual objects. For example, if the user throws the apple-shaped ball, then it will fly in the virtual space, and if the user throws the watermelon-shaped ball, it will fly in the virtual space. Additionally, the user can control the virtual space with previously registered poses, and the user can see the different virtual spaces according to their location. If the user moves to the left, they can see the right side of the virtual space, and if they move to the right, the user can see the left side of the virtual space. Fig. 3 illustrates the data flow of Interactive Experience Room.

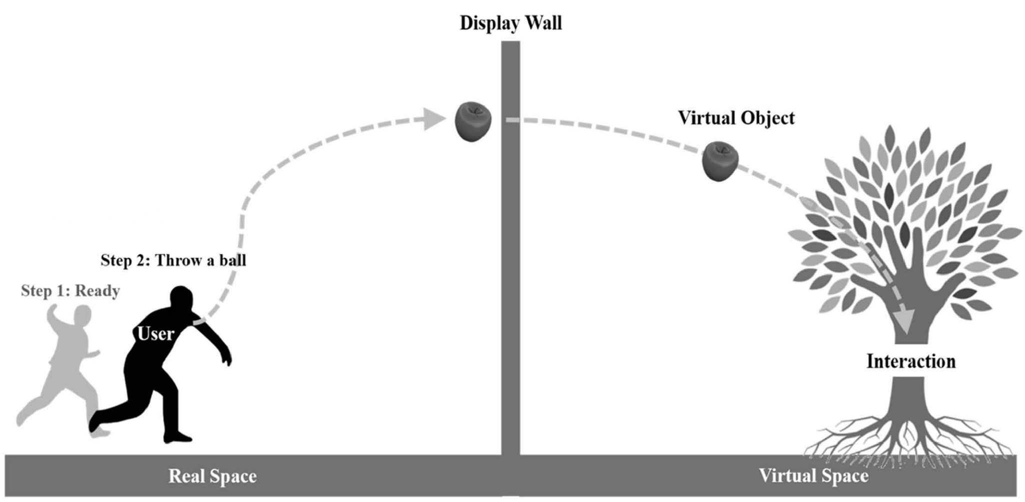

Fig. 1. Concept of Interactive Experience Room. The space in which the user actually stands and the virtual space are divided. The display wall is the boundary between these two spaces, and we created special device that connect these two spaces. The user can interact with virtual objects using the special device.

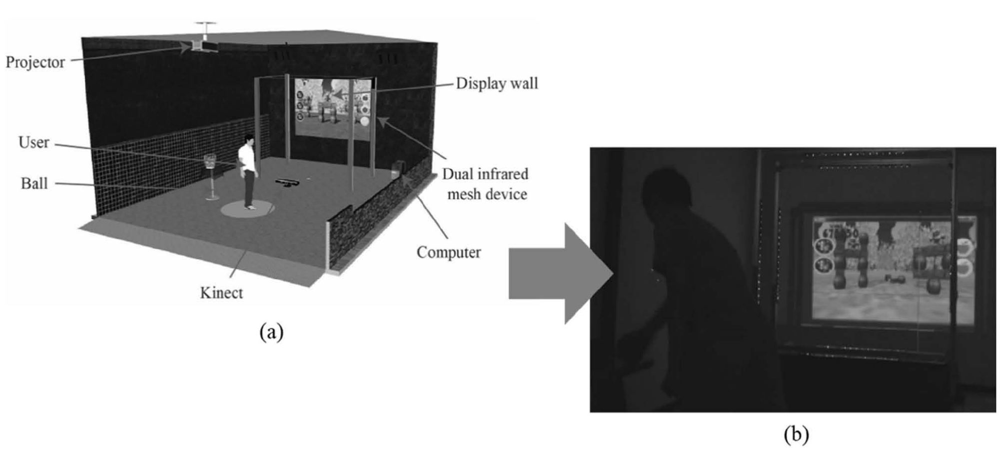

Fig. 2. (a) Components of Interactive Experience Room: when the user throws a ball at the wall, the ball appears in the virtual space and interacts with virtual objects. (b) Actual image of Interactive Experience Room.

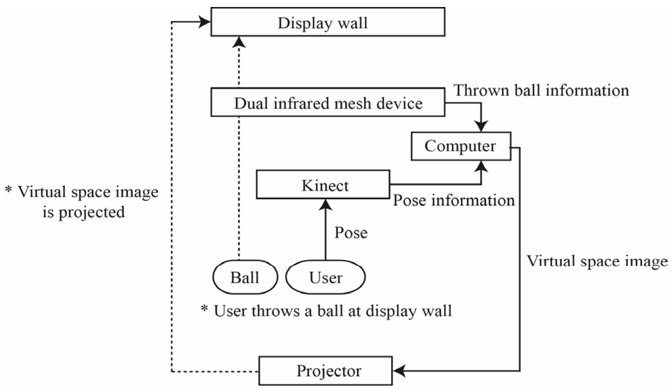

Fig. 3. Data flow of proposed system.

3.2 Estimating Thrown Ball Data Using Dual Infrared Mesh Device

The dual infrared mesh device which is equipped with a front infrared ray mesh, a rear infrared rat mesh, and a control panel tracks the location, velocity, and size of the thrown ball and interacts with virtual objects with the information received. The device consists of N of infrared transmission sensors and receivers along the x and y axes, as shown in Fig. 4. The infrared ray from the transmission sensor is delivered to the receiver sensor and the pairs of infrared ray shaped meshes. When the thrown ball passes the device, the infrared rays that do not reach the receiver sensor enable the calculation of the location, velocity, and size of the ball. The control panel controls the transmitted and received information from the sensor and delivers the calculated information to the computer. The calculation of the information on the ball is shown below.

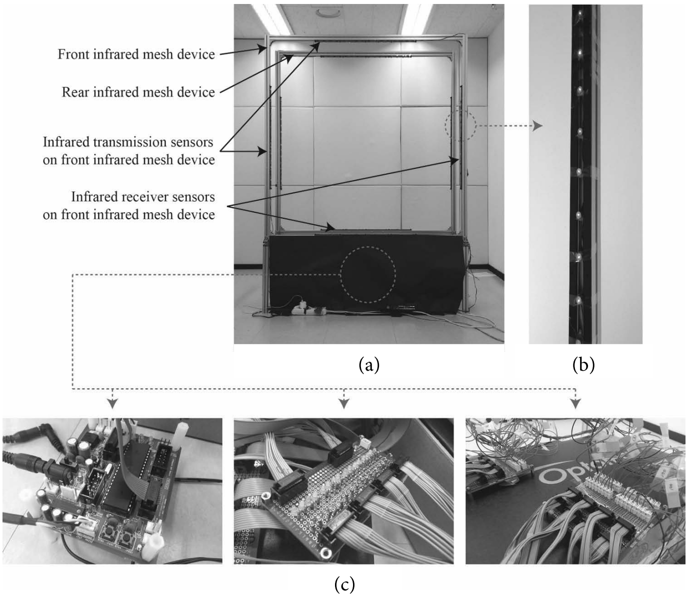

Fig. 4. Structure of infrared mesh set consisting of front infrared mesh, rear infrared mesh, and control panel. Each infrared mesh is comprised of infrared transmission and receiver sensors. (a) Dual infrared mesh device, (b) infrared sensors, and (c) control panel.

3.2.1 Estimation of ball position

The dual infrared mesh device estimates the start position of the ball in virtual space according to the location of the user's thrown ball. There are infrared rays that do not reach the receiver sensor, which causes an interference act when the ball passes the dual infrared mesh device. The moment that the ball reaches the mesh is the detection point, and the location of the center of the ball (CX_1, CY_1) as it passes the front mesh can be calculated with Eqs. (1), (2), and Fig. 5, which provide a weighted average of the infrared ray location in which the interference act occurred.

$$CX_1 = \frac{(x_1 \times t_{x_1}) + (x_2 \times t_{x_2}) + \cdots + (x_n \times t_{x_n})}{t_{x_1} + t_{x_2} + \cdots + t_{x_n}} = \frac{\sum_{n=1}^{N_x} x_n t_{x_n}}{\sum_{n=1}^{N_x} t_{x_n}}, \tag{1}$$

$$CY_1 = \frac{(y_1 \times t_{y_1}) + (y_2 \times t_{y_2}) + \cdots + (y_n \times t_{y_n})}{t_{y_1} + t_{y_2} + \cdots + t_{y_n}} = \frac{\sum_{n=1}^{N_y} y_n t_{y_n}}{\sum_{n=1}^{N_y} t_{y_n}}, \tag{2}$$

where N_x, N_y is the number of interference acts that occurred on the x and y axes, x_n, y_n is the location of the infrared ray sensor on the x and y axes, and t_{x1}, t_{y1} is the delay time after the interference act to reconnect the rays.

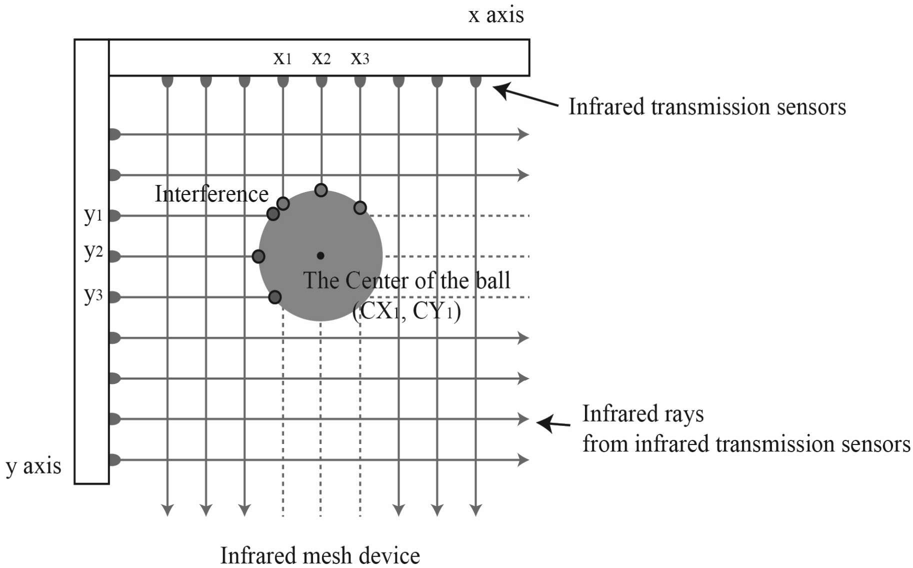

Fig. 5. Estimating the ball position (CX1, CY1) in infrared mesh with Eqs. (1) and (2).

This uses the same idea; the moment the ball reaches the mesh is the detection point, the location of the center of the ball (CX_2, CY_2) as it passes the front mesh can be calculated with Eqs. (1) and (2) (CX_2, CY_2) indicates the coordinates in the virtual space, which are used for the start point from which the ball starts to fly in the virtual space.

3.2.2 Estimation of ball velocity

We can estimate the speed of the ball thrown by the user, which is the actual speed in virtual space. Fig. 6 and Eq. (3) show the velocity, *v*, in the virtual space. We assume that when the ball travels the distance, d, between the front and rear infrared ray sensors, it travels in a uniform motion.

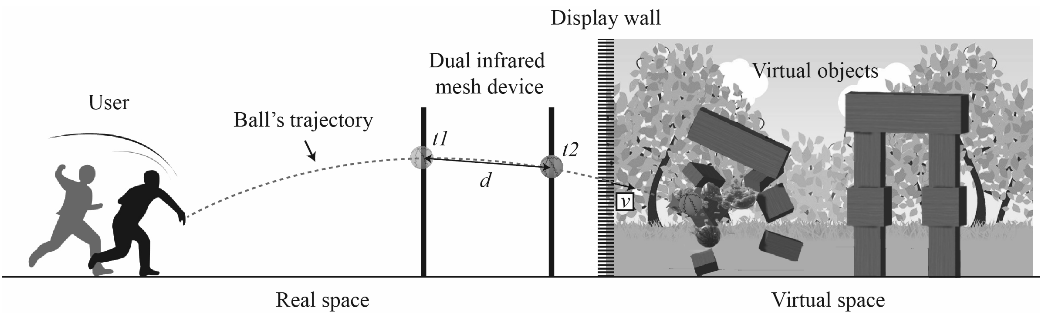

Fig. 6. Estimating velocity of thrown ball with Eq. (3).

$$\mathrm{v} = \frac{d}{(t_2 - t_{1)}}, \tag{3}$$

where d is the distance between the center of t_2 (CX_1, CY_1) and (CX_2, CY_2), t1 is the time the ball takes to pass the front infrared ray device, and t_2 is the time the ball takes to pass the rear infrared ray device.

3.2.3 Estimation of ball size

With the calculation of the size of the thrown ball, the type of ball that was thrown can be distinguished. Depending on the size of the ball, the type of ball is also changed inside the virtual space. The size of the ball can be obtained with Eqs. (4) and (5):

$$\mathrm{s} = (nk)^2, \tag{4}$$

$$\mathrm{n} = \min\left(N_x, N_y\right), \tag{5}$$

where N_x and N_y are the number of interfered infrared sensors in the x axis and y axis, respectively, and k is the distance between the infrared sensors. Since the ball size is defined in advance, the type of ball that was thrown by the user can be distinguished according to its size.

3.3 User's Pose Recognition Using Kinect

Kinect [22], developed by Microsoft, is a device that recognizes human motions without the need for a special device, like a marker, attached to the body, and it has been used in many studies on human motion recognition. Kinect is composed of a RGB camera that can recognize images and a depth sensor that can calculate the depth of an object. Using Kinect, the RGB image, depth image, and joint tracking data of the user can be easily acquired with the Kinect SDK (Software Development Kit). The joint tracking data indicates the positions of the joints, and there are a total of 20 [23]. We can determine the user posture using the joint positions. The perceived pose controls the virtual space, and Section 4 explains how a user controls the virtual space. The posture recognition methods using the Kinect are as follows:

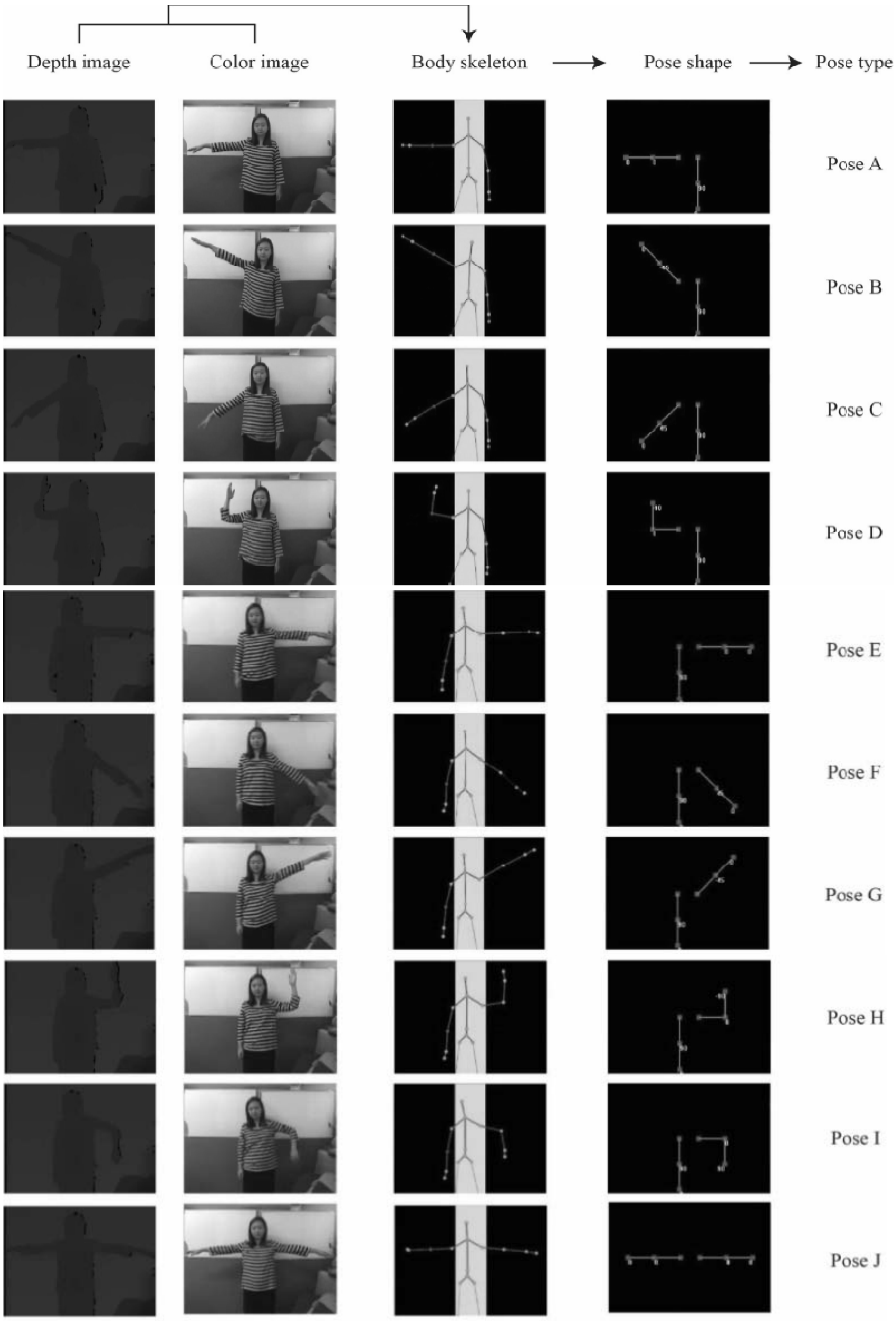

Fig. 7. Results of user's pose recognition.

The positions acquired by Kinect are 3D coordinates, and we convert the 3D joint positions to 2D coordinates. The joint positions that have been changed to 2D coordinates are connected to each other and become the skeleton structure of the human body. The segment corresponding to the arm in the skeleton structure changes to the pose shape with the modification and rotation of the line. Using the angle and position of the pose shape, we can determine a user's pose. For example, if the left and right segments of a pose shape are straight lines parallel to the x axis and y axis, respectively, the corresponding pose shape is Pose A. Additionally, if the left and right segments of a pose shape are a diagonal line rotated to 45 degrees and a straight line parallel to the y axis, the corresponding pose shape is Pose B. With this method, we can recognize a total of 16 posture types, as shown in Fig. 7. However, in the demonstration, the virtual space can be controlled using 4 out of 16 postures; this is described in more detail in Section 4.

4. Development for Testing Interactive Experience Room

In order to use the Interactive Experience Room practically, test contents was needed; therefore, we created a shooting game. We chose a shooting game for the following reasons: Firstly, it is natural for a ball thrown by a user to transform into a flying virtual ball in the game. Secondly, because it is easy and fun, users of diverse ages can enjoy it more than other types of games. In this section, the developed shooting game is introduced.

4.1 Purpose and Rules of Game

The setting of this game is a fruit farm, and the user plays as a farmer who must get rid of aliens coming to steal the fruit. The user throws the ball beside him to the farmer, who can then expel the alien. As shown in Fig. 8, if the structure the aliens are standing on is destroyed, aliens fall to the ground and runs away. If the ball directly hits the aliens, the balls bounces off the aliens. Therefore, the user should focus on destroying the structure. The shape of the ball thrown by the user looks like that of real fruit, so it is possible to experience more enjoyment and become absorbed in the game. The game ends if all four stages are cleared. The process of this game is shown in Fig. 9.

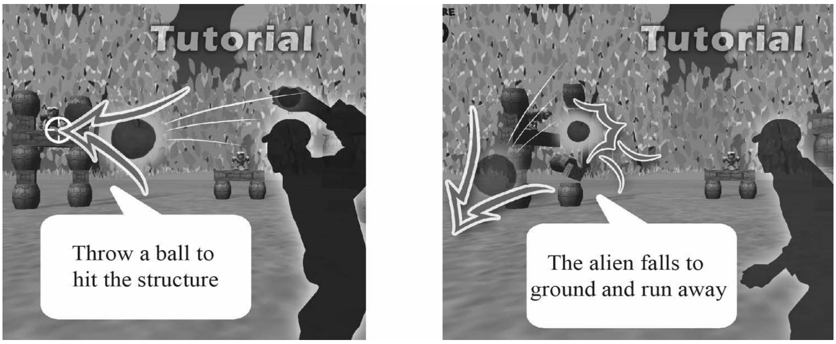

Fig. 8. It is impossible to defeat the aliens by hitting them directly with the ball; thus, the player has to destroy the structure the aliens are standing on to defeat them.

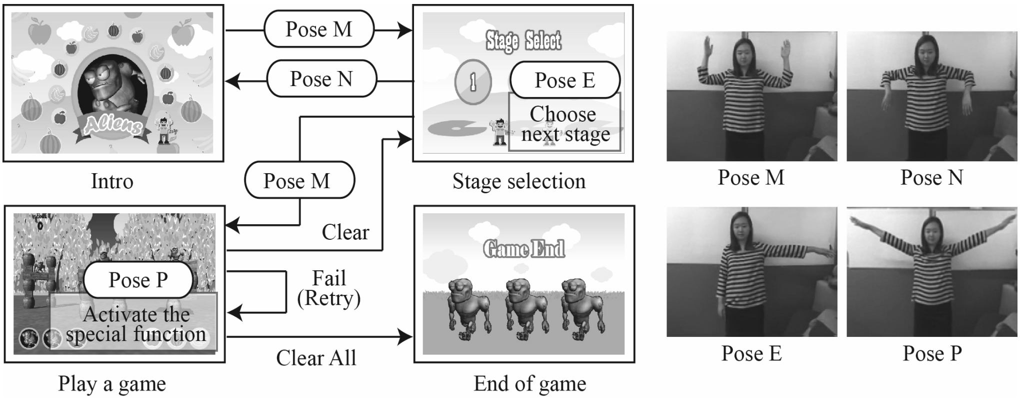

Fig. 9. Process of game-play: The game consists of four scenes (Intro, Stage selection, Game play, and End of game) and the game flow as follows: Each recognized pose is used for the game menu selection and activates a special function of the thrown ball.

- **Intro**: When starting the game, this is the first screen, and the user can move to the stage selection screen by using Pose A.
- **Stage selection**: In this game, there are a total of four stages. The user selects a stage with Pose C, and the selected stages can be played by using Pose A.
- **Game Play**: After all the aliens have been defeated, the stage is clear, and the screen returns to the stage selection screen. If the user fails to clear the stages, they can be replayed. Additionally, the user can generate a special effect by using Pose D.
- **End of game**: If all four stages are cleared, the end of game screen is shown.

4.2 Type of Thrown Ball

User can throw three types of ball: apple, watermelon, and banana, and the dual infrared mesh set can distinguish the type of ball thrown according to the predefined ball size. As shown in Fig. 10, the apple is the most common throwing weapon, the watermelon is more powerful weapon than the apple, and the banana is a scattering weapon if users take a specific posture while the ball is flying.

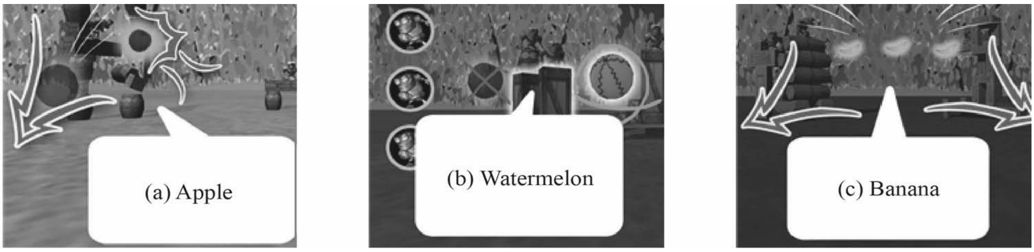

Fig. 10. The user can throw three types of balls: (a) The apple has the lowest destructive power and it can only destroy a wooden structure. (b) The watermelon is more powerful and can destroy both wooden, and iron structures. (c) The banana has the same power as the apple, but it can be divided into several parts if a specific posture is taken. It is useful for destroying closely adjoining structures.

4.3 Various Game Strategies

As the number of balls is limited in each stage and the structures are placed differently, users must plan their ball throws. For example, in Fig. 11(a), the structure is designed to be destroyed easily. Therefore, users can easily expel the aliens. However, in Fig. 11(b), Target Structure B is covered by Target Structure A. At a specific moment, the user must throw the ball parabolically and destroy the hidden structure B. In Fig. 11(c), the iron structure cannot be destroyed by the apple. Therefore, the watermelon, which is more powerful than the apple, should be used to destroy the structure. Lastly, in the case of Fig. 11(d), by using one banana instead of two apples, two aliens can be expelled at a one time. The stage described above is made to verify the performance of the Interactive Experience Room, and we can add and delete stages with various difficulty levels.

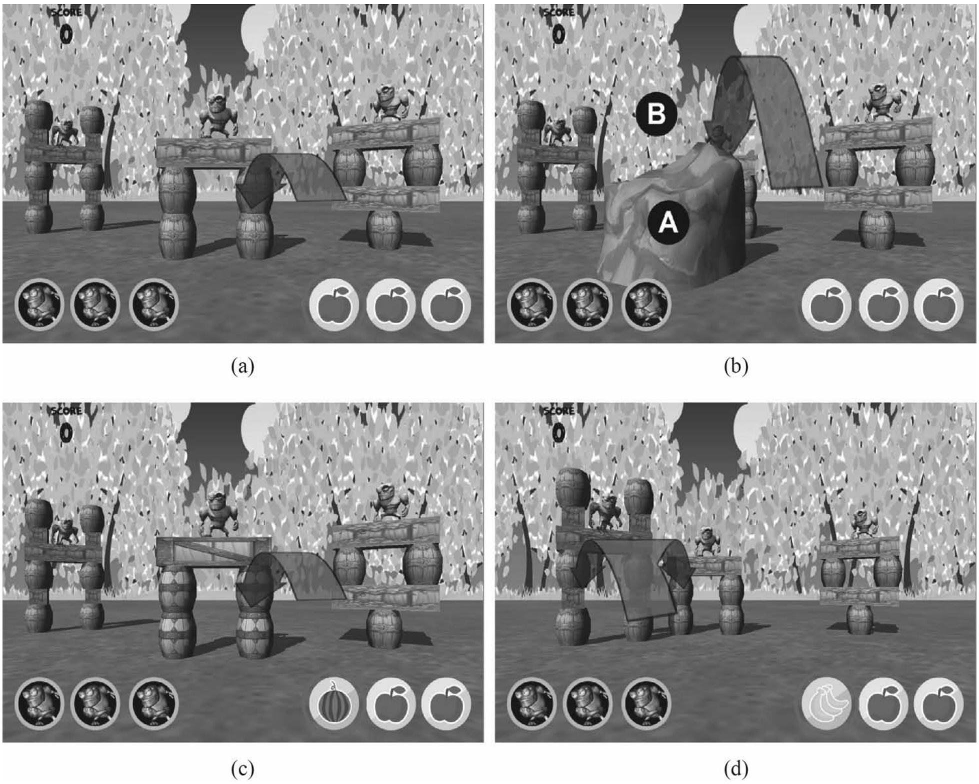

Fig. 11. Various ball-throwing strategies in different stages.

4.4 Support of 3D Stereoscopic Images

The proposed method supports side-by-side-type 3D stereoscopic images to increase the sense of realism and the 3D effect. In order to achieve this, we install two virtual cameras in the game space and make left and right images, as shown in Fig. 12. The two images are combined into one 3D image by a projector, and the 3D effect can be perceived by using polarizing filter glasses. To minimize 3D nausea, we tested and adjusted the depth of the assigned objects inside the game space several times.

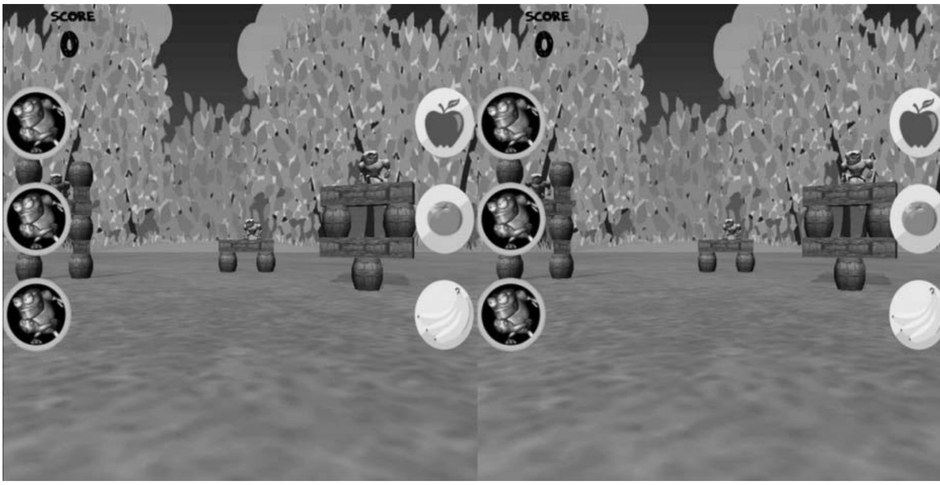

Fig. 12. Example of 3D stereoscopic image.

5. Experimental Setup and Result

The proposed Interactive Experience Room can transmit the data from the Kinect and dual infrared mesh devices with a computer, and the virtual space is constructed based on the transmitted data. The dual infrared mesh devices each have 16 infrared transmission and receiving sensors for the front and rear infrared mesh devices. The infrared controller consists of an ATmega-128 board, which can transmit calculations of the position, velocity, and size of the balls to the computer. The data sent from the dual infrared mesh devices can be used to represent the flying balls in the virtual space, and the data transmitted to Kinect can be used to control the virtual space, such as stage selection, through the recognition of the user's postures. Additionally, to increase users' absorption in the virtual space, real balls thrown by the user, the models of which were three kinds of fruits of different sizes, were used. Because the virtual content is developed by using the Unity 3D game engine, which is an easy and fast process, it is simple to add or modify the virtual space. To verify the performance of the Interactive Experience Room, we conducted three experiments targeting 22 users. The first experiment was performed to determine the ball detection accuracy of the dual infrared mesh set. The second was a posture recognition accuracy experiment. Finally, a survey of user satisfaction with respect to the virtual space (shooting game) was performed.

The first experiment was a ball detection accuracy test for the dual infrared mesh sets. In this test, the user threw three different types of balls, and; each was thrown 10 times. We then tested the detection of balls types and the position accuracy, and we asked users about the ball position accuracy (i.e., whether balls flew in the intended direction). As shown in Table 1, the position accuracy was usually high (89%). This shows that the dual infrared mesh sets usually recognize the type of ball correctly. However, the smaller the size of the ball, the lower the position accuracy tended to be (i.e., 93.9%, 87.8%, and 81.8% for the large, medium, and small ball sizes, respectively). This phenomenon occurred for two major reasons. The first reason is the insufficient number of infrared sensors. The second is the misalignment between the infrared transmission and receiving sensors. Currently, because the infrared sensors are placed on the frame, if the frame is impacted, the infrared sensors will be out of joint. This problem could be improved if the number of sensors were increased and finer sensors were allocated the wall rather than the frame.

Table 1. Accuracy of ball detection performance

	Accuracy (%)	
	Ball type	**Ball position**
Largest ball	95.4	93.9
Middle-sized ball	92.4	87.8
Smallest ball	89.3	81.8

The second experiment was conducted to determine the user posture recognition accuracy. This experiment showed how accurately Kinect recognized the user's posture in front of it. The players performed 16 postures at random and used each three times, and we then tested if the recognized postures matched the real ones. Table 2 shows the results of the second experiment, which showed high accuracy (more than 90%) for all postures.

Table 2. Accuracy of user's poses recognition

Pose type	Accuracy (%)	Pose type	Accuracy (%)
Pose A	98.4	Pose I	93.9
Pose B	93.9	Pose J	98.4
Pose C	92.4	Pose K	96.6
Pose D	98.4	Pose L	95.4
Pose E	93.9	Pose M	100
Pose F	96.6	Pose N	90.9
Pose G	92.4	Pose O	95.4
Pose H	93.9	Pose P	98.4

Table 3. Results of questionnaire for game players (unit, %)

Question	Very positive	Positive	Average	Negative	Very negative
1. Is the level of difficulty appropriate?	31.8	22.7	27.3	4.5	13.6
2. Did the ball fly in the prospective direction in the game when you threw it?	4.5	22.7	22.7	40.9	9.1
3. Did the poses work properly for the selection menu or the special functions of balls?	27.3	45.5	18.2	9.1	0.0
4. Did the thrown balls stimulate your interest in the game?	40.9	22.7	18.2	9.1	9.1
5. Is the Interactive Experience Room appropriate for enjoying virtual space?	13.6	50.0	31.8	4.5	0.0
6. Would you play this game again?	27.3	40.9	13.6	13.6	4.5
Average	24.2	34.1	22.0	13.6	6.1

The last experiment involved giving the game players a questionnaire on their qualitative experience. Table 3 shows the survey that consisted of six questions with five options (very positive, positive, average, negative, and very negative) each.

The averages for each question were 24.2%, 34.1%, 22.0%, 13.6%, and 6.1% for very positive, positive, average, negative, and very negative, respectively. However, as shown by the results of the first experiment, 40.9% and 9.1% answered negatively for the second question, so the ball detection accuracy needs to be improved. Nevertheless, it can be concluded that the proposed methods lead to interest in the game and help increase its appeal, as indicated by the positive answers given for Questions 4–6. These responses can be used to improve subsequent experiments.

6. Conclusion

This paper proposed an Interactive Experience Room to maximize the sense of immersion and reality in virtual spaces and expand real experiences. We made dual infrared mesh devices that could detect moving balls in order to represent the thrown balls in the virtual space. This had the advantages of increasing the user's physical activities and sense of immersion, because, unlike existing methods, special devices did not need to be attached to the user's body. Additionally, we used Kinect as the recognition method for user posture and for controlling virtual spaces. In the test content, as a small number of postures were used, we reduced the probability of user errors or user input confusion due to too many postures. The thrown balls and user postures interacted with the virtual objects and influenced the virtual space.

Even though the Interactive Experience Room was constructed based on the proposed methods, it seemed to have room for improvement. The most important aspect was increasing the accuracy of the ball thrown by the users. It is anticipated that this can be ameliorated by attaching the infrared sensors to the fixed wall. In future, we will improve the performance of the proposed methods with various experiments and apply the results to many other types of virtual reality content.

Acknowledgement

This work was supported by the BK21 Plus Program through NRF grant funded by the Ministry of Education (No. 31Z20150313339).

References

[1] R. T. Azuma, "A survey of augmented reality," *Presence*, vol. 6, no. 4, pp. 355–385, 1997.

[2] R. Azuma, Y. Baillot, R. Behringer, S. Feiner, S. Julier, and B. MacIntyre, "Recent advances in augmented reality," *IEEE Computer Graphics and Applications*, vol. 21, no. 6, pp. 34–47, 2001.

[3] G. Burdea and P. Coiffet, "Virtual reality technology," *Presence*, vol. 12, no. 6, pp. 663–664, 2003.

[4] W. Piekarski and B. Thomas, "ARQuake: the outdoor augmented reality gaming system," *Communications of the ACM*, vol. 45, no. 1, pp. 36–38, 2002.

[5] M. Takemura and S. Haraguchi, “BLADESHIPS: an interactive attraction in mixed reality,” in *Proceedings of the 2nd IEEE/ACM International Symposium on Mixed and Augmented Reality*, Tokyo, Japan, 2003, pp. 356–357.

[6] A. D. Cheok, K. H. Goh, W. Liu, F. Farbiz, S. W. Fong, S. L. Teo, Y. Li, and X. Yang, “Human Pacman: a mobile, wide-area entertainment system based on physical, social, and ubiquitous computing,” *Personal and Ubiquitous Computing*, vol. 8, no. 2, pp. 71–81, 2004.

[7] Z. Zhou, A. D. Cheok, Y. Li, and H. Kato, “Magic cubes for social and physical family entertainment,” in *CHI'05 Extended Abstracts on Human Factors in Computing Systems*, Portland, OR, 2005, pp. 1156–1157.

[8] A. A. Rendon, E. B. Lohman, D. Thorpe, E. G. Johnson, E. Medina, and B. Bradley, “The effect of virtual reality gaming on dynamic balance in older adults,” *Age and Ageing*, vol. 41, no. 4, pp. 549–552, 2012.

[9] P. Milgram and F. Kishino, “A taxonomy of mixed reality visual displays,” *IEICE Transactions on Information and Systems*, vol. 77, no. 12, pp. 1321–1329, 1994.

[10] E. M. Thompson, “Is today's architecture about real space, virtual space or what?” *Northumbria Working Paper Series: Interdisciplinary Studies in the Built and Virtual Environment*, vol. 1, no. 2, pp. 171–178, 2010.

[11] C. Saunders, A. F. Rutkowski, M. van Genuchten, D. Vogel, and J. M. Orrego, “Virtual space and place: theory and test,” *MIS Quarterly*, vol. 35, no. 4, pp. 1079–1098, 2011.

[12] E. F. Anderson, L. McLoughlin, F. Liarokapis, C. Peters, P. Petridis, and S. de Freitas, “Developing serious games for cultural heritage: a state-of-the-art review,” *Virtual Reality*, vol. 14, no. 4, pp. 255–275, 2011.

[13] H. Kato and T. Kato, “A marker-less augmented reality based on fast fingertip detection for smart phones,” in *Proceedings of 2011 IEEE International Conference on Consumer Electronics (ICCE)*, Las Vegas, NV, 2011, pp. 127–128.

[14] F. Wientapper, H. Wuest, P. Rojtberg, and D. Fellnerm, “A camera-based calibration for automotive augmented reality head-up-displays,” in *Proceedings of 2013 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, Adelaide Australia, 2013, pp. 189–197.

[15] D. F. Abawi, J. Bienwald, and R. Dorner, “Accuracy in optical tracking with fiducial markers: an accuracy function for ARToolKit,” in *Proceedings of the 3rd IEEE/ACM International Symposium on Mixed and Augmented Reality*, Arlington, VA, 2004, pp. 260–261.

[16] W. Friedrich, “ARVIKA-augmented reality for development, production and service,” in *Proceedings of 2002 IEEE/ACM International Symposium on Mixed and Augmented Reality* (ISMAR2002), Darmstadt, Germany, 2002, pp. 3–4, 2002.

[17] X. Zhang and N. Navab, “Tracking and pose estimation for computer assisted localization in industrial environments,” in *Proceedings of 5th IEEE Workshop on Applications of Computer Vision*, Palm Springs, CA, 2000, pp. 214-221.

[18] A. I. Comport, E. Marchand, and F. Chaumette, “A real-time tracker for markerless augmented reality,” in *Proceedings of the 2nd IEEE/ACM International Symposium on Mixed and Augmented Reality*, Tokyo, Japan, 2003, p. 36.

[19] Y. Uematsu and H. Saito, “AR registration by merging multiple planar markers at arbitrary positions and poses via projective space,” in *Proceedings of the 2005 International Conference on Augmented Tele-Existence*, Christchurch, New Zealand, 2005, pp. 48–55.

[20] G. Reitmayr and D. Schmalstieg, “Collaborative augmented reality for outdoor navigation and information browsing,” in *Proceedings of 2nd Symposium on Location Based Services and Tele-cartography,* Vienna, Austria, 2004, pp. 31-41.

[21] A. Stafford, W. Piekarski, and B. Thomas, “Implementation of god-like interaction techniques for supporting collaboration between outdoor AR and indoor tabletop users,” in *Proceedings of the 5th IEEE and ACM International Symposium on Mixed and Augmented Reality*, Santa Barbara, CA, 2006, pp. 165–172.

[22] Z. Zhang, “Microsoft Kinect sensor and its effect,” *IEEE Multimedia*, vol. 19, no. 2, pp. 4–10, 2012.

[23] K. LaBelle, “Evaluation of Kinect joint tracking for clinical and in-home stroke rehabilitation tools,” Master’s thesis, University of Notre Dame, 2011.

Green Bang http:// orcid.org/0000-0003-0016-3937

She received PhD course from the Soongsil University in 2016. She is a BK21 Post-Doctoral Research Positions at the Soongsil University at Seoul, Korea, in 2016–2017. Her primary research interests include virtual space design, user experience and artificial emotion.

Jinsuk Yang http:// orcid.org/0000-0002-3489-7309

He is a PhD student at Soongsil University, Seoul, Korea. He received his B.S. degree in Department of Media at Soongsil University in 2009. Since 2009, he has been working in the fields of computer graphics. Currently, his primary research interest lies in level design for computer games.

Kyoungsu Oh http:// orcid.org/0000-0002-7106-7865

He is a professor of Global Media Department at Soongsil University, Korea. He received B.S., M.S., and Ph.D. degrees in Computer Science from Seoul National University, Korea in 1994, 1996, and 2001, respectively. Current research topics include global illumination, shadow, image based rendering and computer games.

Ilju Ko http://orcid.org/0000-0002-2376-9264

He received the PhD course from the Soongsil University in 1997. He is a professor at the Soongsil University at Seoul, Korea, in 2003–2017. His primary research interests include image processing, virtual space design, user experience and artificial emotion.