

Projection Mapping: Interactive Operation using Kinect



Makoto Sakamoto, Takahiro Shinoda, Takahiro Ishizu, Masahiro, Amane Takei, Takao Ito

Abstract: Recently “entertainment computing” (EC) technology becomes a hit term in Japan. There is a well-known “projection mapping” in this EC. Projection mapping is a video technique that synchronizes real space and virtual space, and the fascinating world view that the fusion of both produces attracts worldwide attention. On the other hand, recently, works combining dancer performance with projection mapping to create a fantastic world are drawing attention. However, in order to make the content persuasive, it is necessary for the performer to perform precise work, such as accurate alignment of the image coordinates of the moving object in the projection video, and it is not easy for everyone to do so. In this study, we aim to entertain not only the people who see the projection mapping but also the performer through the interaction with the projection mapping. So, we prototyped an interactive projection mapping that changes according to user’s movement by projecting to the user. This time we focused on sports like baseball and soccer, and we projected the ball to the user by projection mapping so that we can experience pitching and lifting. Furthermore, we conducted a questionnaire survey to evaluate the sense of use of this system, and the results showed that many people can enjoy by this projection mapping.

Keywords : Entertainment Computing, Interactive Projection, Projection Mapping, Kinect

I. INTRODUCTION

In recent years, projection mapping has become increasingly noticed and exciting. Many people have seen projection mapping to buildings, such as in theme parks.

For example, there are “Once upon a time” held at Tokyo Disneyland from May 2014 to November 2017, and a closing ceremony of the “Rio Olympics” that began in August 2016.

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Currently, projections are also being made on familiar items such as clothes, faces, and notebooks.

There are some instances. For example, some artist directs the dancer and projection mapping to overlap using 6 vertical visions. The other instance is that we can see the white costumes become screens during the performance at the world's largest ad festival held in Cannes, making them one after another brightly. There are cases where graphics have been projected.

Projection mapping will entertain us in many ways. However, in the conventional projection mapping, since the viewer mainly views and enjoys the projected image, it is considered that the viewer's sense of immersion in the content is insufficient.

In this study, by projecting to the participants, we propose an interactive projection mapping that changes according to the participants' movements.

II. PROPOSAL

A. Equipment Used

▪ Kinect for Windows

Kinect for Windows is available from Microsoft. It’s a peripheral device that enables operations by body movement, gestures, sound, etc. without using a controller.

Kinect has an infrared sensor, an RGB camera that acquires 8-bit 3-channel (RGB) image data, a depth image sensor that acquires distance (depth) image data from Kinect, and a sound microphone that estimates the position of a sound source.

Also, Kinect’s feature is "posture recognition technology", recognizes the whole human body and performs operations by its movement. Thereby, it is possible to estimate where the parts of the body are by using the depth image.

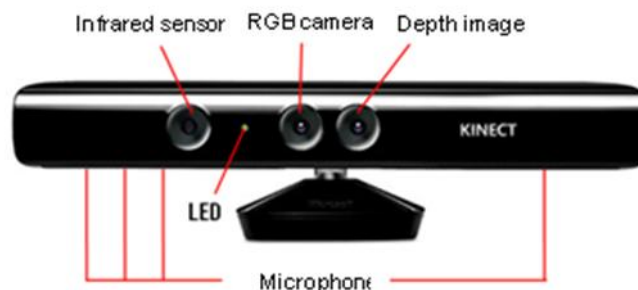


Fig. 1. Kinect for Windows [1]

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- Projector
The projector used for projection.

B. Development Environment

- OS: Windows10
- Development environment: Visual Studio 2017
- Development language: C++
- OpenNI2
OpenNI is an interface for using Kinect's available cameras and sensors with Kinect preferences, image acquisition, distance measurement, and microphones. It is also used in this research because it can be linked with OpenCV, an image processing library.
- NiTE
NiTE is used to get data (eg gesture recognition, motion tracking etc) from Kinect. [1]
- OpenCV
Perform texture mapping on the ball using OpenCV library.
In this study, we use sphere mapping.
- OpenGL
OpenGL is used for image acquisition and output, and for rendering.

III. OUTLINE OF THE SYSTEM USED FOR RESEARCH

A. User detection program

It was programmed to display seven screens: Ball, Color, Depth, User, Skeleton, Combination (for projection), and Combination PC (for PC).

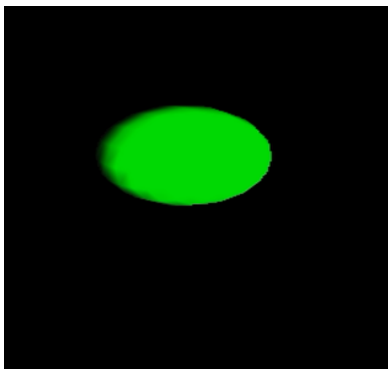


Fig. 2. "Ball" screen display



Fig. 3. "Color" screen display



Fig. 4. "Depth" screen display



Fig. 5. "User" screen display



Fig. 6. "Combination" and "Combination_PC" screen display

The skeleton is displayed on the screen as shown in Figure 7 and is assigned a number as shown in Figure 8. By acquiring this number, the user's pose can be detected.

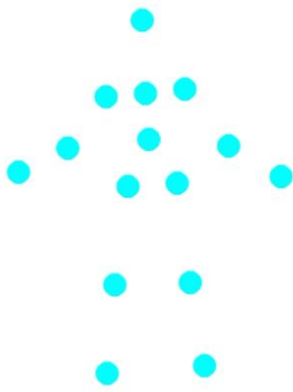


Fig. 7. "Skeleton" screen display

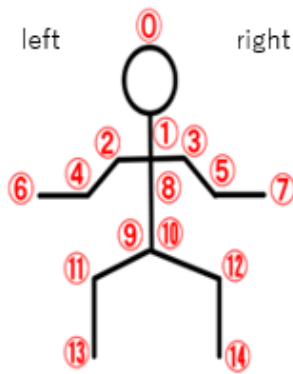


Fig. 8. "Skeleton" number

Table- I: "Skeleton" number

No	Sample
0	HEAD
1	NECK
2	SHOULDER_LEFT
3	SHOULDER_RIGHT
4	ELBOW_LEFT
5	ELBOW_RIGHT
6	HAND_LEFT
7	HAND_RIGHT
8	TORSO
9	HIP_LEFT
10	HIP_RIGHT
11	KNEE_LEFT
12	KNEE_RIGHT
13	FOOT_LEFT
14	FOOT_RIGHT

We did a projection of "combination" on the subject, and the projection mapping changes according to the movement of the subject. This time, we implemented the movement of baseball pitchers for right-handed people and the movement of football lifting. This system has two modes: baseball mode and soccer mode.

When system startup, Skeleton recognition may become unstable. Therefore, there is a possibility of switching to an unintended mode. In order to prevent that, we pose "Attention". This pose corresponds to the case where the difference between the left and right shoulder y-coordinates is less than 100 mm and the difference between the left and right elbow y-coordinates is less than 150 mm. (See Figure 8). When a series of operations of the mode is completed, it is initialized. Therefore, projection can be performed continuously. The screen remains black before switching to each mode.

B. Baseball mode

As you move the pitcher, baseball balls and baseball stadiums are projected. In addition, it sounds when you throw a baseball ball.

The ball gradually decreases as the flight distance increases in order to make the ball appear to be thrown deep into the mapping.

When the position of the ball becomes larger than the threshold value of the x coordinate (the left end of the screen as seen from the examinee), the ball disappears and is initialized.

The procedure will be described below.

Hold hands around chest (Recognize by matching of the following six conditions).

- If the difference between the x coordinate of the left elbow and the x coordinate of the center of the torso is less than 180 mm.
- If the difference between the y coordinate of the left elbow and the y coordinate of the center of the torso is less than 180 mm.
- If the difference between the x coordinate of the right elbow and the x coordinate of the center of the torso is less than 180 mm.
- If the difference between the y coordinate of the right elbow and the y coordinate of the center of the torso is less than 180 mm.
- If the difference between the y coordinate of the neck and the y coordinate of the left hand is less than 180 mm.
- If the difference between the y coordinate of the neck and the y coordinate of the right hand is less than 180 mm.

Roll up the right hand to come above the head and the ball appears and starts to move.

When recognizing that the y coordinate of the rolled up right hand is higher than the y coordinate of the center of the head, the ball appears and starts to move.

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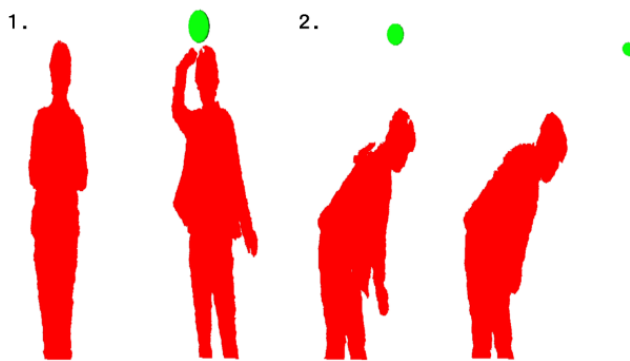


Fig. 9. Screen display of “Combination” when playing baseball (No background)

C. Soccer mode

When you act to lift a ball, soccer balls and soccer stadiums are projected. In addition, it sounds when you kick up a soccer ball.

The screen remains black until subjects move lifting.

If the position of the ball is lower than the y coordinate threshold (bottom of the screen), the ball will disappear and be initialized.

When the right knee is kicked up so as to be as high as the right waist, the ball appears (it is recognized under the following conditions).

- When the y coordinate of the right knee is kicked higher than the position 300 mm lower than the right waist, the ball appears and starts to move up.

Continuing to lower the right knee, the ball keeps going down.

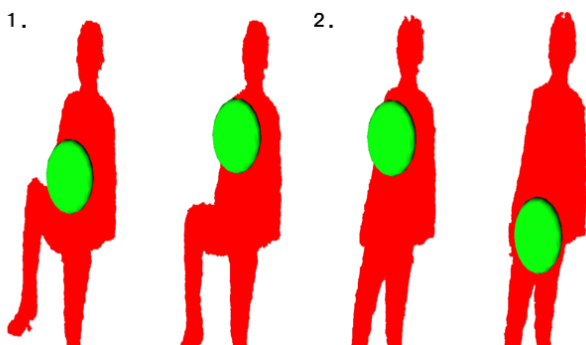


Fig. 10. Screen display of “Combination” when playing soccer (No background)

In addition, the movement of lifting uses the following physical operation.

The y coordinate upward is positive and the center of the screen of the projection mapping is set to $y = 0$.

v_0 v'_0 : initial velocity

t : time

g : ($g = 9.8 \text{ m/s}^2$) Gravitational acceleration

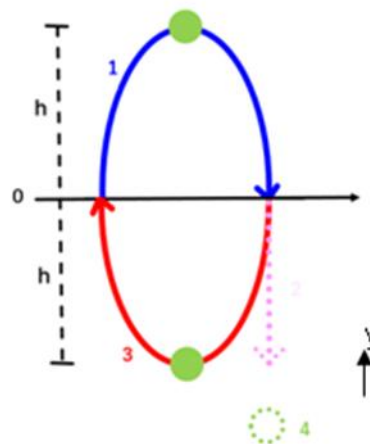


Fig. 11. Physical operation used to implement the movement of lifting

- When the position of the ball is $y \geq 0$.

$$y = v_0 t - \frac{1}{2} g t^2$$

take

$$y = 25 * t - \frac{1}{2} g t^2$$

for

$$\text{for } v_0 = 25$$

- When the position of the ball is $y < 0$.

Fall at constant speed.

When I acted to kick the ball

$$y = v'_0 t - \frac{1}{2} g t^2$$

The position of the highest point of the ball is represented by $y = h$ (see Fig. 11)

The position of the ball at the time of kicking up the ball is represented by $y = -h$ (see Figure. 11 and Figure. 12).

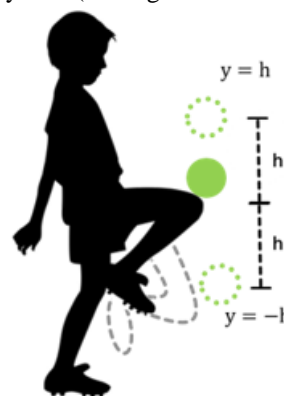


Fig. 12. he position of the ball at the time of kicking up the ball

The height of the kicked ball shall be up to the highest point of the ball in order to perform a continuous lifting operation. In order to realize this, the following calculation is performed (see Figure. 11).

- From 1 (see Figure. 11)

$$v^2 - v_0^2 = 2(-g)h$$

The speed of the highest point is

$$0 - v_0^2 = 2(-g)h$$

From

$$v = 0$$

Therefore

$$v_0 = \sqrt{2gh}$$

- From 3 (see Figure. 11)

$$v^2 - v_0'^2 = 2(-g)(2h)$$

The speed of the highest point is

$$0 - v_0'^2 = 2(-g)(2h)$$

From

$$v = 0$$

Therefore

$$v_0' = \sqrt{4gh}$$

- From the above

$$v_0' = \sqrt{2}v_0$$

therefore

$$v_0' = v_0 * \sqrt{2}$$

$$v_0' = 25 * \sqrt{2} \approx 35.4$$

Therefore

$$y = 35.4 * t - \frac{1}{2}gt^2$$

- The ball disappears when the ball falls below the threshold (under the screen).

IV. EXECUTION RESULT

The execution result is as follows.

“Combination” is projected around the human body and its surroundings.

- Baseball mode



Fig. 13. Baseball mode execution result

- Soccer mode



Fig. 14. Soccer mode execution result

V. EVALUATION EXPERIMENT

In order to obtain the evaluation of the projection mapping created this time, we asked 13 university students to cooperate as a participant and guaranteed the questionnaire.

A. Evaluation method

We asked the following questions in the questionnaire survey.

- The operation method easy to understand? (5 grades were evaluated, 5 is a good rating and 1 is a bad rating)
- What is difficult for people who have difficulty understanding. (free description)
- Is there a feeling of immersion? (5 grades were evaluated, 5 is a good rating and 1 is a bad rating)
- Opinion and improvement points. (free description)

B. Experiment result

The results of evaluation experiment are shown below.

For the questionnaire of how easy it is to operate, the average is 4.77, and there are many voices that the operation method is easy to understand.

Therefore, there was no one to answer the questionnaire whether Person what points are hard to understand.

For the questionnaire that is immersive, the average is 3.61, which resulted that it is almost immersive.

However, the opinion that “There is an immersive feeling for the person watching the projection mapping, but it is not for the person who is doing it” is also gathered.

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As a good point in the free description, “It is good to be able to continue projection continuously”, “It is interesting that the ball moves according to the pose”.

As an improvement point, “I want the speed of the ball to change according to the speed of the movement”, “The movement of the ball is slightly delayed” Many opinions were received such as to amplify the immersive feeling.

There were also some opinions asking for additional functions such as “I think it would be nice if this system some image at the first black screen”, “I think it would be better for this system to be able to map the image in many surface”, “I wish I could play more than one person in this system”, “I want the image to change with not tired action”.

VI. CONSIDERATION

In terms of realizing projection mapping with a simple operation, since we were able to obtain high evaluation, we believe that many people will enjoy this projection mapping.

However, regarding the feeling of immersion, we got the result that it is roughly the case, we proved that there is still room for improvement. “There is an immersive feeling for the person looking at the projection mapping, but not for the person who is doing it.” It seems to be for the opinion as because the subject cannot actually see the projection mapping.

Also, it is thought that there is a time lag from the time Kinect recognizes the skeleton to the time, So it is reflected in the projection for the opinion that “The movement of the ball is slightly delayed”.

Future tasks are as follows.

The first one was for right-handed people this time, so it is to target left-handed and double-handed people.

The second challenge is to add baseball / football movements such as batter and shoot as well as pitchers and lifting, allowing two players to play catch ball and adding other events.

The third is that since the ball was one kind this time, it is necessary to perform texture mapping to match the event, such as baseball balls for baseball or soccer balls, In addition. And users may also add functions to amplified the immersive feeling, such as installing a screen on which the user himself / herself can be seen during the evaluation experiment.

VII. CONCLUSION

In this research, using Kinect, we created an interactive projection mapping whose mapping changes according to human movement. Thus, as the number of projection mappings that change according to the movement of a person increases, for example, the artist has adapted the artist to the mapping movement so far. However, from now on mapping can match the artist’s movements. By doing this, we think that it is possible to reduce the gap of movement between each other and to make a more realistic stage performance.

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Makoto Sakamoto received the Ph.D. degree in computer science and systems engineering from Yamaguchi University in 1999. He is presently an associate professor in the Faculty of Engineering, University of Miyazaki. His first interests lay in hydrodynamics and time series analysis, especially the directional wave spectrum. He is a theoretical computer scientist, and his current main research interests are automata theory, languages and computation. He is also interested in digital geometry, digital image processing, computer vision, computer graphics, virtual reality, augmented reality, entertainment computing, complex systems and so forth. He has published many research papers in that area. His articles have appeared in journals such as Information Sciences, Pattern Recognition and Artificial Intelligence, WSEAS, AROB, ICAROB, SJI,IEEE and IEICE (Japan), and proceedings of conferences such as Parallel Image Processing and Analysis, SCI, WSEAS, AROB and ICAROB.



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