Abstract—In this paper, we propose an interactive projection system in which a user can see 3D scenes without glasses. The system regards the 3D position of the viewer's face which is detected with Kinect as the viewer's viewpoint position and projects images according to the viewpoint position. In addition, the system enables the viewer to interact with virtual objects by using the 3D positions of the hands that are also detected with Kinect. We implemented two applications based on the proposed method and realized image projection with motion parallax as if the objects existed in real space, and also realized interaction using depth information. As a result of subjective evaluation, we confirmed that the proposed system with motion parallax gives stereoscopic effect to users.

Keywords—projector-camera system; virtual reality; 3D interaction

I. INTRODUCTION

In recent years, interactive projection systems are attracting attention. However, most systems only present non-stereoscopic scenes [1, 2]. On the other hand, a system that presents stereoscopic scenes is developed [3], but the user has to wear 3D glasses. The systems that present pseudo-3D images with motion parallax have also been proposed [4, 5, 6]. These systems project images according to the user’s viewpoint position and give stereoscopic effect to the user. However, the images are presented in a display, which restricts the size of the presented images.

Therefore, we propose an interactive projection system which gives a user stereoscopic effect using motion parallax. The system detects the 3D positions of the viewer's face and hands with a depth camera (Kinect). Then the system generates images using the face and hand positions and projects the images according to the viewer’s viewpoint position. In this way, the viewer can experience pseudo-3D images with motion parallax without wearing 3D glasses and interaction with virtual objects using the viewer's hands. A similar system using three sets of projectors and depth-cameras has already been proposed [7], but our system has simpler configuration and can be used for exhibition and digital signage.

II. SYSTEM

Figure 1 shows the system configuration. The system consists of three components: a camera, a projector, and a Kinect. The camera and the projector are used to perform 3D measurement of a projection plane. The projector is also used to project generated images. Kinect is used to detect positions of markers that are put on the projector, a viewer's face and hands, and is installed so that it can capture images including the markers and the viewer.

The flow of the processing is described below. First, the system performs 3D measurement to obtain the shape of the projection plane. The system projects moving line on the projection plane and captures images with the camera. The system computes the 3D coordinate from the corresponding pair of 2D coordinates in the projection image and the camera image. Second, the 3D position of the projector is obtained by calculating the centroid of the two markers put on the projector that are detected with Kinect.

The positions of the user's face and hands are detected using Kinect skeleton tracking. The detected coordinates are converted into the coordinates centered at the projector. The position of the user's face is regarded as the viewpoint position and the images of 3D scenes that are projected to the viewpoint are generated. Projective texture mapping using the images is performed on a virtual projection plane and image projection according to the viewpoint position is realized [8]. Thus, the system presents pseudo-3D images with motion parallax and enables the viewer to see 3D scenes. Moreover, interaction with virtual objects is realized by generating images using the detected hand positions.
III. APPLICATIONS

We implemented two applications based on the proposed method. The first one is an application mainly for presenting 3D images as shown in Fig. 2. A viewer can obtain stereoscopic effect by moving the viewpoint position from the change of objects’ appearance and depth difference from the background. The second one is an application mainly for interaction. A viewer can hit virtual balls with viewer’s hands against a real wall as shown in Fig. 3 and interaction using depth information was realized.

Fig. 2. Application for showing 3D images.

Fig. 3. Application for interaction.

IV. EVALUATION

We conducted an experiment to investigate whether the proposed method can give stereoscopic effect to users. We recruited six undergraduate students in their twenties. We asked the participants to view images of the application with motion parallax that is shown in the last section and those without motion parallax. In the application without motion parallax, objects translate uniformly according to the user’s movement, and the appearances do not change. The participants viewed images for one minutes per each condition with walking around freely. The half of the participants viewed images with motion parallax first, and the other participants viewed images without motion parallax first. After that, we asked the participants to answer the following questions with 5-point Likert scale.

- Did you obtain stereoscopic effect from the images? (three-dimensionality of images)
- Did the objects look floating in the air? (three-dimensionality of objects)
- Did you enjoy viewing the images? (enjoyment)

Figure 4 shows the mean score for each item and each condition. The scores for the condition with motion parallax were higher for all items. The result of paired t-test showed that there were significant differences for all items ($p=0.002$ for three-dimensionality of images, and $p=0.012$ for three-dimensionality of objects, and $p=0.001$ for enjoyment).

Fig. 4. Result of subjective evaluation.

V. CONCLUSION

We proposed an interactive projection system which gives a user stereoscopic effect without glasses using motion parallax. The system detects the 3D position of the viewer's face using Kinect and projects images according to the viewpoint position. Also, the system enables the viewer to interact with virtual objects by using the 3D positions of the user’s hands. As a result of subjective evaluation, we confirmed that the proposed system with motion parallax gives stereoscopic effect to users. Future works include improving the recognition accuracy, projection to non-planar surfaces, and creation of more attractive applications.

REFERENCES