# Abstract

The emerging technologies of Augmented Reality (AR) and Virtual Reality (VR) have been applied in various applications. The recent achievement of the related hardware development includes GateBox, Occlusion-Aware AR device. The user feeling of the immersion of virtual objects is not easy to be fulfilled, because pervious systems only displayed them inside the devices. The sense of the existence of the virtual object is reduced because virtual objects are clearly visible on the display regardless of the user's individual differences in visual acuity, and the visual field is restricted by the size of the display.

To address these issues, this thesis proposes a 3D projection system, that performs real-time stereoscopic projection by the tracked head mounted projector. A virtual object or a distorted image of a CG character is projected on a projection surface such as desktop, and various interactions can be performed. The user can always see the stereoscopic image and can interact with the virtual object more naturally than using which display. In addition, it can be presented to the user more natural superimposition of CG objects in the real space.

The proposed system includes three steps. First, Experimenter aligned the space in the real space and the virtual space where the interaction takes place, and the system operates. In addition, in the space where the registration is performed, a mesh is generated at the same position as the position in the real space. Next, user use own hands to perform the interaction between the virtual object and the CG character. We aim to present the virtual objects and CG characters to the user by always projecting a stereoscopic image according to the user's movement.

This work used HTC Vive and SteamVR, perform room scaling to align the virtual space with the real space.

This work used a tracker to match the size and position of the virtual desk and real desk. First, a desk to be a projection plane is placed in the room-scaled real space. Next, the tracker is sequentially placed over the four corners of the desk, and the coordinates of that position are acquired each time. We generated mesh in virtual space based on the acquired coordinates. Also, by adding the collision detection function at the same time as the mesh generation, the CG character can freely walk on the generated mesh.

The shake of the virtual camera caused by sensing movement of the user is reduced by using Lerp (Linear Interpolation) decay that moves smoothly between two points.

We attached the tracker and LeapMotion to the headgear using paper clay and

camera holder. In addition, a holder for attaching LeapMotion to the helmet is created using a 3D printer. The small projector was disassembled and mounted on LeapMotion.

In the evaluation experiment of this system, the user interacted with virtual objects and CG characters using the proposed system. Seven subjects participated in the experiment. After the experiment, we did a questionnaire survey to evaluate usability.

In the interaction with the object, the user performs push/pull and gripping actions with own hand and observes the state. In the interaction with the CG character, The CG character follows the virtual ball thrown by the user toward the projection surface and throws the ball back.

The operation of the CG character is performed by the movement of the user's head. First, the initial position of the CG character is set as the center of the projection range, and the position of the CG character in the virtual space and the position in the real space are synchronized. Next, if the CG character is located more than a certain distance from the center of the projection range, the CG character moves to return to the center of the projection range. This is the operation of the CG character. The CG character is designed two heads high, and the height is about 30cm.

After interacting with the CG contents, a questionnaire survey was conducted to evaluate the developed system. The evaluation uses a five-point scale.

From the result of evaluation, we confirmed the usefulness of the proposed system and interaction. In addition, the behavior of the subject and the reaction to the projected contents were also confirmed.

By using the proposed method, it is expected to provide new entertainment in haunted houses, route guidance in museum, and an attraction in a theme park. In addition, it is possible to provide the feeling of actually having an adventure with a character and to further enhance the entertainment by applying this system to a location-based AR game such as Pokémon™ GO. In addition, research using toys and research eliminate loneliness can be applied to the therapeutic fields such as loneliness, stress relief, and healing.

The possible future works may include the realization of complex interactions. It is possible to project a three-dimensional image without distortion onto uneven surfaces taking into account the projection. Furthermore, outdoor usage becomes possible if we can capture the real environment in real-time using SLAM approaches.