A Projection-Based Mixed-Reality Display for Exterior and Interior of a Building Diorama

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Abstract

This paper proposes an interactive display system that displays both of the exterior and interior construction of a building diorama by using a projection-based Mixed-Reality (MR) technique, which is useful for understanding the complex construction and the spatial relationships between outside and inside. The users can hold and move the diorama model using their hands/body motion, so that they can observe the model from their favorite viewpoint. Our system obtains both of the user's information (the viewpoint and the gesture) and the diorama model's information (the pose) in 3D space by using two RGB-D cameras. The CG image corresponding to the user's viewpoint, gesture and the pose of the diorama is rendered by Dual Rendering algorithm in real time. As the result, the generated CG image is projected onto the diorama to realize MR display. We confirm the effectiveness of our proposed method by developing a pilot system.

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1. Introduction

AR (Augmented Reality) or MR (Mixed Reality) techniques are installing to exhibitions in museum and showrooms to promote better understanding of visitors. Commonly, tablet devices are used for realizing such display systems. However, it bothers the visitors to hold such device throughout their observation. Projection-based MR merge real and virtual world by projecting virtual CG (Computer Grahics) objects onto real objects after transforming the shape of the CG model to fit the real objects. User can observe the MR scene without putting on any display devices [BIMBER]. It also has advantages comparing with other MR display (e.g., HMD: Head Mounted Display, 3D Display) such as 3D sickness or convergence insufficiency. In this research, we propose a projector-based MR display system that shows both of the exterior and interior construction of a building diorama.

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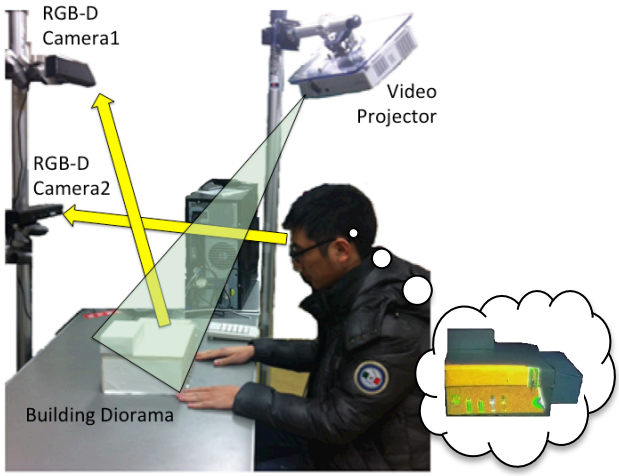

Figure 1. *Our system configuration: It obtains both of the user's information (the viewpoint and the gesture) and the pose of the diorama model in 3D space by using two RGB-D cameras, and projects the virtual appearance onto the diorama model.*

2. Projection-Based MR Display System for a Building Diorama

As shown in Figure 1, our proposed system consists on two RGB-D cameras, a building diorama as a projected screen (real object) and a video projector. All devices are calibrated in advance. The RGB-D camera-1 extracts point-cloud of the diorama to estimate the pose (position and orientation) in 3D space. The other RGB-D camera-2 captures the user to measure the viewpoint and to estimate the gesture expressed by the upper body. The CG models of the exterior and interior of the building are generated by using Google SketchUp in advance. It is possible to accurately render the appearance of virtual objects (CG models), and project the appearance onto the diorama model in real time by applying Dual Rendering algorithm [BROWN].

2.1 Pose Estimation of a Building Diorama

Object tracking is one of the most interested research topics in computer vision. However, in the environment of our system, it is difficult to estimate the pose of the diorama by using the techniques. Since the appearance of the diorama is dynamically changed by projection images and the environment is generally darkish. Thus, we develop a method to estimate the pose (position and orientation) of the diorama by using VFH (Viewpoint Feature Histogram) [BOGDAN].
In the off-line processes, we generated the VFH-dataset of a target diorama by observing the CG model (CAD data) at various viewpoints. In the on-line processes, the point-cloud data of the target scene is calculated from the captured depth image and the camera's intrinsic/extrinsic parameters (camera1). In this system, we assume that the target diorama is set on a plane such as a tabletop, so that the points-cloud data can be segmented into the

target diorama (foreground) and the other region (background) easily. By comparing with the VFH-dataset and the VFH descriptors of the segmented foreground point-cloud, we estimate the ID of the captured diorama, and calculate the pose by using CRH (Camera Roll Histogram) [ALDOMA] and ICP (Iterative Closest Point) algorithms.

2.2 Gesture of a User

Our system does not require users to put any devices (i.e., hands and head free). In order to maintain the advantage, we develop an interface to switch the projected video on the diorama. The pose of the user's upper body is estimated as a bone-data composed with 20 joints by applying Open-NI Library to the captured RGB-D image (camera2). Then, the following three types of gesture are identified.

(1) Selecting the structural hierarchy of the CG model such as building, floor, room and object.
(2) Selecting the focusing target in a same hierarchy such as a room or furniture.
(3) Moving the focusing target.

2.3 Projection Mapping onto the Diorama

To display an accurate appearance for the user, our system estimates the position of the user's viewpoint using the bone-data described in the pervious section. We use Dual Rendering technique to eliminate the distortion cased by the 3D shape of the target diorama model (i.e., motion parallax).

3. Developing a Pilot System

As shown in Table 1, our proposed system consists on a building diorama as a projected screen, a video projector, two RGB-D cameras for extracting 3D information of the building diorama and a user and a computer for information processing. Additional information such as switching the CG model is given by a keyboard and a mouse. The system is coded by C++ and C# and CG rendering part is realized by OpenGL.

Some examples of the displayed MR scene are shown in Figure 2. By seeing through the outside wall, the user can understand the inner structure of the diorama with perceiving the spatial relation ship between the exterior and interior construction. When we display too much CG information in the see-through display, it is difficult to understand the spatial relationship. In our system, users can control the displayed layer of the CG model using their body motion (gestures) so that only focusing objects are observed. We believe that such features help user to understand about the exhibitions in museum and simulate the layout of the rooms and furniture in showroom.

Table 1. *Hardware configuration of our system*

Equipment	Item	Specification
Computer	CPU	Intel Core i7-3770 3.4GHz
	Memory	16 GB
	Graphics board	NVIDIA GeForce GTX 650
Projector	Display resolution	1024 pixels x 768 pixels
RGB-D camera (Microsoft Kinect)	Field of view	Horizontal: 57 degree
	Observable range	500-10,000 mm
	Resolution of depth image	640 pixels x 480 pixels
	Depth sensing error	1-3 cm

4. Conclusion

We proposed an interactive display system that displays both of the exterior and interior construction of a building diorama by using a projection-based MR. Users could hold and move the diorama model using their hands/body motion as they want. The projected CG image was generated by referring the user's viewpoint, gesture and the pose of the diorama in real time. As we developed a pilot system, it was confirm that our proposed method is useful for display exhibitions in museum and simulation in showroom.

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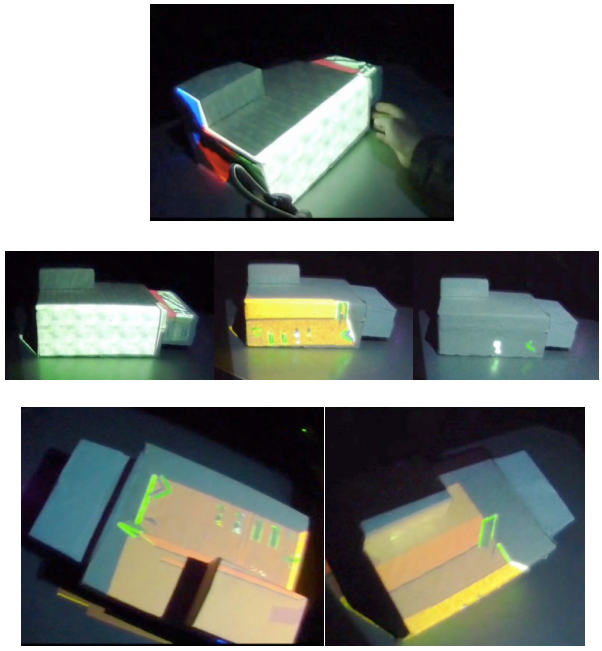

Figure 2. *Examples of the displayed MR scene. (Top) Users can hold and move the diorama model using their hands/body motion. (Middle) Selecting the structural hierarchy of the displayed CG model such as building, floor, room and object. (Bottom) The CG image corresponding to the user's viewpoint is rendered by Dual Rendering algorithm in real time.*