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Building-Scale Virtual Reality:

Reconstruction and Modification of Building Interior Extends Real World

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ABSTRACT

A method is presented that extends the real world into all buildings. This building-scale virtual reality (VR) method differs from augmented reality (AR) in that it uses automatically generated 3D point cloud maps of building interiors. It treats an entire indoor area a pose tracking area by using data collected using an RGB-D camera mounted on a VR headset and using deep learning to build a model from the data. It modifies the VR space in accordance with its intended usage by using segmentation and replacement of the 3D point clouds. This is difficult to do with AR but is essential if VR is to be used for actual real-world applications, such as disaster simulation including simulation of fires and flooding in buildings. 3D pose tracking in the building-scale VR is more accurate than conventional RGB-D simultaneous localization and mapping.

KEYWORDS

3D Pose Estimation, 3D Scene Reconstruction, 3D Scene Segmentation, Augmented Reality, Disaster Simulation, Virtual Reality

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1. INTRODUCTION

Augmented reality (AR) technology, which combines virtual space/objects with real-world space/objects, has been attracting much attention as a way to “extend the real world.” There are two approaches to AR: optical see-through (as used in Microsoft’s HoloLens headset)) and video see-through (as used in Apple’s iPhone with ARKit). With both approaches all real-world objects that come into view must be recognized in real time, which requires much overhead.

Virtual Reality (VR) technology, on the other hand, is used to create a completely new world, one usually unrelated to the real world. Room-scale VR enables users to roam around a room, but it does not work well unless it can replicate situations in the real world.

We addressed this shortcoming by devising a method for capturing information about a situation in the real world and using it to build a virtual world in which things unrelated to the target task are removed from view. This method can be used to make the entire interior of a building a virtual space in which multiple users can act naturally, such as moving from room to room. With this “building-scale VR” method, the environment can be changed in accordance with the intended usage of the space.

Building-scale VR requires the ability to virtualize a real-world situation at low cost and to accurately track actions in a large real-world space. Furthermore, a technique is needed for molding the corresponding virtual space so that it suits the intended use.

We previously presented a method for automatically generating a 3D indoor map and converting it into VR content that can be used to simulate a disaster situation for use in training (Nagao & Miyakawa, 2017). Although stationary objects such as walls and floors can be modeled automatically, movable objects such as desks and chairs need to be scanned manually. Moreover, accurately tracking a person’s movements in the indoor environment is impossible. Our proposed method overcomes these problems by automatically generating a 3D point cloud map, detecting objects in the point cloud, and replacing them with more appropriate representations (e.g., 3D models). A point cloud is a set of data points in 3D Euclidian space. A person can be accurately tracked throughout the entire indoor area by using deep learning. The proposed method thus lays the foundation for achieving building-scale VR.

This foundation for building-scale VR incorporates results from several fields: 3D scene reconstruction, 3D pose tracking, and 3D scene segmentation. The 3D scene reconstruction is done automatically using an autonomous mobile robot equipped with inexpensive devices, making its use less expensive than using the conventional method. The 3D pose tracking is done using an extended version of outside-in pose tracking, which has already been put into practical use. The result is tracking with almost the same accuracy within and beyond the range of external sensors. The 3D scene segmentation is based on conventional segmentation and uses a database of 3D models to alter the 3D virtual space in accordance with its intended usage.

Building-scale VR has a wide range of potential applications. It can be used for virtual training in disaster situations, in line with the idea of Nagao and Miyakawa (2017). The training could be for not only evacuation in case of fire but also for various firefighting activities. It could also be used to enable people to experience of behaviors in a flood situation. Other applications include support for presentations and discussions in virtual meeting rooms. Specifically, a three-dimensional map of a meeting room in the real world could be created, and presentation slides and other materials could be displayed on a virtual screen, enabling a meeting to be held in the same way as in the real world. Moreover, 3D objects could be displayed, which would help facilitate the meeting by enabling the participants to refer to them. Such a meeting can be held only in a space that extends the real world.

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