MR Sand Table: Mixing Real-Time Video Streaming in Physical Models

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Abstract

A novel prototype of MR (Mixed Reality) Sand Table is presented in this paper, that fuses multiple real-time video streaming into a physically united view. The main processes include geometric calibration and alignment, image blending and the final projection. Firstly we proposed a two-step MR alignment scheme which estimates the transform matrix between input video streaming and the sand table for coarse alignment, and deforms the input frame using moving least squares for accurate alignment. To overcome the video border distinction problem, we make a border-adaptive image stitching with brightness diffusion to merge the overlapping area. With the projection, the video area can be mixed into the sand table in real-time to provide a live physical mixed reality model. We build a prototype to demonstrate the effectiveness of the proposed method. This design could also be easily extended to large size with help of multiple projectors. The system proposed in this paper supports multiple user interaction in a broad area of applications such as surveillance, demonstration, action preview and discussion assistances.

Keywords: Mixed Reality; Spatial Augmented Reality; Video Streaming; Sand Table

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems — Artificial, augmented, and virtual realities; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality

1 Introduction and Related Work

Mixed Reality (MR) has become a hot research field in the last few years. As an important branch of MR, spatial augmented reality [1] technology updates the surface appearance of real objects with various of projectors, optical elements such as mirror beam combiner, transparent screen, and holograms. It provides an information space that physically exists and multiple users could interact with the space together. Compared with Head-Mounted Display(HMD), users share the same environment and usually are not required to wear or carry devices on their bodies.

There have been several researches on Spatial AR. Raskar et al. [2] presented Project "Shader Lamps", which projects customized content onto a neutral and diffuse object to change its appearances. On this basis, Grossberg et al. [3] improved Shader Lamps by controlling the appearance of an arbitrary object using a projector and a camera. Bermano et al. [4] proposed to augment physical avatars using projector-based illumination to increase their expressiveness.

In this paper, we proposed a novel design of MR Sand Table which embraces multiple real-time video streaming into a physically united view based on a real scene. Different from previous works, networked live video streaming is incorporated into a physical model projection with alignment and blending to mix the real and virtual environments. The physical sand table is created from the real scene of the video area. The input video streaming is aligned with the physical sand table and projected on its corresponding areas. Then the video content is rendered in the sand table in real-time, which is synchronize with the real scene. This system supports multiple user interaction in a broad area of applications such as surveillance, demonstration, action preview and discussions.

2 Prototype Design

The prototype of the MR Sand Table consists of a physical sand table, a projector and a computer, which fuses multiple video streaming of the real world, such as the acquisition of local real-world scenarios surveillance cameras.

The physical sand table is made by engraving machine or 3D printer according to a certain proportion of the real scene which is neutral and diffuse. The surface of projection area is made by light colored diffuse reflection material. The sand table could add some buildings or microfilm model of vegetation to improve the appearance of the sense of reality. This method can achieve high accuracy of the model, which is conducive to fuse three-dimensional models and video streams.

Our primary consideration was to build a display system to project the fused video streaming to the sand table. The whole prototype is built from structural aluminum components. The projector is located just above the sand table which placed on the tabletop. The video streaming captured by the video cameras is transmitted to the workstation through the network. Figure 1 illustrates a prototype of MR Sand Table.

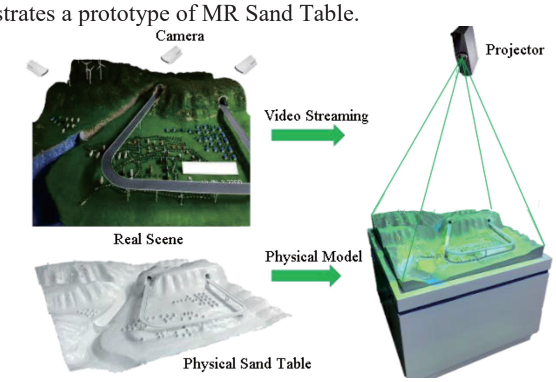

Figure 1: Prototype design of MR Sand Table.

3 Making Method Outline

Here we describe briefly the making method outline used for the projector calibration, input video streaming alignment and blending. Different from usual approaches, we use image processing based method to implement MR Sand Table configuration. Our method mainly involves three steps to achieve the goal.

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The first step is to calibrate the projector with the sand table. We use a secondary camera near the projector to help the process. With help of the method presented in [5] three homography matrixes among projector, secondary camera and physical sand table could be established. The background image can be correctly projected on physical sand table with the homography matrixes.

The next step is to align input video streaming with the background image. Firstly, for each video stream, we grab one frame to pick at least four pairs of feature points which is exactly the same position between this frame and background image. In this way, we could estimate the homography matrix between the input video streaming and background image. Then we use an image deformation method to adjust error, in which a moving least squares based image deformation with the extension of line segments is used to align the input video streaming accurately.

The last step is to merge the overlapping area among different input video streaming. A border-adaptive blending scheme is designed to make the border appearing seamless. At first, a minimum error boundary is calculated with the method presented in [7]. And then, a brightness diffusing method is conducted to merge the overlapping area. An example result is illustrated in Figure 2.

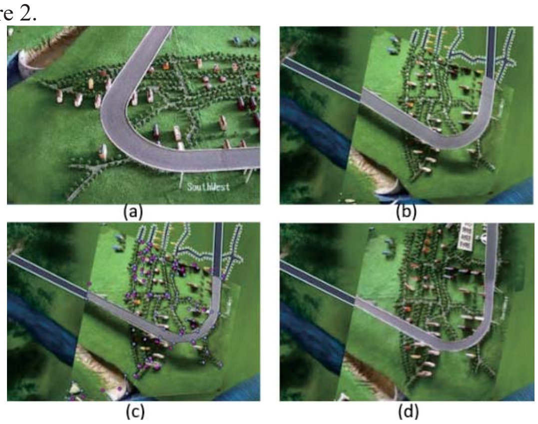

Figure 2: Result of blending. (a) Input video streaming. (b) Coarse alignment result. (c) Accurate alignment result. (d) Blending result.

4 Experiments

We use a 3m × 3m scene model as the target area and video streaming is obtained from two surveillance cameras. The cameras are about 60 degrees from the horizontal plane. The physical sand table is 70cm off the floor, made by white Acrylonitrile Butadiene Styrene plastic which makes the sand table suitable to be projected.

Prior to use, we need to initialize the prototype with three steps. First of all, the projector and the auxiliary camera are placed on the frame. Secondly, a checkerboard pattern is projected on the tabletop to estimate the mapping between the projector and the camera. Lastly, the sand table is placed on the tabletop to estimate the mapping between the camera and the physical sand table. In this way, the mapping between the projector and the physical sand table could be estimated indirectly.

Each video cameras should be calibrated for the first time use. The surveillance cameras should be correctly connected. By choosing one of them to pick 20 pairs of coordinate at the corresponding position, the system calculates the perspective transformation matrix between the video streaming and the base map. Then the Moving Least Squares based image deformation method is used for accurate alignment to eliminate detail error. Eventually, the parameters are saved as configuration files to use in real time. With the same method, other video cameras are correctly calibrated.

Before the operation, the system need to load the configurations obtained from the making method in the last section. The cameras will have consistent parameters with the same configurations unless they are moved, so each frames of video streaming could be deformed according to the calibration results in the configuration files. The prototype will automatically uses the border-adaptive image blending method to fuse video streaming for overlapping area. An example of the deformed images of the real-time frames is illustrated in Figure 3.

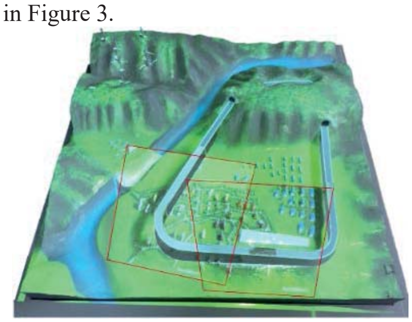

Figure 3: the real-time MR sand table. The Input video streams are marked by the red quadrilaterals.

5 Conclusion and Future Work

In this paper, we proposed a novel design of MR Sand Table which embraces multiple real-time video streaming into a physically united view based on a real scene. The physical sand table was fabricated by low-cost 3D sculpture with the simple isohypse lines of the terrain. We proposed a two-step MR alignment scheme which estimates the transform matrix between a video source and the sand table for coarse alignment, and deforms the input frame using moving least squares for accurate alignment. A border-adaptive image blending method is used to make the overlapping appearing seamless. We build a prototype to demonstrate the effectiveness of the proposed method. The prototype could also be easily extended to large size with help of multiple projectors. It has many possible applications such as surveillance, demonstration, action preview and discussion assistances.

Acknowledgments

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