Auto-Calibration of Multi-Projector Displays with a Single Handheld Camera

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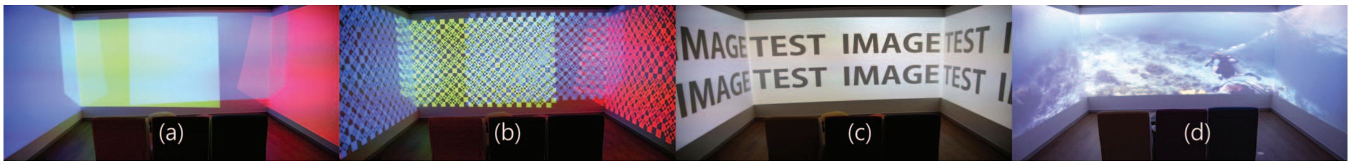

Figure 1: (a): Uncalibrated state, (b): Projected patterns, (c): Calibration result, (d): Panoramic content on display

Abstract

We present a novel approach that utilizes a simple handheld camera to automatically calibrate multi-projector displays. Most existing studies adopt active structured light patterns to verify the relationship between the camera and the projectors. The utilized camera is typically expensive and requires an elaborate installation process depending on the scalability of its applications. Moreover, the observation of the entire area by the camera is almost impossible for a small space surrounded by walls as there is not enough distance for the camera to capture the entire scene. We tackle these issues by requiring only a portion of the walls to be visible to a handheld camera that is widely used these days. This becomes possible by the introduction of our new structured light pattern scheme based on a perfect submap and a geometric calibration that successfully utilizes the geometric information of multi-planar environments. We demonstrate that immersive display in a small space such as an ordinary room can be effectively created using images captured by a handheld camera.

Index Terms: I.3.3 [Computer Graphics]: Picture/Image Generation—Display algorithms; I.4.1 [Image Processing and Computer Vision]: Digitization and Image Capture—Imaging geometry; I.4.1 [Image Processing and Computer Vision]: Digitization and Image Capture—Camera calibration; I.3.3 [Hardware]: Input/Output Devices—Image display

1 Introduction

A spatial immersive display (SID) provides users with an enhanced level of immersion and presence. Thanks to these improved user experiences, SID has rapidly widened the area of its potential applications. Some of the recent applications include entertainment, scientific visualization, medical imaging, aerospace engineering, and virtual reality to name a few.

An immersive feeling is often created by wide viewing angles and high-resolution displays. Typically, these large displays require the use of a multi-projection system. One notable example is the CAVE Automatic Virtual Environment (CAVE) which was introduced as the first application based on a projection system to achieve SID [6]. Since then, there have been many studies that facilitate the building of a multi-projection system [2]. To further increase usability, a technique for building a scalable display given casually positioned projectors has also been introduced [17].

Multi-projection systems entail a complex calibration process in order to create a single imaginary display. This process is divided into geometric and photometric calibration steps.Typically, the user who performs these two calibration steps should possess professional knowledge in order to perform the construction and maintenance of the display. Auto-calibration techniques based on the use of a camera have been researched to expedite this elaborate projector installation process and to minimize user intervention [2].

Most of the existing studies try to establish a relationship between the camera and the projector through the use of an active structured light technique and a camera feedback system [17][4]. Some techniques require that the camera observes the entire projection area [17][4][19]. An increased number of mounted cameras are often needed for the expansion of the display to satisfy this requirement. In a small space such as an average room, it is difficult to setup multiple cameras without blocking some part of the multiplanar display.

Recently, researchers have attempted to reduce the number of required cameras by adopting a computer-controlled pan tilt unit (PTU) camera [5][10][20]. However, the preparation of a PTU can incur additional hardware and implementation costs. In addition, the installation of the unit has an associated challenge, as the camera must be placed at a location where it can observe the entire projection area just by rotating itself. In small spaces, there is insufficient distance between the camera and the display surface for this to work. Because of these constraints, multi-projector calibration is still considered difficult compared to a typical, single projector installation.

We propose a novel approach that utilizes a single handheld camera to achieve auto-calibration of multiple projectors in a multiplanar space. Our contribution includes a flexible codification scheme of structured light patterns based on a perfect submap and image stitching techniques that extract geometric information. The utilization of the perfect submap based spatial light pattern can estimate an entire projection area with only partially captured pattern images. Stitching these spatial pattern images reconstructs the geometric information of the multi-planar space. Due to the collaboration of the spatial light pattern and the image stitching technique, the camera does not need to be specially constrained while it cap-

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