Simple and Accurate Geometric Correction with Multiple Projectors

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ABSTRACT

In this study, we demonstrate that it is possible to provide accurate multi-projection over a whole space using a simple procedure and commercially available cameras by arranging multiple projectors freely. Increasing research interest in projection mapping is providing growing opportunities for application of this technique, resulting in a mounting need for simple and highly accurate image projection techniques for entire spaces. Effective projection is difficult to achieve using only one projector, but the use of multiple projectors requires highly complex projection techniques. In this study, we propose a novel and effective geometric correction technique that combines the use of a fish-eye lens camera and a standard lens camera.

CCS CONCEPTS

• **Human-centered computing** → **Mixed / augmented reality**; **Virtual reality**;

KEYWORDS

Geometric Compensation, Projector-Camera System, Gray Code Projection, Fish-eye Lens

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1 INTRODUCTION

Projection mapping is increasingly popular, but it requires seamless image projection over a wide area. Image projection is highly convincing for commercial purposes or stage effects. Ideally, the creation of an environment for image projection should be a simple process.

However, it is difficult to project onto the whole of a space using only one projector. CAVE[Cruz-Neira et al. 1993] is one type of immersive display, but it has the drawback of requiring the construction of a dedicated projection space. RoomAlive[Jones et al. 2014] is well-known system for image projection onto a common space. Because it uses multiple ProCam Units, though, small errors are generated by the cameras' internal and external parameters, and a large number of cameras are needed in proportion to the number of projectors. Although correction of distortion using Gray Code patterns can achieve image projection with high accuracy[Garcia-Dorado and Cooperstock 2011][Jordan and Greenspan 2010], the range of measurements is restricted to within the angle of view of each camera. If a wide-angle lens is used for measurement, the resolution per unit area falls, resulting in low measuring accuracy. Although higher resolu-tion cameras are increasingly available, measuring accuracy over wide areas remains unsatisfactory. Image projection can be carried out using multiple cameras in combination, but these systems tend to be extremely complicated. This situation prompted us to search for a simple procedure that can achieve accurate multi-projection over a wide area.

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2 OUR APPROACH

In this study, we used a space-encoding method that employs Gray Code projection incorporating a fish-eye lens. We combined a standard lens camera, to obtain accurate measurement data, with a fish-eye lens camera, which takes in a wide area at low resolution, to provide accurate multi-projection over an entire space.

Standard-lens cameras can provide highly accurate images, but their angle of view is restricted, making them unsuitable for wide spaces. On the other hand, although a fish-eye lens camera has low spatial resolution, it has a wide range of view. Also, unlike a wide-angle lens camera, directional information can be acquired. Therefore, by combining accurate images from a standard lens camera with wide-area images obtained using a fish-eye lens camera, it is possible to obtain images of the projection space with high accuracy. By combining images from both cameras, the direction information in the projection space from the fish-eye lens camera can be assigned to the standard lens camera. Image projection over the whole of the space can thus be achieved.

To combine measurement data from both cameras, close correspondence between the data is required. For this, internal and external parameters are crucial. Acquiring images with the same Gray Code pattern from each camera eliminates the need for the parameters to be derived. On the other hand, to correspond with a fish-eye lens camera, the data acquired from a standard lens camera needs to be downsampled. If the Gray Code data from a standard lens camera is downsampled according to the data from the fish-eye lens camera, the data from both cameras will correspond. If the projection space has continuous surfaces, it will be assumed that the surface is locally planar; and based on this assumption, to obtain accurate pixel correspondence from a standard lens camera, the direction information from the fish-eye lens camera in the projection space needs to be linearly interpolated. We can now compensate the direction information of the fish-eye lens camera. We can thus use the correspondence from the standard lens camera and the relative relationship among the Gray Code data from both types of camera to achieve image projection with high accuracy over an entire space.

3 CORRESPONDENCE BETWEEN FISH-EYE AND STANDARD LENS

Individual Gray Code numbers are assigned employing Gray Code projection using the ProCam System, allowing each pixel to be recognized. The Gray Code pattern is taken from the center of the projection space using the fish-eye lens camera. The standard lens camera is positioned to acquire the Gray Code pattern appropriately from each planar surface. If the Gray Code pattern is taken with both cameras, the position of the cameras can be varied arbitrarily, allowing the number of devices to be minimized. Use of a shared Gray Code projection considerably simplifies the measurement procedure.

The Gray Code data is acquired from the images taken by both cameras. When combining the data from the cameras, the main aim is to ensure correspondence between the cameras' coordinate axes. The standard lens camera can accurately resolve Gray Code images, so full pixel correspondence can be obtained (Fig.1:left). However, this is not the case with the fish-eye lens camera because of its low resolution, so instead, the correspondence is made between regions of multiple pixels(Fig.1:right). This allows the center of gravity of each region to be derived. We assume that the projection space is locally planar. Correspondence between the coordinate axes of both cameras is needed to be able to derive the coordinate axis consisting of the center of gravity in a contiguous region. Using this process, the more accurately acquired correspondence between the standard lens camera and the projector is applied to the whole of the projection space obtained from the fish-eye lens camera.

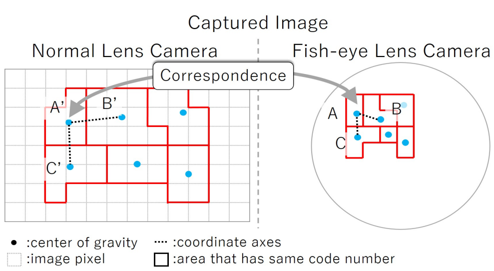

Figure 1: Gray Code from each lens camera

A point P' on the coordinate system of the standard lens camera can be represented as the center of gravity A', B', C' (Fig.2:left). This relationship is fed through to the coordinate system of the fish-eye lens camera with a corresponding known center of gravity A, B, C, and the corresponding point P is calculated (Fig.2:right). From these correspondences, it is possible to acquire pixels from the fish-eye lens camera that are mapped onto the coordinate system of the standard lens camera.

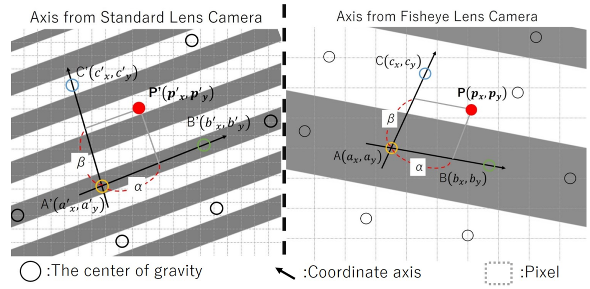

Figure 2: Correspondence between coordinate axes

4 RESULTS

We implemented our proposal, and projected our images on a wide space. We used one fish-eye lens camera and one standard lens camera, and a maximum of six projectors (1280 x 800).

Figure 3: Results of image projection over a wide space

Figure3 shows that images projected from individual projectors can be successfully corrected. The upper part of Fig.3 shows images projected onto the ceiling, and the lower part shows images projected onto both ceiling and wall. This technique can therefore achieve image projection onto different surfaces or project more than one image onto various surfaces. The number of projectors can also be further increased.

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