Cuboid based Geometric Calibration: A Preliminary Study

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Abstract: We present a noble geometric method to calibrate a camera using a single cuboid composed of six rectangles. We attach LEDs on each vertex of a cuboid, which helps to detect quadrangle vertices even in dark environments. Then we reconstruct a set of quadrangular faces as perspective projection of rectangles. Finally, we apply CLC (Coupled Line Cameras) based rectangular calibration method to each detected quadrangle. We show that multiple perspective quadrangles are more precise and efficient than a single rectangle based camera calibration.

Keywords: Camera calibration, geometric method, CLC (Coupled Line Cameras)

1. INTRODUCTION

Camera calibration and geometric reconstruction are key components in many applications such as mixed reality (AR/VR) and robotic manipulations. Usually, this process requires special rigs and/or complex numeric computations.

We propose a noble geometric method to calibrate a camera and to reconstruct a rectangle geometry at once using a single cuboidal rig composed of six rectangles. Especially, we attached LEDs on each vertex of a cuboid, which helps to detect quadrangle vertices even in dark environments. Then we reconstruct a set of quadrangular faces as perspective projection of rectangles. Finally, we apply CLC (Coupled Line Cameras) based rectangular calibration method [1] to each detected quadrangle. We introduce our initial ideas and preliminary results on experiments. We show that multiple rectangles help to reduce the noise and to enhance the precision accordingly.

2. EXPERIMENT

We first experimented with a single rectangle with various aspect ratios. We attached LEDs to each vertex of the black rectangular papers with various aspect ratios. Then, we detected the positions of LED vertices from the sequence of input images taken from varying camera positions and orientations. For each set of detected vertices q_j , we defined a quadrilateral Q_i . Figure 1 shows several input images and corresponding reconstruction results.

We applied CLC to each quad Q_i to reconstruct the original rectangle G_i and its aspect ratio a_i . Figures 2 shows the results for four types rectangles taken in 150 frames while the camera was moving freely. The experiment shows that, even with the physical fabrication error, CLC well reconstructs the original aspect ratio in the most of frames. Note that special errors occur when the camera is perpendicular to the rectangle plane, which is the typical limitation of CLC.

In the second experiment, we designed a cuboid rig with squares faces. The cuboid is fabricated with a black acrylic panel. We attached red LEDs on each vertex with Raspberry Pi controllers. See Figure 3.

For calibration and reconstruction tests, we moved the camera around a cuboid with LEDs on while recording the image sequences.







Fig. 2 Aspect ratios of reconstructed rectangles in the sequence of 150 frames. Aspect ratios are of 1, 2, $\sqrt{2}$ and 1.3 from the top left and clockwise.



Fig. 3 Image of our cuboid rig with black acrylic faces. Red LEDs are attached to each vertex and controlled by Raspberry Pi.

For processing the input video, we first developed an automatic vertex detection and quad formation method to apply rectangle based calibration and reconstruction method of CLC [2]. Figure 4 shows the sample images of LED cuboid with different numbers of visible faces. Input images were taken in the dark environment to enhance the visibility of LEDs. Exception handlings are included for noisy and ambiguous inputs. Figure 5 shows the result of applying out method to the sequence of continuous frames.



Fig. 4 Three configuration types of cuboidal faces and their automatic reconstruction: (a) one quad, (b) two quads, and (c) three quads. Input images and detect quads are in left and right column, respectively.

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Fig. 5 Detected vertices and faces of multiple rectangles from a sequence of input images.



Fig. 6 Effects of multiple rectangles. A sequence of 100 frames contains images of LED cube with 2 or 3 faces. The orange represents the mean aspect ratios at each frame.

We tested the effect of multiple rectangles in calibration and reconstruction. Note that CLC gives the camera parameters and the aspect ratio of an unknown rectangle at once for a single image of a rectangle. From the experiment, we could observe that the precision of aspect ratio (which also implies the camera parameters) increase with multiple rectangles. See Figure 6.

3. DISCUSSION

The preliminary results encourage us further study on this topic. Based on more precise fabrication of LED cuboid, we need to enhance the experimental confidence. Then, we can apply the method to actual AR (augmented reality) applications. Specially, we are interested in projector-based AR environment.

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