Simultaneous Geometric and Radiometric Calibration of a Projector-Camera Pair
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Introduction

We present a novel method that allows for simultaneous geometric and radiometric calibration of a projector-camera pair. It is simple and does not require specialized hardware. Our method performs on par with current approaches that all require separate geometric and radiometric calibration, while being more efficient and user friendly. It is especially well suited in structured light systems for 3D object scanning that utilize continuous scene encoding methods (e.g., phase-shifting).

Design of calibration patterns

The projected pattern is specifically designed to allow for simultaneous geometric and radiometric calibration of the projector. The red pixel intensities (in %) of the squares vary across the chart. Example intensities are shown in the top-right corner. The printed pattern is composed of a conventional yellow-white checkerboard of identical dimensions to that projected. With this choice of colors, we are able to isolate the two patterns in different color channels in the captured images.

Results

We capture 2 images per calibration board orientation and perform geometric and radiometric calibration at the same time, whereas other methods [3,4,5,6] perform only geometric calibration. This results in ample time savings.

Algorithm flowchart

STEP 1: Non-aligned patterns

Image of non-aligned superposed patterns

Blue image channel: printed pattern

The printed and projected patterns are isolated in the blue and the red camera channels, respectively.

Red image channel: projected pattern

Strong signals of the printed and projected patterns allow for a reliable automatic corner detection [1].

Automatic corner extraction

We undo the prewarp by fitting the image of the projected pattern onto the captured pattern. Given the projected and captured values of each square, we estimate the response function of the projector by fitting a power function:

\[ \text{RMSE} = \sqrt{\sum_{i} \left( \frac{g_i^e - g_i^m}{g_i^e} \right)^2} \]

where \( g_i^e \) and \( g_i^m \) are the intensity values of the printed and projected patterns, respectively.

Average intensity extraction

STEP 2: Aligned patterns

Image of aligned superposed patterns

Blue image channel: printed pattern

The projected pattern is prepwarped such that it is aligned with the printed pattern when projected. We apply a composite homography by relating the printed pattern to the camera, and the camera to the projector:

\[ H_{p} \cdot H_{c} \cdot H_{p} \cdot H_{c} \cdot H_{p} = H_{c} \]

The projected pattern is also shifted by half a printed square to allow for radiometric calibration.

Automatic corner extraction

We perform a planarity test to validate the performance of the radiometric calibration in a real-world scenario. The test consists of fitting a plane into a print cloud and estimating its fit. We therefore reconstruct a flat board by using a phase-shifting SL code. We perform these reconstructions of the flat board, of size 10 x 10 cm, by projecting (a) linear patterns, gamma compensated patterns with (b) gamma computed using a ground truth method, and (c) gamma computed using our proposed method. Our method is vastly superior to (a), thus confirming the need for radiometric calibration. It is also faster and more convenient than (b), demonstrating the effectiveness of simultaneous geometric and radiometric calibration.

References