Pixelwise Illuminance Registration for Displays at Oblique Perspectives

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Abstract

A motorized railing system with camera rotation is proposed for automatic optical inspection for large-sized displays. Our algorithm for pixel registration in this scenario was successfully demonstrated to register pixelwise illuminance of a commercial display at different camera panning angles.

1. Introduction

Light-emitting diode (LED) splicing displays have seen a wide application in large-scale advertisement displays, or in exhibition venues due to its high efficiency and high dynamic range. However, due to manufacturing limits and environmental problems, these LED displays could produce uneven brightness between individual pixels, or between each spliced LED module. Detecting these pixel defects on displays in regular consumer electronics can be done with a single camera, but with large-scale displays, it is impossible to capture the entire panel due to the limited field-of-view and resolution of the camera system. Therefore, we propose a motorized camera railing system with additional rotation motors to capture multiple screenshots for later analysis, but this method introduces distortion to the captured images.

In this paper, we will introduce a workflow to capture images of a display using a single camera, undistort the image caused by rotation, then detect each pixel of the display in the images, and produce a pixel illuminance map for later analysis. The preliminary result shows that the proposed method has the capability to accomplish pixelwise illuminance registration under oblique viewing angles.

2. Method

2.1 Imagery Optics

The complete pixel registration workflow is shown in Fig. 1. To achieve more accurate results in pixel illuminance registration, we first must eliminate the Moiré effect. The ratio of sampling rate must be at least 2×2 sensor pixels per display panel pixel to ensure no unwanted fringes appear in the captured image. In our imaging system, we ensured that the ratio of sampling rate was at least 3×3 sensor pixels per display pixel.

2.2 Image Geometric Transformation

Capturing a photo of the display at an angle will cause the image to distort, and is not ideal for automated pixel registration down the line. To combat that, we warped the image back via geometric transformation by displaying a reference image in addition to our regular RGBW test images for the camera to capture. In this work, a checkerboard image was chosen to be the reference image for calculating the projection transformation matrix. This matrix was estimated by detecting the location of the checkerboard corner points in the oblique image [1] and their corresponding locations in the reference checkerboard image [2].

2.3 Pixel Registration

We achieved pixel-wise registration by locating the coordinates of every display panel pixel in the transformed test photos from the previous section. In order to eliminate the background, the transformed image is binarized based on Otsu's method [3]. The binarized image then undergoes a series of morphology processes to remove any additional artifacts. Lastly, we can find the centroid of every display pixel in the binarized image.

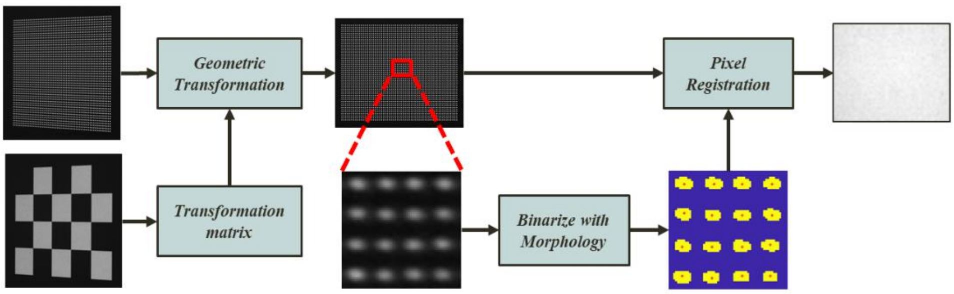

Fig. 1. Proposed pixel registration method

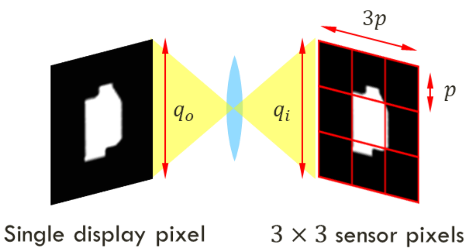

Fig. 2. Sampling rate to avoid Moiré patterns

3. Experiment

To validate the proposed algorithm, a display panel was imaged by a camera under four different camera panning angles ($\theta_y = 0°, 15°, 30°, 45°$) as shown in the first column of Fig. 3. The second column represents the corresponding pixel registration result output by the proposed algorithm. We captured multiple photos in a dataset and compared the average SSIM between the registered photo captured at 0 degrees, and photos captured at other camera angles. The result in Fig. 4. shows that the proposed method is able to successfully register display pixel illuminance data at different camera panning angles.

4. Conclusion and future work

In this work, we proposed a workflow to accurately detect individual panel pixels and register their illuminance data, without the camera being confined to a perpendicular perspective. Combined with Mura detection and compensation algorithms down the line, we believe that our workflow could help both the display industry during the manufacturing process, and the entertainment industry during the display calibration process.

5. Acknowledgment

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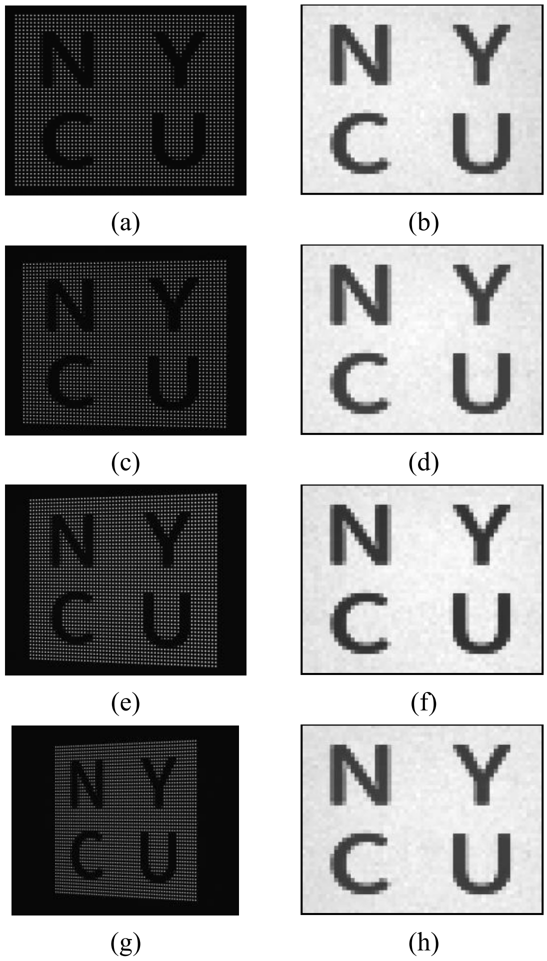

Fig. 3. The testing display panel captured at different pan angles (a) 0 degrees (c) 30 degrees (e) 45 degrees, and the corresponding pixel registration results on (b) 0 degrees (d) 30 degrees (f) 45 degrees.

θ_y	15°	30°	45°
μ_{SSIM}	0.9523	0.9468	0.9518

Fig. 4. The average SSIM comparing photos captured and registered from 15 to 45 degrees camera panning angle, and photos registered from 0 degrees.

Reference

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