DUAL-FISHEYE LENS STITCHING FOR 360-DEGREE IMAGING

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Conclusion

This paper introduces a new method for stitching images taken from 360-degree cameras with dual-fisheye lens. It uses a novel two-step alignment algorithm that compensates for the mechanical misalignment between the two fisheye lenses and adaptively maximizes the similarities in the boundary regions of the images for adjusting any misalignment caused by the changing of object depth in the stitching areas. In summary, the proposed approach compensates for fisheye lens' intensity fall-off, unwarps the fisheye images, then registers them together using the proposed adaptive alignment, and applies blending on the registered images to create a 360x180-degree panorama that is viewable on 360-degree players. Results show that not only this method can stitch the Samsung Gear 360 images that have limited overlap, but it can also produce well-stitched pictures even if there are objects that are at an arbitrary distance to the camera and stand in the lenses boundaries.

Introduction

The Problem

The images generated by the dual-fisheye lens have limited overlap leading to unsatisfactory results when being stitched by the conventional feature-based stitching methods [1][2], as shown in **Fig. 2**.

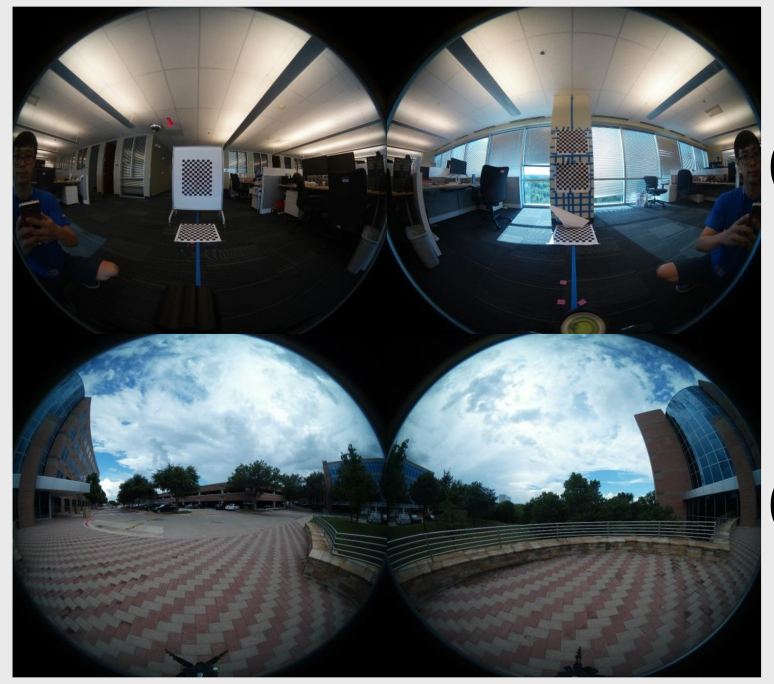

Fig. 1. Images taken by the Samsung Gear 360. Each fisheye image covers a field of view (FOV) of 195 degree and has a limited overlap with each other. (a) A person sitting close to the camera stitching boundary. (b) A scene with fence, building and patterned background.

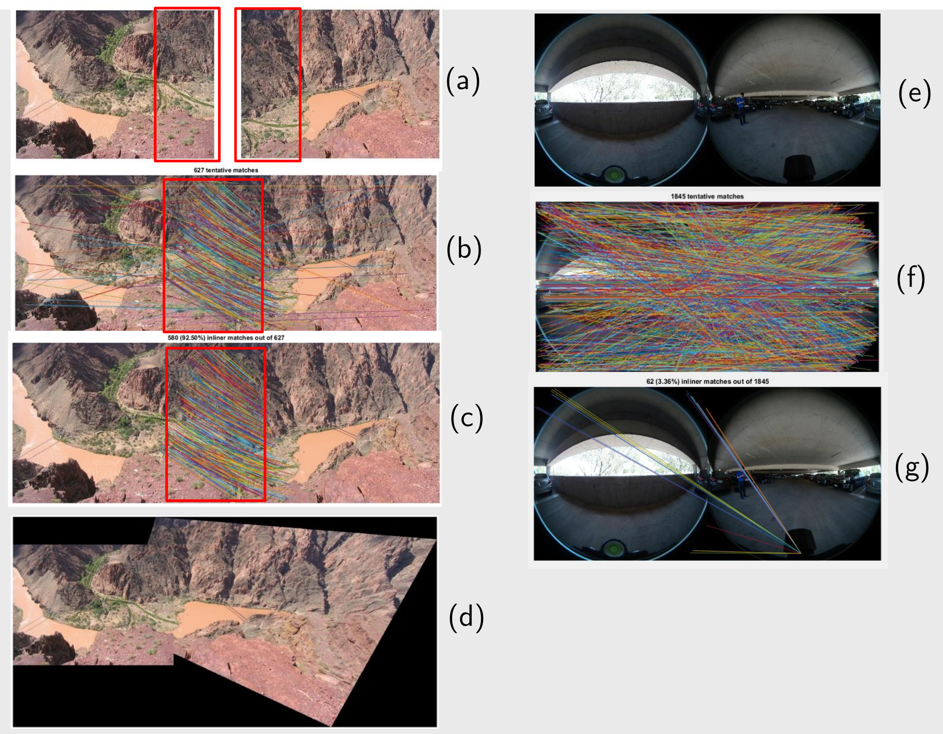

Fig. 2. Image stitching illustration. Left column: (a) Regular pictures with good overlaps. (b)(c) Features Matching using SIFT and outlier removal using RANSAC. (d) Image warping and panorama creation. Right column: (e) Fisheye images taken by Samsung Gear 360. (f)(g) Features Matching (using SIFT) and outlier removal (using RANSAC). Courtesy: VLFeat [3] toolbox.

Our Approach

The proposed algorithm has four main steps, as shown in **Fig. 3**.

- Light fall-off compensation: measure and compensate for the intensity fall off of the camera's fisheye lenses.
- Fisheye Unwarping: transform the fisheye images to an equirectangular projection format that is viewable on 360-degree viewers.
- Two-step Alignment: our proposed adaptive alignment to register the fisheye unwarped images.
- Blending: blend the aligned images using a linear function.

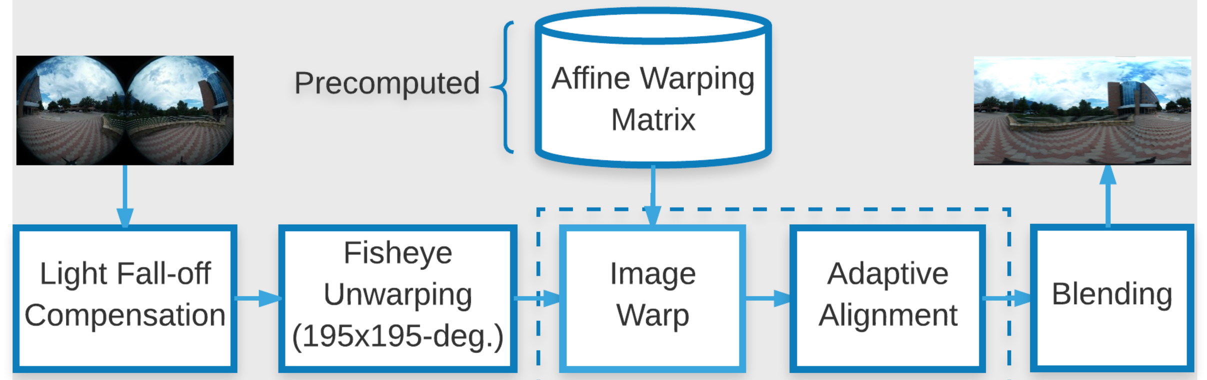

Fig.3. The proposed processing flow.

Light Fall-off Compensation

Use a polynomial curve to estimate the intensity fall-off from the center of the fisheye image.

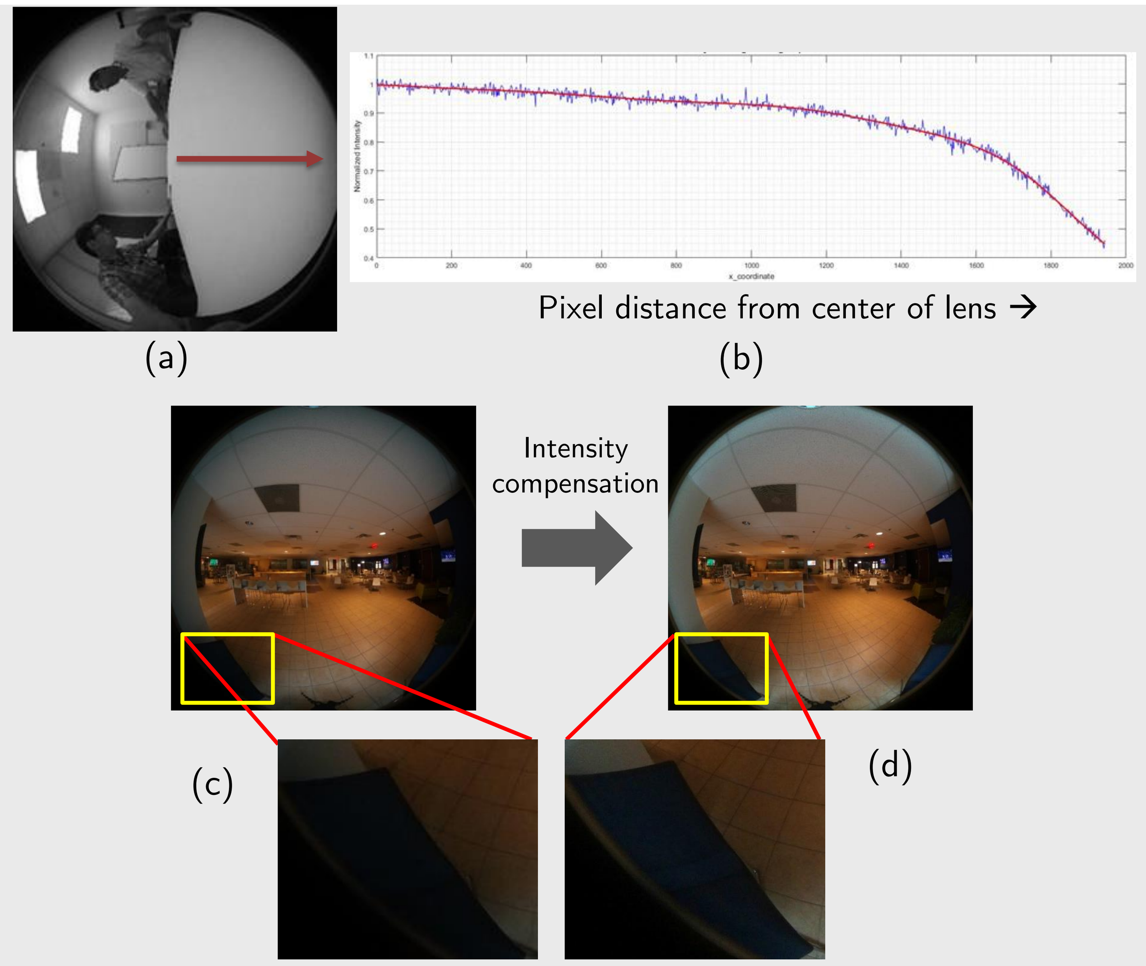

Fig. 4. (a) Image taken by Gear 360 that used to measure the light fall-off curve. (b) The light fall-off curve reconstructed by a polynomial function. (c) The original fisheye image (light fall-off when moving away from center of the image). (d) The fisheye image after the compensation (This light fall-off is compensated for by multiplying the pixel values in the image by the inverse of the light fall-off curve).

Fisheye Unwarping

Convert the fisheye coordinates to 3-D spherical ones and derive the distance from the center of the sphere assuming equidistance relation of the fisheye lenses. The output equirectangular-projected image is viewable on 360-degree viewers such as PTGui 360 Viewer.

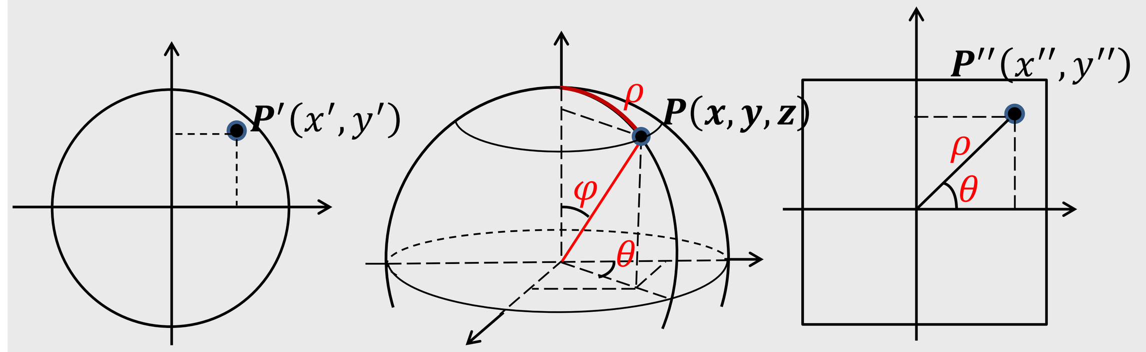

Fig. 5. The Unwarping Illustration.

The Proposed Image Alignment

As shown in **Fig. 7** after unwarping the images are not aligned with each other. Therefore, we proposed a novel **two-step** image alignment for dual-fisheye lens-generated pictures.

Fig. 6. The 360x180-degree panorama after unwarping.

Step 1: Lenses Mechanical Alignment

Compensate for the mechanical misalignment between the two fisheye lenses. Use checkerboards for control points selection. Solve an overdetermined system in a linear least-squares sense for a 3x3 warping matrix to align the images. This step is computed offline.

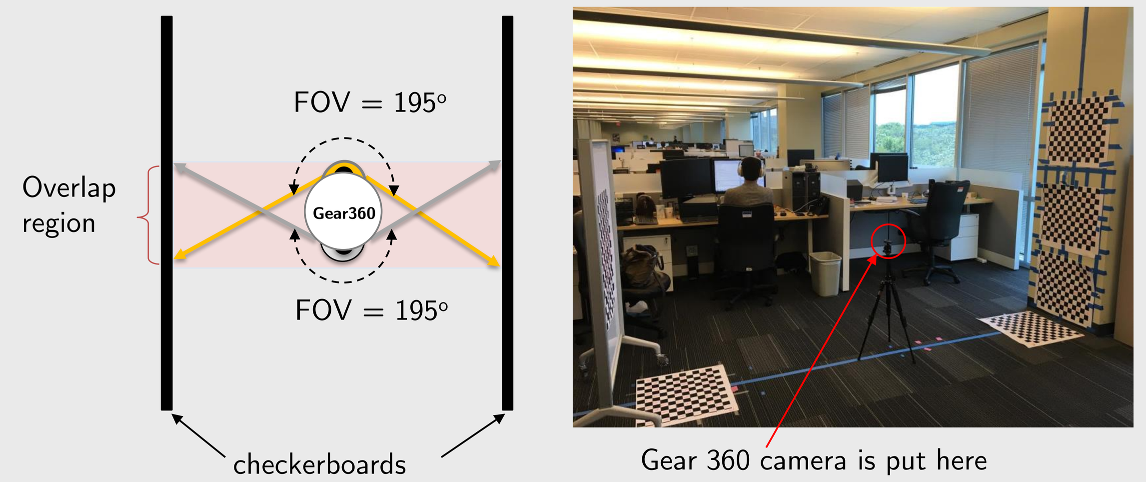

Fig. 7. Experiment Setup for Gear 360 Dual-lens Misalignment.

Step 2: Adaptive Alignment

The Problem

- The depth of the object in the overlapping areas changes → misalignment to the scene.
- Need a second alignment that works adaptively to the scene, on top of the first alignment.

Our Approach

- Propose a novel adaptive alignment that involves a fast template matching using normalized cross-correlation [4] for objects in the overlapping region.
- Estimate an affine matrix at position where the maximum value of the cross-correlation occurs (best match) using 8 pairs of vertices as shown in **Fig. 8**.
- Warp the bottom image by the estimated affine matrix to align it further with the top one. **Fig. 9.** shows that this adaptive alignment helps align the object sitting close to the camera boundary.

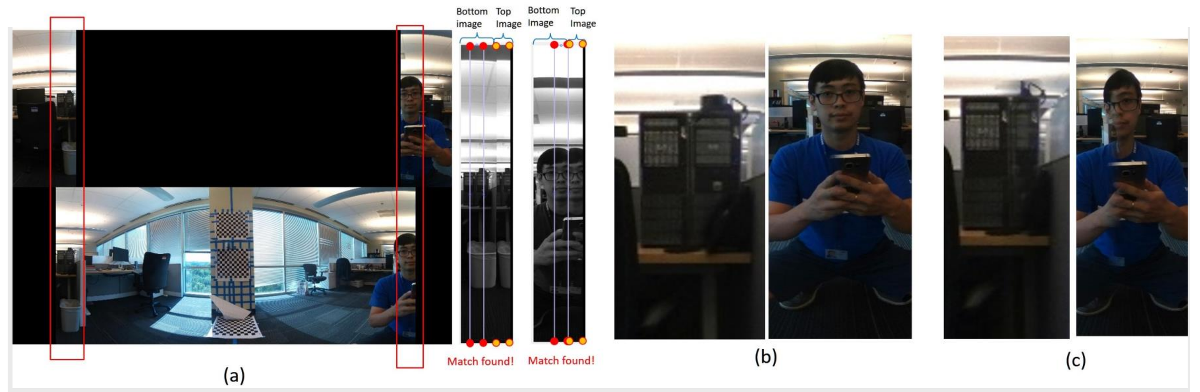

Fig. 8. (a) A person close to the camera and between the lens boundary. (b) The blended overlaps with the proposed adaptive alignment (discontinuity minimized). (c) The blended overlaps without the proposed adaptive alignment (very visible discontinuity).

Fig. 9. The 360x180-degree panoramas stitched by the proposed method. Original images are shown in Fig. 1.

Future Work

We would like to study more on an efficient auto color balance for the fisheye-generated images, and a weighted least-squares-based approach for the first image alignment to achieve more accurate stitching.

References

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