3D Stereo Reconstruction Using Multiple Spherical Views

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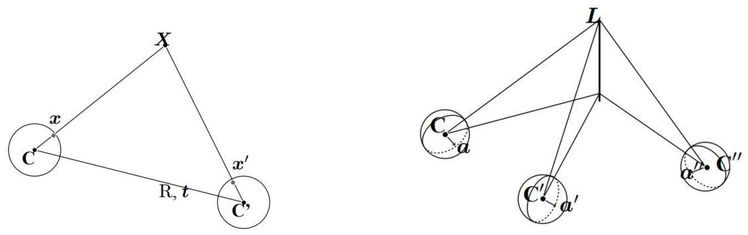
Motivation

360° stereoscopic image capture makes it easier to capture full scenes in a limited number of images. Because of this quality, it is useful to utilize the these spherical images in computer vision and virtual reality applications such as depth estimation and 3D scene reconstruction. Using a single pair of spherical images allows us to perform depth estimation from one perspective, but utilizing multiple viewpoints during scene reconstruction can allow for more robustness when creating translated views. We aim to use disparity maps generated from multiple viewpoints to improve 3D reconstruction of spherical scenes.



The above figures show two-viewpoint (epipolar) vs. Three-viewpoint geometry for spherical cameras. 3 camera sources can allow for more accurate triangulation during 3D scene reconstruction.

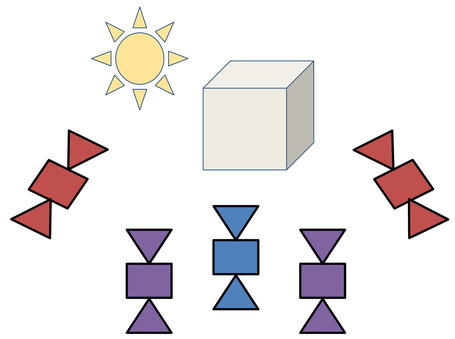
Related Work

Previous work has been done with 2-viewpoint spherical geometry for 3D reconstruction using omnidirectional cameras[1], similar to the Ricoh Theta cameras we utilize in our project. Three view geometry for spherical cameras has since been explored and derived by Torii et al[3]. In relation to 3D reconstruction from spherical data, Schonbein et. al.[1] utilize spherical cameras for omnidirectional reconstruction of worlds. Additionally, while utilizing undistorted pinhole modeled cameras, Seitz et. al.[2] advocate for the use of multiple (up to hundreds) of viewpoints for dense 3D reconstruction.

[1] Schonbein, Miriam, and Andreas Geiger. "Omnidirectional 3d reconstruction in augmented manhattan worlds." *Intelligent Robots and Systems (IROS 2014), 2014 IEEE/RSJ International Conference on*. IEEE, 2014.
[2] Seitz, Steven M., et al. "A comparison and evaluation of multi-view stereo reconstruction algorithms." *Computer vision and pattern recognition, 2006 IEEE Computer Society Conference on*. Vol. 1. IEEE, 2006.
[3] Torii, Akihiko, Atsushi Imiya, and Naoya Ohnishi. "Two-and three-view geometry for spherical cameras." *Proceedings of the sixth workshop on omnidirectional vision, camera networks and non-classical cameras. Citeseer (cf. p. 81)*. 2005.

Methodology

Capture System



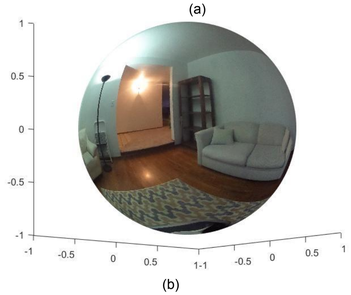
Our 5-camera capture system. Each camera location contains two vertically stacked spherical cameras, which capture 360° spherical views, centered at the camera location. From this setup we can utilize 2 to 5 cameras for disparity map rectification.

Reconstruction Algoithm

1. Initial Disparity Map Calculation
   For each camera location, we calculate a disparity map using a windowed similarity accumulator. Median and closing filters are used to fill in small holes, and background regions are detected and smoothed using bilateral filters.
2. Viewport Extraction
   A 110° by 120° viewport is extracted, representative of a typical head mounted display viewport.
3. Multi-Disparity Map Rectification
   Using SIFT matches, we can filter and average disparity readings of matched keypoints in the image while suppressing incorrect background noise.
4. Depth Map Calculation
   Using the fact that we are viewing a spherical camera, we can calculate its real-world depth at each pixel using its corresponding spherical angle.
5. 3D Reconstruction
   We explored two possible methods for 3D reconstruction. The reference image can then be warped onto the resulting depth map (shown below), or depth readings at matched locations can be represented as a point cloud.

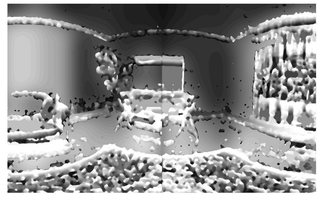
Experimental Results

(a)

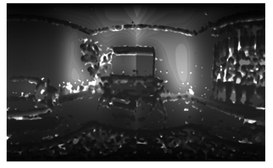


(b)

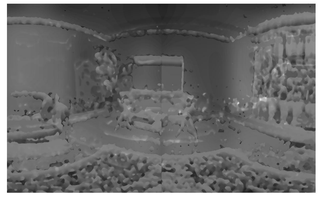
(c)



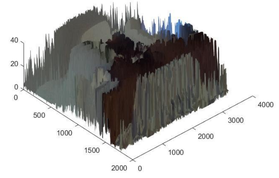
(d)



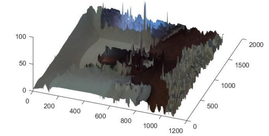
(e)



(f)



(g)



(h)

(a) Initial stereo image for center camera. (b) Stereo image wrapped around sphere (c) Initial disparity map generation for single camera. (d) Extracted viewport. (e) Reduction of false disparities after matching with other cameras (e) Calculated depth map (f) Reconstruction with single disparity map (g) Reconstruction using two disparity maps.