A Low Cost Multi-Camera Array for Panoramic Light Field Video Capture

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Overview

The recent rise of consumer 6 degree-of-freedom (6-DOF) VR head-sets and cell-phone based AR has increased the need for rich 3D content. However, most current 6-DOF content uses synthetic 3D models and textures that are far from photorealistic, especially on low powered mobile devices. In contrast, light field video can capture real-life photorealism while maintaining full freedom of movement. However, existing light field video cameras are expensive and unwieldy [Milliron et al.2017; Wilburn et al.2001], while portable solutions have been applied only to static scene capture as in [Over-beck et al.2018] or have a small viewing baseline [Smith et al.2009; Wang et al. 2017].

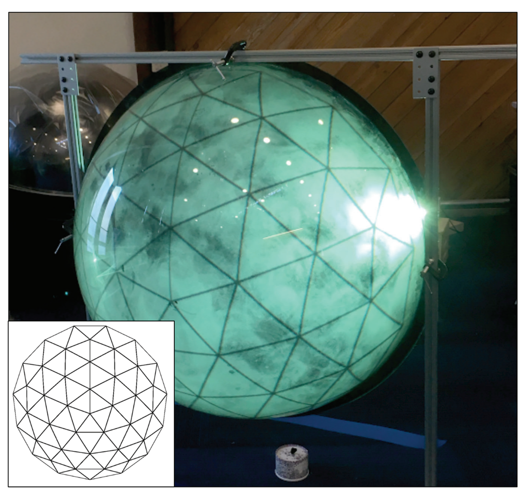
Here we present a low-cost, portable multi-camera system for capturing panoramic light field video content. Our system can capture light fields at high resolution (>15 pixels per degree) with a wide field of view (>220°), a large viewing baseline (0.8 meters), at 30 frames per second. Combined with modern view interpolation algorithms [Flynn et al. 2019; Mildenhall et al. 2019; Penner and Zhang 2017; Zhou et al. 2018], our system can render objects placed as close as 33-cm to the surface of the array. The dome, mounts, triggering hardware and cameras are inexpensive (roughly $5k for parts) and easy to fabricate.

Design & Fabrication

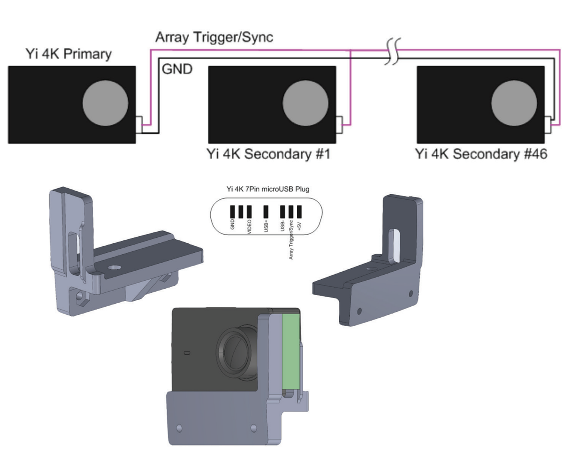
The array consists of 47 Yi 4K action cameras. A single "master" camera controls the others via a 2-wire trigger/synchronization cable. A 7-pin USB connection on each camera charges the array and transfers USB 2.0 data. Each camera uses its own built-in battery, which offers roughly one hour of recording time.

Synchronization: The Yi 4K software supports an "array mode" that enables master camera control of the following features: (1) sync master camera settings to the entire array, (2) start/stop recording, and (3) powering down the array. Once it receives the "start recording" signal, each camera relies on internal timing for image capture. Our array synchronization tests indicate that the cameras begin recording within 4ms of each other and the intra-array temporal drift is less than 1/2 of a video frame time @ 15 minutes.

Layout: We placed cameras at the vertices of a v3 icosohedral tiling of a 92-cm diameter sphere. The sphere itself is fabricated from a 6-mm thick sheet of acrylic shaped into a hemisphere using a draped plastic thermo-forming process (theplasticsguy.com). To position the cameras on the hemisphere we projected a perspective image of the camera layout into the dome. Cameras were mounted into custom 3D printed brackets fitting the inner curve of the dome structure.



(a)



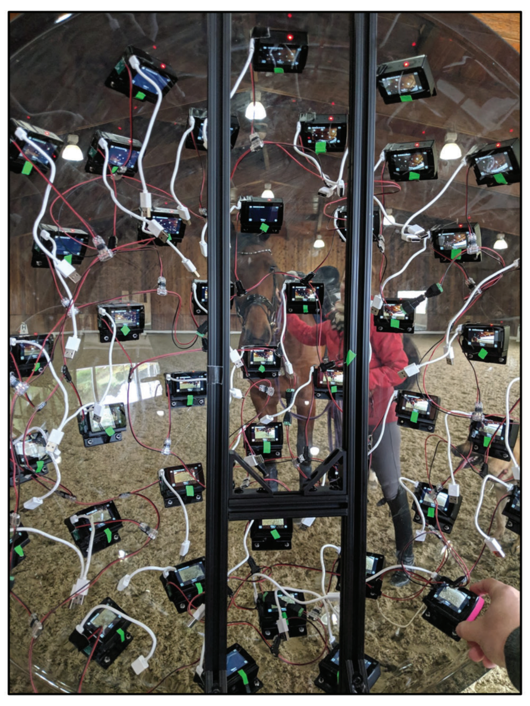
(b)

Figure 2: Cameras in our light field video camera array are **(a)** placed at vertices of a geodesic tiling of a sphere and **(b)** mounted using custom 3D printed brackets.

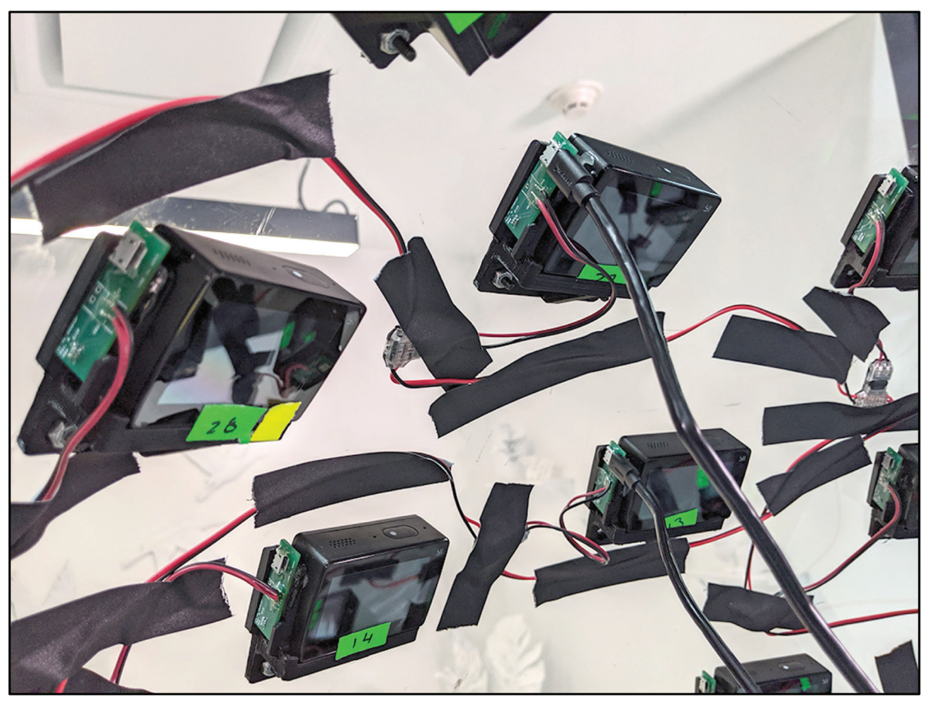
(a)

(b)

(c)



(d)



(e)

Figure 1: Our light field video camera system photographically captures moving subjects and their 3D environment. The recorded light field data enables exploration of three-dimensional movies with 6 degrees of freedom. **(a)** Our rig is built using a low-cost (~$150), semi-transparent acrylic dome. **(b)** The rig is light-weight. It can be easily carried by one person or packed into the trunk of a sedan. **(c, d)** The plastic dome acts as a natural viewfinder, making it easy to frame the subjects and compose a shot by looking through the surface of the camera rig. **(e)** During a shoot, individual cameras run off their internal batteries. This provides roughly an hour of capture time. After a shoot data can be downloaded and the cameras can be charged via USB connections.

The Geometry of Spherical Light Field Capture

Our array was designed to capture fully immersive 6-dof spherical light field content. Figure 3 illustrates (in a simplified 2D view) how camera spacing and rig diameter impacts the size of the viewing baseline and the distance to the closest object that can be recorded by the spherical array.

Ray Intersection Volume Radius: We see that the diameter of the array and the nominal 120°×90° field of view of each Yi 4k camera influences the size of the ray intersection volume (red circle); i.e. the area of overlap in the angular sampling recorded by each camera in the array. This is the "sweet spot" where wide FOV views can be synthesized without missing rays or viewpoint interpolation artifacts.

Closest Object Distance: Light field reconstruction is only possible for objects that are visible from at least two cameras (green dotted circle). This suggests a trade-off between the "closest object distance" and the inter-camera spacing distance for a given array radius. In our array an inter-camera spacing that ranges from 16-cm to 19-cm results in an approximate closest object distance of 79-cm.

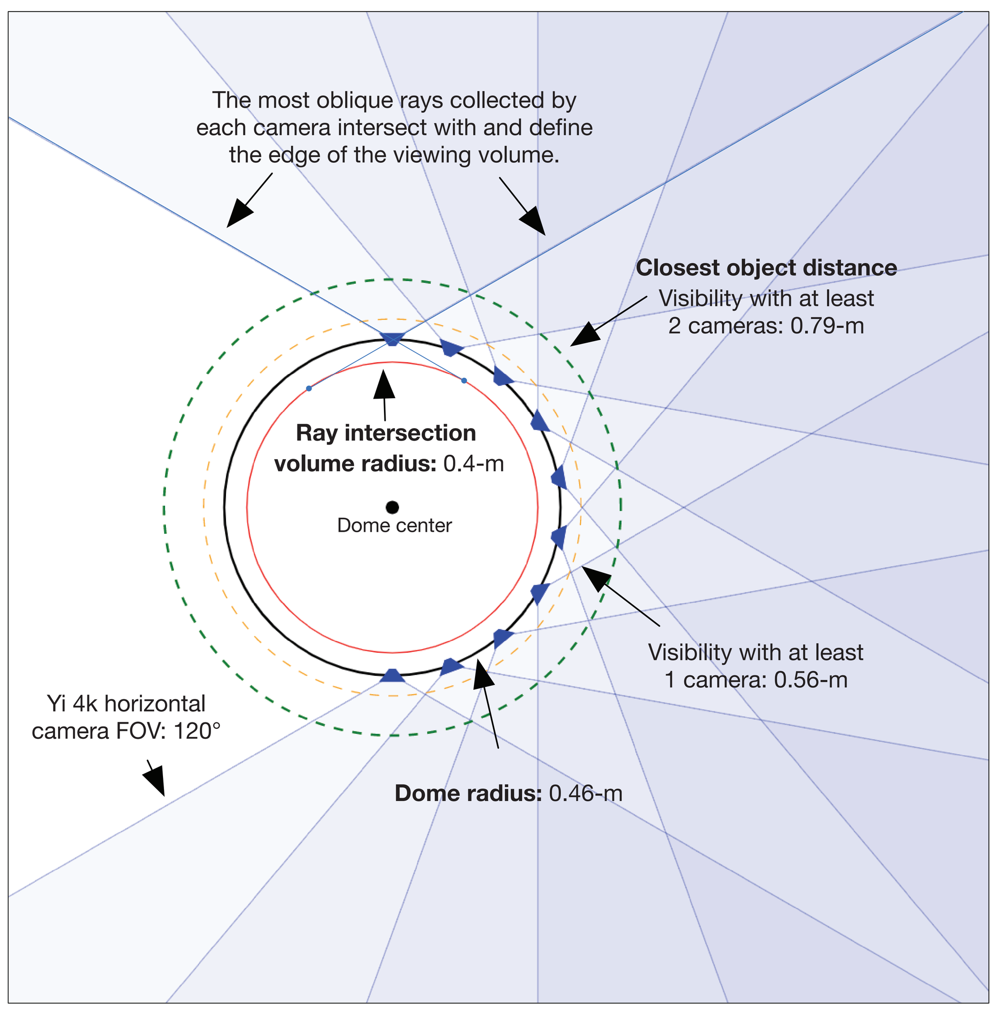


Figure 3: A simplified two dimensional version of our camera array (viewed from the top down).The radius of the array and the inter-camera spacing determine the viewing baseline and closest object that can be captured as a light field by the array.

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