A Wide-Field-of-View Monocentric Light Field Camera

Donald G. Dansereau[1], Glenn Schuster[2], Joseph Ford[2], and Gordon Wetzstein[1]

[1]Stanford University, dgdanser@stanford.edu, [2]University of California San Diego

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Light Field Toolbox

Abstract

We describe the first single-lens wide-field-of-view (FOV) light field (LF) camera. Wide-FOV LF imaging has widespread applicability in augmented reality, autonomous driving, drone navigation and robotic perception in general. We use a monocentric lens to overcome the limitations of conventional lenses, and demonstrate indoor and outdoor capture of LF panoramas spanning 138° over 72 MPix. We introduce a relative spherical parameterization and virtual field flattening approach that make wide-FOV LF capture practical.

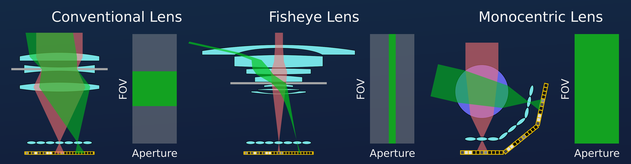
Motivation

Low-power low-latency 3D perception: Robotics, AR, VR

- Wide-FOV and LF imaging simplify real-time perception
- Native capture of colour, depth, speculars, transparency, occlusions [5], ...
- Simplified object and hand segmentation and tracking, odometry, localization, material recognition, change detection [3,4,7,8], ...

Monocentric Lenses

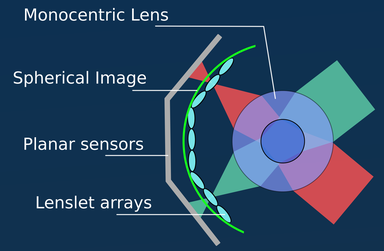
Conventional optics cannot accommodate wide-FOV LF capture, so we employ a monocentric lens built from concentric glass spheres.



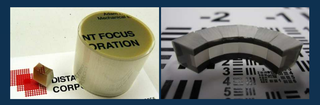
(left) Conventional Cooke triplets have a narrow FOV;
(center) Fisheye lenses have a wide FOV but limited aperture / LF baseline;
(right) Monocentric lenses have a wide FOV and aperture, enabling LF capture.

Optical Design

A monocentric lens produces a spherical image, which we capture using tiled sensors and lenslet arrays [6].



No Fiber Coupling

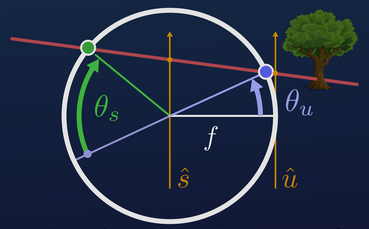


Conventionally fiber bundles are used to mate spherical images with planar sensors. We replace these with 4D LF processing.

Prototype

(left) The optical prototype: a novel relay system and a rotating arm emulate tiled sensors; (top) The main lens and lenslet array; (bottom) The monocentric lens compared with a Lytro Illum and a conventional fisheye lens; (right) Outdoor capture.

Representation & Processing



$\theta_u \approx \hat{u}$
$\theta_s \approx 2\hat{s}$

Camera-centered
f = main lens focal depth

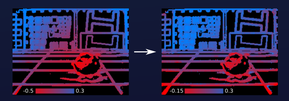
Relative Spherical Parameterization

- Supports a wide FOV, unlike planar LFs
- Locally similar to planar LF with radial depth
- Many LF algorithms work unmodified

Decoding and Processing

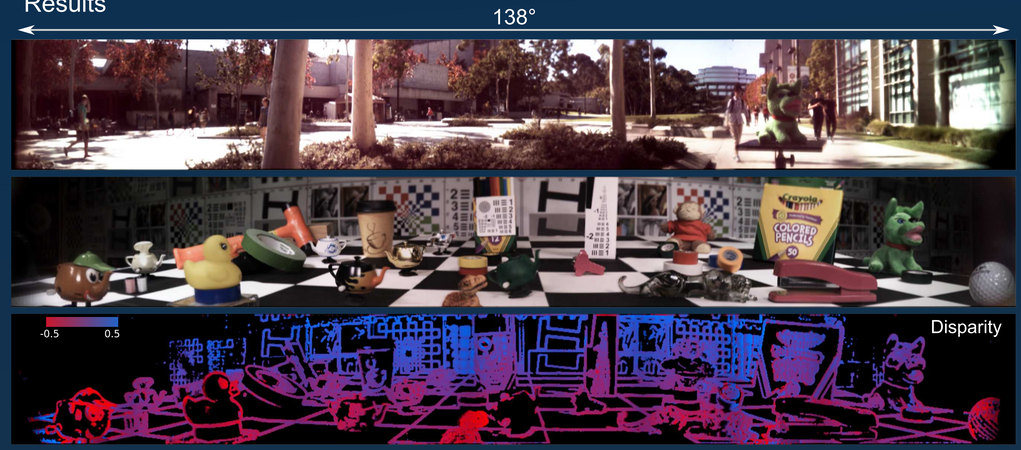
- Minor modifications to LF Toolbox [2]

Virtual Fiber Bundles

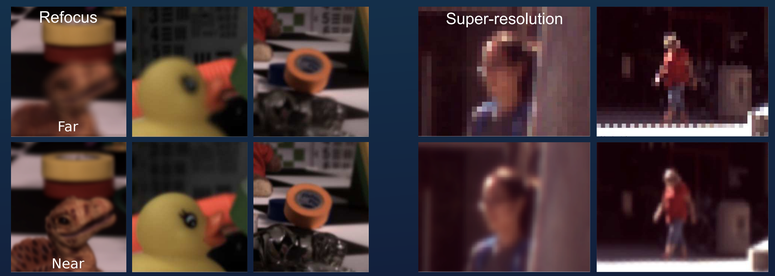


Corrects LF curvature at sensor

Results



138° 72 MPix (15 × 15 × 1600 × 200) LF panoramas captured through a single lens. Shown are 2D slices of the 4D structure. Disparity (above), and refocus and super-resolution (below) use standard LF algorithms [1,5].



Conclusions

We demonstrated an optical prototype capturing 138°, 72-MPix LF panoramas. We coupled a monocentric lens and planar sensors using lenslet arrays and LF processing, and introduced a parameterization and toolchain for efficiently representing and processing wide-FOV LFs.

This work presents the first steps towards practical, compact, wide-FOV LF capture.

References

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