EE 367 Project: Seeing through obstruction

Wanling Liu, Ye Li, Kefan Wang

{liuwl, liye5, kefanw}@stanford.edu

Stanford
Electrical Engineering

Motivation

When capturing images through a fence, the scene can be occluded by the foreground obstructions. With a light field camera, such grid-patterned fence can be removed with various perspectives that a single shot provides. We seek out solutions using Lytro images to remove unwanted obstructions and preserve the background information as perfect as possible.

Previous Work

Removing obstructions has been actively investigated in different aspects with various algorithms. Researchers have proposed various computational approaches to remove reflecting or occluding elements and recover background scene using image sequences [2], aperture [3], or image self-similarity [4], but investigations of using information provided by light field cameras are much fewer.

Datasets and Data Processing

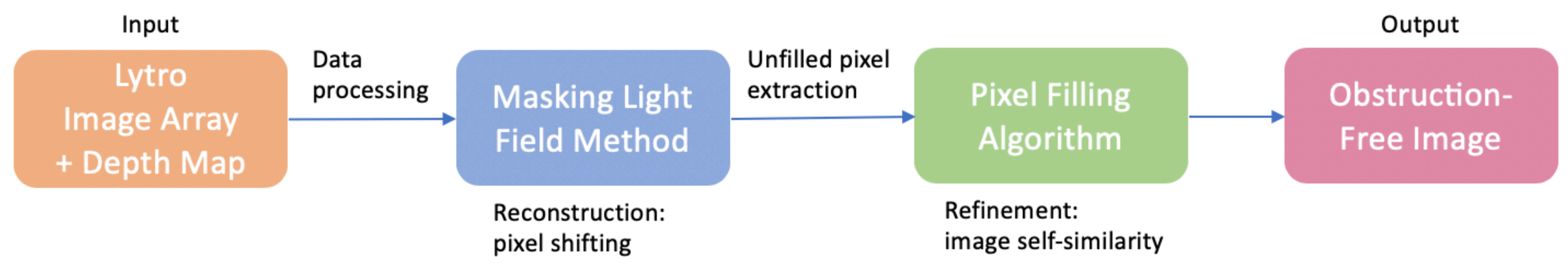
- Stanford Lytro Light Field Archive
  http://lightfields.stanford.edu/occlusions.html
- Captured by Lytro Illum camera with depth map:
  - We took pictures by ourselves and process the raw data by *Lytro Desktop*, *LytroPowerToolBeta* and *Matlab*

Key Ideas

- Currently, people usually use light field cameras to refocus on different parts of the scene
- Image array + depth map: incorporate geometry information
- Why it works: images in the array encode **different views of the scene**, and different images are **obstructed in different parts**
- LF Image Processing + Shift Calculation + Refinement

Image processing pipeline and algorithm

Pipeline:



Masking LF Method (MLFM)[1]:

$L^{(u,v)}$ Sub-image with coordinate (u, v)

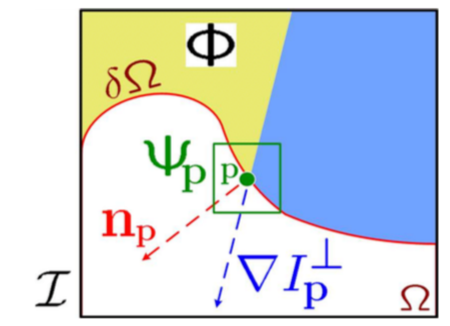
$M^{(u,v)}$ Fence mask on sub image L(u, v)

$\delta_{b/f}$ Shift units for foreground/background estimation

$$I(x) = \Sigma_{u,v}(1 - M^{(u,v)}(x + \delta_b^{(u,v)})L^{(u,v)}(x + \delta_b^{(u,v)}))$$

$$M^{(u,v)}(x) = M^{(0,0)}(x + \delta_f^{(u,v)})$$

Pixel Filling Algorithm (PFA) [5]:



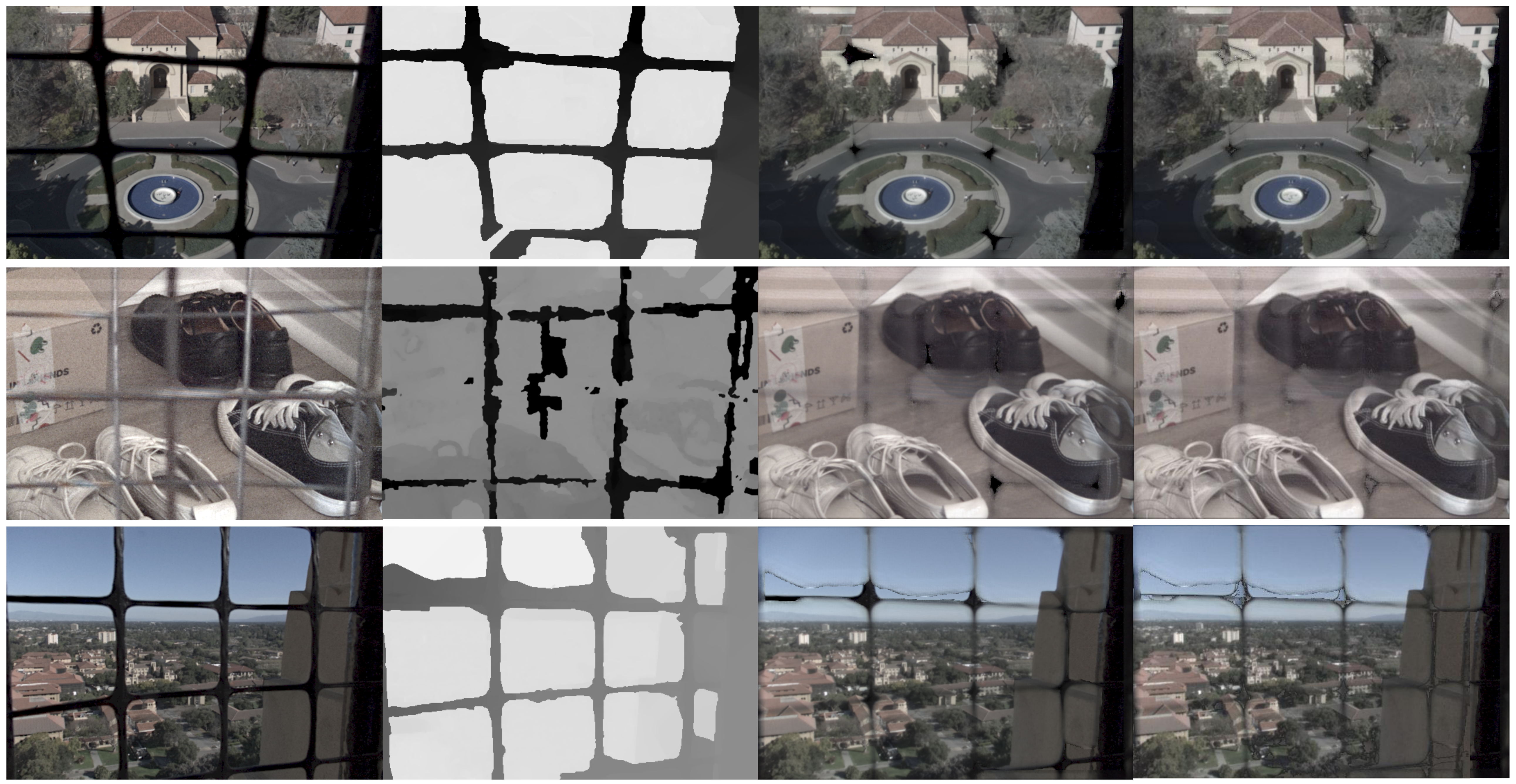
$$P(\mathbf{p}) = C(\mathbf{p})D(\mathbf{p})$$ Priority

$$C(\mathbf{p}) = \frac{\sum_{\mathbf{q} \in \Psi_{\mathbf{p}} \cap (\mathcal{I} - \Omega)} C(\mathbf{q})}{|\Psi_{\mathbf{p}}|}$$ Confidence

$$D(\mathbf{p}) = \frac{|\nabla I_{\mathbf{p}}^{\perp} \cdot \mathbf{n}_{\mathbf{p}}|}{\alpha}$$ Data

Results

Original Image | Depth map | MLFM only | MLFM + PFA



Evaluation

Models	MLFM	PFA	MLFM + PFA
Runtime (s)	~70s	~5000s	~70s (MLFM) + 400s (PFA)

Models	MLFM	PFA	MLFM + PFA refinement
pros	Short runtime; Stable results	Only need 1 image + 1 depth info; No unfilled pixels	Short runtime, Better visual reconstruction
cons	Complex image pre-processing; Visual imperfections (unseen pixels)	Unstable; Depending on images and hyper-parameters; Long runtime	Still has small artifacts (can be improved with more accurate depth map)

Conclusion and Discussion

- Our approach improves LF obstruction-free image.
- In conclusion, we use pixel location calculation algorithm to reconstruct the obstruction-free image, and furthermore, we utilize pixel filling algorithm to fill areas that haven't been seen from the LF camera for visual refinement
- There are some artifacts around the fence edge, which can be further improved by better depth map.
- Our approach might work better if we do more fine-tuning (window size of pixel filling algorithm, better extraction of unfilled pixels, etc.)

Reference

[1] Scott McCloskey. "Masking light fields to remove partial occlusion". In:2014 22nd Inter-national Conference on Pattern Recognition .IEEE. 2014, pp. 2053–2058.
[2] Tianfan Xue et al. "A computational approach for obstruction-free photography". In: ACM Transactions on Graphics (TOG) 34.4 (2015), pp. 1–11.
[3] Paolo Favaro and Stefano Soatto. "Seeing be- yond occlusions (and other marvels of a finite lens aperture)". In: 2003 IEEE Computer Soci- ety Conference on Computer Vision and Pattern Recognition, 2003. Proceedings. Vol. 2. IEEE. 2003, pp. II–II.
[4] Yanxi Liu et al. "Image de-fencing". In: July 2008, pp. 1–8. DOI: 10.1109/CVPR.2008. 4587493.
[5] Antonio Criminisi, Patrick Pe ́rez, and Kentaro Toyama. "Region filling and object removal by exemplar-based image inpainting". In: IEEE Transactions on image processing 13.9 (2004), pp. 1200–1212.