Advanced Depth Estimation and Refocusing with Light Fields

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Highlights

- **Depth Estimation**: we implemented Adelson's method for depth estimation from light fields [1].
- **Refocusing**: we also implemented Ng's Fourier Slice Photography Theorem for refocused images from light fields [2].
- **Analysis**: we report quantitative and qualitative analysis for our reproduction results.

Motivation

- In homework 5, we implemented basic depth estimation and refocusing algorithms.
- In this project, we are interested in exploring more advanced algorithms that might achieve better results.

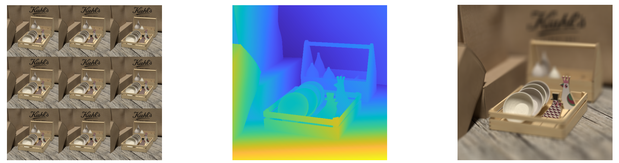


Figure 1: Example light field and the resulting disparity map and re-focused image.

Dataset

- **Heidelberg 4D Light Field Benchmark**: 9x9x512x512x3 synthetic light fields with ground truth disparity map [3].
- **Stanford Light Field Archive**: 16x16x1024x1024x3 real-world light fields acquired by Stanford Computer Graphics Lab [4].

References

[1] E. H. Adelson and J. Y. A. Wang, ``Single lens stereo with a plenoptic camera,'' *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 14, pp. 99--106, Feb 1992.

[2] R. Ng, ``Fourier slice photography,'' *ACM Trans. Graph.*, vol. 24, p. 735–744, July 2005.

[3] K. Honauer, O. Johannsen, D. Kondermann, and B. Goldluecke, ``A dataset and evaluation methodology for depth estimation on 4d light fields,'' in *Asian Conference on Computer Vision*, Springer, 2016.

[4] S. U. C. G. Laboratory, ``The new stanford light field archive,'' 2020.

Depth Estimation

$$disparity = \frac{\sum_P (I_x I_{v_x} + I_y I_{v_y})}{\sum_P (I_x^2 + I_y^2)}$$

$$confidence = \sum_P (I_x^2 + I_y^2)$$

I: intensity, $I_{x,y}$: spatial derivative, I_{v_x,v_y}: viewpoint derivative

Qualitative Results

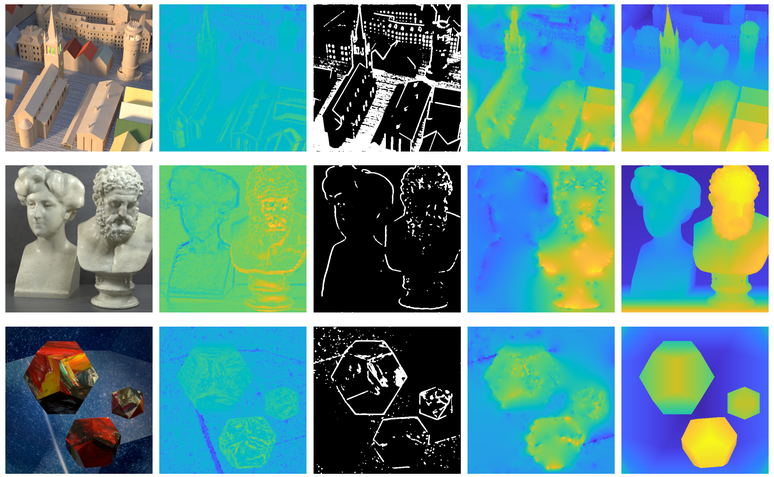


Figure 2: Example qualitative results.

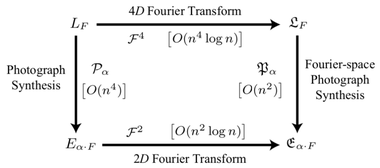
Quantitative Results

Table 1: Example evaluation with MSE and PSNR.

scene	town	greek	platonic	dishes	cotton	antinous	dino
MSE	1412	4084	3776	5506	8518	5939	2421
PSNR	16.63	12.02	12.36	10.72	8.827	10.39	14.29

Fourier Slice Photography

- Implementation pipeline and time complexity [2]



- Fourier Slice Photography Theorem [2]

$$\mathcal{P}_\alpha \equiv \mathcal{F}^{-2} \circ \mathfrak{P}_\alpha \circ \mathcal{F}^4$$

Analysis

- Refocus with different $\alpha = F'/F$

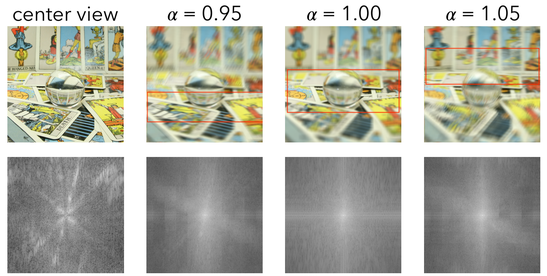


Figure 3: Focus on different depths by changing α.

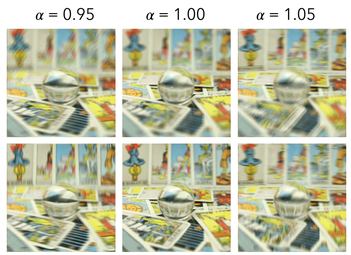


Figure 4: top:16x16; bottom:8x8

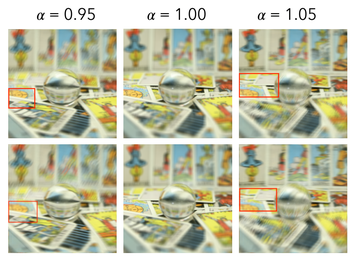


Figure 5: top:2x; bottom:1x

- **Impacts of light field size**: in figure 4, larger light field size will achieve much better refocusing effect, especially when $\alpha \neq 1$.
- **Impacts of padding** : as shown in figure 5, adding more padding when pre-computing could achieve slightly better performance.