Super-Resolution with Light Field Cameras

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I. Motivation

Light field cameras suffer an inherent tradeoff between angular and spatial resolution due to the inclusion of microlenses between the primary objective lens and the sensor plane. Pixel super-resolution is a computational imaging technique used to increase the pixel count in an image by combining multiple lower resolution images taken with different offsets (sub-pixel shifts). In many applications, the prospect of capturing multiple low-resolution images that can be formed into a high-resolution image in a single shot is very attractive. Here I propose to use a light field camera to achieve this single shot multiple low-resolution capture as the basis for generating super-resolved light field images.

II. Related Work

Development of the first consumer-grade light field camera was spurred by Ren Ng's graduate work at Stanford, where he demonstrated that the addition of a microlens array atop an image sensor could provide valuable information about the geometric distribution of light through the primary lens [1]. Further work led to the development of the focused plenoptic camera (also called plenoptic 2.0 camera), in which the microlenses image the focal plane of the main lens, rather than being focused at infinity (see Fig. 1) [2]. Georgiev and Lumsdaine described their approach to overcoming the limited spatial resolution of light field cameras using a super-resolution technique in [2]. Other researchers from Pelican Imaging have also described super-resolution methods for light field data collected from a miniature 4x4 lens/camera array [3]. Their approach is likely to be more relevant for images from traditional light field cameras, such as the Lytro Illium.

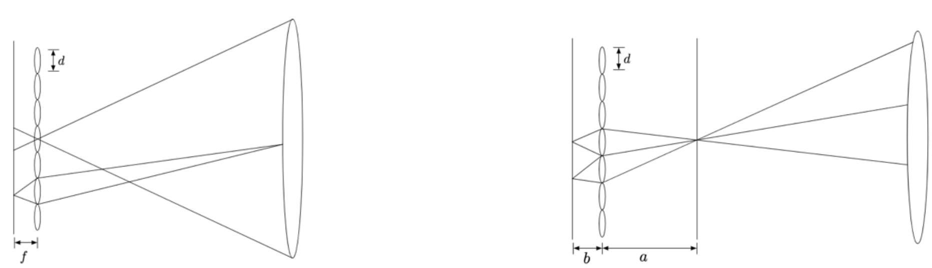

Figure 1. Schematics of a traditional plenoptic camera (left) where the microlenses are focused at infinity and focused plenoptic camera (right) where the microlenses are focused at the focal plane of the primary lens. Taken from [2].

III. Project Overview

In this project, I will focus on super resolving the images from the two types of light field cameras described above (traditional and focused plenoptic cameras), as well as comparing the performance of different super-resolution techniques to these two classes of images.

IV. Milestones, Timeline & Goals

Below is a list of intermediate and major milestones that will be achieved during the course of this project. A timeline, given in terms of term weeks and calendar dates, is also provided as a guide and means of measuring intermediate progress.

Week 6 — Understand Existing Work & Project Motivation

- 2/12/20: Submission of project proposal.
- This task consists primarily of familiarizing myself with existing work and understanding the contributions these works have made, as well as the limitations they have identified. In particular, I will focus on understanding the tradeoffs in super resolution dictated by the different architectures of traditional light field camera and focused light field camera architectures.

Week 7 — Collect Data & Implement Image Registration/Parallax Correction

- Here, I will focus on acquiring light field images/data from both Lytro Illium and Raytrix cameras. Datasets from [4] and [5] as well as others linked on the Stanford Light Field Archives, appear to be particularly relevant.
- I will also work on implementing the necessary image registration/parallax correction required to enable super-resolution from a light field image.

Week 8 — Implement Super Resolution

- This week I will begin to implement super resolution methods, most likely beginning with the gradient descent update scheme used in Homework 4, then advancing to other techniques described in the literature such as the minimum-a-posteriori formulation approach described in [3].

Week 9 — Comparison of Super-resolution Applied to Light Field Images

- Here, I will continue implementing super resolution techniques on traditional light field (e.g. Lytro Illium) and focused light field (e.g. Raytrix) images. I will focus on comparing the performance of different super-resolution techniques when applied to these two datasets.

Week 10 — Presentation of Results

- 3/11/20: Submission of poster and video presentation.
  - Note that I will be traveling for field work beginning on 3/7, so I plan to submit a video recording of my presentation rather than attending the poster session in person.
- 3/13/20: Submission of project report and code.

V. References

[1] Ng, R. "Digital light field photography." Ph.D. Thesis, *Stanford University*, 2006. Adviser: Patrick Hanrahan.

[2] Georgiev, T. and Lumsdaine, A. "Superresolution with Plenoptic Camera 2.0." *Adobe Technical Report*. April 2009.

[3] Venkartaraman, K. et al. "*PiCam*: An Ultra-Thin High Performance Monolithic Camera Array." *ACM Trans. Graph.* 32, 6, Article 166. November 2013.

[4] Ahmad, W. et al. "Matching Light Field Datasets from Plenoptic Cameras 1.0 and 2.0." *3DTV-Conferenc*e, IEEE 2018.

[5] Guillo, L. et al. "Light Field Video Dataset Captured by a R8 Raytrix Camera (with disparity maps)." April 2018.