Simulated Programmable Aperture with Lytro

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1 Introduction

In recent years, many researches are conducted in coded apertures for various applications including refocus (Veeraraghavan et al. [2007]), deblur (Zhou and Nayar [2009]), denoise (Liang et al. [2008]) and depth of field estimation (Levin et al. [2007]). To demonstrate the effect of a certain coded aperture, usually a camera system with modified or programmable aperture is built for the purpose. (Liang et al. [2008], Nagahara et al. [2010]) However, the recent development in light field cameras might have provided a new option for us. With the consumer light field camera Lytro (Ng [2006]), we are able to capture an array of images of the same scene, from which we can effectively simulate apertures of various shapes. As a result, we would no longer need to build complicated system for each aperture. Instead, we could generate the simulated results through image computation.

2 Project Goal

The goal of the project is to explore and analyze the possibility of simulating various aperture from images captured by Lytro. More specifically we would like to evaluate two use cases.

The first use case is in the field of creative photography. For years, photographers have been utilizing the out-of-focus blur to add aesthetic value to their work. By changing the shape of the aperture, we are able to create different blur shapes. Fig. 1 and Fig. 2 are two photos with different blur shapes. We would like to achieve results similar to the photo taken by the masked lens from a Lytro camera.

The second use case is in the field of light field camera research. Liang et al. [2008] designed a device with programmable aperture for light field acquisition and provided some corresponding post-processing algorithms. As one of the steps in light field acquisition, multiple images are captured with different aperture patterns through multiple exposures. The results are thus a set of multiplexed light field images. Then the set of images are demultiplexed to achieve individual light field (pin-hole) images. According to the paper, such pre-processing steps help reduce noise for the light field images comparing to taking individual light field images directly. We would

Figure 1: Photo taken by a conventional lens

Figure 2: Photo taken by a masked lens

like to verify the result reported by the paper and further analyze the reported aperture shape for both Gaussian and Poisson noise while the original paper only presented denoising results on Gaussian noise.

3 Work Flow

3.1 Creative Photography

For creative photography, we plan to shoot some out-of-focus night scenes with Lytro, so that we can have nice out-of-focus light spots to work with. By selection the corresponding views from the image array, we can achieve specific shape of blur. We would like to design algorithms to simulate several popular out-of-focus blurs, a.k.a. bokehs. These bokehs are usually created by a shaped mask on lens like heart-shaped, star-shaped, ring-shaped and so on. Similar results can be obtained by picking and multiplexing a sub set of the images captured by Lytro.

3.2 Denoising in Light Field Acquisition

In Liang [2009], details on the multiplexing and demultiplexing process for denoising in light field acquisition are presented. We will focus on simulating equivalent operations from images captured by a Lytro.

3.2.1 Image Multiplexing

The example presented in Liang [2009] captured the light field by taking nine multiplexed images under nine exposures. To simulate this operation, we will select the corresponding views from the image array captured by Lytro and merge the view together. We will then add noise in MATLAB to the nine images separately to simulate the noise in three exposures. In the paper, Gaussian noise is assumed and analyzed. We can analyze both Gaussian noise and Poisson noise by choosing different noise models.

3.2.2 Image Demultiplexing

The example presented in Liang [2009] then demultiplex the nine images to recover the images that would be captured from the individual pin holes. These recovered images are referred to as the 'light field images'. The same operation would be performed on the simulated multiplexed images as well.

3.2.3 Result Analysis

Liang [2009] compared the demultiplexed result to the image captured directly from a pin-hole aperture, which is referred to as the light field image without multiplexing in the paper. In our case, we can select the corresponding view from the images captured by Lytro and add the same amount of noise that we added to the simulated multiplexed images for the comparison purpose.

3.2.4 Further Analysis

Time permitted, we can further experiment with larger the multiplexing patterns since we have a higher angular resolution with Lytro. We can also experiment the vignetting correction algorithm presented in Liang [2009].

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