Scene-independent Super-resolution for Plenoptic Cameras

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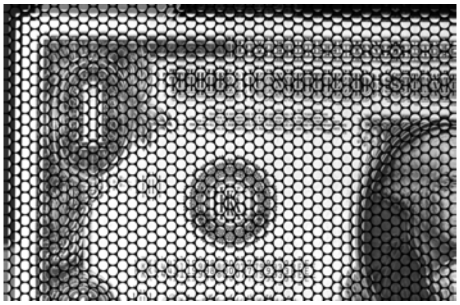

Figure 1: *Our Super-resolved Image.*

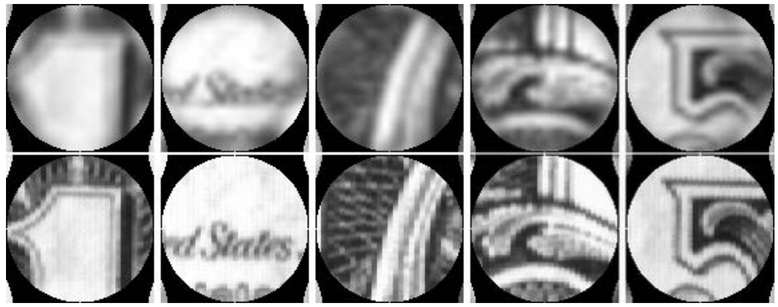

Figure 2: *5x super-resolved microlens image(top: bi-cubic, bottom: proposed).*

1 Introduction

Current designs of plenoptic cameras with a microlens array usually have to deal with a trade-off problem between spatial and angular resolutions, i.e., spatial resolution is reduced to capture angular light variation on the sensor. Spatial resolution can be recovered by using super-resolution techniques that require sub-pixel accuracy registration of images[Wanner and Goldluecke 2013; Georgiev and Lumsdaine 2009]. However, image registrations often fail due to many scene-dependent factors such as occlusions and reflections, and such errors cause visible artifacts in super-resolution results. To address this problem we propose a scene-independent super-resolution framework based on a unique characteristic of the plenoptic camera; we found that the sub-pixel registration can be performed by displacement of Epipolar Plane Images (EPIs) that depends only on the intrinsic and extrinsic parameters of plenoptic cameras. Our proposed approach generates high resolution microlens images by a simple rearrangement of pixels acquired by dense multiview plenoptic cameras. Experiment results show that the proposed approach achieves high quality super-resolution.

2 Super-resolution Approach

Our super-resolution approach can be achieved by increasing EPI resolution. The coordinate system of an EPI obtained by using a camera m is denoted by n_m-i_m, where n_m is a sequential number of microlens images and i_m is an image coordinate of each microlens image. By increasing EPI resolution in the i_m dimension, super-resolution for a microlens image can be achieved. The displacement Δ_n and Δ_i between two EPIs extracted from camera m and $m+1$ can be expressed as follows.

$$\begin{bmatrix} \Delta_n \\ \Delta_i \end{bmatrix} = \begin{bmatrix} n_{m+1} \\ i_{m+1} \end{bmatrix} - \begin{bmatrix} n_m \\ i_m \end{bmatrix} = \delta \begin{bmatrix} -\frac{Bl}{A} \\ \frac{f}{Fw_p} \end{bmatrix}$$

where l is the microlens pitch, f is the distance between the microlens array and the image sensor, w_p is the image sensor pitch, B is the distance between the main lens and the microlens array, F is the main lens focal length, A holds $1/A + 1/B = 1/F$, and δ is the distance between neighboring plenoptic cameras. This equation shows Δ_n and Δ_i are scene-independent and can be calibrated beforehand. The intensity of a pixel at sub-pixel positions in an EPI is directly acquired by slightly shifted cameras with decrimal Δ_n and Δ_i.

In practice, we firstly capture images by a slightly moving plenoptic camera, and then EPIs of each images are obtained. Our approach needs only $N \times N$ viewpoints to achieve a Nx super-resolution image but some pixels are affected by vignetting. We captured more viewpoints to get alternative pixels to avoid vignetting effects. Each pixel in the obtained EPIs is rearranged into a sub-pixel of a high resolution EPI on the basis of the displacement parameters Δ_n and Δ_i. Note that because Δ_n is significantly smaller than Δ_i, displacement in the n_m direction is ignored. Finally, high resolution microlens images are generated by converting high resolution EPIs.

3 Results

We tested our approach using a plenoptic camera (Raytrix R5). We moved the camera and took images at 676(26x26) viewpoints in a grid, with each point 0.2mm apart. These images were used to upscale with the pre-calibrated geometric parameters Δ_n and Δ_i. Figure 1 and 2 compare our 5x super-resolution results with 5x upscaled microlens images obtained by bi-cubic interpolation. It can be seen that our super-resolved images are clearer than those obtained with the conventional method. We conclude our approach has the potential to significantly improve the resolution of light field cameras, which are already emerging on the consumer market.

References

GEORGIEV, T., AND LUMSDAINE, A. 2009. Superresolution with plenoptic camera 2.0. *Adobe Systems Incorporated, Tech. Rep*.

WANNER, S., AND GOLDLUECKE, B. 2013. Variational light field analysis for disparity estimation and super-resolution. *IEEE Transac. PAMI 3*, 606–619.

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