Translation-capable Panorama Using Light Field Imaging

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Abstract: In this project, we present an approach of generating translation-capable panorama using light field imaging. Compared with other panorama light fields imaging methods, we simultaneously adjust focal stack and field of view to simulate the virtual translation of the light field cameras. The translation range is in several centimeters for panorama; so the method works best for a micro scene.

1. Introduction

Panorama imaging has been gaining increasing popularity over the past few years especially for commercial applications like 360 degree image/video in virtual reality. Panorama imaging, which almost becomes standard feature for any modern digital camera or smart phone, bringing customers immersive experience with wide field of view (FOV). 360 degree cameras further expand the FOV to the entire sphere panorama; in other words, it enables 3-degree of freedom (pitch, yaw and row) in the scene. The next level of immersiveness would be 6-degree of freedom (6 DOF) which means both rotation and linear translation of the image.

However, current 360 cameras with either fish-eye lens such as Ricoh Theta S and Samsung Gear 360, or camera rigs such as Facebook 360, inherently lack the information for 6 DOF image reconstruction. The only imaging technology that could possibly be used to create 6 DOF images is Light Field imaging. In contrast to conventional imaging techniques, light field imaging collects both spatial and directional information of the scene in a 4 dimensional parametric space. In post-processing, these 4D light fields can be used for generating synthetic images of special effects like refocusing, depth sensing and translation parallax [1].

In this project, our goal is to add linear translation capability to conventional panorama. We present an approach to use an off-the-shelf light field camera (Lytro Illum) to capture a cylindrical light field and develop the shift-add algorithm for translation-capable light field panorama reconstruction.

2. Related work

Incorporating panorama reconstruction to light field imaging is not straightforward. Directly stitching multi-perspective images of the input light fields using classical panoramic reconstruction will cause severe artifacts on the boundaries when applying refocusing effects in post-processing [2]. The alternative method, proposed by researchers at Johannes Kepler University Linz, Austria, is to calculate focal stacks in all images first and then stitch these images individually [3]. This method eliminates the previously synthetic refocusing difficulties with the panoramic image. However, it makes strong assumption of a Lambert surface scene as it directly concatenate the three-dimensional images, leading to other artifacts of anisotropic reflections. The same research group at Kepler University Linz went on to solve the anisotropic reflection associated problems by computing ray entries directly to reconstruct a panoramic light field [4]. Their approach include parameterization, registration, and blending of cylindrical panorama light fields, which is computationally expensive. It takes 1-2 hours for the panoramas to be fully computed. They also need an initial calibration step of light field cameras, similar to the previous reported light field imaging study [5].

Our approach takes multiple light field images at pre-determined angles just like the mentioned studies do. But instead of trying to fit panorama stitching into the light field refocusing operation, we virtually move the camera position while keep the focal length as a constant and then we stitch them together to get a translated panorama. Our panorama reconstruction do not depend on depth sensing.

3. Virtual camera translation in LF

The camera we use is a Lytro Illum which outputs a 434×625×15×15 light fields. Thanks to the multiple slightly different perspectives of images in this 4D light field image data, virtually moving the light field camera position in post-processing becomes possible.

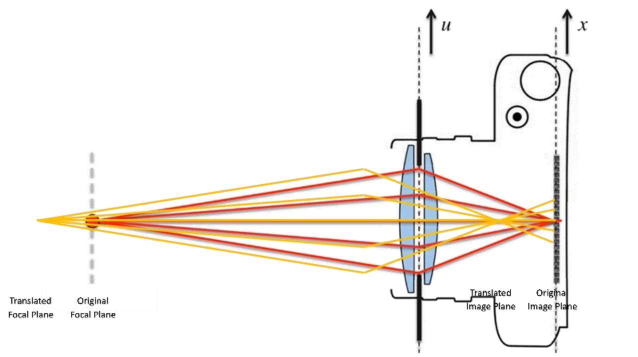

Figure 1 Illustration of light ray changes as virtual translating the camera.

Virtually translating the camera includes two steps: first is to compute focal stacks from the light field images. Former study has already shown the standard shift-add algorithm to accomplish this task [6], with the following equation

$$i_d(x) = \int l_0(x - dv, v)\, dv$$

$$l_0(x, v) = l_d(x + dv, v)$$

Where i_d is the synthetic refocus image, d is the computational image plane displacement, l_0 and l_d are the light field parametrization at original image plane and translated plane, and x and v represent the two reference planes of light field parametrization.

Secondly, to simulate the field of view change effect as translating the camera, we also need to perform cropping of the original field of view that correspond to refocusing. In other words, we are adjusting the focal plane and FOV simultaneously as if the focal length doesn't change to the viewer.

In our imaging setting, the FOV of the camera is 43.5º, we are using only 30º of the camera FOV as our original FOV allowing us to translate both forward and backwards. We keep the focal length to be 30mm and our focal plane at a distance of 26cm. The following figure shows virtual camera translation for a single light field. In this synthetic image operation, translation range is the key parameter for real application. Given the imaging setting we have, the camera can be virtually moving up to ± 13cm in both parallel and orthogonal directions.

Figure 2 Moving forward 13cm virtually in the scene

4. Translated panorama reconstruction

As mentioned in previous section, combining panorama reconstruction with synthetic refocusing operation is not straight forward, so does virtual translation in light field. In fact, not only the virtual translation vector but also the FOV adjustment changes for light fields taken at different pre-determined angles. The correlation between virtual translation and FOV in terms of angles also affect the virtual translation range, reducing it to only several centimeters around the center as shown in the following figure.

Figure 3 Virtual translation range for single LF (left) and panorama (right).

Therefore the procedure for reconstructing the translated panorama is to first compute all the virtual translation vector to make sure they fall into the translatable region, then compute the individual translated light field image and finally stitch them onto a cylindrical surface using standard image alignment and stitching techniques [5].

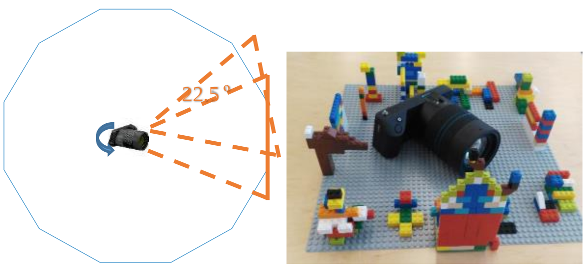

Figure 4 LF panorama capture setup

In order to preserve enough image overlap to reconstruct panoramas, we rotate the Lytro Illum around its shutter and take the light field images every 22.5 °. We take five light field images to stitch which sums up to a 100 FOV. The following shows the virtual translation of this panorama.

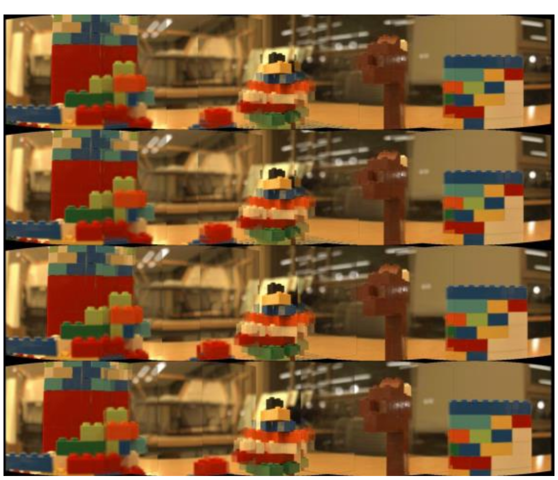

Figure 5 Moving forward 4cm virtually in the scene

5. Conclusions

As a summary, we use off-the-shelf light field camera to take multiple light fields at pre-determined angles, develop an algorithm to adjust focus and FOV accordingly at the same time to simulate virtual translation of the light fields, and finally stitch them together to get a translation-capable panorama. On a scale of centimeters, we demonstrate the potential of generating 6DOF images by using light field.

One major limiting factor for our implementation as well as the future work would be calibrating the lens of Lytro Illum to pre-correct the distortion in the overlapping region of the panorama. We also need to design an optical-mechanical stage to stabilize the panorama capturing.

Reference

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