All in-Focus Light Field Viewer

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1 Introduction

Light field rendering [Levoy and Hanrahan 1996] is a method for generating free-viewpoint images from pre-acquired images captured by an array of cameras. Since it is based on the constant depth assumption, we can see some focus-like effects on the synthesized images [Isaksen et al. 2000] when the distance between cameras is not small enough. This means that, when the light field is undersampled, objects apart from the assumed depth cannot be synthesized clearly. These objects are *out-of-focus*, and appear with blurring and ghosting (See Fig. 1 as examples).

In order to solve this problem, we presented a basic theory in [Takahashi et al. 2003], and will publish its quantitative evaluations in [Takahashi et al. 2004]. In this paper, we developed an interactive viewer based on this theory that can generate *all in-focus* images at arbitrary viewpoints from undersampled light fields. On the viewer, we introduced a smoothing function to suppress noises which are visible when the viewpoint is moving. In addition, we achieved interactive frame-rates by adopting just two reconstruction filters while we used three in [Takahashi et al. 2003].

2 Algorithm

Our algorithm consists of two steps. First, for a given viewpoint, we synthesize tens of *differently-focused* images by changing the assumed depth of light field rendering. Then, the *in-focus* regions of those images are integrated into a final image in real time.

The essential point of our algorithm is how to select *in-focus* regions from *differently-focused* synthetic images. For this purpose, we generate two sets of *differently-focused* images (set (A) and (B)) by light field rendering. Set (A) is generated from all of the pre-acquired images, and set (B) is from their subsamples. If a region of an object is *in-focus* at a certain depth, the object appears almost identically in (A) and (B), otherwise it appears differently. Therefore, we use the difference between (A) and (B) for detecting *in-focus* regions.

Our algorithm does not need any pre-estimated geometry. In contrast, we estimate a view-dependent depth map by comparing (A) and (B) for each viewpoint. We apply a real-time smoothing operation to the depth map in order to suppress noises on the final synthetic image. Although our algorithm is simple and the estimated depth is not completely accurate, we can produce all *in-focus* images at arbitrary viewpoints with high quality.

3 Experiments

We developed a software on a Pentium 4 3.2 GHz PC with an OpenGL supporting graphics card that has a NVIDIA GeForce FX 5800 processor built-in. As the light field data, we use "the multi-view image data courtesy of University of Tsukuba, Japan." The light field consists of 81 (9×9) images, each of which has 256×192 pixels.

In this experiment, the number of the assumed depths is set to 10. We generate the set (A) from 9×9 images, and the set (B) from 5×5 images. The size of synthesized images is set to 256×256 pixels. Shown in Fig. 2 are some experimental results. We can see that those synthesized images are *all in-focus*; the whole scene appears clearly and sharply. We achieved interactive frame-rates (8.76 fps).

Figure 1: Examples of light field rendering. Left: the nearest building is *in focus*. Right: the farthest building is *in focus*.

Figure 2: Results of the proposed *all in-focus* light field rendering. Miniature City, Doll, Plants scenes are rendered for arbitrary viewpoints.

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