A Simple Method for Light Field Resampling

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Figure 1: a) Resampling sparse light field captured as panoramic images at four corners of a rectangle along a diagonal of the rectangle. Images generated with: b) averaged radiance, c) selected radiance and d) prior radiance.

ABSTRACT

We propose a simple method to generate new views of a scene using a sparse light field generated from a few panoramic images. We introduce a virtual sphere centered at a new viewpoint as a screen for projecting rays of the light field to get resampled images. Our method creates new views directly from a light field and thus provides a way to build virtual reality system which is more stable than using 3D modeling and rendering and less distorted than image morphing approaches.

CCS CONCEPTS

• **Computing methodologies~Image-based rendering**

KEYWORDS

virtual reality, light field, view interpolation

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1 INTRODUCTION

Image-based approaches have advantages on cost and image reality comparing with computer graphics for virtual reality, as described in [Shum and Kang 2000]. Recently, omnidirectional cameras became popular and so did watching panoramic movies. The concept was first proposed in [Chen 1995] as QuickTime VR, but it provides no degrees of freedom except for view direction. A representative of another type of application is Google Street View which allows selecting the location to go next, but users are forced to jump to the next location abruptly.

The concept for describing all rays at any location toward any direction is proposed in [Adelson and Bergen 1991] as a plenoptic function. Though the concept enables to make new views, it is practically impossible to obtain rays densely. By narrowing spatial and angular range, practical approaches were reported in [Gortler et al. 1996] and [Levoy and Hanrahan 1996]. Recently, [Zhao et al. 2013] proposed the way to interpolate two images and [Kawai et al. 2016] extended it to two dimensions, but they are still impractical due to them being unstable in feature point matching and unavoidable distortion.

2 TECHNICAL APPROACH

We target a sparse and unstructured light field to ensure the practicability of constructing a ray database. A sparse light field is obtained by shooting panoramic images at several locations in target space. We next introduce a virtual sphere centered at a novel viewpoint as a screen for projecting stored ray samples. Finally the outer surface of the sphere is brought out as a panoramic image at the given viewpoint.

2.1 Representation of Light Field

Radiance of a ray passing through a point (x, y, z) toward a direction (φ, θ) is describable as a five dimensional function $P(\varphi, \theta, x, y, z)$ by eliminating time and wavelength dimensions from the original seven dimensional plenoptic function. We now focus on a static scene and represent just three wavelengths as P_R, P_G and P_B instead of a continuous distribution. As is known, assuming a light goes straight and ignoring occlusion, a five

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dimensional light field can be reduced into four dimensional function. While some equivalent representations are possible, we store the radiance of each ray as $P(\varphi, \theta, x_I, y_I)$ by introducing an intercept (x_I, y_I) through which the ray passes on the xy-plane. This representation contains arbitrary ray elements without the loss of generality, except for strictly horizontal rays. Each intercept can be calculated from the known location of the omnidirectional camera and a direction vector of each ray estimated from the location of the pixel arranged in equirectangular projection.

2.2 Virtual Sphere Screen

We introduce a virtual sphere centered at a novel viewpoint with a certain radius to resample a set of rays necessary for constructing a new view. We use the outer surface of the sphere as a projection screen onto which each ray in the light field is projected. The screen is divided into an arrangement of pixels with a certain sampling interval, and we take the screen out as a panoramic image at the new viewpoint after completion of the projection. This approach obtains the correct radiance if the object is located just on screen and it contains no specular component even if the actual distance to each object is unknown. The detailed operation of the projection is illustrated in Figure 2. A ray intersects the surface of the sphere at most twice, as an inward and an outward penetration. We collect only the inward penetration and discard the outward one since the outward ray goes away from the viewpoint and becomes invisible. The inward penetration is always calculated as the first intersection of the directed ray and the spherical screen.

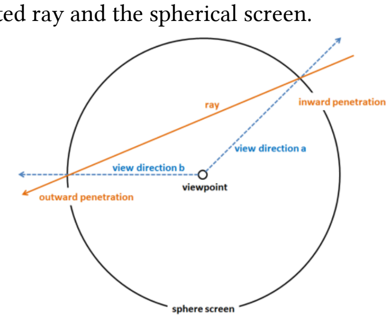

Figure 2: a ray penetrates a sphere twice. The inward intersect denotes incoming ray for the viewpoint while the outward one does outgoing one.

2.3 Selecting Projection

Since each ray is projected independently onto the screen, some pixels may acquire two or more rays, and some may acquire none. We cannot determine the radiance of a pixel if no rays penetrated it. A simple solution to the problem is to repeat the projection with multiple screen resolutions. This allows vacant pixels to replace radiance with approximation by referring to a lower resolution screen. On the other hand, we need a procedure for determining the radiance if two or more rays penetrated a pixel. As we have no geometrical information, it is impossible to estimate the correct radiance based on three dimensional analysis. To take an average radiance of multiple rays is the simplest way for approximation. However, it is predicted that the procedure generates a blur or ghost on the images. In order to keep the image quality as clear as the original panoramic images, we select one from the projected rays and use its radiance with no interpolation. We introduce an inner product of a viewing direction at the pixel and a ray direction as rating, and the ray coming from the closest direction to the looking direction is selected by finding a ray with the smallest score.

3 RESULTS AND FUTURE WORK

We inspected the method with a sparse light field captured in an office room. We took four panoramic images at four corners of a rectangle, and generated novel views along a diagonal of the rectangle. Figure 1(b) shows an example generated by taking a radiance average in which a ghost occurs as we predicted. However, the transition of the scene is smooth and reasonable. Figure 1(c) shows a result by selecting rays with the smallest inner product. Here the image became clear to the same degree as the original images, but the unpleasant demarcations are observed at the borders of regions where the rays came from different original images. One interesting suggestion is shown in Figure 1(d). This view was generated by collecting rays from a specific original image prior to others. Some objects such as the black display monitor were successfully reproduced during transition with less ghost and boundaries. It suggests assigning a priority according to the facing direction will ensure image quality at least around the region to be displayed.

Though results show that our method has advantages to [Kawai et al. 2016] of its full automatic processing and eliminated distortion, a way to estimate a fairer radiance is expected. Another problem for real-time rendering is computation cost. We tested under conditions in Table 1 and generated each frame in almost 2 seconds with no optimization.

Table 1: Conditions on experiment

Number of rays	800,000
Image resolution	1240 x 620 pixels
CPU	3.2GHz Intel Xeon

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