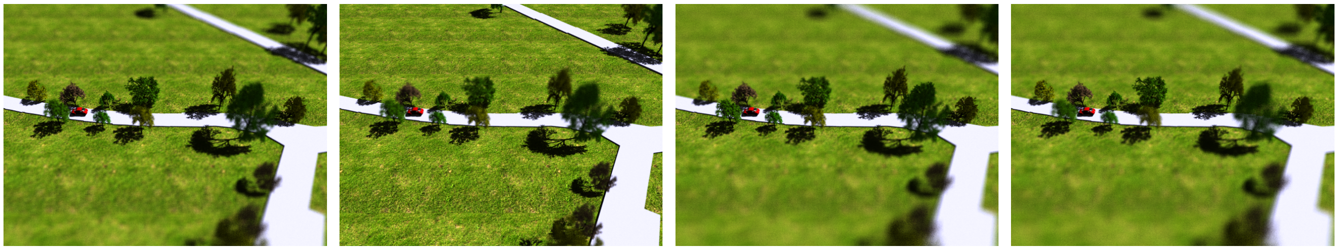
Simulating Depth of Field Effects Taken by a Camera with a Tilt-Shift Lens

Tomoe Nakane Masashi Baba Shinsaku Hiura Naoki Asada
Hiroshima City University



(a) (b) (c) (d)

Figure 1: *(a) an ordinary blurred image using a thin lens, (b) a pan-focus image generated using a tilted lens, (c) a narrow focus image generated using a reverse tilted lens, (d) a narrow focus image generated using a lens which has twice the aperture size of (a).*

1 Introduction

In order to make realistic CG images, it is important to use a camera model which is based on actual lens systems. Objects in focus appear sharp in a real image, but other objects not in focus appear blurred. This kind of effect is called the depth of field (DOF) effect. DOF is the distance between the nearest and farthest objects in a scene that appear acceptably sharp in an image. Potmesil [Potmesil and Chakravarty 1981] proposed a method to simulate such blur effects. In the proposed method, an image was created using a pinhole camera model and a blur was added in the post-process. Cook [Cook et al. 1984] proposed distributed ray tracing which traces several rays for one pixel and simulated DOF effects caused by a real lens. Among various lens effects, the effect of a tilt-shift lens has not been simulated. The purpose of our study is simulating DOF effects by a tilt-shift lens.

2 Simulation

The tilt-shift lens can control the focal plane against the image plane by tilting the lens. It can change the size and the range of the blur by tilting the lens. Usually, tilting the focal plane to let more objects in the depth of field is called "tilt", and tilting the focal plane to let less objects in the depth of field is called "reverse-tilt". The focal plane, the lens plane and the image plane intersect at the same line. This is called the Scheimpflug principle. As shown in Figure 2, θ is the angle between the optical axis and the focal plane, and θ' is the angle between the optical axis and the lens plane. The angle θ' of the lens plane is obtained from the Scheimpflug principle, focal distance U and focal length f as follows.

$$\theta' = \tan^{-1}\left\{\frac{(U+f)\times\tan\theta}{f}\right\} \quad (1)$$

We extended the source code of 3D renderer, POV-Ray, and simulated DOF effects by a camera with the tilt-shift lens. POV-Ray employs distributed ray tracing method. This method can simulate the effect of DOF taken by a camera with an ordinary thin lens. By changing the aperture of a lens, we can control the amount of the blur. The larger the aperture of a lens is, the bigger the blur is.

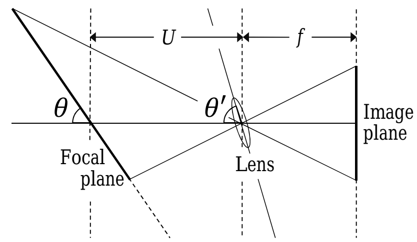


Figure 2: *Camera model of a tilt-shift lens.*

3 Result and Consideration

Figure 1 shows examples of generated images which simulate DOF effects. Fig. 1 (a) is generated by using an ordinary thin lens. Fig. 1 (b) is the image with a tilt effect. In this scene, the focal plane is parallel to the ground, and θ is $45°$, and θ' is $87.4°$. Almost all objects, except for the tree tops are in focus. Fig. 1 (c) is the image which has a reverse-tilt effect. For this situation, θ is $-45°$, θ' is $-87.4°$, and the focal plane is perpendicular to the ground. The blur is increased, because the area of the ground in the DOF is narrow. Fig. 1 (d) is the image generated using a normal lens with the aperture twice as large as that of the lens for Fig. 1 (a). The degree of blur in the upper and lower regions of Fig. 1 (d) is similar to that of Fig. 1 (c). However, the differences in the range of blur caused by the different angle of the focal plane appear on the trees near the road in the center.

Generally speaking, the aperture of real cameras cannot be changed arbitrarily, but we can change the aperture of the camera model arbitrarily. That is the advantage of CG. On the other hand, if the aperture is fixed, the range of DOF is fixed. Even in such cases, we can control the region in focus and the degree of blur more freely by tilting the focal plane. We simulated that kind of effect by using the tilt-shift lens.

References

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