A Thin Lens Based Camera Model for Depth Estimation from Defocus and Translation by Zooming

Masashi Baba, Naoki Asada, Ai Oda, Tsuyoshi Migita
Department of Intelligent Systems
Hiroshima City University
{baba,asada,ai,migita}@cv.its.hiroshima-cu.ac.jp

Abstract

Depth recovery is a central concern in computer vision, and many methods were proposed for the monocular depth estimation by zooming as well as focusing and irising. In the past, there are two distinct approaches in depth by zooming; one is from motion parallax along the optical axis using a pinhole camera model, and the other from defocus using a thin lens camera model. This paper presents a new camera model that accounts for both effects of defocus and lens center translation by zooming. We first discuss the optical properties of zoom lenses, then present a thin lens based camera model that describes the mutual relationship between zoom, focus and iris parameters. Using this model with calibration results, we have performed some experiments with real images and evaluated the accuracy of the depth information recovered from defocus and lens center translation. Experimental results have demonstrated the validity of our camera model and also shown its applicability to the depth estimation from defocus and translation by zooming.

1 Introduction

Zoom lens systems are widely used in various types of cameras because of the imaging flexibility and versatility; that is, we can take images with arbitrary magnification, focus and brightness conditions by controlling zoom, focus and iris settings. In computer vision, however, since such a zoom lens system has complex optical properties and thus it is difficult to model it, there are few works to deal with the zoom lens effects totally. The purpose of this study is to develop a new camera model that describes the mutual relationship between zoom, focus and iris parameters and to show its applicability to the depth estimation by zooming.

Depth recovery is a central concern in computer vision, and many methods were proposed for the depth estimation by focusing[1, 2, 3, 4] and irising[5, 6, 7]. In these studies, while the camera models and lens parameters are different, all of the methods are established on a common principle; the image blur is observed when the imaging system has a finite lens aperture and the degree of defocusing depends upon the distance between the lens and the object, therefore the depth information is derived from the image blur.

On the other hand, some researchers are interested in a zooming effect that is the lens center translation along the optical axis of the lens, and they have developed a method called depth by zooming[8, 9, 10]. This approach is based on the motion parallax using a pinhole camera model, which means that the image blur caused by zooming is ignored.

Recently, we have reported another approach to the depth recovery by zooming [11] in which the depth information is estimated from defocus by zooming. The study developed a thin lens based camera model that describes the defocusing by zooming, focusing and irising, yet the lens center translation is not considered.

In this paper, we propose a new camera model of zoom, focus and iris parameters that accounts for the image blur as well as the lens center translation. In the following section, we first discuss the optical properties of zoom lens parameters, then present a thin lens based camera model. Using this model with calibration parameters, we will show some experimental results with real images and accuracy evaluation of the depth from defocus and translation by zooming.

2 Camera Model

Zoom lens systems have three parameters, zoom, focus and iris, and those imaging effects are observed as follows. **Zoom** allows to take images with arbitrary magnification of a scene without changing the focused distance and image brightness, see Fig. 1(d)(e). **Focus** enables to take focused images of an object at any distance with varying the image magnification slightly without changing the image brightness, see Fig. 1(a)(b)(c). **Iris** is capable of controlling the image brightness with changing the depth of field, see Fig. 1(f)(g).

Table 1 summarizes these imaging effects in terms of three parameters. The image magnification is main and side effects of zoom and focus, respectively. This suggests that