A New Camera Calibration Method Taking Blur Effects into Account

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1 Introduction

Camera calibration is an important issue in both computer vision and computer graphics. Therefore, many works have been done to obtain camera parameters from real images. One of the most famous calibration methods is proposed by Tsai [Tsai 1987], which uses several feature points of known positions. However, since his method is based on the pinhole camera model, defocus effects made by a real lens system are not concerned. In this paper, we propose a new camera calibration method that takes into account both geometric information of feature points and blur width of edges.

2 Camera Calibration

Although we proposed a camera model for the monocular depth estimation by zooming, only internal camera parameters were calibrated [Baba et al. 2002]. We extend the previous work to calibrate external camera parameters. Figure 1 shows the thin lens based camera model that we use. In the figure, w is an effective focal length which is defined as a distance between the lens center O and the image plane. d is an effective lens diameter, U is a focused distance. c is defined as a distance between the frontal position of the actual zoom lens R and the lens center O.

As shown in Figure 2, the relationship between the world coordinate (X_w, Y_w, Z_w) and the camera coordinate (X, Y) is represented by the following equations.

$$X = w\frac{r_1X_w + r_2Y_w + r_3Z_w + T_x}{r_7X_w + r_8Y_w + r_9Z_w + T_z + c} \quad (1)$$

$$Y = w\frac{r_4X_w + r_5Y_w + r_6Z_w + T_y}{r_7X_w + r_8Y_w + r_9Z_w + T_z + c} \quad (2)$$

where r_l are elements of the rotation matrix $\mathbf{R}$ and T_m are elements of the translation vector $\mathbf{T}$.

The blur width b of a point P is a function of d, w, c, U, and object distance s. From the geometric relationship of these parameters, b is obtained by

$$b = wd\left|\frac{1}{s+c} - \frac{1}{U+c}\right|. \quad (3)$$

where s equals the camera coordinate z of the point P.

By minimizing E in the following equation, we can estimate the camera parameters such as $\mathbf{R}$, $\mathbf{T}$, w, and d.

$$E = \sum_{i=1}^{n}\left\{(X_i - \hat{X}_i)^2 + (Y_i - \hat{Y}_i)^2 + (b_i - \hat{b}_i)^2\right\} \quad (4)$$

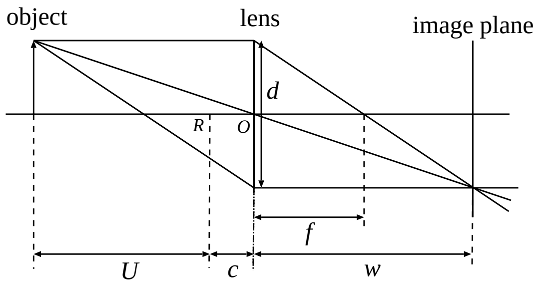

Figure 1: A thin lens camera model.

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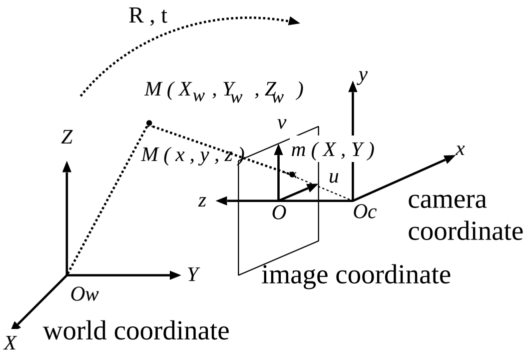
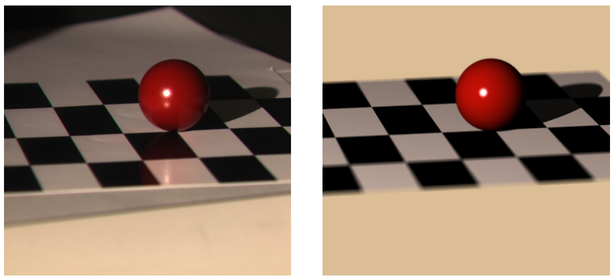


Figure 2: Relationship between world and image coordinates.

where n is the number of feature points, $\hat{X}_i$, $\hat{Y}_i$, $\hat{b}_i$ are image coordinate and blur width of the feature point P_i obtained from the image.

We have performed some experiments with real images and have evaluated the accuracy of the calibration result. From the basic experiment using checker board containing 25 feature points, we found that the average position error of feature points was 0.58 pixel and that the error was enough small to use for an image synthesis. Figure 3 (a) is a real image of a calibration target with a red spherical object, and figure 3 (b) shows the generated image using the camera parameters obtained by the camera calibration.



(a) Real image. (b) Synthesized image.

Figure 3: Image synthesis results.

3 Conclusion

This paper has presented a novel camera calibration method that takes into account both geometric information and width of blur in an image. The experimental results have demonstrated the validity of our camera calibration method and have also shown its applicability to the image synthesis.

References

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