Focal Length Calibration for Depth Recovery Using a Focusing Technique *

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Abstract

The work presented in this paper is related to *Depth Recovery from Focus*. The approach starts calibrating focal length of the camera using the Gaussian lens law for the thin lens camera model [1]. Two approaches are presented based on the availability of the internal distance of the lens.

Key Words : Active Vision, Camera Calibration, Depth from Focus, Depth Recovery.

1 The background

Using the *Gaussian lens law* we can relate the distance to the object d_o, the focal lenght of the lens f, and the distance of the image plane d_i [1].

2 Obtaining the internal distance

The distance of the image plane, i. e., the internal distance is calculated focusing the image using the Tenengrad method with a window of at least 20x20 [2]. This distance can be obtained manually or in motor steps.

3 Using the actual distance

3.1 The focal lenght and the distance function

A method for calculating this intrinsic parameter is presented. Once a range of operation has been defined, two focusing actions in both extremes of the range are performed. Relating both focused points using the *Gaussian lens law* in terms of both internal distance, we can calculate f.

$$d - d' = \frac{fD}{D - f} - \frac{fD'}{D' - f} \tag{1}$$

Once the focal lenght has been obtained for the camera situation, a distance function can be easily obtained.

$$D' = \frac{f\left((d - d') - \frac{fD}{D-f}\right)}{(d - d') - \frac{fD}{D-f} + f} \tag{2}$$

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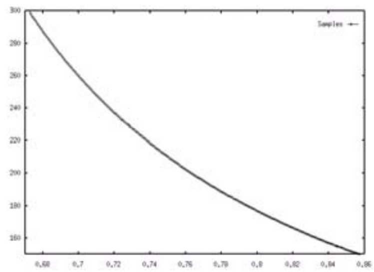

Figure 1: Empirical relation obtained relating internal and external distances in cm.

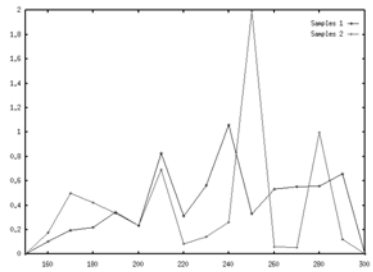

Figure 2: Error percentage between measured distance and actual distance (cm.).

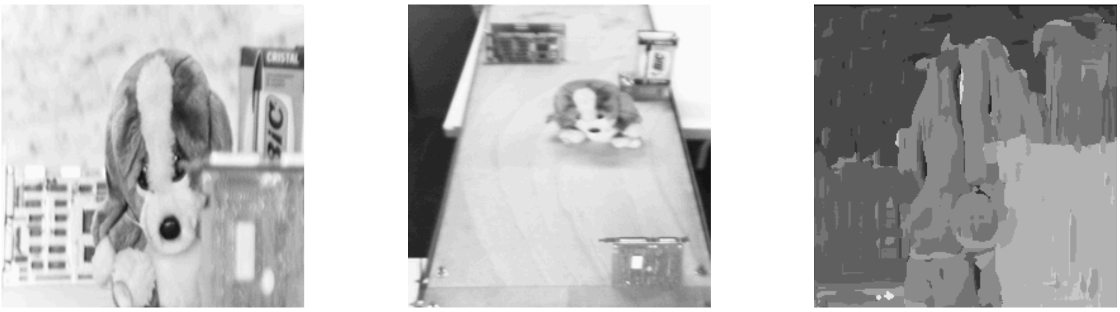

Figure 3: From left to right, the scene, the scene from another point of view and the depth map recovered using tenengrad 15x15.

4 Using the motor steps

4.1 The model

Motor steps need to be mapped to the internal distance range, at the same time we consider an additive error or offset for both distances. The external distance is considered as $D = D' + D_0$ and the internal as $d = nk + d_0$, n is the number of motor steps d_0 and D_0 are the offsets. Applying the *Gaussian lens law* we obtain an expression for the actual external distance D'.

$$D' = \frac{f(nk + d_0) - D_0(nk + d_0 - f)}{nk + d_0 - f} \quad (3)$$

5 Experiments

Using the first approach, once the focal lenght has been calibrated, it is possible to obtain the distance to the object using (2). An experiment was performed using a checkerboard test target. The relation between the internal and the external distances can be seen in Fig. 1. Sampling in the operative range we achieved the errors presented in Fig. 2.

Currently we are working with the motor steps, adjusting the parameters in (3) using a least squares method. The focal lenght obtained is not far to the one obtained by rotating the camera, but the distance errors, focusing manually, are 5/100 in this moment.

References

[1] E. Hecht y A. Zajac. *Óptica.* Addison-Wesley 1988.

[2] E.Krotkov. *Focusing.* International Journal of Computer Vision, 1, 223-237 (1987).