A Simple and Accurate Camera Calibration for the F180 RoboCup League

Ryad Benosman, Jerome Douret, and Jean Devars

Laboratoire des Instruments et Systèmes d'Ile de France,
Université Pierre et Marie Curie,
T 22, coul 22-12, 2eme,
4 place Jussieu,
75252 Paris cedex 05,
Boite 164, France
rbo@lis.jussieu.fr, jdouret@citilog.com, devars@ccr.jussieu.fr

Abstract. Camera calibration is a very important issue in computer vision each time extracting metrics from images is needed. The F180 camera league offers an interesting problem to solve. Camera calibration is needed to locate robots on the field with a very high precision. This paper presents a method specially created to easely calibrate a camera for the F180 league. The method is easy to use and implement, even for people not familiar with computer vision. It gives very acurate and efficient results.

1 Introduction

The robocup F180 league relies on computer vision to locate its robots. Camera calibration is then a very important task to achieve as any slight error in the positionnning will introduce uncertainities in the localization of robots leading to wrong decisions of the behaviour.

Most camera calibrations methods that can be found in the litterature are dedicated to specific tasks, mainly to retreive depth from a binocular vision system. These methods are in most cases too complicated and give too much information that are not necessary in the case of the F180 league.

Camera calibration is usually applied, to find a model of a camera. Calibration patterns are usually used. Since few years in special cases where the camera describes a motion, it is possible to determine the unknown parameters, but these techniques remain uncertain due to degenerencies of the mathematical models[1].

Camera calibration tries to determine the intrinsics and extrinsics parameters of the camera. Intrinsics parameters are the pixels' size, the focal length and the image coordinates of the camera viewpoint[2]. The extrinsics parameters concern the rotation and translation to be applied to pass from the camera coordinates system to the world coordinates system, represented by the calibration pattern.

Retreiving the intrinsics and extrinsics parameters is not needed in the F180 camera configuration. In fact the field and the top of the robots are flat. As we

A. Birk, S. Coradeschi, and S. Tadokoro (Eds.): RoboCup 2001, LNAI 2377, pp. 275–280, 2002.

will see, a simple use of colineations [6]would easely solve the problem. Camera parameters are not even needed.

Many problems in computer vision require a determination of the mapping between points of a scene and their corresponding image locations.

We can then decompose the projection problem. Knowing the position of a point in the field we can compute its location in the image. Applying the opposite transformation, we can, given a pixel in the image compute its line of sight vector [3][4][5].

The simpliest model to describe camera geometry is the pinhole model. Light rays coming from in front the camera converge at a point called the focal point and are projected onto the image plane at the back of the camera. To avoid having a reversed image the image plane is usually positionned in front of the camera. The distance between the focal point and image plane is called the focal length.

A lens can be modelled by a pinhole model, but as a lens is rarely perfect, we usually have to correct the lens distorsions. The paper is organized as follows: the first section introduces the linear transformation which are usefull to map the projection between the image and the field. Section three deals with the problem of correcting lens distorsions. Section four gives a solution to handle the mapping between the image and the field for points that are at different heights. Finally section five gives practical information on how to implement the method.

2 Determining Linear Transformation

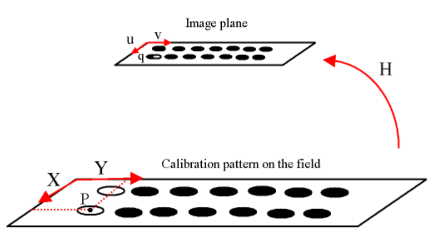

Fig. 1. Linear interpolation between image coordinates and field's points

Let q be an image point which projective coordinates are $[u, v, 1]$ (see Fig.1) its cooresponding point on the field is the point $P = [x, y, 1]$. The relation that connects these points is linear. The linear transformation between q and P is given by :

$$q = HP$$

Where H is 3×3 matrix, given n measurments on each plane we can form the over-determined system :

$$[p_1, p_2 ... p_n] = H [P_1, P_2, ..., P_n]$$

or

$$p_i = HP_i$$

The system can be solved using least squares methods by computing the pseudo-inverse matrix

$$H = \left[P_i^t P_i\right]^{-1} P_i^t p_i$$

3 Correcting Lens Distorsions

Lens distorsions lead to a wrong repartition of the incoming rays on the CCD matrix.

The distorsion is radial, which means that a point is translated according to a coeficient $k : d = d \rightarrow \Delta d$.
We have the following relation that links image coordinates to the radial translation :

$$\frac{\Delta u}{\Delta d} = \frac{u}{d}$$
$$\frac{\Delta v}{\Delta d} = \frac{v}{d}$$

We have the following relations where u_d and v_d are the distorted image coordinates and u_{nd} and v_{nd} the non distorted ones :

$$u_{nd} = u_d + \Delta u_d = u_d * \left(1 + k_1 * d^2 + ... + k_2 * d^{2n}\right)$$
$$v_{nd} = v_d + \Delta v_d = v_d * \left(1 + k_1 * d^2 + ... + k_2 * d^{2n}\right)$$

The calibration pattern provides a high number of points, the system is then over-determined we can then find an estimation of the k_i as explained in the previous section. For a better accuracy we used a pattern composed of circles where the gravity center of each circle is extracted with a subpixel accuracy.

4 Taking into Account the Height

The Linear interpolation gives a mapping between field points and image points, if we just apply the transformation on the image points we will not take into acount the error introduced by the height of the robot as shown by Fig.2. We need then to compute a second linear transformation between the image and another plane at a different height L as shown by Fig.3

For each calibration pattern point q appearing on the image using the linear tranformations estimated, we compute its corresponding points in the field (plane P_1) and in P_2 the second calibration plane. Knowing the height L separating the field and the second calibration plane, points P_1 and P_2 can be rewritten as follows :

$$P_1 = (x_1, y_1, 0)$$
$$P_2 = (y_1, y_2, L)$$

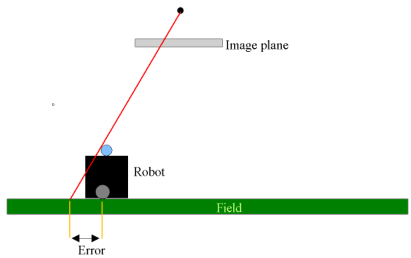

Fig. 2. Localization's errors

We can then compute vector P_1P_2, vector $P_1P_2^n$ is the normalized version of it. We then calculate a scalar $\lambda = \frac{P_1P_2}{P_1P_2^n}$. Finding the position of the pixel point q on a virtual plane located at a height $L^{'}$ is then given by : $\lambda^{'} = \frac{L^{'}\lambda}{L}$. The coordinates of point P_3 on the virtual plane at height $L^{'}$ can be then be retreived as follows :

$$P_3 = P_1 + \lambda^{'} P_1P_2^n.$$

Once the position of point P_3 is known and supposing we apply this to all image points we can then estimate a linear transformation between the image coordinates and the coordinates of their corresponding points on the virtual plane located at a height $L^{'}$.

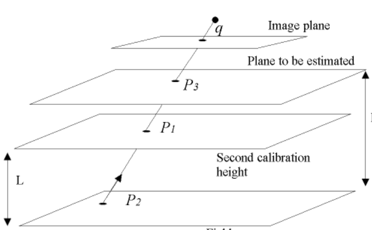

Fig. 3. Computing pixels mapping on a virtual plane placed at a height L'

Fig.4 illustrates the experimental results, we can clearly see the error in the positioning according to the height.

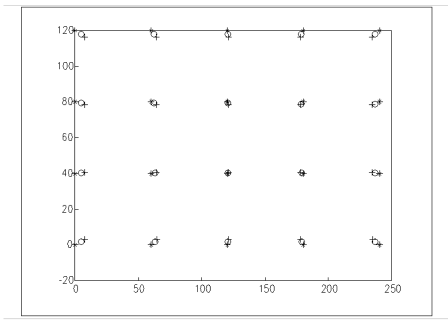

Fig. 4. Experimental results of the estimation of a virtual plane $*$ represents the position of points on the field, o points on the second calibration plane, $+$ the estimated position of points on the virtual plane

5 Practical Use

UPMC-CFA team used this calibration method to locate its robots during the RoboCup European championships and RoboCup 2000. The method is very simple to implement, the first advantage is that computing a robot's position is not time consuming as it deals with four multiplications and two additions. We computed a linear transformation for each present height. One for the ball, one for our robots and one for the other teams. The use of the ping pong ball was also taken into account which means two other transformations. The method was very precise specially if subpixel information are extracted from the image. Most of the errors in the localisation were due to the fact that it is hard to know the angle of view of the ping pong ball, inducing wrong height estimations. We solved this problem which also concerns the ball by computing two transformations one on the height of the ball and another on the three quater of its height, we then calculated a mean matrix. We used a calibration pattern made of paper and for the second height we used plants pots which top was painted green. Fig.5 gives an idea of what the calibration scheme. The code will be soon available for download on the url : www.robosix.org.

6 Conclusion

This paper presented a calibration method that we beleive presents all the requirements for a very simple calibration technique for teams willing to participate to the F180 league and not familiar with the computer vision field. The method

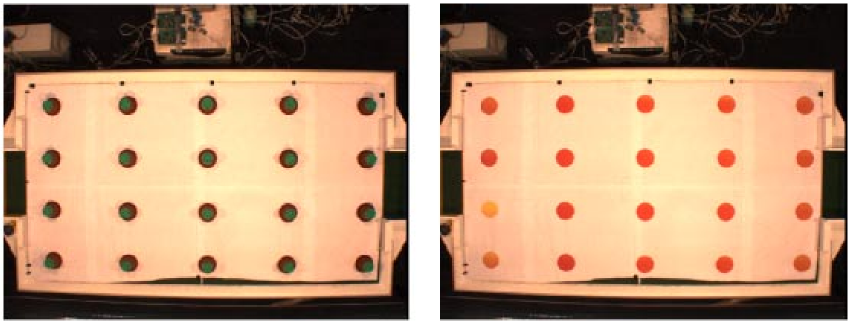

Fig. 5. Calibration pattern

presents many advantages which are mainly simplicity, accuracy and efficiency. Compared to other calibration methods, it does not need to retreive any camera model and deals directly with linear equations very easy to solve. The method is also very easy to implement as it deals with a small amount of data. The accuracy can be increased using more points. The method is not time consuming allowing quick computations. The results and images presented in this paper are those used during the last robocup.

References

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