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A Study on Image Calibration Technique for Autonomous Robot

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***Abstract*— Camera calibration and image processing is the most important factor in computer vision. Some of the techniques that are applied in the process of calibration are linier, technical and non technical linier with two stages. Calibration techniques can be implemented, for example in the Autonomous Robotic Soccer. The process of calibration is one of the key factors of success in robotic soccer game. Currently, the team succeeded in doing with the camera calibration is a good team who will be able to win the match.**

***Keywords*— image calibration, technique, robotic soccer.**

I. INTRODUCTION

Autonomous robots need to track object [1]. Object tracking relies on predefined robot motion and sensory model. The robot vision is to estimate the positions of target. In this research, we study a scheme to apply computer vision for autonomous robot movement. The scheme is concerning to the development of calibration vision. The system, will find out the precise object based on image calibration on CCD camera. The further works are to develop automatic calibrations system and image processing algorithm to perform measurement of calibration parameter. In this research, we divide the system into hardware and software framework.

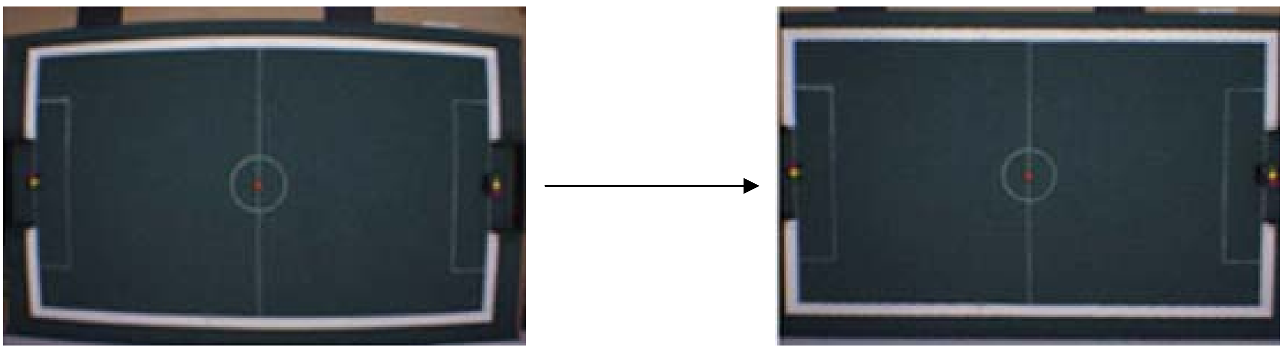
A camera's calibration process is one of the most important problems in computer vision. Its purpose is to obtain through a camera, an estimation of the parameters to transform a point in the real world to a point in an image. To carry out the camera's calibration, some techniques have been applied for example based on vanishing points [2].

In contrast, object can move randomize anywhere in a path. The system integrates lighting system, acquisition devices or camera, personal computer, image processing software, and Autonomous Robot. The camera will capture images under suitable lighting condition [3], [4]. Then, the image enters the software to be analyzed and processed. Although most of typical camera is sensitive to the environment then it would be necessary to control the lighting condition. The lighting condition can be controlled using dimmer control based on the requirement of object being observed. However, camera calibration is crucial in order to obtain undistorted image [5], [6].

It is crucial to extract the camera parameter in order to obtain normal images. Then, fundamental matrix has to be estimated to minimize the correspondense problem is to obtained through camera, an estimation of the parameters to transform a point in real world to a point of image. Fig. 1 shows distorted image and normal image. The distorted image was captured by using CCD camera.

II. AUTONOMOUS ROBOT

Autonomous robots are intelligent machines capable of the tasks in the world of themselves, without explicit human control. Examples range from autonomous helicopters to Roomba, the robotic vacuum cleaner. Autonomous robot was ascribed to robotics systems function without human supervision. In fact, from ancient times, people have tried to build systems that have no direct control [7]. Autonomy is somewhat flexible, that there are different "forms of autonomy" to inconsistencies in its use. Two of the most important are: energetic and computational autonomy [8].



(a) Distorted Image (b) Normal Image

Fig. 1 Distorted and normal image

Until today, autonomy has mostly from the perspective of the calculation. For example, in the event of a battery-powered robot that will carry out its task without external intervention. After completion of the task, or if the battery is too low, the robot will back to the base for charging and /or new instructions. On the one hand, certain aspects of the robot's behavior can be seen as autonomous as computers and control decisions. On the other hand, without a human in the loop, the robot would not be able to return to his energy to the task. In this sense, our long-term goal is to develop a robot, the energy for themselves from their own environment. In this context, our definition of an autonomous agent is rather that of Stuart Kauffman, but without the burden of self-reproduction [9].

Research on autonomous robotic in many areas has been done. One of the research areas is Robotic Soccer. Robotic Soccer is a five on five soccer competition between small, fully autonomous robots. The player diameter is 18 cm (12x12x15 cm), and they play on a field as big as that used in table tennis. The games are involves 5 subsystems, i.e. Vision, Strategy, Wireless Communication, Onboard Control, and Hardware Implementation, essential for avoiding opponent's, directing the ball the opponent goalie, and defending own goalie from the opponent's defence.

The complete design of the robot soccer system [10] is shown in Fig. 2. The system is divided into hardware and software frameworks. The hardware framework is consists of the field for robot played soccer, autonomous robot, CCD camera, computer, bluetooth access point, and lighting system. Assume that field has a part that locate robot to moving. While ball is moving over on the field, camera will capture images of autonomous robot and the ball around the field. The images will be transferred into computer via firewire port. Furthermore, images will be processed and analyzed by the software. The system will send instruction of strategy of robot soccer and strategy for doing activities.

III. METHODS

A. Image Processing Framework

The design of the image processing on the mobile robot cannot be released from the device sensors and artificial intelligence [11]. Therefore, the vision system is one of the main part in an autonomous robot. This vision of the robot is the ability to feel any changes in their environment and then processed by the system so that the robot can respond to conditions or circumstances that occur. Vision systems in autonomous robots are generally not only one, but they can be more than one so that further research is needed on the stereo vision robot that can catch the object in three dimensional.

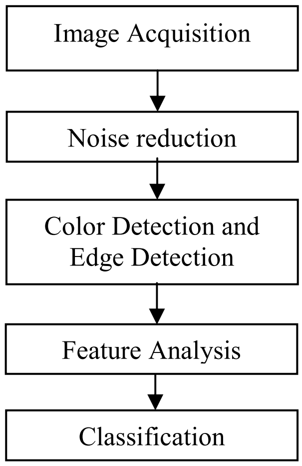


Fig. 3 Image processing framework

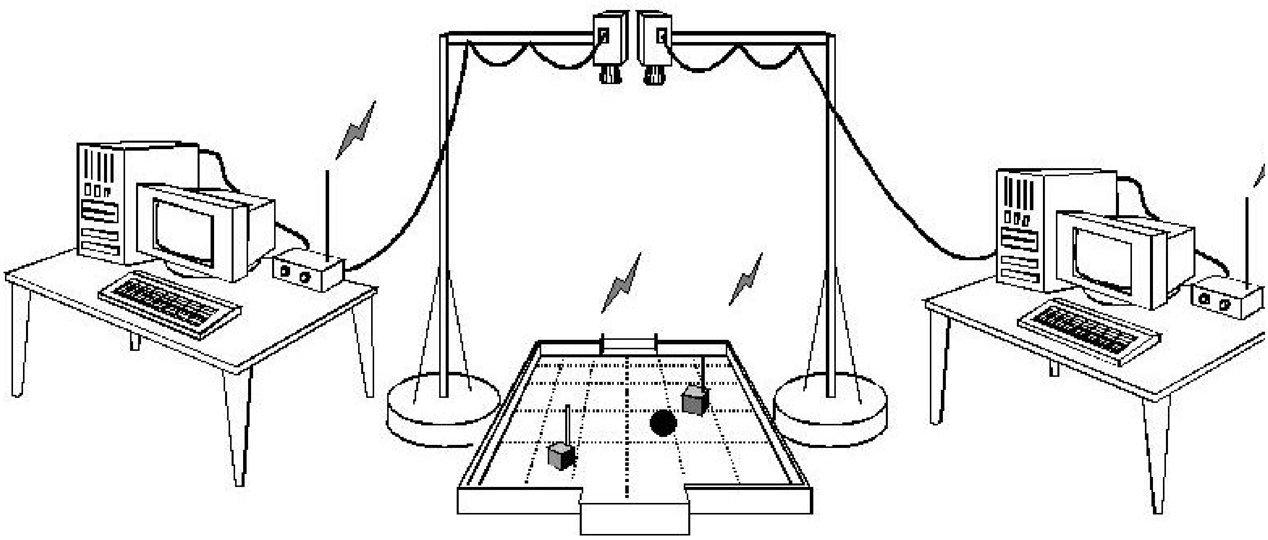


Fig. 2 System design

The main purpose of vision system is the process to recognize the object by the camera. The process to recognize the object on the mobile robot is the process of mapping the environment so that the robot can recognize the direction to get the object and can avoid the obstacle or barrier. As shown in Fig. 3, the processes of introducing the image of the autonomous robot are as follows [12]:

1. Image Acquisition – This step is aim capture and transmits the image from the scene to computer host.
2. Noise Reduction – This step suppress noise introduce by acquisition process.
3. Color Detection and Edge Detection – This step detects sharply changes in image.
4. Feature Analysis – This step is aim to extract feature descriptors and analysis.
5. Classification – Compares feature descriptor from previous step and its standard requirement.

B. Image Calibration

A process of calibration the camera is one of the most important problems in computer vision. Its goal is to get through a camera, to estimate the parameters of a transformation in the real world to a point in an image. To perform the calibration of the device, some techniques based on vanishing points, planar patterns and homographies, one-dimensional objects, and single images from parallelepipeds [13].

Camera calibration is the process of determining the internal camera geometric and optical properties, as the intrinsic parameters, and/or the 3-D position and orientation, which are extrinsic parameters of the camera frame relative to a certain world coordinate system. These camera calibration parameters used to determine 3D world coordinates from the 2D image coordinates, as the computer. For all applications where accurate 3D world coordinates to be determined from their 2D image coordinates, the camera calibration with a higher accuracy will gain an initial [14].

Most of the methods for camera calibration are usually based on the pinhole camera model. In the first step, the camera is taking an ideal (undistorted) image, with a perspective projection with pinhole camera geometry, example taking into account the intrinsic parameters of camera model and lens distortions, which are two types: radial and tangential. Thereafter, the calibration parameters R (rotation matrix) and T (translation vector) are defined by a rigid equation, the transformation from the camera coordinate system into the object world coordinate system [15].

The calibration begins with the collection of a sample image from the camera. After images were acquired, a valid vision is for the camera. The horizontal and vertical limits of the vision field must match the same physical points of the pattern. The third step consists of the horizontal calibration for the acquired images. In this step, the horizontal correction of images is resulting in new horizontally undistorted images. The fourth step refers to the vertical calibration of the resulting images from the previous step. The new images are horizontal and vertical distortion free. At the end of the procedure, with the same pixel coordinates in the images acquired by the camera with the same physical location of the pattern.

In the last step of calibration, it is necessary to establish a relationship between the image and model points to a linear relationship in the horizontal component and a polynomial relationship in the vertical component. Fig. 4 shows the calibration technique for the camera.

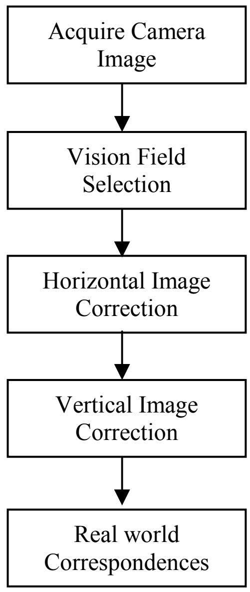


Fig. 4 Calibration technique

C. Horizontal Image Correction

The horizontal image correction for the camera is in the following steps:

(a) Acquisition of a number of vertical points from the image, the horizontal zeros of the image after image correction horizontally.

(b) Polynomial determining the relationship between the position (y) the vertical and the position (x) of horizontal points (1)-$x_{initial, CAM}$ (y).

(c) Acquisition of a number of vertical points from the image, the horizontal borders of the end of the horizontal image after image correction.

(d) Polynomial determining the relationship between the position (y) the vertical and the position (x) of horizontal points (2)-$x_{final, CAM}$ (y).

(e) The creation of a new horizontally corrected image, with horizontal length of (3), where the position in x of each pixel compared to the distorted image is determined by (4)-$x_{c, CAM}$ (x, y). The Y coordinate of each point remains the same [15]:

$$x_{initial,\, cam}(y) = f(y) \quad (1)$$

$$x_{final,\, cam}(y) = f(y) \quad (2)$$

$$I_{width} = W_{max\ rectangle}\, N_{rectangles} \quad (3)$$

$$x_{c,cam}(x,y) = \frac{x - x_{initial}(y)}{I_{widthc} / (x_{final,cam}(y) - (x_{initial,cam}(y))}$$

$$0 \leq x < I_{Width};\ 0 \leq y < I_{Height};\ 1 < cam \leq 2 \quad (4)$$

where cam is the camera number; $W_{max\ rectangle}$ of the dimension in pixels of the width of the widest rectangle image this value must be equal for an images; $N_{rectangles}$ the number of rectangles between two points, the horizontal zero of the image, and the horizontal end of this limit value must be the same images and I_{Widthc} image after image width horizontal correction.

D. Vertical Image Correction

The vertical image correction for the camera divided into the following steps:

(a) Acquisition of a number of horizontal points from the image, which is the vertical zeros of the image after correction of vertical image.

(b) Polynomial determining the relationship between the position (x) from the horizontal and the position (y) of the vertical points (5)-$y_{initial,\, CAM}$ (x).

(c) Acquisition of a number of horizontal points from the image, the borders of the vertical end of the image after correction of vertical image.

(d) Polynomial determining the relationship between the position (x) the horizontal and the position (y) of the vertical points (6)-$y_{final,\, CAM}$ (x).

(e) the creation of a new vertically corrected image, with a horizontal length of (7) where the position in y of each pixel compared to the horizontally corrected image, it is clear from (8)-$y_{c,\, CAM}$ (x, y). The X-coordinate of each point remains the same [15]:

$$y_{initial,\, cam}(x) = f(x) \quad (5)$$

$$y_{final,\, cam}(x) = f(x) \quad (6)$$

$$I_{Heightc} = H_{max\ rectangle}\, N_{rectangles} \quad (7)$$

$$y_{c,cam}(x,y) = \frac{y - y_{initial}(x)}{I_{Heightc} / (y_{final,cam}(x) - (y_{initial,cam}(x))}$$

$$0 \leq x < I_{Width};\ 0 \leq y < I_{Height};\ 1 < cam \leq 2 \quad (8)$$

rectangle where H_{max} is the dimension of the pixels in the height of the highest image rectangle must be equal to this value for an image; $N_{rectangles}$ the number of rectangles between two points, the vertical zero of the image, and the vertical end of this boundary value should be the same images, and the picture $I_{Heightc}$ amount of vertical correction of this value must be the same for images.

IV. Expected Result

Distortions can be classified by "barrel distortion" (also known as negative bias) and "pincushion distortion" (also known as a positive bias). The distortion is defined by the following formula. The standard lens distortion ratio is ≤ ± 3% [16].

$$(\%) = \frac{|h_0' - h_0|}{h_0} \times 100\ \% \quad (9)$$

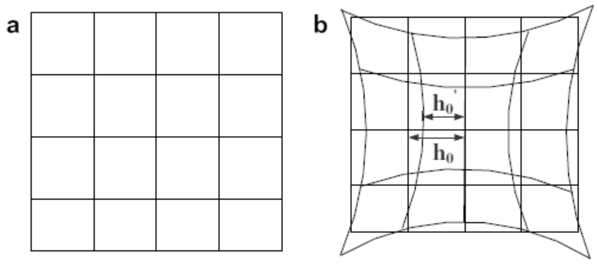


Fig. 5 Definition of distortion

Distortion is determined by the difference in the distance of the image and the optical axis, according to the different lateral magnification. We know that the bias is a problem in the optical design. The ultimate goal of the lens designers is to eliminate this problem, especially in the design of wide-angle lens. Fig. 5 shows the definition of distortion.

In many cases, the distortion problem is complicated and must be accompanied by a more accurate method. The measurement of the distorted images by using a CCD camera system developed. In our research, we propose a modified linear regression algorithm, the position of a moving on CCD camera for the automatic distortion measurement system. Our research will produce a new automatic distortion calibration for online systems. In the distortion automatic measuring system, a modified linear regression algorithm determines the position of a moving object.

V. Conclusion

Research on image calibration in many areas has been done. Camera calibration in the framework of three-dimensional machine vision is the process of determining the internal camera geometric and optical characteristics (intrinsic parameters) and / or 3-D position and orientation of the camera relative to the framework of a certain world coordinate system (extrinsic parameters) [17]. In many cases, the overall performance of the machine vision system strongly depends on the accuracy of the calibration of the camera.

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