Algorithm of Location of Chess-Robot System Based on Computer Vision

Shuying Zhao[1], Chao Chen[1], Chunjiang Liu[2], Meng Liu[1]

1. School of Information Science & Engineering, Northeastern University, Shenyang, 110004
E-mail: zhao_shy@163.com

2. Preparing Office of Science Park of Shenyang, Shenyang, 110015
E-mail: syttcjj@163.com

Abstract: This paper demonstrates the principle of the robot chess system based on computer vision. According to improved Hough transform, a new image recognition method was proposed to settle the problem of the Location in the robot chess system. Application results show that this method has the high performances in robustness, speed and accuracy.

Key Words: Chess-Robot, Hough transform, Image Processing, Curve Detection

1. INTRODUCTION

The precise target location is always the difficult and hot spot of computer vision research. In this system, because of the influence of light condition and image pickup equipment, the process of collecting images produces various noises, and the precise chessman location is a key technology. Main method of detecting digital graphics, such as straight line, circle and elliptic, is always Hough transform. Hough transform was proposed at 1962 by P.V.C Hough which is a patent technology [1] based on images' edge detection. Hough Transform, a new image detection ideal, calculates the set of parameter space according to every pixel point of images' edge and judge graphics. Many scholars have proposed lots of improved methods. Jack Sklansky proposed slope detection and circle localization [2], simplified calculation by analyzing parameter space [3]. G.C. Stockman proposed the method [4] of template matching and hardware acceleration. Wayne Niblack proposed precisely locating straight line algorithm [5] based on prediction estimation and he also improved this method [6]. So far, it has not been analyzed detailly on the accuracy and efficiency of locating circle.

This paper proposes image recognition algorithm to improve Hough transform based on studying the algorithm, reduces the calculation by using location method based on template matching in parameter space. The paper, based on analyzing error, proposed the self-adaptive block operation and threshold estimation which realized the efficient and precise chess locating. As many core algorithm, it has been successfully applied to computer vision area.

2. PRINCIPLE OF VISION RECOGNITION IN CHESS-ROBOT SYSTEM

The chess-robot system is, based on computer vision, mainly composed of computer vision system, computer workstations, robot control system, industrial manipulator and chessboard. This has four different models including Chinese chess, the final phase of Chinese chess, Jumping chess and Gobang interacting with audience at the same time.

The principle of the chess-robot system is presented as follow. System will finish the chessman recognition and location after acquiring images of the chessboard from computer vision system. Then, system analyses the state of the chess game and sends instructions according to the decision system in computer workstations. Last, the industrial manipulator collects and drops the chessman. At the same time, the audiences will be hinted by sound equipment to play chess with robot. After that, system acquires the real time information of chess game again according to the computer vision system, and inputs the informations to the computer workstations to implements a whole cycling process. The locale photo of the system is shown in Fig.1, and the framework picture of the system is shown in Fig.2.

Fig 1.Chess-robot

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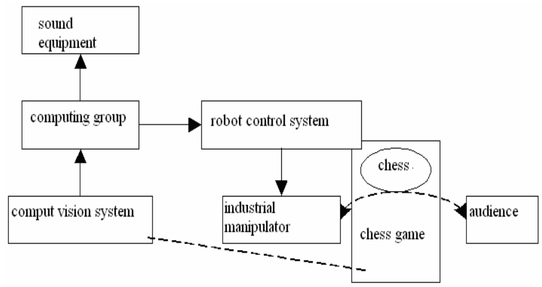


Fig 2. Structure diagram of chess-robot system

3. FAST AND PRECISELY CHESS LOCATION ALGORITHM

Chess-robot competes in four chess games at the same time, so it needs better performance in real time. Meanwhile, the industrial manipulator can not pick up the chess as usual when there is too much chess location error. Above all, this system mainly studies how to fast and precisely locate chess.

3.1. Traditional Hough transform

Hough transform is one of the basic methods of recognizing geometric shape from images. And it's basic thought of detecting circle is that mapping the edge points in image to parameter space, then accounts the accumulated value from all coordinate elements in parameter space and judge the size and position of circle according to the accumulated value. The equation of circle in descartes coordinate system is

$$(x-x_0)^2+(y-y_0)^2=R^2 \tag{1}$$

To locate the position of circle center (x_0 , y_0), we need 3-d parameters matrix (x,y,R) which generate parameters space with accumulator. When 3-D parameters matrix (x,y,R) satisfying the equation (1), the corresponding coordinate of maximum $P_{\max}(x_0,y_0)$ is the coordinate of the circle (x_0,y_0) after accumulating relative units in $\boldsymbol{P}(x_0,y_0)$.

3.2. Pretreatment

In order to eliminate noise and extract edge at the real experimental conditions, we presorted an image as background image without any chess. After that, we subtracted the image extracted real-time with the background image that will produce an image with less noise which reduce the calculating work and enhance the calculation efficiency. Subtracting algorithm is a simple and effective method to extract target without the limitation in stationary background. The background image is $f_0(i,j)$, and the real-time image is $f_1(i,j)$, then awaiting treated image is

$$f(i,j)=f_1(i,j)-f_0(i,j) \tag{2}$$

Hough transform mainly use the information of image edge, it's precondition is precise extracting image edge. Laplace second-order edge detection operator is used to processing the above images in experiment, is second-order differential operator which is a scalar. It is sensitive to saltation gray scale that it can extract image edge well. We can use the difference to approximate it in digital image. The Laplace calculation of $f(i,j)$ is

$$\nabla f(i,j)=f(i+i,j)+f(i-1,j)+f(i,j+1)+f(i,j-1)-4f(i,j) \tag{3}$$

3.3. The chess recognition algorithm based on improved Hough transform

This paper proposes the improved Hough transform algorithm based on analyzing the principle of Hough transform. Based on analytic expression (1) and the thought of original Hough transform, the original Hough transform algorithm is accelerated by template matching. Based on self-adaptive statistical algorithm, the problem of time-consuming exists in traditional Hough transform $f_0(i,j)$ is solved effective by the possible circle center position $\boldsymbol{P}_{possible}(x_0,y_0)$ instead of the maximum $P_{\max}(x_0,y_0)$ with adding window processing to locate the central position (x_0,y_0) . At the same time, we realize the function of precisely locating position of every circle center in complex round background. Algorithm flow is shown in Fig3.

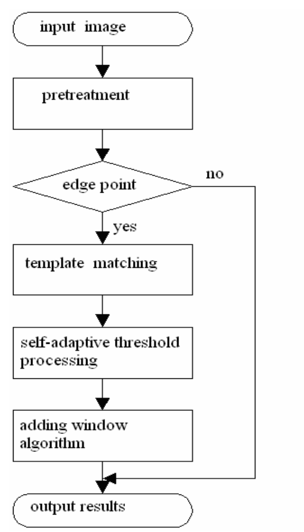


Fig 3.Improved Hough transform algorithm flow

The thought of Hough transform is that the mapping of every edge point is a circle in original image space to parameter space. In traditional algorithm, the huge calculation work is produced by detecting 3-D parameter matrix (x,y,R) point by point whether they are fit for the analytic expression (1). Because of the particularity of the circle, when the detection curve is a circle, it can be transform to a circle with the center (x,y) and the radius R in parameter space. The original points passed by are accumulated by accumulator $\boldsymbol{P}(x_0,y_0)$ in parameter space. Furthermore, it can process the way of template matching in parameter space by creating template. As shown in Fig.4, solid line is edge and dashed line is projection of edge in parameter space, the central point O crossed by dashed line circle is the position of circle center in image space. The position of circle with the center (0,0) and the radius R is stored in template created. If it is accorded with the condition of edge point by judgment, the value of accumulator $\boldsymbol{P}(x_0, y_0)$ will be calculated in template. The template matching method reduces the huge calculation amount.

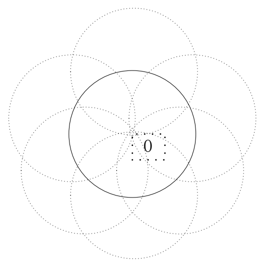


Fig 4. Principle diagram of template matching

If the value of accumulator $\boldsymbol{P}(x_0, y_0)$ obtained through template matching algorithm exceed the threshold $P_{\text{threshold}}(x, y)$, it is the possible center position $\boldsymbol{P}_{possible}(x_0, y_0)$ by judging the self-adaptive threshold $P_{\text{threshold}}(x, y)$. As shown in Fig.5, the value of point in parameter space accumulator $\boldsymbol{P}(x_0, y_0)$ could be the possible position of circle center $\boldsymbol{P}_{possible}(x_0, y_0)$. The more edge points it has, the more value of accumulator is close to value of engineering test.

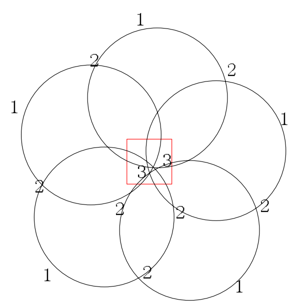


Fig 5. Principle of accumulator value of parameter space

We can draw a conclusion; the value of accumulator $\boldsymbol{P}(x_0, y_0)$ in parameter space will be larger when the distance between parameter space and the position of circle center is shorter. At the same time, the certain error may exist before detecting center and real center because of the existence of various noises. After we analyze the mean square error [3] and the Gaussian random error, the result shew that the possible position of circle center $\boldsymbol{P}_{possible}(x_0, y_0)$ includes the real position of circle center. According to the statistics, it is improved the migration of circle center that cause the random error.

Self-adaptive threshold $P_{\text{threshold}}(x, y)$ is calculated based on the result of accumulator. If it is 0.8 times more than $P_{\max}(x_0, y_0)$ it will be the reasonable value according to the experiment result. In order to improve the precise, we designed the adding window algorithm. As is shown in Fig.4, the red window is the added window. According to judging self-adaptive threshold, the possible center $\boldsymbol{P}_{possible}(x_0, y_0)$ is processed by adding window algorithm. The width of window is the width of 8 pixels. The possible center position $\boldsymbol{P}_{possible}(x_0, y_0)$ is processed by adding window. We can get the equation of center position in window range after superposition and taking mean value.

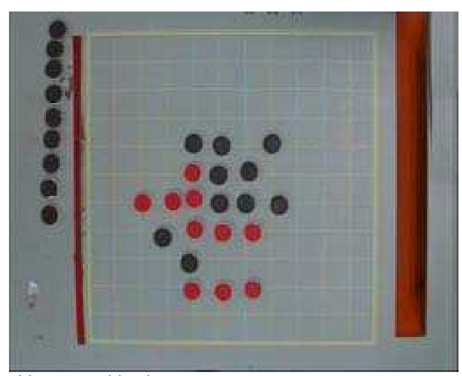
$$x_0 = \frac{\sum x_i}{i}, y_0 = \frac{\sum y_i}{i} \tag{4}$$

Among them, i is the number of the possible circle center determined by self-adaptive threshold in the window, x_i, y_i are the coordinates of the position of the possible circle center. Center errors caused by the changing of light condition are improved effective by determination of self-adaptive threshold and adding window algorithm, It achieves the goal of improving the precision.

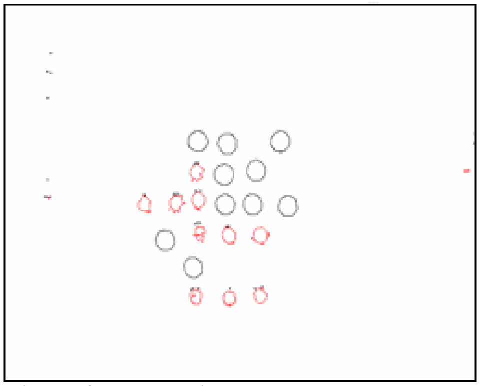
4. EXPERIMENTAL RESULTS

This recognition algorithm has practical effect in application. To show the result of the location recognition of chessman conveniently, we mark the green region among red chessmen and blue region among black chessman as the possible centre of the circle $\boldsymbol{P}_{possible}(x_0, y_0)$ which is located by the algorithm. The centre of the crossing-forked is the located center of the circle by the algorithm. The experiment result is shown in Fig.6.

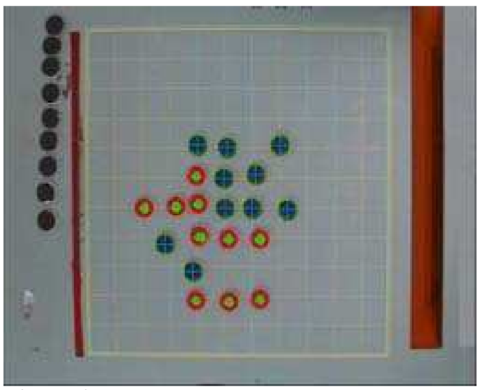
The result indicated that all the chessman appeared in chessboard achieved the accuracy location. After the detection of the running of the practical system, the recognition rate can reach 98%, the recognition time is in 10ms level, and the recognition error is within 1 pixel, which improved that we achieved our expected result.



(a) Awaiting recognition image



(b) Edge image after preprocessing



(c) Location results

Fig.5. results image of recognition chessman

5. RESULTS

In the paper, we propose a improved Hough transform algorithm based on the analysis of the principle of Hough transform which aims at the difficult and important problem in the accuracy location of chessman in the chess-robot system, the practical running result indicated that the computer vision recognition subsystem running in this algorithm can support the whole running of the chess-robot effectively and in real-time, also reliability and Robust.

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