# A Pattern Recognition System Based on Computer Vision
## ——The method of Chinese Chess recognition

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## Abstract

*A Chinese chessman pattern recognition system is presented. First, system structure is introduced, and chessman image pretreatment is discussed. Then primarily discusses the chessman recognition algorithms. Because of direction haphazardry, chessman recognition is quite different from character recognition. This paper presents two kinds of chessman recognition algorithms — RC and concentric circle algorithm for feature extraction. Then choose a relatively suitable recognition algorithm by comparing their time complexity and accuracy.*

*Index Terms — computer vision, Pattern Recognition, chess, algorithm*

## 1. Introduction

As one of the quintessence in Chinese traditional culture, Chinese chess is very popular, and lots of users register Chinese chess game on Internet. However, it is insufficient in playing on computer, because it can't produce a high reality scene. Currently companies are prepared to design chess robot which key technology is the pattern recognition. In the study, it is the main task of pattern recognition to recognize location information and types of chessman on the chessboard. There are more recognition researches of character than chessman, such as "Chinese Character Recognition Based on SOM and Triangle Feature Extraction"[1], "A Character Recognition System Based on FPGA"[2] and "Deformed Letter Recognition Based on Similarity between Binary Trees"[3-4]. Because of direction randomness, chessman recognition is quite different from character recognition, and the character recognition can not be directly used in chessman recognition. Thus it needs to discuss chessman recognition.

## 2. System structure

As shown in Fig 1, the hardware consists of CCD Camera, Video Capture Card and Computer. The system works as follows. Video Capture Card converts the analog image signal captured by CCD Camera into digital image signal, and sends digital signal into computer to be processed by software. The software recognizes chessman location information. Then chessman image is segmented from overall image. Finally, recognizes the chessman type using the image.

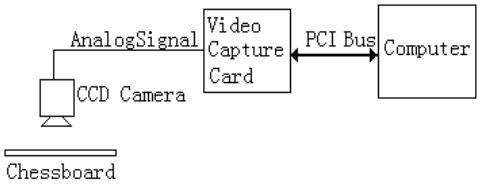



Fig 1 Hardware structure

According to the functions, the software is divided into image capture, chessman location, image segmentation and chessman recognition module [5]. Image capture module mainly controls Video Capture Card capture images from CCD Camera; Chessman location module determines the location information of the chessman on the chessboard; Image segmentation module segments chessman image from overall image. Chessman recognition module recognizes the chessman type. This paper focuses on chessman recognition module, which is divided into pretreatment and chessman recognition.

## 3. Image pretreatment

It is the main purpose of image pretreatment to separate character from the chessman image. Image preprocessing includes gray processing, binarization and filtering.

### 3.1. Gray processing

Gray processing converts color image into gray image by calculating the relative number recording as [6]

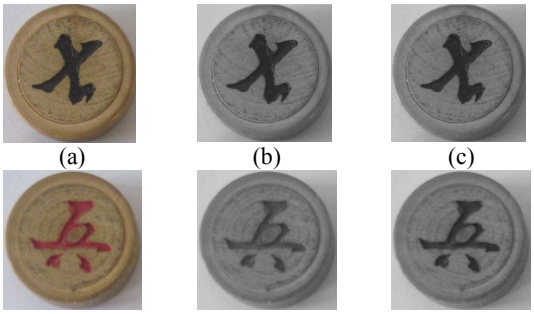
$$Gray=0.299R+0.587G+0.114B \quad (1)$$

Chessman color is divided into the black and red. We get a quite distinct gray image (Fig2 (b)) of black chessman by equation (1); while the gray image (Fig2 (e)) of red chessman is not ideal as a result of minor contrast between the foreground and background. On the other hand,

experiments suggest that green component of chessman image have strong anti-interference capability. Therefore, we propose equation (2).

$$\text{Gray}=1.0\,G \qquad (2)$$

The gray image effects of black and red chessmen are more ideal used formula (2), as shown in Fig2 (c) and Fig2 (f).



(a) (b) (c) (d) (e) (f)

Fig 2 Gray processing

### 3.2. Binarization

The purpose of binarization is to separate foreground character from gray image. The main influential factor is to select the threshold [7]. There are some methods to select threshold, such as global threshold, local threshold and dynamic threshold. According to the features of Chinese chess, we adopts optimal threshold based on gray histogram [8] fitting curves.

First, calculate the gray histogram (Fig3 (b)). If the interval of [0, 255] is divided into $0<x_0<x_1<\ldots<x_n<255$, then the fitting model is given by

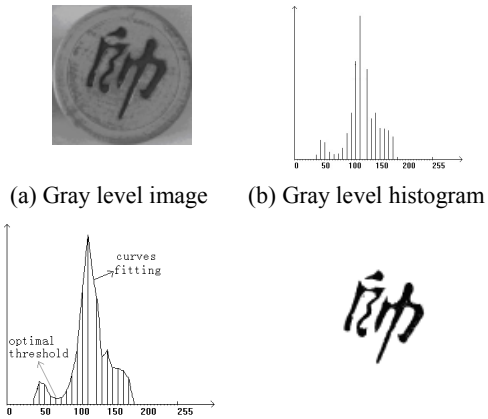
$$f(x_i)=\sum_{j=0}^{n} B_{ij}(x_i)$$

where $B_{i0}(x)=\begin{cases}1 & x_1 \le x \le x_{i+1}\\ 0 & else\end{cases}$

and

$$B_{ij}(x)=\frac{x-x_i}{x_{i+j}-x_i}B_{ij-1}(x)+\frac{x_{i+j+1}}{x_{i+j+1}-x_{i+1}}B_{i+1j-1}(x) \qquad (3)$$

[9]




(a) Gray level image (b) Gray level histogram

(c) Curve fitting (d) Binarization image

Fig 3 Binarization

Since the color depth of the character is deeper than background's and the pixels of the character are more than background's, optimal threshold is given by

$$t=\min(x_i),\quad f'(x_i)=0, f''(x_i)>0$$

where f□ is first derivative and f″ is second derivative. The system can automatically determine optimal threshold by continuous vertex of gray histogram (Fig3 (c)). Fig3 (d) illustrates binarization result of optimal threshold.

### 3.3. Filtering

The filtering is applied to the image for eliminating the interference, because binarization image {b(x, y)} maybe contain spots as Fig4 (a) shown. According to the features of Chinese chess, filtering adopts binary connectivity algorithm. In order to into account: p(x, y) for the current pixel value, and p'(x, y) for the filled value as defined in equation (4). Fig 4 shows the filtering effect.

$$p'(x,y)=\begin{cases}255 & if\ (\sum_{i=-1}^{1}\sum_{j=-1}^{1}p(x+i,y+j)\ge 5*255)\cap p(x,y)=0\\ 0 & if\ \sum_{i=-1}^{1}\sum_{j=-1}^{1}p(x+i,y+j)\le 2*255\cap p(x,y)=255\end{cases} \qquad (4)$$

(a) (b)

Fig 4 Effect image of binary connectivity filtering

## 4. Chessman recognition

A board is divided into red side and black side which includes sixteen chessmen of seven types. Though most chessman character is different from others, a few red and black sides' characters are same. Thus chessman color is regarded as recognition code such as 1 for black and 0 for red. Two kinds of chessman recognition algorithms — RC and concentric circle algorithm are implied to extract feature. Both algorithms use binarization image so as to generate recognition code, and then recognize the chessman compared with the standard code of database.

### 4.1. RC (Rate-Connectivity) algorithm for feature extraction

RC algorithm is described as follows. It extracts three image features namely foreground proportion, foreground connected number and chessman color, to form recognition code.

The realization steps are as follows.

(1) Calculate foreground proportion code

Foreground proportion code is the foreground pixels percentage of the total pixels as defined in equation (5).

$$\text{Proportion code}=100*\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}c(x,y)/N^2 \qquad (5)$$

$$c(x,y)=\begin{cases}1 & if\ P(x,y)=0\\ 0 & if\ P(x,y)=255\end{cases}$$

(2) Calculate foreground connected number

Initializes ‘count’=0. And take the first P(i, j) which pixel value is 255 as the seed point.

Step 1: The points which pixel value are 255 among pixel (i+1, j), pixel (i+1, j+1), pixel (i+1, j-1) and pixel (i, j-1), are added to the set which contain pixel (i, j). The others which pixel value is 0 and not in the sets, are added to a new set.

Step 2: If j<N, then j++; otherwise j=0 and return (1).

Step 3: i++ and return (1), until i>N.

Step 4: ‘count’ is the number of the sets.

(3) Generate recognition code

Recognition code = proportion code $*10^2$ + connected number * 10 + color code. Table 1 shows the chessman code of the red side.

Table 1 Code of RC algorithm for feature extraction

| Chessman |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
| Foreground proportion (%) | 28 | 11 | 34 | 26 | 30 | 38 | 19 |
| Foreground connected number | 3 | 1 | 2 | 2 | 1 | 1 | 3 |
| Color code | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Recognition code | 2830 | 1110 | 3420 | 2620 | 3010 | 3810 | 1930 |

### 4.2. Concentric circle algorithm for feature extraction

Algorithm is described as follows. Draw a circle which origin is the center of the image and radius is the equal increasing interval. Record the times that each circle gets through black pixels of chessman binary image {b(x, y)} until interval numbers sequence of each chessman is different. Then both the sequence and chessman color are implied to form recognition code.

The realization steps of the algorithm are as follows.

First, initialize R=N, i=2, k=0 and count[N]=0. And set d=d+R/i. Then draw a circle with the improved Bresenham algorithm [10].

(1) Dawn the first point (R/2, R) which centre is (R/2, R/2).

(2) Calculate the decision parameters: p0=2R-3, px0=-6 and py0=4R-4.

(3) For each location of $x_k$ (k = 0, 1……), if $p_k$>=0, then the point bellow circle is ($x_k$+1, $y_k$) and recurrence relation are $x_k+1=x_k+1$, $y_k+1=y_k$, $p_k+1=p_k+px_k$ and $px_k+1= px_k-4$; if $p_k$<=0, then the point is ($x_k$+1, $y_k$-1) and recurrence relation are $x_k+1=x_k+1$, $y_k+1=y_k-1$, $p_k+1=p_k+px_k+ py_k$, $py_k+1=py_k-4$.

(4) Identify the other seven symmetrical points in the octant.

(5) Transform each pixel location (x, y) to the actual location given by x=x+d and y=y+d.

(6) If the pixel value of current point is 255, while the next pixel value is 0, then ‘count [k] ’+ 1

(7) Repeat (3) – (6) until x>= y.

(8) k+1.Then if k<=i-2, return(2).

Finally, compare each chessman value of count [0] +… count [i-1]. If there are some equivalent value, then i+1, d=0, k=0 and return (2), until d>=R; otherwise it is over.

Table 2 displays experimental result of the red side

Table 2 Code of concentric circle algorithm for feature extraction

| Chessman |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
| 1/3*R | 5 | 4 | 6 | 6 | 6 | 4 | 6 |
| 2/3*R | 3 | 2 | 3 | 2 | 4 | 5 | 0 |
| Color code | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Recognition code | 530 | 420 | 630 | 620 | 640 | 450 | 600 |

## 5. Experiment and analysis of the results

System hardware adopts HIKVISION DS-2CD852 as CCD Camera, HIKVISION DS-4000HC as Video Capture Card and PC (Pentium 4 3.0GHz, 512M SDRAM). System software uses Windows XP and Microsoft Visual C++ 6.0. The system captures 10 * 32 chessman pictures which have different intensity of light from ten boards. Then adopts RC algorithm and concentric circle algorithm, the recognition accuracy are 90.5% and 98.8%. The recognition time and experimental results are shown in Fig 5.

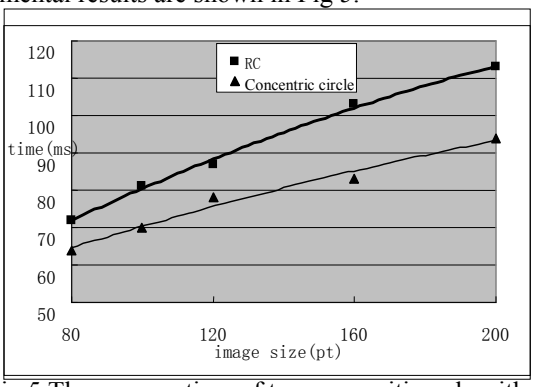



Fig 5 The average time of two recognition algorithms

Because each pixel value of the image needs to be calculated, the time complexity of RC algorithm is $O(N^2)$. The worst time complexity of the concentric circle algorithm is $O(N^2)$ due to the radius (R=N) as the calculation scale. However, the experiment shows that it can calculate different recognition code when ’k’ is 3.

## 6. Conclusion

Chinese chess recognition system based on computer vision uses two algorithms-RC and concentric circle algorithm. The experimental results show that although algorithms are both rapid and accurate, the concentric circle algorithm is more suitable compared with RC algorithm in the field of time complexity and accuracy.

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