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# A gobang man-machine experiment demonstration system based on visual guided

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**Abstract.** For the complex, abstract and learning difficulty of artificial intelligence and in order to improve the student's interest in robotics and artificial intelligence, a gobang man-machine experiment demonstration system is designed based on visual guided. The function of fast identification and localization is realized by the machine vision. The efficiency and accuracy of the gobang search algorithm is enhanced by improved traditional algorithm. The trajectories of the robot are planned by using the quintic polynomial interpolation algorithm. Therefore, chess pieces are placed fast and steady by robot. Developed a human-computer interaction interface by using MFC, which can display chess process and set program parameters. Experiments show that the system can achieve man-machine chess function, the winning probability of the robot is 83.3% and the draw probability is 10%.

**Key words.** Man-machine chess; Socket communication; Search algorithm; Trajectory planning; Machine vision.

## 1. Introduction

Father of artificial intelligence Turing said in 1950, "Chess is an abstract activity, and it is one of the purely intelligent areas in which machines can compete with human[1]." At present, most researchers have devoted to the study of game software based on computer or mobile phone, but the software does not have real environment as the game, prolonged using lead person to produce visual fatigue and even disgusted[2]. The gobang man-machine experiment demonstration system can imitate the real environment of chess. Chess player's interest to robot and artificial intelligence is improved. Recent years, there are few researches on man machine playing robot at home and abroad, which is in the early stage, such as the article about application in experiment teaching of gobang game system, which completed

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the set of game system, but its image processing algorithm is not effective and do not give a concrete achieving method of algorithm and the control method of robot[3]. Although the gobang man-machine game system is established, mobile platform research about gobang robot do not explain the implementation of chess algorithms. Users who use iron chess do not have a better experience[4]. Gobang robot chessboard recognition based on Labview only provide the chessboard recognition method, but no system building method[5].

Based on the above problems, the gobang man-machine chess experiment demonstration system is developed, through the machine vision system accurately identified and positioned chess pieces. The traditional Alpha-Beta Gobang algorithm has been improved and the efficiency of the algorithm has been improved. The trajectory of the robot is planned using the quintic polynomial interpolation algorithm of joint space, the trajectory of the robot is smoothed and the mechanical vibration is reduced when the speed is satisfied.

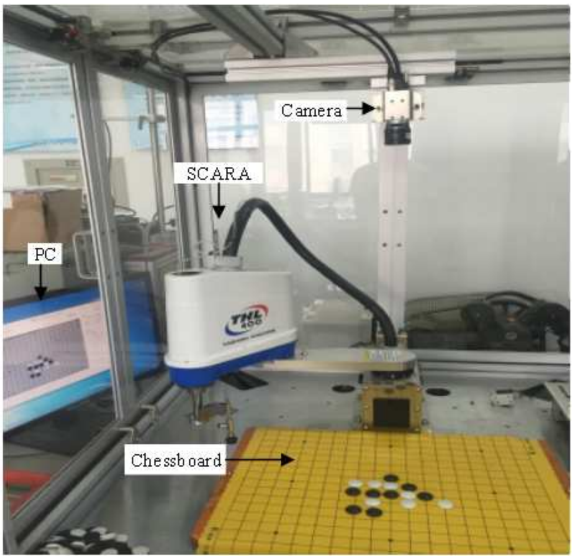


Fig. 1. system constitution diagram

## 2. System constitution

Gobang robot system is mainly composed of machine vision system, robot grasping system and human-computer interaction interface. As shown in Figure 1, mainly including camera, SCARA robot, PC and chessboard. The robot completes the grappling and putting down the pieces, image processing algorithm, Gobang game search algorithm and robot trajectory planning algorithm are integrated in PC. The man-machine interface completes the control of the whole program, shows the real-time playing chess picture and sets program parameters and so on.

## 3. Visual system design

### 3.1. Image acquisition

Using IMI tech Amazon2 series of industrial cameras in placecountry-regionKorea[6], using Gigabit Ethernet GigE protocol standards, the use of Sony progressive scan CCD chip, which has higher image quality. It connects with PC through Ethernet, and the acquisition frequency is adjustable. First, the C++ interface of the camera is obtained by installing the driving software of the IMI camera, and then transplant the interface function to Visual Studio2015 for secondary development. When the camera class library is included, the camera's data is read by instantiating the camera handle class. Through OneFrameGrab to get a frame image of camera, and save the data in a fixed location, to achieve real-time reading IMI camera function[7].

### 3.2. Camera calibration

In the machine vision application, the calibration of the camera parameters is a very critical link, the accuracy of the calibration results and the stability of the algorithm directly affect the accuracy of the results of the camera work[8]. Robot grips and sets pieces are located on the same plane, and the camera is mounted directly above the plane. Using Halcon calibration plate for calibration, 18 calibration plate pictures are collected, and then call Halcon calibration operator calibrate_cameras calibration, get the camera's internal and external parameters. After obtaining the camera parameters, you can get the actual distance of each pixel on the image coordinates in the world coordinate system. And the relationship between image coordinate system and the robot world coordinate system can be obtained through the coordinate system transformation formula.

### 3.3. Chess location algorithm

In the process of playing chess, the robot through the machine vision to real-time identify and locate pieces that the user set. When the user completes setting chess, the camera collects a photograph, and then uses the background subtraction algorithm to find the difference between the picture taken with the robot after the chess game, the resulting image is the position of the user setting chess, and then through the template matching method to get the exact position of the pieces on the chessboard. A standard feature template for black and white pieces is required before template matching. The algorithm idea is as follows:

The first step is to find the gray gradient of the ROI region image, and use the Sobel operator to process the image, which can return the pixel gray value (GX) in the X direction and the pixel gray value (GY) in the Y direction. Use the following formula to calculate the gray value and gradient directions of the current pixel.

$$\begin{aligned} Magnitude &= \sqrt{Gx^2+Gy^2} \\ Direction &= \arctan(\tfrac{Gy}{Gx}) \end{aligned} \tag{1}$$

In the second step, a non maximum suppression algorithm (NMS) is used to search the local maxima of the gradient direction, and the non maximum elements are suppressed to refine the edges. The non-maximum suppression algorithm tracks the left and right pixels in the edge direction, if the gray value of the current pixel is smaller than the left and right pixel gray values the current pixel gray level will be suppressed.

In the third step, double threshold algorithm is used to extract and connect the edge. After non-maximum suppression algorithm is processed, a small amount of non-edge pixels may be included in the results, so it should be selected based on threshold. Double threshold selection and edge join method by assuming that one of the two thresholds is a high threshold TH and the other is a low threshold TL. The edge pixel below TL is discarded, any edge pixel above TH is retained. The edge pixel value between TL and TH is not discarded if it can connect to a pixel greater than TH by edge and all edges of the pixel are larger than the minimum threshold TL. Finally, the image template is saved.

After the template is established, the template matching algorithm for the background subtracted image is shown in Figure 2. The measure of similarity uses the normalization process, and the image contains the more similar the value of the image output is closer to 1. The formula is as follows:

$$S_{u,v} = \frac{1}{n}\sum_{i=1}^{n} \frac{(Gx_i^T \cdot Gx_{(u+xi,v+yi)}^S) + (Gy_i^T \cdot Gy_{(u+xi,v+yi)}^S)}{\sqrt{Gx_i^{T^2} + Gy_i^{T^2}}\sqrt{{Gx_{(u+xi,v+yi)}^T}^2 + {Gy_{(u+xi,v+yi)}^T}^2}} \tag{2}$$

$Gx_i^T Gy_i^T$ represent the template images X and Y gradient directions.

$Gx^S Gy^S$ represent X and Y gradient directions of the images to be matched.

The normalized similarity measure can obtain the similarity score between the current image and the template, and the threshold MinScore of Score is set to 0.75. Finally, the image coordinates of the pieces are translated into world coordinates according to the result of camera calibration, so that the accurate position of chess pieces in the chessboard is decided. After several matching experiments, the accuracy of the matching is 98%, and the maximum absolute error of the matching is five pixels, and the average matching time is 30ms.

## 4. Design of gobang game algorithm

AI Gobang chess algorithm using valuation function to complete the analysis of the current game, and then use the improved minimal minimum search algorithm to search the location of chess pieces that robot set.

In the gobang game, the two sides will be called A and B. In turn, a game tree is constructed according to the possible method of A and B, and all the methods are listed[9]. In a game tree, the value of A win is 5000000, the B is 5000000, and the value of draw is 0. When the turn is A, select the methods which value of the child-node is the maximum; and when it is the turn of the B, select the methods that the value of the child-node is the minimum. For the value of the intermediate

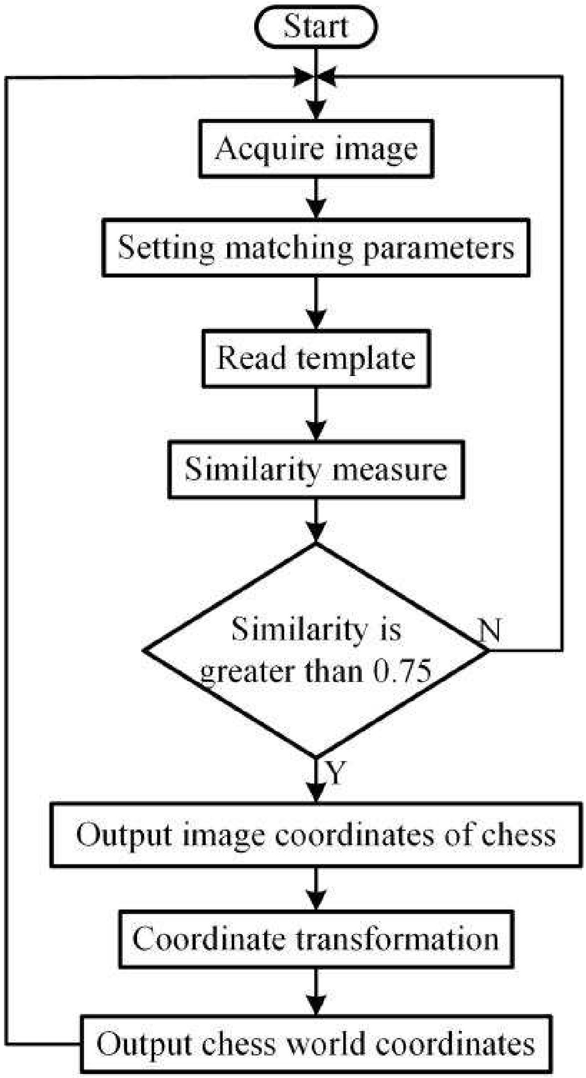


Fig. 2. flow chart of template matching

node, if the corresponding situation of the node is A in turn, the value of the node is the largest value of all nodes. If the corresponding situation of the node is B in turn, the value of the node is the smallest value of all nodes. In order to determine the position of the pros and cons of both sides, set up a valuation function to evaluate and analysis the chessboard, the sum of the valuations of each point is valuations of current position. As for gobang, a little good or bad is related to its four directions around the situation. These four directions are vertical, horizontal, upper left, right lower, upper right and left lower. The situation in each direction is as follows: death, death two, death three, death four; single / double live, single / double live two, single / double live three, single / double live four or five links[10]. In each case, there is a corresponding score, and the four direction score is added to the point of score or valuation. The function of valuation is used to evaluate each situation of game, and then uses minimax search algorithm to find the best method for the robot in the game tree.

The traditional minimax search algorithm searches every branch of the game tree, the algorithm is complex and the search time is long. In view of this problem, combined with the actual situation of Gobang chess, the algorithm is changed as follows:

(1) When the center of the board 12*12 range without a chess piece, AI chooses the center of the board to set a piece.

(2) Considering of a set that will be pointed, not all empty points are as a point, but a point that with the 6*6 range of the union as a point set.

(3) At the current point for the AI will win, do not search, directly put down.

(4) The valuation of the chessboard, do not need to add the valuation of each point, but need to add the valuation of point that surrounded with the 3*3 range of the union.

(5) Double layers of search depth is used to assume all the points that will be set, and to analyze chessboard. Then, assume your opponent at the next step, and analysis again, finally search to get the most favorable method.

Using C++ in Visual Studio to complete the design of the algorithm, respectively established FAI, FController and FPlayerBase class. FAI class gives the position of chess pieces, FController class controls the entire progress and determines the winning or losing, FPlayerBase class is mainly used to save the current position of black and white pieces.

Experiments show that this improved algorithm can complete the analysis of the chess game, the search efficiency is improved significantly that only 0.1s can give the position of chess pieces. However, the computation time of the traditional algorithm is 0.5s.

## 5. Design of robot grasping and placing program

SCARA (Selectively Compliance Robot Arm Assembly) robot is a kind of planar joint type industrial robot. It has four joints, and three rotating joint axes are parallel to each other to realize plane positioning and orientation. It is widely used in plastics industry, automobile industry, electronic product industry, pharmaceutical industry and food industry and so on[11]. The coordinate information of chess pieces is received by using the communication function of the robot and PC, then chess pieces are grabbed to complete chess playing action.

### *5.1. Robot trajectory planning algorithm*

In order to make the robot's chess action fast and accurate, and reduce mechanical shock and vibration, five polynomial interpolation algorithm is adopted to plan the trajectory of robot point to point in the joint space. Robot kinematics modeling is the basis of trajectory planning, and the robot kinematics model can be divided into forward kinematics and inverse kinematics. Kinematic modeling of SCARA robot is carried out by D-H method.

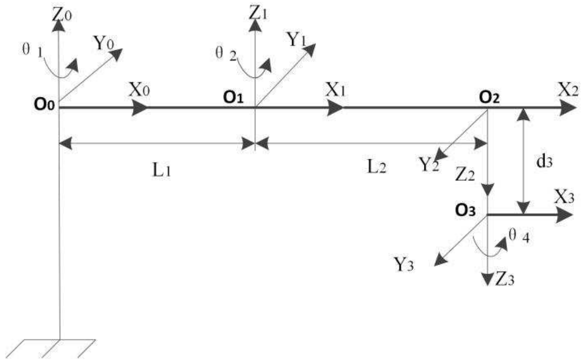


Fig. 3. D-H coordinate system of SCARA robot

As shown above, the following conclusions can be obtained from the coordinate transformation relationship. Among them, $^0$T4represents the transformation relation of robot end coordinate system $O_3$ to base coordinate system $O_0$.

$$^0T_4 =^0 T_1^1T_2^2T_3^3T_4 = \begin{bmatrix} C_{12-4} & S_{12-4} & 0 & L_2C_{12}+L_1C_1 \\ S_{12-4} & -C_{12-4} & 0 & L_2S_{12}+L_1S_1 \\ 0 & 0 & -1 & -d_3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{3}$$

The $C_{12-4}$ represents $Cos((\theta_1+\theta_2)-\theta_4)$ and the $S_{12-4}$ represents $Sino((\theta_1+\theta_2)-\theta_4)$. The last column of equation (3) represents the displacement that the end effector of the robot relatives to the base coordinate system ($P_x$, $P_y$, $P_z$). Formula (4) can be obtained.

$$\begin{cases} Px = L_2\mathrm{Cos}(\theta 1+\theta 2)+L_1\mathrm{Cos}\theta 1 \\ Py = L_2Sin(\theta 1+\theta 2)+L_1Sin\theta 1 \\ P\mathrm{z} = -\ \mathrm{d}_3 \end{cases} \tag{4}$$

By formula (4), as long as the robot end effector of the world coordinates ($P_x$, $P_y$, $P_z$) is known, all robot joints of the angle of rotation can be obtained.

After the robot modeling is completed, the interpolation algorithm is used to plan the trajectory of robot. At present, the main interpolation algorithms include polynomial interpolation, B spline interpolation, Bessel curve interpolation, exponential function interpolation, and spline interpolation four elements. In this design, five polynomial interpolation algorithm is used to fit the trajectory of the robot. The fitting curves and constraints of the algorithm are shown as formula (5) and (6). Among them, $\theta$frepresents the joint endpoint angle, $\theta$0represents joint's starting angle.

$$\begin{aligned} \theta(t) &= a_0 + a_1 t + a_2 t^2 + a_3 t^3 + a_4 t^4 + a_5 t^5 \\ \dot{\theta}(t) &= a_1 + 2a_2 t + 3a_3 t^2 + 4a_4 t^3 + 5a_5 t^4 \\ \ddot{\theta}(t) &= 2a_2 + 6a_3 t + 12a_4 t^2 + 20a_5 t^3 \end{aligned} \tag{5}$$

$$\begin{aligned} \theta_0 &= a_0 \\ \theta_f &= a_0 + a_1 t_f + a_2 t_f^2 + a_3 t_f^2 + a_4 t_f^3 + a_5 t_f^4 \\ \dot{\theta}_0 &= a_1 \\ \ddot{\theta}_0 &= 2a_2 \\ \ddot{\theta}_f &= 2a_2 + 6a_3 t_f + 12a_4 t_f^2 + 20a_5 t_f^3 \end{aligned} \tag{6}$$

The formula of angular displacement of joint space can be obtained by the above formula, as shown in equation (7). When the robot gets the "playing chess" instruction, the world coordinates of the starting point and the end point can be obtained. The rotation angles of the robot joint at the starting point and the end can be obtained from the modeling results. Then, five polynomial interpolation algorithm can be used to obtain the angular displacement formula of each joint, and the trajectory planning is completed.

$$\begin{aligned} \theta(t) &= \theta_0 + \frac{10(\theta_f-\theta_0)}{t_f^3} t^3 + \frac{15(\theta_0-\theta_f)}{t_f^4} t^4 + \frac{6(\theta_f-\theta_0)}{t_f^5} t^5 \\ \dot{\theta}(t) &= \frac{30(\theta_f-\theta_0)}{t_f^3} t^2 + \frac{60(\theta_0-\theta_f)}{t_f^4} t^3 + \frac{30(\theta_f-\theta_0)}{t_f^5} t^4 \\ \ddot{\theta}(t) &= \frac{60(\theta_f-\theta_0)}{t_f^3} t + \frac{180(\theta_0-\theta_f)}{t_f^4} t^2 + \frac{120(\theta_f-\theta_0)}{t_f^5} t^3 \end{aligned} \tag{7}$$

Algorithm verification. The trajectory, fitted by five polynomial interpolation algorithm, of the first joint at the robot is simulated in MATLAB. The simulation results are shown in figure 4. The joint rotates for three seconds??from 0 to 1.25 radians. The simulation results show that the speed, acceleration and jerk curve of robot motion are all smooth and continuous, which meets the requirements of trajectory planning. And it can reduce the impact and vibration of machinery greatly.

### *5.2. Design of robot communication program*

Robot communication program are written in TSPC software. Its main function is to complete the pawn capture and placing action according to the rotation angle of each joint of the received mobile robot. Every time after receiving the data, each joint of the robot is moved according to the data. And then determining whether the placing is completed. If completed, moving the robot to the initial position and waiting for the next data.

Sending and receiving robot data by disordered communication. Using PRINT and INPUT commands to communicate with the robot program. The data received by the controller is put into the variables specified by INPUT commands. And using

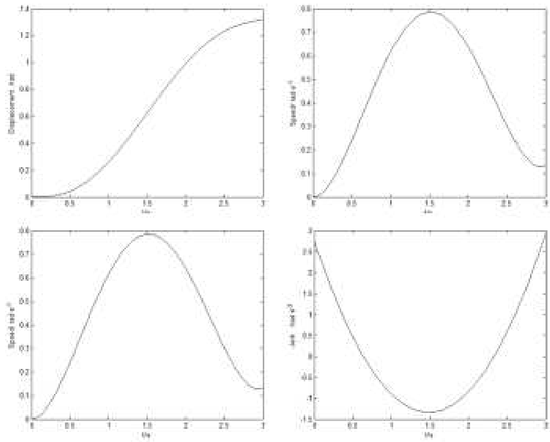

Fig. 4. Joint trajectory simulation

the received data by referring to the variables. In Visual Studio, a server based on Socket communication is developed by C++. The IP1 port of the robot controller as the client is connected to the server running on the PC. The rotation angle of each joint after the trajectory planning is sent to the robot by the server in real-time.

## 6. Experimental Verification

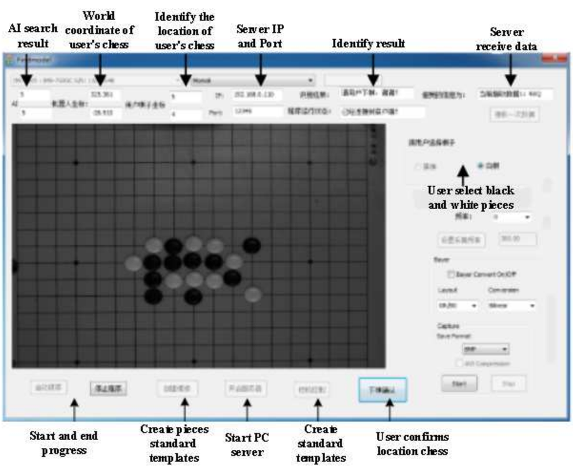


Fig. 5. human-computer interaction interface

The interactive interface is developed by using MFC in Visual Studio. The camera reading, image chess localization algorithm, backgammon game algorithm and five polynomial trajectory planning algorithm are integrated in the program.

The human-computer interaction interface is shown in figure 5. First, the camera can be opened through clicking the selection bar and choose the black or white chess through the interface button. Then, clicking the open server button to open the server, the robot controller is connected to the server automatically. After the connection is successful, the REQ is received and displayed. Click on the start button to start the program. Through the interface chess picture and robot AI algorithm place position are showing in real-time. The place location of user and the status of Socket communication also are displayed on the interface.

Thirty students were recruited and divided into three groups to test the system. After the experiment, the functions of the system were normal, and the function of man-machine chess was completed. The man-robot chess result is shown in the following table.

Table 1. Man-robot chess result

| Group name | Number of robot victories | Number of robot failures | Number of draw |
|---|---|---|---|
| 1 | 8 | 1 | 1 |
| 2 | 9 | 1 | 0 |
| 3 | 8 | 0 | 2 |

## 7. Conclusion

In order to improve the student's interest in learning robot and artificial intelligence, an experimental demonstration system of gobang man-machine game is designed based on visual guidance and improved search algorithm. Through machine vision the functions of identification and location chess pieces were completed. The maximum absolute error of positioning is five pixels, and the average time of identification is 30ms. Using the improved minimax search algorithm to get chess position of the robot, the search process can be completed in only 0.1 seconds. Then, the position of chess pieces is sent to the robot, and the trajectory of the robot is planned using the quintic polynomial interpolation algorithm. The simulation results show that the impact and vibration of the robot can be reduced effectively. After man-machine chess test, the winning probability of the robot is 83.3% and the draw probability is 10%.

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