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Tripod Robot Control System Based on Improved Hamiltonian Path Planning Algorithm

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Original Research Article

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Abstract: Tripod robot system can replace the manual to complete industrial control action simple but repetitive work, such as in the industrial production line of the sorting work. In the actual control, how to quickly and accurately identify the color and shape of the object, at the same time in the shortest time to place it in the specified location, is an urgent problem to be solved. Tripod robot control system based on improved Hamiltonian path planning algorithm , combining the corner detection and corner filling algorithm can accurately identify the shape of the object; using the greedy algorithm to realize the local optimal solution, a dynamic programming algorithm to achieve the global optimal solution, solves the problem of sorting in the shortest time. Experimental results show that the system can achieve the sorting of objects accurately and efficiently.
Keywords: Sorting; Corner filled; Greedy Algorithm; Dynamic programming.

INTRODUCTION

The whole design system needs to complete the basic process is: using of the installation of the camera, to take pictures of the work platform; obtaining the color and shape of the geometry on the platform ; Calculating the angle between the geometric figure of the outer ring and the inner ring geometry, and obtaining the coordinate position; through the coordinates, controlling Tripod robot to pick up all the geometric bodies on the outer ring and put them into the correct position of the inner ring. Working platform and camera installation location as shown in Figure 1.

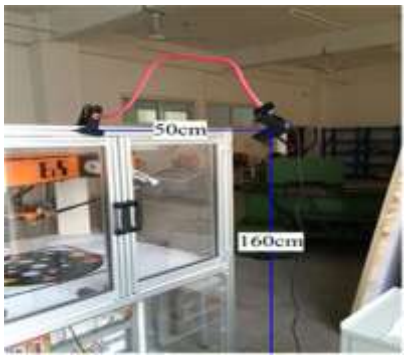


Fig-1: working platform and the installation position of the camera

In order to achieve the above functions, the system is divided into three parts: the creation of human-computer interface, image processing, path planning.

The man-machine interface design

The man-machine interface is written by MFC, with a few key buttons, the status display box and the graphic display box. The interface design has the following characteristics:

- The operation is simple. Just click on the button "take pictures", "identification", "correction", "automatic operation" to run, no need to set.
- Intuitive and strong. In the image box of the interface it can show the acquired picture, the processing of the 9 target corners.
- Easy debugging. The added status display box, which prompts the occurrence of errors and warnings, can facilitate

the user to fix the error. At the same time can display the output of the geometry of the coordinates, color, angle and other information. The man-machine interface effect is shown in figure 2.

Fig-2: effect diagram of man-machine interface

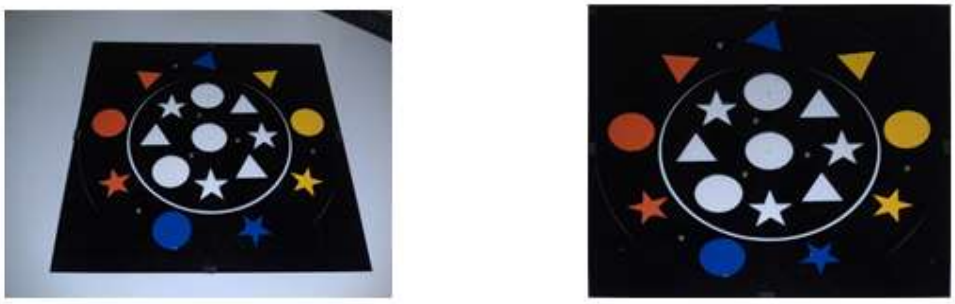
Image processing section

Image processing includes image preprocessing, target segmentation, color recognition, shape recognition, coordinates and rotation Angle calculation.

The pretreatment of the image

Image correction

When the camera is mounted on the side, the acquired image will be distorted, which is very unfavorable for the recognition of the shape and the location of the coordinates, so the image must be corrected. Obtain all corners of the image using the acquisition corner function CV Good Features to Track (), and then save them in an array. All corners are filtered, and only the corners that satisfy the certain threshold in the outer border of the square are the desired corner points. After four vertex coordinates are obtained, the transform matrix is calculated using CV Get Perspective Transform (), and the image is corrected to the image taken from the top view using the affine transformation Cv Warp Perspective () function. Correction effect as shown in Figure 3.



(a) The actual tilt image (b) The corrected image

Fig-3: The correction effect comparison chart

Other preprocessing

In order to achieve the goal of detection and color recognition tasks, need to the next step after correction of image preprocessing. Specific processing steps shown in Figure 4.

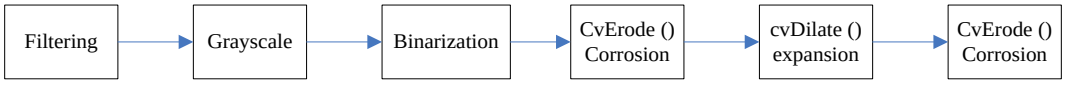


Fig-4: Schematic representation of other preprocessing

CvErode () corrosion then cvDilate () expansion, open operation can be realized, and the discrete points or swim silk, burr is filtered. Finally cvErode () corrosion, called closed operation, can sew the breakup, which prepare for canny operator after testing the biggest contour.

Target segmentation

First, the circle is detected by the cvHoughCircles () Hough transforms function. By setting different detection radius and accuracy to detect the different location and the size of the circle, randomly select a small circle on the outer ring and obtain its center coordinates. With a slightly larger than the circle of the square ROI intercept it, and then its center as a benchmark, 40 degrees clockwise increments, relative to the center of the picture the same radius, with the same square ROI box to select the corresponding geometry, segment the nine independent goals. Compared with the whole image processing, after the target segmentation can save 40 times the memory space, greatly improve the efficiency of the program.

Color identification

Traverse the small square ROI area of the pixel, read its RGB value. Define an array num [3] to save the color feature, if read to the corresponding interval of the RGB value, the corresponding element value plus 1.

Table-1: Color recognition algorithm

RGB selected conditions	Color range	Array of color features
(B>G&&G>R&&B>90)	Blue interval	num[0]++
(R>G&&G>B&&(R-G)<57&&R>120)	Yellow interval	num[1]++
(R>G&&G>B&&(R-G)>63&&R>120)	Orange interval	num[2]++

Compares the size of the three element values of the array, the largest of which is the color of the current geometry.

Shape recognition algorithm

Corner detection and padding algorithm

For each small square ROI, the corners of the geometry are detected. For the general case, the detection of three corner points is the triangle; the detection of five corner points is the five-pointed star. But due to environmental concerns (light intensity, reflective), each point on the image brightness is different, this leads to the same shape geometry with a corner point detection, get different number of angular point [1]. For example, the triangle only detects two corner cases. When the corner is missing, call the corner fill algorithm to calculate the padded corner and filled undetected corner.

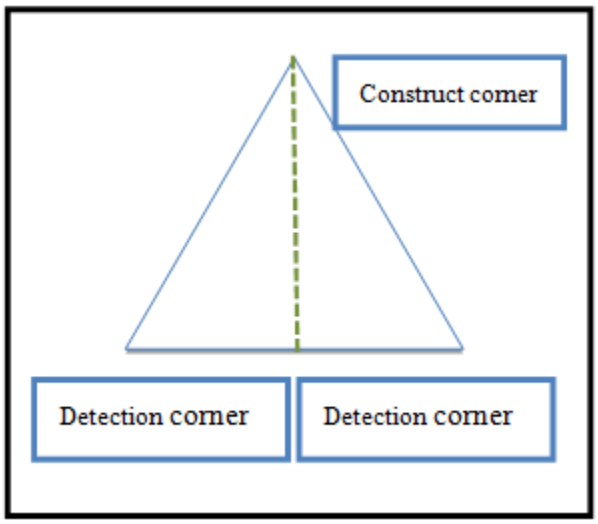


Fig-5: Triangle corner structure diagram

For an equilateral triangle, the length of the triangles can be determined from the known two points, since the distance from the corner to the known two points is determined, so that if the center line equation is calculated, the possible corner points can be calculated coordinate. The solution of the equation has two, that is, the calculated possible corner points are two. Due to the small square ROI constraints, excluding ROI outside the corner, the real corner can be obtained.

Shape recognition

By calculating the geometry of the area to determine the shape of the geometry, the specific identification steps are as follows:

- The first step is to gray, binarization, filtering, corrosion expansion and other basic treatment.
- Acrylic panels will be reflective and cracks repair the background color, fill the gap with black.
- Through the canny edge detection to detect small square ROI in all possible contours, calculate the contour

circumference, to find the maximum profile, that is, the outer contour of each geometry.

- The edge is inflated so that the outer contour is completely closed.
- Use the CV Draw Contours () function to fill the outline with white.
- The area inside the contour is calculated by the CV Contour Area () function.
- The size of the area determines the shape of the geometry.
- The shape determination is based on Table 2.

Table-2: Area to determine the shape algorithm

Area determine	Shape	Feature
(38000,+∞]	Round	The largest area
(15900,38000]	Triangle,	The area is centered
(0,15900]	Five-pointed star	The smallest area

Rotation angle calculation

Geometry itself has a certain angle of rotation, and therefore needs to get its rotation angle through image processing, and then transmitted to the robot. The rotation angle is also calculated by the corner detection method. The algorithm steps are as follows:

- Using the corner detection and fill algorithm for each square ROI in the geometry of the corners.
- Correcting the corner point error correction algorithm.
- Through the mathematical calculation of the geometric center rotation angle.

To the five-pointed star as an example: connecting corner and five-pointed star geometric center, calculate the connection angle and the small square ROI Y axis angle, get 5 angle values. Assuming that the pentagrams are rotated by θ degrees, then the resulting five angles are approximately 5 values around θ, θ + 72, θ + 144, θ-72, θ-144, to deal with these five values, get five approximates the θ Angle value. To sort these five values, get rid of the maximum and the minimum, and the average of the remaining values is taken as an estimate of the value of θ.

Path planning

Determine the end goal distribution structure

If the same color of the geometry placed in the same area, the results will be placed in the following two cases [2].

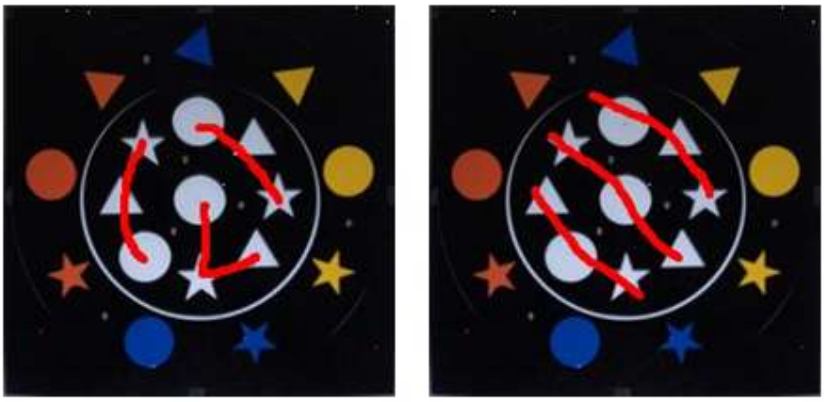


Fig-6: Two combination schematic diagram

Case 1: there is a triangular area, two linear areas. Triangle area has three different target locations, consider the color is not at the same time for different situations, so a total of $3 \times A_3^3 = 18$ kinds of distribution.

Case 2: there are three linear areas. There are two different target location in the straight line area, considering the color is not the same for different situations, so a total of $3 \times A_3^3 = 12$ kinds of distribution.

There are 30 kinds of end target distribution structure, and the nine known objects starting point coordinates, and 9 coordinates, can construct a weighted to the table. Robot border access each vertex case can only obtain the shortest path, this can be equivalent to the Hamiltonian path.

Determine the picking path algorithm

Greedy Algorithm

In the first step, the robot begins to be located at the zero point of the robot coordinate, and the coordinate of the nine geometries of the outer ring in the coordinate system of the robot is known. The distance between the geometric centers coordinates and the zero point can be calculated and the geometry with the shortest distance is selected as the object. Assuming that the first step selects the blue triangles, the blue triangles have the corresponding placement positions for some kind of end point object distribution structure, and the distance is saved in the total path variable.

In the second step, move the manipulator to find the next geometry. Also calculate the current mechanical arm coordinates to the remaining distance geometry center coordinates, choose the shortest distance, grab the geometry, and put it in the end of the target location. The third to ninth steps, similar to the second step, capture the remaining geometry, calculate the total path length.

Step 10, repeat the first to ninth steps for 30 different destination distribution structures, calculate 30 total path lengths, and select the shortest path. The eleventh step, the shortest path corresponding geometry fetching order transmitted to the robot.

Dynamic programming

The pick-up path is similar to the problem of calculating the shortest path between cities in daily life and production. For example, a person who travels frequently between cities A and E wants to know which path from city A to city E has the shortest route [3].

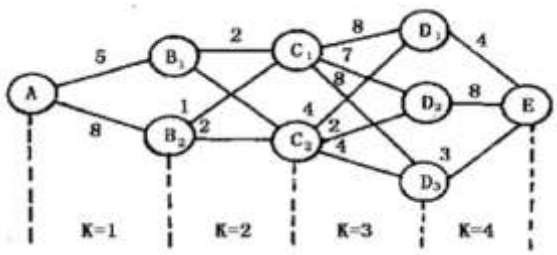


Fig-7: schematic

There are two solutions to the problem of finding the shortest path in general: the sequential recursive method and the inverse sequential method. Sequential recursive method and greedy algorithm are essentially the same. Inverse recursion is described below.

For the above diagram, the reverse-recursive procedure is as follows:

When K = 4, consider the fourth stage, starting from the E-node, from the forward to the front, using $f4(Dk)$ to represent the shortest distance from the E-node to the Di-node. $f4(D1)=4,\ f4(D2)=8,\ f4(D3)=3$

When K = 3, the last two phases are combined, use f3 (C1) to express the shortest distance between the 4th and 3rd stage to the C1 node.

$$f3(C1)=\min\{\ d(D1,C1)+f4(D1),\ d(D2,C1)+f4(D2),\ d(D3,C1)+f4(D3)\}=\min\{\ 8+4,7+8,8+3\}=11$$

So this stage to C1 shortest path is $E-D_3-C_1$.

$$f3(C2)=\min\{\ d(C2,D1)+f4(D1),\ d(C2,D2)+f4(D2),\ d(C2,D3)+f4(D3)\}=\min\{\ 4+4,2+8,4+3\}=7$$

So this stage to C2 shortest path is $E-D_3-C_2$

When K = 2, the last three phases are considered together. F2 (Bi) represents the shortest distance from the last three stages to the Bi node.

$$f2(B2)=\min\{\ d(B1,C1)+f3(C1),\ d(B1,C2)+f3(C2)\}=\min\{\ 2+11,3+7\}=10$$

So the shortest path to B1 end point is $E-D_3-C_2-B_1$

$$f2(B2)=\min\{\ d(B2,C1)+f3(C1),\ d(B2,C2)+f3(C2)\}=\min\{\ 1+11,2+7\}=9$$

So the shortest path to B2 end point is $E-D_3-C_2-B_2$

When K = 1, the first four phases are considered together.

$f1(A) = \min\{ d(A, B1) + f2(B1), d(A, B2) + f2(B2)\} = \min\{ 5 + 10, 8 + 9\} = 15$.

The shortest path is $A - B_1 - C_2 - D_3 - E$. And the shortest distance from A to E is $f1(A) = 15$.

The actual operation process

Step 1: For each end point target distribution structure, calculate the distance between the nine geometries in the inner disk and the zero coordinates, and add the distance from the outer ring to the inner disk and save the result.

Step 2: before the final geometry in place, the eight geometry have been in place, this means that the final geometry of the precursor will be one of the first eight geometry. Similarly, calculate the distance between the eight geometries from the point where they were captured to the end position, and save the total distance of the last two steps. The third step to the ninth step: similar to the second step, complete the placement of the precursor geometry.

RESULTS

TCP communication between PC and Tripod robot is established, and the coordinates, angle and sequence of each geometry are sent to the robot platform.. Run the system to control the robot to achieve control of the crawl and place the work. System operation interface shown in figure below.

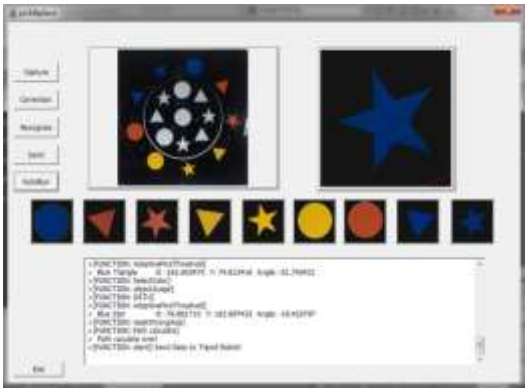


Fig-8: system operation interface

The system uses the phone comes with the camera to obtain the image, with image distortion, high resolution, suitable for occasions and more anti-interference ability. Phone comes with flash, better able to adapt to low-light environment, and no additional acquisition of light, it can change in adaptive lighting environment; In the pre- processing stage of the image, filtering, banalization, corrosion and dilation are adopted to prepare the next image. In the color recognition phase, a large number of RGB values of blue, yellow and orange are extracted, and the rules of R, G and B are calculated and found. The number of pixels satisfying the color discrimination rule is traversed by the ROI region. The color with the largest eigenvalue is the target color; in the stage of shape recognition, cvHoughCircles. Hough transform is used to detect the circle, while for the recognition of triangle and pentagon, it is determined by the combination of corner detection, corner filling algorithm, shape conflict algorithm and geometry area algorithm.; In the calculation of rotation angle, corner detection is adopted to eliminate the inner vertex and the wrong vertex, calculate the deviation angle of each vertex relative to the center, calculate and remove the maximum value and the minimum value; In the path planning stage, the greedy algorithm is used to solve the Hamiltonian path, that is, the greedy algorithm is used to calculate the local optimal solution, and the dynamic programming algorithm is used to determine the global optimal solution. The experimental results show that this system has the advantages of high precision, intelligence and humanization, which is worthy of application and popularization in the field of industrial sorting.

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