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An Algorithm for Recognizing Colored Target Based on Characteristic Differences

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Abstract: The study proposes an algorithm for recognizing colored target based on characteristic differences. It introduces the concept of characteristic differences and improves the SSDA (Sequential Similarity Detection Algorithm), by analyzing SSDA with fixed threshold, SSDA with self-adaptive threshold, combining the characteristics of colors, shapes and sizes of colored targets. The results of experiment of detecting and capturing targets with robot arms show that the improved SSDA based on characteristic differences reduces the computational complexity, improves target identification accuracy, with better real-time, compared with SSDA with fixed threshold and SSDA with self-adaptive threshold.

Key words: Image matching, SSDA, colored target, characteristic differences

INTRODUCTION

Machine vision is an important content of artificial intelligence, the main function of which is the recognition and position of targets. Robots can take appropriate actions, such as effective intercept, capture and so on, only by identifying and determining the location of the target coordinates accurately. Therefore, machine vision is the key point of research in the fields of logistic, modern manufacture and military affairs. Recently rapid identification of colored target has become the research content as more and more colored cameras are used to obtain the image information.

Currently the main method of target recognition is to use the image matching algorithm in image processing technology which is the way to determine the location of target coordinates of the image in the environment and obtain the target coordinates in the robot space by the coordinate transformation. The real-time of image matching algorithm impacts on the response speed of robots, as an important indicator to measure the merits of the algorithm.

In 1972, Barnea presented a rapid image matching algorithm (Barnea and Silverman, 1972): Sequential Similarity Detection Algorithm (SSDA) which improved the efficiency of image matching effectively and was easy to implement. Some improved methods have been proposed to increase the algorithm speed. Literature (Hong and Zhu, 1988) presented using the relationship of image to choose appropriate point sequences to calculate the matching error. Literature (Hatabu *et al*., 2003) proposed an optimization method based on analysis of deciding when to end the calculation. Literature (Shen *et al*., 2009) gave out an SSDA based on image edge characteristics and reduced matching time. The study improves the SSDA through taking the characteristic differences of colored target into account and making full use of the characteristics of colors, shapes and sizes, so that to achieve rapid and accurate recognition of targets.

BASIC SSDA

Early basic SSDA was fit for targets recognition based on black-and-white image. It removed mismatching points rapidly, reduced computation and improved search speed according to the property that the accumulated error increased quickly when the template did not on the matching point; while on the contrary and it increased slowly.

Given a target template T with the size of M×M, a real-time image S with the size of N×N. Assume the gray level of image is L, then 0 = S (I, j) = L-1, 0 = i, j = N-10 = T (m, n) = L-1, 0 = m, n = M-1. T is moving on S. The search graph under the template is called subgraph $S^{i,j}$, where i, j is the coordinate of upper left pixel in this subgraph, named reference point. The algorithm is described as follows,

- Absolute error is defined:

$$\varepsilon(i,j,x_k,y_k) = \left| S^{i,j}(x_k,y_k) - \hat{S}(i,j) - T(x_k,y_k) + \hat{T} \right| \quad (1)$$

Where:

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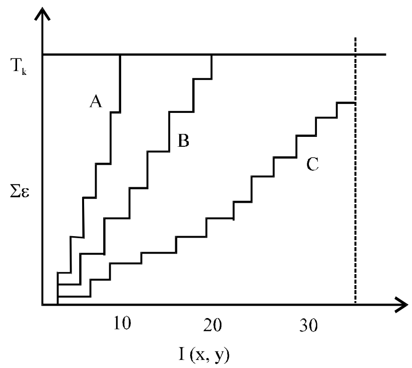

Fig. 1: Error growth curve in SSDA

$$\hat{S}(i,j) = \frac{1}{M^2}\sum_{x=1}^{M}\sum_{y=1}^{M} S^{i,j}(x,y) \quad (2)$$

$$\hat{T} = \frac{1}{M^2}\sum_{x=1}^{M}\sum_{y=1}^{M} T(x,y) \quad (3)$$

- Select a threshold T_k which will affect the success rate of matching let the upper left point in the search graph S as the beginning point, choose randomly pixel point in subgraph $S^{i,j}$, calculate the error ε_1 between it and corresponding point in T, then select the second point according to the ranks of order, calculate the error ε_2,……, add up all those errors until the accumulated value is greater than T_k, note down the accumulated times r, the detection surface of SSDA is defined by:

$$I(i,j) = \left\{ r \left| \min_{1\le r\le m^2} \left[\sum_{k=1}^{r} \varepsilon(i,j,x_k,y_k) \ge T_k \right] \right. \right\} \quad (4)$$

- Let the point that I (I, j) is the greatest as the matching point, because many accumulations are required so that the total error Σε is greater than T_k. It is shown as Fig. 1 which gives accumulative error growth curves A, B and C on the reference point. A and B means the template T is not on the match point and at this time Σε increases quickly and is over the threshold. Σε increases slowly in curve C, so it is likely to be a candidate match point

Self-adaptive threshold SSDA: In basic SSDA, T_k is necessary. It is not necessary for summary to the end when calculating the accumulative error but to judge whether the error is above the threshold or not at every step. When it is above the threshold, the comparison is stopped and the summation accumulative times are written down as a function. This function is small in the uncorrelated area which means the calculative times are small in the uncorrelated area. Therefore, the algorithm reduces the calculation and has more real-time compared with other matching algorithms.

According to the difference of threshold, the SSDA is divided into three types: SSDA with fixed threshold, SSDA with monotone increasing threshold sequence and SSDA with self-adaptive threshold sequence. The difficult is the selection of threshold for SSDA with fixed threshold and monotone increasing threshold sequence. Because of the nonlinearity of SSDA, the processing speed is very fast and the accuracy is high with good threshold, the processing speed is very slowly with too big threshold and the accuracy is low with too small threshold. Therefore in the practical application, the SSDA with self-adaptive threshold sequence is adopted.

SSDA with self-adaptive threshold sequence regards the matching accumulative error Σε of initial point as the initial value of self-adaptive threshold sequence. Then it chooses the second point and carries on match detecting. In the process of detection, if the accumulative error is above the initial value of self-adaptive threshold sequence, the calculation is stopped and the next match detection is began. If the accumulative error of this point is below that of the former point, the accumulative error of this point takes the place of that of the former point and becomes the new threshold. And so it goes on, the matching point will be found quickly.

IMPROVED SSDA

Human beings recognize colored targets based on the information of colors, shapes and sizes and so on which is called objective characteristics (Tu *et al*., 2005). There are characteristic differences because the characteristics of different targets are diverse. Considering the experience of human beings recognizing colored targets, we introduce the concept of characteristic difference when using SSDA for matching and recognition image targets which can increase the real-time and accuracy.

- **SSDA for colored images:** Currently most of the machine vision systems obtain visual information from color CCD camera which is based on RGB components of colored images. RGB color space composes any color by combining R (Red), G (Green) and B (Blue). R, G and B are measured using 256 values, where different combinations form a colorful color space (Gao and Zhang, 2005)

  Considering detecting objective image from the colored image including color information, we introduce RGB components and make the further improvement on basic SSDA.In image matching, because the weights of RGB components are different in template image, the

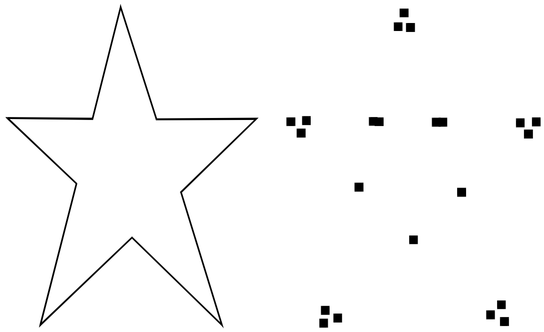

Fig. 2: Pixel points associated with shape

impacts on the image matching are different too. When SSDA is used, the template image and each dimensional space in RGB color space of the image to be matched are calculated, respectively. So, the detection surface of each dimension is obtained: I_R (i, j), I_G (i, j) and I_B (i, j). The detection surface of the whole colored image is defined by:

$$D(i,j) = I_R(i,j) + I_G(i,j) + I_B(i,j) \quad (5)$$

where, the maximum point of D (i, j) is the matched point which makes full use of color information, emphasizes the proportion of different colors have different effects on the matching results and improves the accuracy of the algorithm

- **Selection of objective template:** The improved SSDA of self-adaptive threshold sequence has taken color information into account, combining the concept of characteristic difference of colored targets, then the shape and size information of target should be considered in selection of objective template. Therefore, we use purposive selection instead of random selection when we choose pixel point in matching. When preprocessing the template images, we select some pixel points reflecting the information of shape and size of target which is named correlation pixel points. The RGB components are achieved after processing every pixel point

It is shown as Fig. 2, where the selected pixel points include part of shape information and the distance between them denotes the size of target shape. The selected pixel point cannot be too little, otherwise the relevant information is too little and the matching accuracy is also low. Experiment shows when the number of selected pixel points is more than 15, the better results can be obtained.

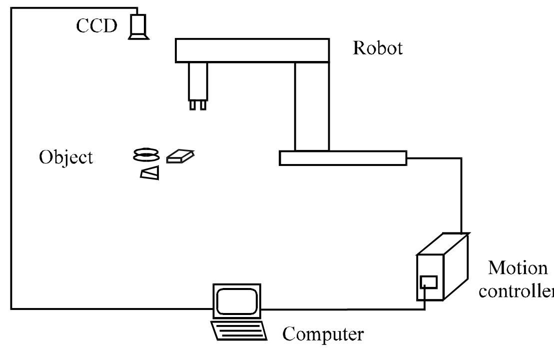

Fig. 3: Hardware graph of the system

- **SSDA based on characteristic differences:** According to the mentioned-above, the SSDA based on characteristic differences of colored target is as follows
- Set up the pixel information of objective template, including the coordinate of selected pixel point (m, n) and the weights of RGB
- Process the image captured by CCD camera and set up the coordinate (i, j) of overall pixel point and the weights of RGB
- Let the objective template cover the image from the upper left corner, select the weights of RGB of the corresponding pixel point with the objective template and calculate the accumulative error as the initial threshold
- According to the self-adaptive threshold algorithm, match the each point of the image successively and find the best matching point
- Since the size of the template is M×M, the coordinate of the reference point is (i, j) corresponding to the upper left pixel point in the template when they are matching. Then the coordinate of the centre point of the target is (I+M/2, j+M/2) which is the coordinate of colored target

EXPERIMENTAL RESULTS

In order to detect the real-time of SSDA based on characteristic differences, we applied the improved SSDA into the machine vision system for recognition and capture of colored target and obtained satisfactory results. The hardware system is composed by GRBA4PAH industrial robot, motion controller, miniature CCD camera, target objects and computer which is shown as Fig. 3. The operation environment is described as follows: the experiment spot is indoors, the targets are some colored objects of various shapes whose size is 50×50 mm, CCD camera is placed on the target platform from 1.7 m and the camera resolution is 320×240.

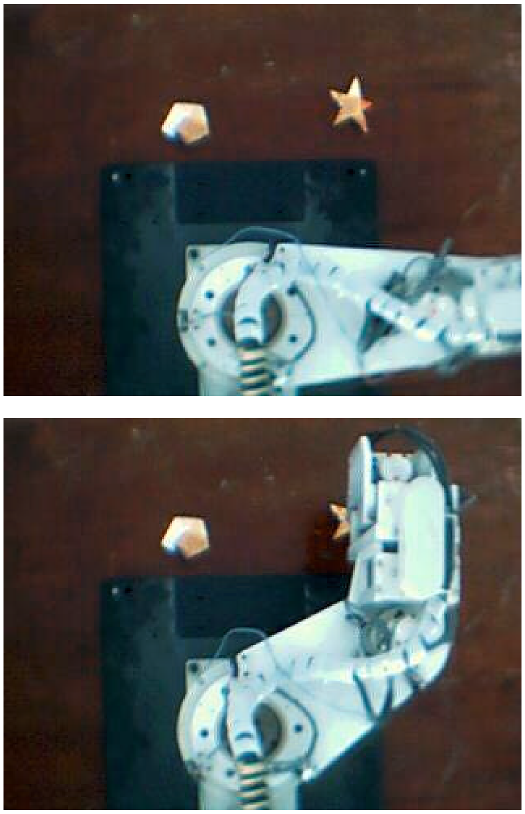

Fig. 4: Recognition and capture of targets with big difference in shape

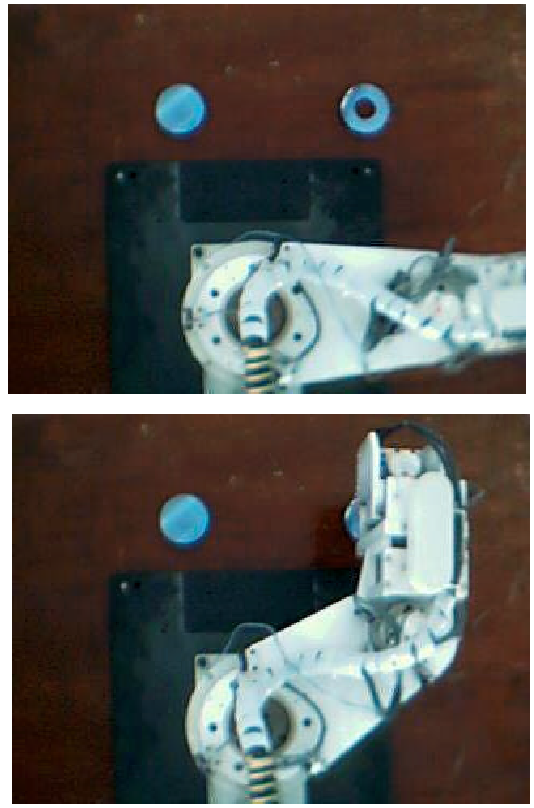

Fig. 5: Recognition and capture of targets with small difference in shape

The experiment process is described as follows. Firstly, the target objects are placed on the experiment platform and the image of the objects are obtained by the camera. Secondly the image is preprocessed by the computer and the image characteristics are extracted, named target template. Thirdly the target objects are placed with other objects, real-time images are obtained by the camera, the matching algorithm is applied to identify and determine the location of the target in the image. Finally the coordinate of the robot space is obtained by coordinate transformation so that the robot can catch the target.

Figure 4 is the identification and capture experiment of two color targets with big difference in shape, a five-sides and a five-pointed star. The machine vision system takes the recognition, where robot arm captures the target of five-pointed star. Fig. 5 is the identification and capture experiment of two color targets with small difference in shape, a circular and a circular ring. Firstly the machine vision makes the recognition, then obtains the target location and makes the robot arm to capture the target of circular ring. The robot arm is above the target which means the position of the arm. After several experiments, the results show that when the image quality is better (the noise of background is dispersed and not much), the results are satisfactory, the recognition rate is high and the location is accurate.

Experiment results show that the matching effect of improved SSDA algorithm based on characteristic differences is the best, where the shorter recognition time and the higher accuracy satisfies the requirements of robot visual servo systems.

CONCLUSIONS

This study studies the impact of the characteristics of colors, shapes and sizes of colored targets on the colored target recognition algorithm and proposes SSDA algorithm based on characteristic differences. The satisfactory results are obtained after improved SSDA is applied in the recognition of colored target. With the development of robot technology, the recognition of complex colored target will have a significant impact on the intelligence of robots and have important applications in the field of industrial and agriculture production and national defense. Therefore, the content of the study has important application value.

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