Multi-target visual recognition and positioning methods for sorting robots

Xinying Liu¹²³, Shoufeng Jin¹²

¹ School of Mechanical and Electrical Engineering, Xi’an Polytechnic University, Xi’an, Shaanxi, China;  
² Xi’an key laboratory of modern intelligent textile equipment, Xi’an Polytechnic University, Xi’an, Shaanxi 710048, China.  
³ Email: 1519826872@qq.com

Abstract. Aiming at the problems of complex shape and random placement of sorting robots, this paper proposes a multi-objective visual recognition and positioning methods for sorting robots. A sorting robot system with visual perception was constructed, which based on the four-degree-of-freedom DOBOT robot. What’s more, the visual system acquires images of multiple targets on the conveyor belt, the image preprocessing algorithm improves the contrast of the sorting targets, thus circular and linear structural elements are constructed in order to fill and smooth the multi-target regions segmented by the largest inter-class variance method. Besides, Establishing centroid coordinates based on image information to identify and locate connected domains of multi-target regions. The experimental results show that the method can achieve statistics on the number of multi-targets. On the basis of the hand-eye calibration of the sorting robot, the multi-objects with complex shapes and random positions are identified and positioned, and the positional information provides the autonomous grasping and sorting for the sorting robot.

1. Introduction

Traditional sorting robots use teaching or off-line programming methods to sort operating targets, however, when the work objects are randomly placed or changed in position, the sorting will fail to achieve, and the work efficiency will be reduced[1-2]. In recent years, with the development of machine vision technology, the recognition, positioning and dimension measurement of the operating target have improved the robot's visual perception ability, and enhanced the robot's environmental adaptability and the function of flexible sorting[3-5]. Wang Yanling et al. put forward a kind of automatic detection of moving object method based on improved background subtraction, for the moving target color and the background similarity and the moving target shadow effect, it is difficult to accurately detect the moving target. The background subtraction in the HSV color space is used to realize the dual background automatic updating so as to solve the target detection problem under the background change [6]. Zheng Jingyi et al. put forward image segmentation method of workpiece which combines a shape prior model with the graph cut method, and measuring the workpiece position information, the experimental results prove that the algorithm can segment detection target artifacts in a complex environment, and effectively master the computing work pieces of grasping posture, which can be applied to block and reflect the work piece grob operation in the conditions of light[7] . Chen Dongliang et al. proposed a workpiece recognition method based on edge matching. The edge
information extracted by Canny operator was used as the matching feature, the improved Hausdorff distance was used as the similarity measure of image matching, and the adaptive generation gap replacement strategy of genetic algorithm was applied in the search process. Experimental results show that the algorithm improves the matching process and can effectively solve the problem of workpiece identification in the case of translation, occlusion and partial occlusion [8]. Liao Jiaji proposed a workpiece visual recognition algorithm based on edge template matching, and calculated the centroid coordinates of the workpiece through the center distance of the image, then sent the attitude information to the robot controller to achieve the purpose of robot sorting [9]. Wang Shiyu put forward the controlled idea of adjusting the speed of the conveyor belt according to the distribution density of the workpiece on the conveyor belt, and achieved the goal of the robot to grab the scattered materials quickly, however, the method is not practical and does not meet the demand of assembly line with production rhythm [10].

Aiming at the problems of complex shape and random placement of sorting robots, this paper proposes a multi-objective visual recognition and positioning method for sorting robot, acquiring images of multiple job targets on the conveyor belt through the visual system. With the largest inter-class variance method fusion morphology algorithm for multiple target image segmentation, the multi-objective connects domain identification, and establishes position model based on image information to locate multiple target. The multi-object recognition and localization of sorting robot is achieved.

2. Sorting robot system

In this paper, a sorting robot system with visual perception is constructed, as shown in Figure 1. The sorting robot is a DOBOT robot with four-degree-of-freedom, the actuator is a pneumatic hand-grip, and the repetitive positioning accuracy is 0.2mm with JHSM300f High-definition industrial camera and 2048×1536 resolution, equipped with 16mm optical lens, the light source is LED white ring light and the illuminance of the light source is 40000Lux. The job target is placed on a conveyor belt with adjustable speed, the speed adjustment range is 0–1 m/s. The computer processes the acquired image for the upper computer controlled terminal and the camera.

![Sorting robot system](image)

Figure 1. Sorting robot system.

3. Extraction of target contour area in sorting operation

3.1. Preprocessing of sorting operative targets

Due to the interference of light and noise in the imaging process, the acquired image contrast of sorting target is low, and the noise pollution affects the extraction of the sorting target. In this paper, gaussian noise in the imaging process is denoised by gaussian filter, compared with the algorithm in reference [10], the normalized algorithm can not only eliminate the uneven illumination but also improve the image contrast. Preprocessing of sorting job targets is shown in Figure 2.
3.2. Extract the contour area of the job object

In order to identify multiple sorting targets, this paper extracted contour areas of each target on the basis of the largest inter-class variance method and the morphological algorithm. As illustrated in Figure 3(a), the largest inter-class variance method was used to segment image in Figure 2(b), due to the processed holes in the sorting target. Therefore, there still exists a black area in the background after the segmented target, and the edge of the target is rough. To solve this problem, this paper constructed circular and linear structural elements based on morphology in order to implement operational procedures including the close and open processes on the binary image in Figure 3(a), fill the hole area, smooth the target edge, and obtain the contour area of the target as shown in Figure 3(b). As can be seen from Figure 3(b), the target contour obtained by the algorithm in this paper is smoother than that by the algorithm in reference [7].

4. Identification and positioning of sorting targets

4.1. A marker of a connected domain

It can be seen from Figure 3(b) that the contour regions of multiple sorting targets are independent regions, and the pixels of each region are connected domains. In this paper, each area is marked, in the binary image of the target in the process of sorting operation is labeled, the white pixel belong to the same connected domains have the same mark, instead, the white pixels belong to different connected domains have different marks, thus each connected domain in the image can be extracted by 8 adjacency way to mark mark different sorting target area with different colors, as shown in Figure 4(a).

4.2. Establishment of localization model

The image centroid information of the image is used to establish the positioning model for the marked multiple sorting target regions, and its expression is

\[ x_c = \frac{\sum_{ij} x_{ij} I_{ij}}{\sum_{ij} I_{ij}}, \quad y_c = \frac{\sum_{ij} y_{ij} I_{ij}}{\sum_{ij} I_{ij}} \]

(1)

Where, \((X_c, Y_c)\) represent the image position of the center of mass, \(I_{ij}\) stands for the image gray scale of the sorting target region, and \(i\) and \(j\) represent the size of the sorting target region.

On the basis of the connected region marker, the number of connected domains is equal to the number of sorting targets. The position of the sorting target calculated by formula (1), which is shown in Figure 4(b).

5. Analysis of experimental data

5.1. Hand - eye calibration of sorting robot

According to Figure 1, Eye_to_Hand system is adopted in this paper, the operational process is as follows. At the beginning, the robot is separated from the camera. Next, the camera is fixed on the bracket. Finally, the coordinate point of the image coordinate system is converted to the coordinate system.

Figure 2. Pre-processing of sorting objects.

Figure 3. Contour area extraction.
point corresponding to the mechanical arm in cartesian coordinate system so as to obtain the conversion coefficient. After the robot returns to zero, we can manually move the end of the robot, and make the end effector touch the positions of the calibration board and the rectangular frame obtains the corresponding robot coordinates as shown in Figure 5, and then obtain the conversion coefficient from the image coordinate system to the robot tool coordinate system through the rotation matrix $R$ and translation matrix $T$.

\[ C = [R | T] = P_e \cdot P_i^{-1} = \begin{bmatrix} 208.499 & 205.400 & 279.295 \\ -41.773 & 48.210 & 51.008 \\ 609 & 613 & 1652 \end{bmatrix}^{-1} \]

(2)

![Connected domain marker.](image1.png) ![Operational target positioning.](image2.png)

**Figure 4.** Identification and positioning of Operational target.

![Calibration plate.](image3.png)

**Figure 5.** Calibration plate.

5.2. Experimental analysis

In this paper, a visual recognition and positioning software for sorting robot is designed and developed to verify the method of sorting targets of aluminum alloy structural parts. The sorting objects are irregular in shape and the thickness is 2 mm, and the experiment is conducted according to ordered placement and random placement.

(1) neatly placed identification and positioning

Two sorting targets of different shapes were selected and placed neatly as shown in Figure 6, the spacing position of each part is random.

As can be seen from Figure 6, for neatly placed sorting objects, whether they are the same shape or not, the number of sorting objects can be obtained through the method in this paper. The centroid position of each target can also be obtained, thus the spatial position of the sorting target can be gained by combining the centroid position with hand-eye calibration parameters, as shown in Table 1.
Figure 6. neatly placed object identification and positioning.

Table 1. Position of neatly placed sorting objects.

| Centroid position (pixels) | Spatial location (mm) |
|----------------------------|-----------------------|
| $x_c$ $y_c$ $x$ $y$ $z$  |
| The first set of strip     |
| 297 443 34.7 -51.4 3.4     |
| 717 427 83.9 -49.5 3.4     |
| 286 1240 33.5 -143.8 3.4   |
| 719 1260 84.1 -146.2 3.4   |
| A second group of massive targets |
| 263 450 30.8 -52.2 3.4     |
| 502 1074 58.7 -124.6 3.4   |
| 254 1036 29.7 -120.2 3.4   |
| 541 932 63.3 -108.1 3.4    |
| 538 1149 62.9 -133.3 3.4   |

(2) identification and positioning of random placement
The sorting targets with different shapes were selected and randomly placed, the specific position can be rounded by Table 2.
As can be seen from Figure 7, the number of randomly placed sorting targets can be obtained through the method in this paper, and the image coordinates of each target can also be acquired. Combining with the hand-eye calibration parameters, the spatial position of the sorting targets can be gained, as shown in Table 2.

| Table 2. Location of randomly placed targets. |
|---------------------------------------------|
| Centroid position (pixels) | Spatial location (mm) |
| $x_c$ | $y_c$ | $x$ | $y$ | $z$ |
| 909  | 336  | 106.4 | -39.0 | 3.4 |
| 254  | 479  | 29.7  | -55.6 | 3.4 |
| 572  | 318  | 66.9  | -36.9 | 3.4 |
| 610  | 712  | 71.4  | -82.6 | 3.4 |
| 841  | 1299 | 98.4  | -150.7| 3.4 |
| 354  | 1239 | 41.4  | -143.7| 3.4 |

6. Conclusion
1) A sorting robot system was constructed with visual perception based on the four-degree-of freedom DOBOT robot. The visual system acquires the images of the multiple sorting operation target by the transportation of conveyor belt. According to experiments, we can count, identify and locate the random positions through sorting operation target with complex shapes.

2) Preprocessing the acquired target images of multiple sorting operations to improve the uneven illumination and image contrast. The largest inter-class variance method was used to segment multiple operating targets, and the circular and linear structural elements were constructed to fill holes and voids in the segmented operating targets and smooth their edges. Therefore, a complete contour area of the sorting operating targets was obtained, and connected domain identification was implemented to count the number of targets.

3) Establishing centroid coordinates based on image information, and locating the centroid of the connected domain region of the sorting target, then obtaining conversion parameters through the hand-eye calibration of the sorting robot so as to provide the sorting robot with positional information for the autonomous grasping and sorting.

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