Wooden pallet image segmentation based on Otsu and marker watershed

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Abstract. Pallet detection is the key step of cargo handling for warehouse robots. In the visual detection, pallet needs to be segmented from the image background. In order to increase the recognition rate and reduce the influence of the surrounding environment and the pattern of the pallet, Otsu algorithm and marker watershed algorithm are combined to realize the image segmentation of the pallet contour. Based on the difference of colour information between the pallet and the background, Otsu algorithm is used to segment the pallet for the first time, and marker watershed is used to complete the target recognition. The experimental results show that the method can effectively solve the problem of over segmentation of the pallet object, and improve the recognition rate, which has some reference value for the design of the visual detection system of the warehouse robot wooden pallet.

1. Introduction

With the continuous development of modern logistics, warehouse robot plays an increasingly important role in intelligent warehouse system, and pallet detection is the key step of cargo handling for warehouse robots [1]. In recent years, the detection methods of pallets are mainly based on vision, lidar, TOF camera and other sensors. Detection methods based on lidar or TOF camera are generally expensive. The warehouse robot equipped with vision detection system usually has auxiliary light source, good lighting conditions in the factory, and the price of vision sensor is relatively cheap, so the pallet detection method based on vision still has important research value.

The detection method based on vision mainly uses specific features to detect the pallet by segmenting the pallet from the image background [1]. The quality of image segmentation is directly related to the effect of subsequent image processing [2], so accurate and efficient pallet image segmentation is an urgent problem to be solved.

Visual detection methods based on colour and geometric features are proposed respectively in [3,4]. Features are generated by colour, edge, and corner information, but they are easily interfered by complex background. The detection method based on visual label is proposed in [5]. The robust detection method based on Harr like feature is proposed in [6]. The stereo vision detection method based on LBP feature is adopted in [7]. Camera and single line lidar are used for detection at the same time in [8]. The joint calibration and registration between sensors are complex [1].

To sum up, the detection method based on vision needs to segment the pallet from the image background. The pallet image segmentation is easily influenced by the background, which reduces the
accuracy of segmentation. Therefore, the paper uses Otsu algorithm and marker watershed to realize the image segmentation of pallet contour.

2. Image acquisition of experimental samples

In the paper, the European universal standard pallet (UIC 435-2) is taken as the experimental object, and the experiment is carried out in the outdoor environment. The length and width of the wooden pallet are 1200mm and 800mm respectively. The size parameters are shown in Fig. 1.

![Figure 1. The size parameters of European standard pallet.](image)

In the experiment, the pallet elevation image is collected to get the contour area, as shown in Fig. 2. Due to the label pattern (e.g. EPAL in Fig. 2), the pallet contour in this elevation direction is more difficult to be segmented than the other three elevation directions of the pallet, so the pallet contour in this elevation direction is selected as the research object.

![Figure 2. Pallet elevation image.](image)

3. Otsu algorithm

In the experiment, Otsu algorithm is used to complete the initial segmentation: firstly, the image is pre-treated, and then Otsu algorithm is used to realize the pallet contour image segmentation.

3.1. Image pre-treatment

Because the collected image comes from the outdoor environment and is interfered by the background, the accuracy of segmentation will be reduced. Considering that there is no barrier in the field of vision when the warehouse robot camera is used, and it is closer to the pallet when recognizing the elevation of the pallet, the pallet is brighter in the image, so the original image is converted to HSV colour space, and only V space data is retained.

3.2. Otsu algorithm

There is abundant colour information in the image of wooden pallet, and it is found that there is obvious difference between the colour of pallet and the background through observation. Using Otsu algorithm is reasonable and efficient in the initial segmentation.
Otsu algorithm is a method to automatically determine the threshold to maximize the variance between classes. This method has the characteristics of simple and fast processing speed [9]. The method selects the optimal threshold according to the histogram information, divides the image pixels into object pixels and background pixels, and takes the maximum variance between classes as the objective function to obtain the optimal segmentation threshold. The advantage of the one-dimensional Otsu algorithm is that it only operates on the histogram of the image and has low time complexity [10]. In the experiment, the characteristics of Otsu algorithm are used to process the pallet image, distinguish the pallet and the background, and obtain the binary image of the pallet.

4. Marker watershed algorithm
Because of the noise of the surrounding environment, the pattern and texture of the pallet and other factors, it is not easy to segment the pallet contour directly by using Otsu algorithm. In the experiment, the binary image of the pallet obtained by Otsu algorithm is segmented to obtain the complete contour of the pallet by using marker watershed.

The classic watershed algorithm is simulated immersion algorithm proposed by Vincent et al. The method is mainly divided into two processes: sorting and submergence. Firstly, the images are sorted from high to low by grey scale level, and then simulated immersion is carried out. The input of watershed algorithm is gradient image [11], i.e.

\[ G(x,y) = \frac{f(x,y)-f(x-1,y)}{2} + \frac{f(x,y)-f(x,y-1)}{2} \]  

(1)

In formula (1), \( f(x, y) \) represents the pixel value of the original image, and \((x, y)\) is the pixel coordinate, and \( G(x, y) \) represents the image gradient.

Traditional watershed algorithm usually results in serious over segmentation [2]. Marker watershed can effectively prevent the occurrence of over segmentation. The mark of the algorithm includes internal marker and external marker. The basic idea is to modify the gradient image by introducing markers, so that the local minimum value only appears in the marker position, and set a threshold value to filter the pixel value, and delete the local area where the depth of the minimum value is less than the threshold value [12].

5. Experiments
In order to verify the effectiveness of the method, more than ten experiments have been carried out on image segmentation with the help of MATLAB software, and good image segmentation results have been achieved. The simulation results are shown in Fig. 3 ~ Fig. 5. Firstly, the original image is converted to HSV colour space, and only V space data is retained. Otsu algorithm is used to segment the image of V space data, as shown in Fig. 3(Left). There are many interference areas in the segmentation results, and the pallet pattern part is separated from the pallet, which is not conducive to image segmentation. It is impossible for the warehouse robot to find the elevation centroid of the pallet and locate the position of the entry in the later stage. Therefore, fill the hole in Fig. 3(Left), and carry out the area opening operation [13] (delete all connected objects which are less than the specified number of pixels from the binary image) to remove the small objects. The result is shown in Fig. 3(Middle). Then, the edge extraction Sobel operator is used to detect the gradient edge of Fig. 3(Middle), and the gradient image is shown in Fig. 3(Right).
Figure 3. The initial segmentation. Left: Otsu algorithm segmentation image. Middle: Filling holes and removing small objects. Right: Gradient image.

At the same time, the image morphology operation is carried out on Fig. 3(Middle). The closing operation is carried out, and then the hole is filled. The image morphology operation result is shown in Fig. 4(Left). Thirdly, the foreground image and the background image are marked. In order to remove the remote background, the threshold value is set for area opening operation, and the connected area smaller than the threshold in Fig. 4(Left) is removed to obtain the foreground image, as shown in Fig. 4(Middle). Fig. 4(Right) is the background image by the operation of erosion on Fig. 4(Left).

Figure 4. The mark of the foreground and background image. Left: Image morphology operation. Middle: The foreground image. Right: The background image.

Finally, the image segmentation based on marker watershed is performed, and the result is shown in Fig. 5(Left). Fig. 5(Right) is the result of pallet contour detection.

Figure 5. The result of marker watershed. Left: The image segmentation result of marker watershed. Right: The result of pallet contour detection.

6. Conclusion
It is feasible to use Otsu algorithm combined with marker watershed for image segmentation of wooden pallet contour. The method can get more accurate segmentation results, which has some reference value for the design of the visual detection system of the warehouse robot wooden pallet.

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