A Visual Detection and Location Method for Soft Fabrics

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Abstract. The soft fabric is prone to burr, fold, enfold and blur, which poses a great challenge to the accuracy of visual edge detection and localization of the autonomous loading and unloading material system of garment robot. In order to overcome the above problems, it proposes an adaptive edge localization method based on double filtering in this paper, which can be used to guide the garment robot to achieve grasping of soft fabric automatically. Firstly, the Gauss filtering and morphological filtering are used to smooth the image, and then it calculates the canny adaptive threshold based on the edge gradient information and detect the edge, finally it locates the coordinates of edge feature extracted. The experiment results show that the method is effective accuracy greater than 96% and robust tested on the real data sets composed of soft fabric. The method has good application value for the autonomous loading and unloading operation of the garment robot and has positive significance for the construction of the intelligent garment factory.

1. Introduction
With the disappearance of the national population dividend manufacturing is facing herniation problems of high labor cost and shortage of labor increasingly. On the other hand, high-speed, high-precision, diversified and personalized production demand is more and more demanding for the degree of industrial intellectualization. The traditional garment industry is a typical labor-intensive industry, the labor cost accounts for a high ratio on the operation cost of enterprises, which makes many garment manufacturers overburdened, so the enterprises place on great expectation for intelligent manufacturing of garment.

Although the trend of personalization and customization of modern garment industry demands for the employees' skill and experience level higher and higher, but the repetitive processes such as "beating, cutting, patching and sewing" are still the necessary link of garment production, in which the cutting and sewing are the core process.

At present, the research content of garment intelligent production is mainly concentrated in the field of garment size measurement, template sewing, cutting and segmentation. For instance: A automatic measurement method of garment size based on machine vision is proposed in [1, 2, 3, 4, 5], which solved the problems of high error rate, high cost and low efficiency caused by traditional artificial measurement; An automatic garment template sewing technology based on machine recognition has been proposed in [6, 7], which improved the pipelining, standardization and efficiency of the clothing operation, and
reduced the dependence of the garment factory on the skilled workers; A machine vision automatic boundary cutting technology of clothing pattern proposed in [8], which realized the automatic boundary cutting of special-shaped full edition dress patterns; An automatic cutting robot system for clothing is studied in [9], which analyzed various technologies of automatic cutting; a design method of model robot for clothing field is introduced in [10], which realized the match between model robot and human body effectively; An algorithm based on Improved Genetic Algorithm for optimal path selection of garment automatic sewing is proposed in [11], which decreased the path conflict probability of irregular clothing.

There are many literature achievements on the aspects of target recognition and grasping, but most of them taking rigid objects as the research object. The research of visual detection and localization for soft clothing fabrics, then guiding the robot to grasp and sort is not yet found. Because the garment fabric is too soft, it brings great difficulty to recognition, localization and grasping. According to the above-mentioned problem, an adaptive edge localization method based on double filter was proposed in this paper, which not only has good effectiveness, but also has good robustness for different forms of soft fabric. The contributions of this paper are as follows:

(1) The industrial robot loading and unloading material system was introduced into the garment manufacturing industry for the first time, which has a good application value for improving the intelligent production level of garment.

(2) An adaptive edge localization method based on double filter is proposed to solve the problem of inaccurate localization caused by the factors such as burr, fold, enfold and blur of soft fabric, which provided the basis for the autonomous grasping and sorting operation of the garment robot.

2. Detection and localization of soft fabric
This section will discuss the implementation process of soft fabric edge localization method. Firstly, it described the working scene of the autonomous loading and unloading material system of the garment robot, and carried out quantitative and qualitative analysis on the different forms of the burr, fold, enfold and blur of the garment soft fabric, on this basis, then an adaptive edge localization method based on double filter is proposed, its implementation of the method is as follows.

2.1. Loading and unloading material system of the garment robot
The loading and unloading material operations existing in each procedure of garment manufacturing, the garment robot autonomous loading and unloading material system is used to replace manual operation to achieve the loading and unloading operations in each procedure. The system conveyed the soft fabric from the AGV car to the conveyor belt and conveyed the soft fabric from conveyor belt to the AGV car after soft fabric handled, the autonomous loading and unloading material system of garment robot is shown in Figure 1.

![Schematic diagram of the loading and unloading material system of garment robot](image-url)
There are two core problems to be solved in the autonomous loading and unloading material system of garment robot: the visual localization and grasping of soft fabrics, this paper focused on the visual localization of soft fabrics.

2.2. An adaptive edge localization method based on double filtering
This section first discusses the process of adaptive edge localization based on double filter: (1) Denoise processing. Gauss filter and morphological filter are used to smooth the gray image, which effectively reduces the noise of soft fabric burr, blur and other noises; (2) Edge extraction. In order to adapt to different gray level images automatically, the edge detection method is used to replace the fixed threshold of the traditional Canny operator based on the edge gradient information to calculate the high and low threshold automatically and to complete the edge detection; In order to improve the continuity of image edges, morphological filter is used again for edge detection, and the contour of external edges is extracted. Finally, combined with the result of camera calibration, the conversion from edge pixel coordinate to three-dimensional space coordinate of soft fabric is realized. The implementation process of adaptive edge localization based on double filtering is shown in Figure 2

![Figure 2. Process of adaptive edge localization based on double filter](image)

2.2.1. Denoise processing. Because of the particularity of the soft fabric, it is easy to produce the noise of burr, folds and enfold during the process of soft fabric processing, this method uses Gauss filter to reduce the noise of fold and enfold, the definition of Gauss filter is shown in equation (1).

$$g(x, y) = Ae^{-\frac{(x-x_0)^2}{2\sigma_x^2}}e^{-\frac{(y-y_0)^2}{2\sigma_y^2}}$$  (1)

Among them, g(x, y) is a Gauss filter image, A is the amplitude, (x0, y0) is the point coordinates of template center (13 x 13 templates are used in the experiment), and sigma x and sigma y are the variance in the X and Y direction respectively.

Because of the edge burr of the soft fabric can easily lead to the discontinuous edge of the detected image, this method uses morphological filter to reduce the noise of the burr to improve the fitting degree
of the edge detection. The basic operation of morphological filter is expansion and corrosion, and the
filter process is shown in equation (2) and (3).

\[ f(x, y) = \max \text{src}(x + x', y + y') \]
\[ (x', y'): \text{element}(x', y') \neq 0 \]

\[ g(x, y) = \min \text{src}(x + x', y + y') \]
\[ (x', y'): \text{element}(x', y') \neq 0 \]

(2) (3)

Among them, \( f(x, y) \) and \( g(x, y) \) are dilated and corroded images respectively. \( \text{src} \) (x, y) is the
original image, element is the kernel (the 5 x 5 kernel is used in the experiment).

2.2.2. Edge extraction. For the color and texture of the garment soft fabric are rich and varied, the edge
detection using the canny operator with fixed threshold is difficult to adapt to the different color and
texture soft fabric images. An adaptive edge detection method based on Canny operator is adopted in
this method, firstly, the whole image is divided into several sub images, and the edge gradient
information of each sub image is calculated, then the dynamic threshold is generated adaptively by
combining the global edge gradient feature information, which improved the automatic degree of edge
detection, the calculation process are shown in equation (4) and (5).

\[ T_{\text{High}} = (1 - U)T_H + UT_H \]
\[ T_{\text{Low}} = (1 - U)T_L + UT_L \]

(4) (5)

Among them, \( T_H \) and \( T_h \) is the global high and low threshold of the whole image, \( T_L \) and \( T_l \) are local
high and low threshold of sub images. \( U \) is the threshold adjustment rate (Experiment \( U=0.3 \)), \( T_{\text{High}} \)
and \( T_{\text{Low}} \) are the finalized high and low thresholds.

After the edge detection of image detected by the canny operator with adaptive threshold, the edge
contour is retained according to the size of the edge contour area, and the outer edge of the image is
extracted, then the extraction of outer edge of image is completed.

2.2.3. Edge extraction. Based on edge extraction, the edge localization process converts the pixel edge
coordinates of the image to three-dimensional space coordinates, so that the robot can accurately grasp
the target object. Edge localization includes edge coordinate extraction, camera calibration and
coordinate conversion.

(1) Edge coordinate extraction. The method obtains the centroid coordinates of the edge images of
the soft fabric by obtaining the contour information of the edge of the image, and represents the position
of the soft fabric with the centroid coordinates.

(2) Camera calibration. The two-step calibration method is used for camera calibration. The black
and white checkerboard with a 6 x 4 angle and a square lattice size of \( 20 \times 20 \text{mm} \) is used as a calibration
template.

3. Experimental verification

3.1. Experimental platform and dataset

In this experiment, we use UR3 robot developed by Universal Robots of Demark and the end executor
produced by Nondead as research platform. A high-definition industrial camera is fixed on the top, and
camera vision covers UR3 robot, cloth and transport vehicle. Because of the usage of pure white and
non-textured fabric in the process of garment production is very small, therefore, in the process of
In order to verify the effectiveness and robustness of the adaptive edge localization method based on dual filtering, two data sets were used in this experiment: (1) the dataset I consists 1000 cloth images randomly shot from a famous clothing factory in Foshan (Format: JPG, resolution: 1024 pixels, 768 pixels. Take 3 images shown in Figure 3 as an example), which are different in size, shape, color, texture and so on to test effectiveness and robustness of the method. (2) The dataset II is from a batch of fabrics with the characterization of burr, fold, enfold and blur picked artificially, which are used to test the robustness of the method further, as shown in Figure 4.

The data set I will be used to test the goodness of fit between detection of adaptive edge localization method based on double filter and manual detection, in order to verify the effectiveness and accuracy of the method. The accuracy rate shown in equation (6) is defined as the similarity between the edge contour of the edge and the contour of the corresponding plate. The accuracy rate of the edge detection is more than 96% as an effective detection, and the center coordinates represent the soft fabric localization. The dataset II will be used to detect the effectiveness and robustness of the method further.

$$\text{accuracy rate} = \frac{\text{edge contour detected}}{\text{plate edge contour}} \times 100\% \quad (6)$$

3.2. Validation verification

For dataset I, edge detection and localization are done by the proposed method, and then the effectiveness and accuracy of this method are evaluated through manual detection. The experimental parameters are as follows: the size of the Gauss filter kernel is 13 x 13, the size of the morphological filter convolution kernel is 5 * 5, the size of the Sobel aperture in the canny operator is 3, and the double threshold is automatically determined. The edge detection and localization of Figure 4(a), Figure 4(b) and Figure 4(c) were carried out respectively by the proposed method, and the running results were shown in Figure 5, the accuracy rate is shown in Table 1.
Table 1. Accuracy of Dataset I.

| Image number | Accuracy |
|--------------|----------|
| Figure 4(a)  | 98.8%    |
| Figure 4(b)  | 97.5%    |
| Figure 4(c)  | 99.1%    |

Qualitative analysis: The experimental results show that the accuracy of the method used in this paper is more than 96% for different sizes, shapes, colors and textures. It shows that the edge localization method proposed in this paper is highly consistent with the artificial detection results, and can accurately extract and locate the cloth images collected by a garment robot.

3.3. Robustness verification

Aiming at dataset II, we further verify the effectiveness and robustness of the method, and the experimental parameters are the same as those in the upper section. The edge detection and localization of burr, fold, enfold and blur shapes show in Figure 6. Were carried out respectively by the proposed method, and the effect is shown in Figure 6, and the accuracy is shown in Table 2.

![Figure 6. Edge detection and localization for four forms, (a) burr, (b) folding, (c) enfolding, (4) blur](image)

Table 2. Accuracy of Dataset II.

| Image number | Accuracy |
|--------------|----------|
| burr         | 97.2%    |
| folding      | 97.4%    |
| enfolding    | 99.1%    |
| blur         | 98.7%    |

Qualitative analysis: The above experimental verification shows that the accuracy of the edge detection and localization method proposed in this paper is more than 96% for four common forms of burr, fold, enfold and blur, which shows that the method has good robustness. In addition, although burr has great influence on edge extraction, this method can solve this problem better.

3.4. Comparison of effect of methods

The edge detection and localization effect contrast experiments of data set I and data set II are carried out by the method proposed in this paper (Proposal), Sobel and Canny algorithm, the result is shown in Figure 7.
Figure 7. Comparison of the effects of Sobel, Canny and Proposal, (a) Dataset I, (b) Dataset II

From Figure 7, we can see that for the image with smooth edges and regular shapes, the edge localization accuracy of Sobel and Canny algorithm is relatively high, but still less than 96%. In addition, the Sobel and Canny algorithms have poor effect on the edge localization of the four different forms of the fabric, especially for the burr shape, which shows that the robustness of the Sobel and Canny algorithms is very poor. By comparing Sobel and Canny algorithm to the edge localization of dataset I and dataset II, we further prove the effectiveness and robustness of the proposed method.

4. Conclusion

In this paper, we studied the problem of visual localization of the soft fabric of the autonomous loading and unloading material system of garment robot used the UR3 robot as research platform, and proposed the method of adaptive edge localization based on double filter. This method can locate the edge of the soft fabric with different color and texture, and it has good robustness to the four common forms of the soft fabric's burr, fold, enfold and blur, which provides effective calculation basis for guiding the manipulator to grasp. The next step is to integrate this method into the robot's autonomous loading and unloading system, and make a comprehensive test and evaluation of the performance of the whole system.

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