Segmentation Algorithm for Machine-Harvested Cotton based on S and I Regional Features

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Abstract: A segmentation method based on regional color information is proposed for the complicated natural impurities in machine-harvested cotton. The color gradient operation of the filtered machine cotton picking image is carried out, and the marked image is obtained by extended minimum transformation operation. The initial segmented image is obtained by using the watershed algorithm on the modified gradient image. Spatial proximity and color information are considered comprehensively in the process of region merging. Saturation S and brightness I as color information feature are mainly used in the paper. In order to make the algorithm more accurately, the information features are updated in the process of merging. The experimental results show that the average segmentation accuracy of the method for natural impurities is 92%.

1 INTRODUCTION

China is the largest cotton producer and consumer in the world, as well as the largest textile producer and exporter, but up to now, a considerable part of the region still rely on manual picking by manpower. Due to the increase of labor cost and the large-scale planting of cotton, the traditional manual picking has become unsuitable, and mechanical picking of cotton has become the mainstream trend. The impurity content of machine-harvested cotton is much higher than that of manual picking. The impurities mainly include cotton leaves, cotton sticks, cotton shells, rigid leaves, dust and other impurities. Therefore, it is especially important to clean up the impurities in cotton (Qing, 2013). In the cleaning of cotton impurities, the types of impurities cleaned are by different equipment. Some cleaning machines mainly clean up the leaf debris and other light impurities, and others cleaning machines mainly clean bell shell, rigid flap and other heavy impurities (Anthony, 1995). The classification and identification of impurities in cotton mining can provide a reference for the adjustment of operation parameters of cotton processing equipment, improve the efficiency of impurity removal, and also provide a guiding reference for the further improvement of cotton picker equipment (Zhang, 2016).

At present, most of the researches are aimed at the identification of the cotton heterosexual fiber (Wang, 2015 and Jiang, 2015), and relatively few researches on the machine-produced seed cotton (Zhang, 2017). Imaging removal methods for cotton impurities are generally used, such as X-ray tomography (Pai, 2004), visible-light imaging (Tantaswadi, 1999 and Yang, 2009), ultraviolet fluorescence imaging (Mustafic, 2014), infrared imaging (Jia, 2005), hyperspectral imaging (Zhang, 2016), and so on. The image segmentation is first performed when the image is processed. Image segmentation is the premise and foundation of the image processing of the machine-harvested cotton. The quality of the segmentation directly affects the subsequent processing effect. The segmentation of the image can lead to the difficulty of the identification of the impurities in the cotton, and even cause the error judgment. At present, the image segmentation method is roughly divided into three categories: the threshold segmentation method, the edge segmentation method and the region segmentation method. The region segmentation method uses the consistency of regions as the criterion to divide the regions of the image, and the

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regions of interest are extracted for further processing. Compared with threshold segmentation and edge segmentation, region segmentation has strong anti-noise ability and good robustness. The threshold method is generally used to segment cotton impurities (Kan, 2010), while the regional segmentation method is less used. In order to quickly classify and identify the impurities of machine picking cotton, a method based on S and I characteristic region is proposed in this paper. In this paper, the marked image of the image is obtained by extending the minimum transformation operation, and the watershed algorithm is used to segment the image on the modified gradient image of the marked image. Then, the region after the initial segmentation is taken as the basic unit of processing, and on the basis of considering the spatial proximity of the image, On the basis of the above, the region merging is mainly carried out with the saturation S and luminance I feature information.

2 REGIONAL MERGER

Watershed algorithm is a morphological segmentation method, which associates the object in the gradient image with the minimum point markers, which is proposed according to the process of immersing terrain on the surface of the water. Holes are drilled at each ponding basin (regional minimum values) in the natural topography, allowing water to submerge the whole terrain from low to high. By constructing the dam to intercept the water in different ponding basins, the resulting dam boundary is the dividing line of the watershed. Each catchment basin is numbered in the order of formation. The watershed algorithm is simple to operate, but due to the existence of noise and texture details of the image itself, the image contains a lot of pseudo-minimum values, which can easily submerge the interested targets, resulting in serious watershed over-segmentation (Li, 2014).

In order to reduce the phenomenon of over-segmentation, the watershed algorithm is used to segment the filtered gradient image, and the vector of color image is used to calculate the gradient directly. On this basis, the morphological marking method of extended minimum transform H-minima operation is introduced to mark the gradient image. By comparing with the given threshold h, the local minimum values whose depth is lower than the threshold value are eliminated and the number of local minimum points is limited, which is similar to the process of filling shallow water basins with irrigation (Soille P, 2008).

2.1 Color Image Gradient Algorithm

There are two general gradient algorithms for color image gradient algorithm. One is to simply decompose the color image into three gray images, solve the gradients of the three gray images respectively, and then add them together. However, because the edge direction of the three components of the image may not be the same, the gradient synthesis results of the three independent components are not accurate enough; the other is the method of finding the gradient directly by the color image vector used in this paper, which is as follows:

$$u = \frac{\partial R}{\partial x} r + \frac{\partial G}{\partial x} g + \frac{\partial B}{\partial x} b \tag{1}$$

$$v = \frac{\partial R}{\partial y} r + \frac{\partial G}{\partial y} g + \frac{\partial B}{\partial y} b \tag{2}$$

Assume that g_{xx}, g_{yy} and g_{xy} is the dot product of u, v, which is:

$$g_{xx} = u \cdot u = \left|\frac{\partial R}{\partial x}\right|^2 + \left|\frac{\partial G}{\partial x}\right|^2 + \left|\frac{\partial B}{\partial x}\right|^2 \tag{3}$$

$$g_{yy} = v \cdot v = \left|\frac{\partial R}{\partial y}\right|^2 + \left|\frac{\partial G}{\partial y}\right|^2 + \left|\frac{\partial B}{\partial y}\right|^2 \tag{4}$$

$$g_{xy} = u \cdot v = \frac{\partial R}{\partial x}\frac{\partial R}{\partial y} + \frac{\partial G}{\partial x}\frac{\partial G}{\partial y} + \frac{\partial B}{\partial x}\frac{\partial B}{\partial y} \tag{5}$$

From this, we can get the vector gradient, which is represented by the angle as follows:

$$\theta(x, y) = \frac{1}{2}\arctan\left[\frac{2g_{xy}}{(g_{xx} - g_{yy})}\right] \tag{6}$$

The value of the change rate in the direction θ is obtained as follows:

$$F_\theta(x, y) = \left\{ \frac{1}{2}\left[(g_{xx} - g_{yy})\cos 2\theta + (g_{xx} + g_{yy}) + 2g_{xy}\sin 2\theta\right] \right\}^{1/2} \tag{7}$$

2.2 Extended Minimum Transformation Operation

The gradient image is subjected to an extended minimal transformation operation with a depth threshold of h, that is:

$$\nabla f^{mark} = H\min(\nabla f \,|\, h) \tag{8}$$

Where ∇f is the color gradient image; ∇f^{mark} is the marked image; $H\min(\cdot)$ represents the morphological H-minima transform; h is the setting depth threshold.

The larger the value of the depth threshold h, the less the number of minimum points to be marked, the less the number of divided regions, but the boundary may be inaccurate. The depth threshold can be set by the specific segmentation object and the segmentation requirement, and the reasonable segmentation result can be achieved.

After the marked image is obtained by the extreme mark, the gradient image is corrected with the minimum operation of morphology, so that the local minimum region of the image only appears in the marked position, and the other pixel values will be "push-up" as needed in order to delete other local minimum regions. The corrected gradient image ∇f^{ws} is:

$$\nabla f^{ws} = IM\min(\nabla f \,|\, \nabla f^{mark}) \tag{9}$$

Where $IM\min(\cdot)$ represents the morphological minimum calibration operation.

The watershed segmentation operation is carried out on the modified gradient image, and the initial segmentation image of machine-harvested cotton is obtained.

$$f^{ws} = WST(\nabla f^{ws}) \tag{10}$$

Where $WST(\cdot)$ represents the watershed segmentation operator.

3 REGIONAL MERGER

There are still many over-segmented regions in the initial segmentation images obtained by marking watershed method, which need to be merged. In this paper, three aspect of the spatial proximity, saturation S and luminance I characteristic information between regions are considered. In order to improve the segmentation accuracy, the region spatial proximity, saturation S and luminance I feature information are updated iteratively in the merging process.

Spatial adjacency represents the adjacent relationship between regions, and only the adjacent regions can merge when the conditions are satisfied. In the concrete operation, the image block after the initial segmentation is marked in the region, and the adjacent relationship between the regions is represented in the form of adjacent relation table (Li, 2014). As shown in Fig. 1, assuming that there are 5 segmented regions in the image, such as A, B, C, D, E, it is necessary to merge the region of the image according to the spatial proximity.

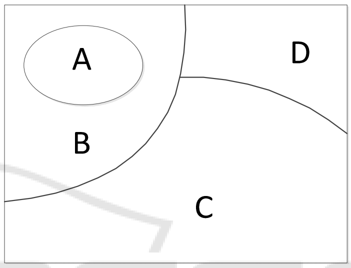

Figure 1. Image segmentation region sketch map.

The table of adjacent relationships established according to this is shown in Table 1. ``1" in the relational table indicates that two areas are contiguous, and``0" means not. In the calculation, first judge whether the two regions are adjacent areas according to the numbers``0" or``1" in the adjacent relation table. If adjacent, further judge whether the areas can be merged according to the area color information. In the process of merging two adjacent regions that meet the judgment conditions, the unified marking numbers of two regions and the elimination of watershed ridge line are completed according to the statistics of the number of marks in the eight neighborhood of pixels on the watershed ridge line.

Table 1. Adjacency relation table.

Adjacency relation		Area name			
		A	B	C	D
Area name	A	0	1	0	0
	B	1	0	1	1
	C	0	1	0	1
	D	0	1	1	0

The iterative operation of the merging process is realized by programming. With the progress of the iterative process, the algorithm updates the segmented region graph and the adjacent relation table, and updates the color feature information of the merged new region at the same time.

Color information feature is a key factor to determine the regional similarity of machine-harvested cotton images. In the image of machine picking cotton, the color information of cotton and impurity is complex. The preliminary research shows that the saturation of impurity is generally higher than that of cotton, and the brightness of cotton is higher than that of impurity. Therefore, the characteristic information of saturation S and brightness I is used to distinguish cotton from impurity effectively. In the process of programming, we first judge whether the two regions are adjacent, then judge whether the region saturation S and brightness I conform to the threshold setting, and merge the regions that conform to the threshold.

4 PROCESS OF IMPURITY DIVISION ALGORITHM

In this paper, the marked watershed algorithm and the region merging algorithm based on color information are combined to segment the cotton impurities. The algorithm has strong anti-noise ability and good stability. Firstly, the median filter is carried out to obtain the filtered color gradient image, the marked image is obtained by extended minimum transform operation, the gradient image is modified by morphological forced minimum operation, the initial segmented image is obtained by watershed algorithm on the modified gradient image, and then the segmented region is merged. The regional adjacent relationship table is established, the adjacent regions are initially merged by the brightness threshold, and the rigid lobe and other regions in the image are merged by the saturation threshold, so as to obtain the final merged picture. In this process, the saturation of impurities is generally higher, the brightness of dark impurities is low, and the brightness of cotton is higher. The algorithm flow is shown in Fig. 2.

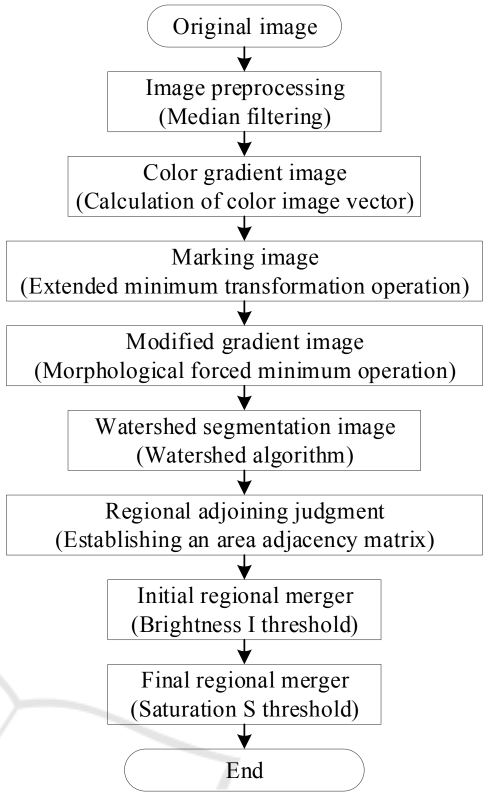

Figure 2. Flow chart of machine-harvested cotton impurities segmentation.

5 EXPERIMENTAL ANALYSIS

5.1 Test Materials and Devices

The image acquisition device, as shown in Fig. 3, mainly includes cotton storage device, light source bracket, industrial camera, quartz glass plate, light source, camera support, shield, dark room and computer. The experimental materials are machine-harvested cotton, including leaf chips, rigid leaves, branches, bell shell, dust and other natural impurities. When collecting the picture, the machine picking cotton is stored in the cotton storage device and pressed on the quartz glass board to take pictures at a certain pressure.

As shown in Fig. 4, the real object of the shooting device is shown in Fig. 4. The camera is selected from the dimension V-EM510C/ M color area array industrial CCD camera, the resolution is 2456 pixels, 2058 pixels, the CCD size is 2/3 ", the GigE Gigabit Ethernet output, the industrial lens is M0824-MPW2, the focal length is 8 mm, and the light source controller is AFT-ALP2430-02, The illumination light source is a four-section bar-shaped LED diffuse light source AFT-WL21244-22W.

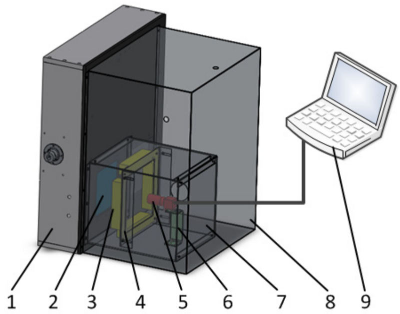

Figure 3. Image acquisition device.

1- Cotton storage device 2-Quartz glass plate 3-Light source 4-Light source bracket 5-Industrial camera 6-Camera bracket 7-Dark room 8-Shield 9-Computer

Figure 4. Shooting device photo.

5.2 Example Segmentation Analysis

The pictures were collected and taken by the experimental device, and the examples of cotton picking by machine were analyzed. Fig. 5 is the original image of a typical example, and Fig. 6 (a) is the image after filtering the median value of the original image. Because the image contains small impurities such as dust and miscellaneous, it needs to be filtered by small window. Fig. 6 (b) is a segmented image obtained directly by using watershed algorithm based on color gradient image. It can be seen that the phenomenon of over-segmentation is very serious. In order to eliminate the phenomenon of over-segmentation, the marked image is obtained by using the minimum expansion operation, and the modified gradient image is obtained by the forced minimum operation. The extended minimum region image and the modified gradient image are shown in Fig. 6 (c), Fig. 6 (d).

The initial segmentation image is obtained by watershed operation on the modified gradient image, as shown in Fig. 6 (e). It can be seen that the impurity boundary in the image is very clear. Compared with the watershed method, the phenomenon of excessive cutting in the marked watershed image is reduced, but it is still very serious. Based on this, the region merging is carried out. Firstly, the image is initially merged by using the brightness I threshold, and the image as shown in Fig. 6 (f) is obtained. It can be seen that the shallow cotton area and the deeper branches, cotton leaves are completely merged, and there are still many areas in the rigid flap and boll shell area that have not been merged. Then the saturation S threshold is used to merge the rigid lobe, bell shell and other regions in the image. As can be seen from Fig. 6 (g), the light color region of rigid lobe and boll shell is merged, and the dark cotton area is still segmented. In the natural state, the color information characteristics of rigid valve are very complex because of external factors such as wind frosting, diseases and insect pests. In the process of segmentation, as long as the outer edge of rigid lobe is completely divided and complete, it is considered that the rigid lobe is perfect. In addition, because of the seed cotton ball and the gap between impurities and cotton, the cotton in this part of the image is darker, and the cotton with dark features is segmented separately.

Fig. 6 (h) is a segmented image obtained by canny operator. From the segmentation effect, canny operator can segment the darker color impurities clearly, but for rigid lobe, bell shell, dark cotton segmentation effect is not good, and canny operator cannot close the edge. The algorithm proposed in this paper has stronger anti-noise ability and higher accuracy for rigid lobe. In this paper it is assumed that the complete continuous edge information of impurities can be segmented, the segmentation is considered to be correct. In this paper, 80 images are processed, and the average accuracy of the segmentation method can be 92%.

Figure 5. Machine-harvested cotton photo.

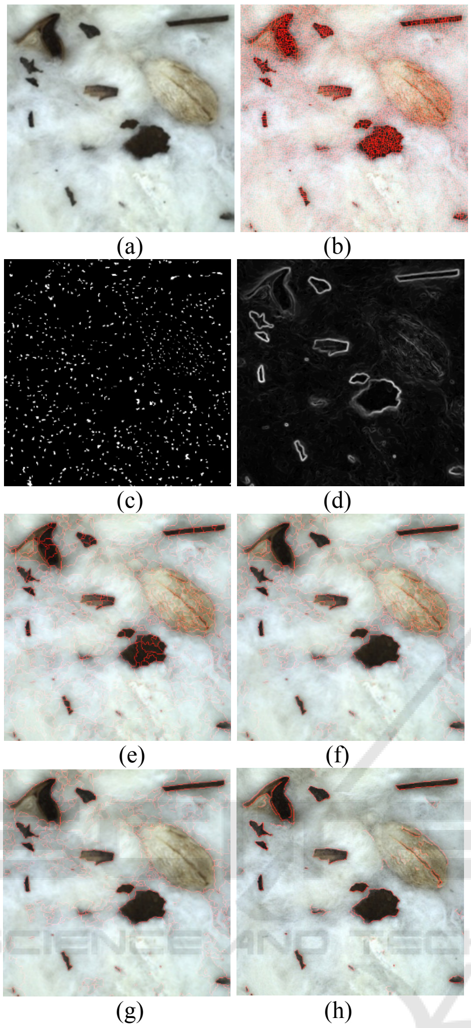

Figure 6. Image analysis process.

6 CONCLUSIONS

A natural impurity segmentation method based on S and I region color information is proposed in this paper for the impurities in machine-harvested cotton. In order to reduce the phenomenon of over-segmentation, the marked watershed algorithm is used to obtain the initial segmentation image by extending the minimum transform operation through the watershed transformation algorithm of color gradient image. The adjacent relationship among the regions is established by the adjacent 8-pixel. Saturation S and brightness I in HSI space are selected as region color features for region merging, and feature information is updated iteratively in the process of merging, which makes the algorithm faster and has strong robustness. The experimental results show that the average accuracy of the segmentation method can be 92% for the natural impurities such as rigid flap, bell shell, branch, leaf chip, dust and so on in machine-harvested cotton.

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