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The research of technology for automatically cutting Patterns' edge with edge extraction via machine vision

QIU Jian-xin[1]，Ding Bin[1]，GAO Fei[1]，LI Jian[2]

1 The Shanghai University of Engineering Science, Songjiang 201620, Shanghai, China

2 Shanghai Textile Research Institute，yangpu200082, Shanghai, China

Abstract: With the designed optical systems, machine vision systems, laser cutting machine body constitute automatic boundary cutting machine vision systems with the clothing patterns. The use of digital image processing technologies, such as filtering, edge detecting and edge tracking algorithms ,has effectively extracted continuous contour of patterns which will significantly distinguish the foreground from background as cutting information of the target edge called cutting vectors, and thus cutting vectors control the laser cutting equipment SPIN1006 to precisely cut the target pattern. This technology can achieve the automatic boundary cutting of the full version of alien costumes' pattern.

Keywords: dress patterns, automatic edge extraction, the laser cutting

CLC Number: TS 941.56；TP 29；TP 391.7

I. Introduction

Garments have different clothing materials, various forms, and colorful patterns. Figure 1 shows a portion of a dress pattern to be cut. At present, the industrial production of dress patterns mainly relies on hand-cutting the dress patterns which have been fabricated. In order to improve the efficiency of cutting production, the quality of the full version of alien costumes' patterns and save the cost about the labors, it is the urgent need to develop automatic cutting technology and equipment for dress patterns. To solve this problem in the actual production, the paper combines the machine vision, digital image processing and the laser cutting processing technology to form the new clothing CAM technology. It has some features, such as high intelligence, convenience and so on. Not only in the garment processing and manufacturing, but also in other types of materials' processing, there are a wide range of the industrial application and technical guidance.

Fig 1 The instance of dress patterns

II. Implementation of automatic cutting dress patterns' boundary based on the machine vision

Based on the research of the machine vision, the specific implementation of automatic cutting technology about boundary of dress patterns is presented as follows: firstly using industrial cameras or CCD digital cameras capture images, and then applying the digital image processing technologies to extract cutting edge parameters which, in turn, control the cutting equipment to cut by boundary[1] automatically. Figure 2 shows the equipment SPIN1006 with machine vision system. Figure 3 shows optical and machine vision system.

Fig 2 The equipment for automatically cutting the dress patterns

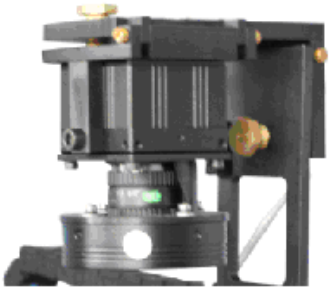


Fig 3 Optical and machine vision system

The hardware of system for automatically cutting by boundary is divided into two parts: the part of obtaining the cutting parameters about boundary and the other part is the implementation of cutting boundary. Obtaining the cutting parameters mainly relies on the machine vision system which consists of the optical system, the CCD sensor, the image acquisition card and computer. The system of completing the implementation of the boundary cutting mainly consists of the control card, execution units, laser and air cooling system. Its structure is shown by figure 4.

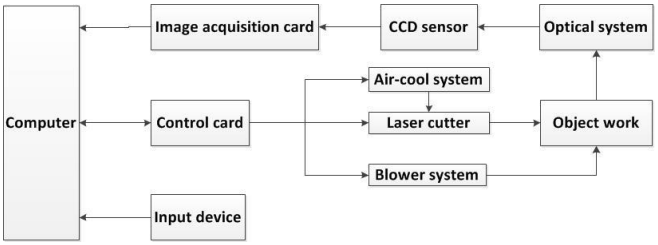


Fig 4 The structure diagram of the laser cutting system with automatic boundary detection

Automatic edge cutting system need to automatically obtain an image of the object by machine vision instead of inputting the cutting parameters, and then apply the digital image processing technologies to detect and track the edge information of the object and ultimately convert the edge information to vector graphics. The edge information is transmitted to the control card to control the actuator and guide the laser cutting head.

III.The intelligent algorithms to extract cutting patterns' edge

One of the key technologies for automatically cutting patterns' edge with edge extraction is accurately detecting the cutting edge of the object to be cut, so that the controller control the laser to cut precisely. For the characteristics of dress patterns to be cut , the use of digital image processing algorithms, such as filtering, edge detection, edge tracking and the positioning of objects (including the center of gravity positioning and the contour positioning) can accurately and effectively extract the edge information of the object. And thus the

successive vectorization of the edge information makes the control system to achieve precise cutting of the dress patterns. The main algorithms involve: (1) Pretreatment of the target image. By designing digital image filter, the image pre-processing algorithm to reduce the noise and enhance the edge information of the target image can improve the accuracy of edge detection and edge traction[1]. (2) The edge detection algorithm. This algorithm is to detect edge information of target image on request. (3) Since the cutting passes every point along an edge, it is vital to study the effective track algorithm so as to track the detected edge and provide the laser cutter with accurate information of cutting trajectory. (4) The vectors of the trajectory information stores, transmits and drives the laser cutting head to pass the expected path.

3.1 median filtering algorithms

Image noise refers to the noisy information that causes distortion and deformation in a image. It is usually the first step to eliminate such noise via the pretreatment of filtering after obtaining an image by visual imaging device[2]. As shown in figure 5, the noise significantly disturbs and blurs the circular outline of the pattern.

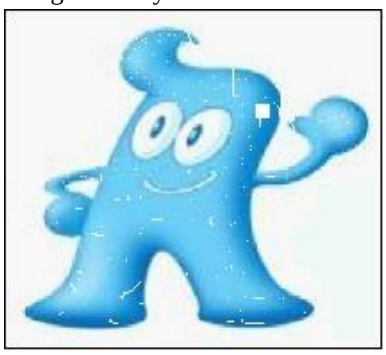


Fig 5 Haibao pattern with the impulse noise interference.

In order to get the clear and valuable information about edge, it is practical to design an appropriate filter to suppress or remove the noise. The poorly chosen filter will blur some important information of the image, but not achieve the desired effective outcome. Then how can not only filter out excess noise in the image, but also can keep the details of the original image (such as edge information) as complete as possible is the primary measure based on the selected image filter.

The median filter, as a typical non-linear low-pass filter， is mainly used to suppress the impulse noise[3]. It not only can completely filter out a sharp wave interferential noise, but also can better protect the edge of the target image. Usually the sliding window of the median filter contains an odd number of points, the gradation value of the specified point is assigned by the mean value of the gradation value of each neighbor point in the sliding window[4][5]. For commonly used two-dimensional median filter window, the window shapes preferably a linear, square, circular, cross-shaped, and its size is usually 3×3.

For calculating the mean value, the key thing is to sort the pixels within the sliding window. And the choice of the sorting algorithm is an important factor to affect the median filtering algorithm. The traditional sorting algorithm is based on the evolved bubble sort method. If the number of pixels in the window is m, the sort of each window performs $m*(m-2) / 2$ times the operations of the pixel comparison， its time complexity is O (m^2). In order to improve the speed of implementation of the median filter, taking the 3×3 median filter as an example, tries a fast parallel median filtering. The figure 6 below shows the 3×3 window pixel array[6].

	The zero column	The first column	The second column
The zero line	p_0	p_1	p_2
The first line	p_3	p_4	p_5
The second line	p_6	p_7	p_8

Figure 6 3X3 pixel arrangement window

Firstly, of each column in the window, maximum, median, and minimum values were calculated, thus obtaining the following three groups of data

The max group: max0 = max [P0, P3, P6], max1 = max [P1, P4, P7], max2 = max [P2, P5, P8]

The median group: med0 = med [P0, P3, P6], med1 = med [P1, P4, P7], med2 = med [P2, P5, P8]

The minimum group: min0 = min [P0, P3, P6], min1 = min [P1, P4, P7], min2 = min [P2, P5, P8]

Thereby it can be analyzed below, the maximum value in the group of maximum and the minimum value in the group of minimum must be the maximum and minimum values of the nine elements, it is impossible one for the median of the remaining seven elements ;the median value of maximum value group is greater than at least 5 pixels, the median value of minimum value group is lower than at least five pixels, then it is impossible one for the medium value of the remaining 5 elements; the maximum value of median value group is greater than at least five pixels, the minimum value in the median value group is at least lower than 5 elements, it is impossible to find the median value in the remaining 3 pixels, and finally to compare the remaining three elements, i.e., minimum value of max group ,the maximum value of the min group and the median value in the med group; identify the median value of these three values in the value of nine elements.

The effect of noise reduction is shown in Figure 7 after four times median filtering on the pattern shown in Figure 5.

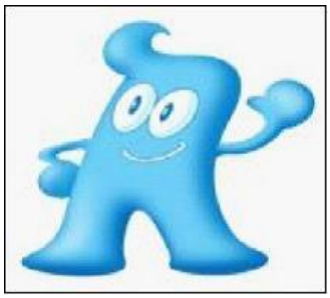


Figure 7 The effect of noise reduction after four times median filtering on the pattern shown in Figure 5

3.2 threshold segmentation algorithms

It is common to realize that there is a gray discontinuity between different regions of the image, i.e. the step changes of gray forms the boundary of those regions[7]. Therefore the algorithm based on the mutation of the color or gray-scale of adjacent pixels can find the boundaries according to gray discontinuity of each pixel in the image so as to segment the scene of our researching object. Threshold segmentation, which is to distinguish the object from the background based on the gray value difference in the image, is an important class of segmentation methods. Choosing a threshold value is the key of using the threshold segmentation. The threshold segmentation algorithm usually has histogram threshold method, iterative method and Neotsu[8].

Histogram threshold method determines its threshold value by analyzing the image histogram[9][10] . In general each picture can generate color distribution histogram (color histogram), Figure 8 shows the histogram got by Halcon (the image processing software) of the dress pattern called Haibao, logarithm of the number of pixels in the vertical axis corresponding to grayscale in the horizontal axis.

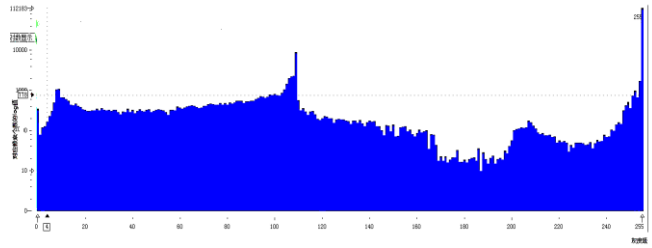


Fig 8 The histogram of Haibao

The image composed of only one object and the background presents the obvious double-peak in the gray level histogram, as shown in Figure 9. For such image, the bottom gray-scale value between two peak values is chosen as a threshold value to segment the image.

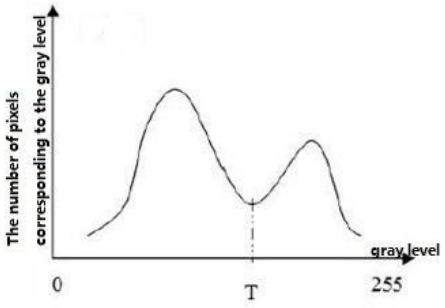


Fig 9 Gray-level histogram with double-peaks

But obviously having the bimodal characteristics of the image will be a relatively rare case. In fact, it is difficult to find such an image. Image is usually composed of a lot of objects and the background, when the histogram is possible to render a plurality of apparent peak, valleys between the peaks are still desirable gray values as the threshold values .In this case, there are a plurality of thresholds to perform the image segmentation, and this method can become a multiple-peak threshold selection. For example, the histogram with three peaks is shown in figure 10. Based on the Multi-peak threshold selection method, using the formula (1) or formula (2) [4]to chose the two optional valleys at the gray-scale value of T1, T2 as the threshold values. In the formulas i, j are the coordinates of pixels.

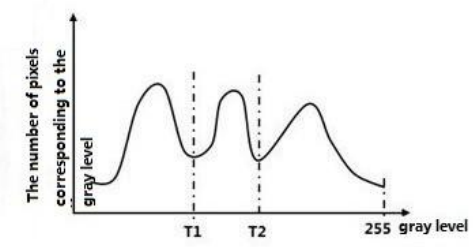


Fig 10 Three peaks gray level histogram

$$f(i,j)=\begin{Bmatrix}0, T_1 \le f(i,j) \le T_2\\ 255, others\end{Bmatrix} \quad \text{formula (1)}$$

$$f(i,j)=\begin{Bmatrix}255, T_1 \le f(i,j) \le T_2\\ 0, others\end{Bmatrix} \quad \text{formula (2)}$$

For the Haibao pattern shown in Figure 7, its threshold can be selected by the multiple-peak threshold, the threshold segmentation condition is optional as (1) with the threshold value T1 = 174, T2 = 232. Figure 11 is the Haibao's binary image after thresholding.

Figure 11 Binary image of pattern Haibao by thresholding segmentation

3.3 edge detection algorithm

Following the completion of the above two algorithms is the image edge detection. Edge detection is the most basic one of the processing steps evolved from the boundary segmentation method. The local discontinuous (or mutations) features, such as gray value mutations, mutations of color and texture mutations, result in the formation of the edge which is the most basic feature in the image. The edge detection method computes the extremes of the first derivative or the zero of the second derivative about the gray function of every pixel through the image to determine which one is the edge point.

The classic edge detection method is the differential operator for image segmentation, which is sensitive to the step change of pixel's gray. This edge detection operator is based on a small neighborhood of pixels in the original image. The gradient operator is one of the most useful edge detection algorithms based on the gray differential. Edge detection often occurs in place where the image gray value has relatively large changes; in the case of discontinuity the place has the larger gray function's gradient. Then researching the better derivational operator has become the key for this approach . Classic edge detection methods belonging to such differential operator are Robert operator, Isobel operator, Prewitt operator, Laplacian operator, LOG operator and Canny operator[11]. Among these commonly used edge detection operators, each of them has its shortcomings and limitations, such as the Laplacian operator[12] often produces a double border. Some other operators such as the Sobel operator often forms the unclosed region. Therefore, in the actual use, the further improvement or optimization of the used algorithm is very necessary. Figure 10 shows the Gauss - Laplace effect and combined effect of Gauss-Laplace edge detection operator and corrosion operator [13] .

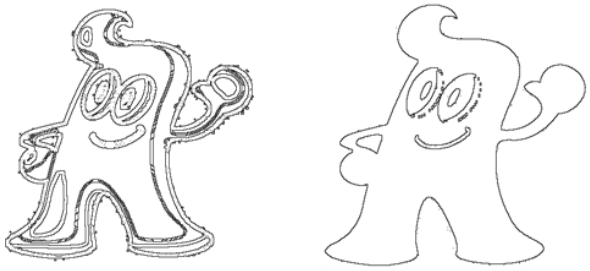
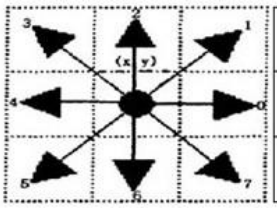


Fig 12 The contrast of the edge extraction effect by Gauss - Laplace operator and subsequent combination of corrosion separately

3.4 edge contour tracking algorithm

The edge tracking follows the edge detection. It is a gradient-based image segmentation method. When perators track the coordinates of the boundary pixels the coordinates are also saved for the preparation of the vector paths. Studying the contour tracking algorithms becomes necessary for the binary image after the process of segmentation and corrosion.

This topic uses the edge tracking algorithm with the eight-neighborhood searching[14][15] to solve the practical problems, the principle is as follows: assumptions that the image point (x, y) is an edge point, the next boundary point must be in the eight-neighborhood of the point (x, y). The coordinates of eight pixels adjacent to the (x, y) and their encodes are shown in figure 13[16][17][18].



(i-1,j-1)	(i,j-1)	(i+1,j-1)
(i-1,j)	(i,j)	(i+1,j)
(i-1,j+1)	(i,j+1)	(i+1,j+1)

Fig 13 The diagram of eight-neighborhood tracking algorithm

How to determine the starting position of the eight-neighborhood search? The procedure of searching the starting position of the eight-neighborhood search is as follows: We will label the point (x,y) as n that serves as its position codes in the eight-neighborhood of the former boundary point, then determine the starting point n of the next boundary point based on formula (3).

$$n = \begin{Bmatrix} n+5; n = 0,1,2 \\ n+5-8; 3 \le n \le 7 \end{Bmatrix} \quad \text{formula (3)}$$

Scan the image from left to right, top to bottom and find the first boundary point P_0 whose value is 0 and its

coordinates (x,y) is saved in the sequence table of the border points. When n=0, successively search the pixels in the eight-neighborhood of the current boundary point in counterclockwise direction. Upon finding the point and f(x,y)=0 firstly, this point will be the next boundary point labeled as P_1, at the same time save its coordinates in the sequence table of the border points; then start form this boundary point and search the next new boundary point until search ends. Specific process is shown in figure 13.

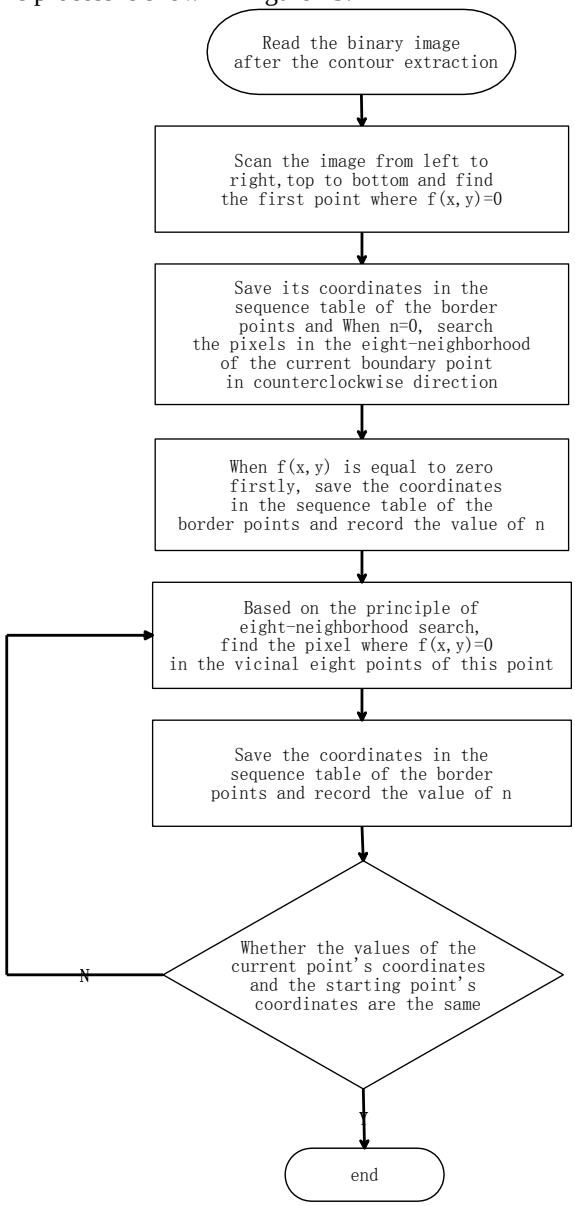


Fig 13 8 connected boundary tracking algorithm

3.5 Vectorization of target contour

In the study of this subject, use a two-dimensional array as a data structure to store the coordinates of the edges of objects. By saving the coordinates of boundary points in tracking target contours, the edge information of the image call be put into digital information and then controller will directly issue the command pulse to a stepper motor to guide the laser cutting head in defined route.

For a point set that has a linear regular variation of the edges of the material to be machined in the manufacturing process of laser cutting machine. As shown in figure 14, line in the middle part from point a (x0, y0) to point I (x1, y1) presents linear change, but the other parts don't.

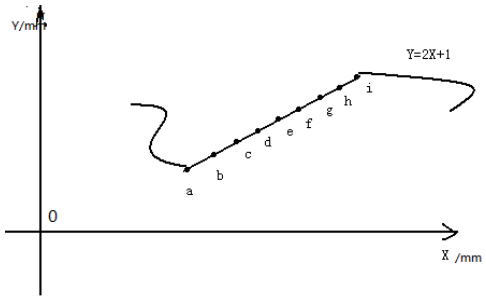


Fig 14 Contour example

So it is considered that in the process of processing a point set, we will use computer to linear vector coordinates extracted. The slope formula is as follows:

$$k = \frac{y_1 - y_0}{x_1 - x_0}$$

Use the slope formula to linear fit all the coordinates in the image one by one, according to the different accuracy requirements set different relative errors and record the points that meet the requirement, then keep the starting point and the end point of the array containing this series of points whose coordinates change linearly. Finally, directly pass the coordinates of these two points to the laser cutting machine for cutting a continuous straight line, so time is saved while the quality of the cut is improved.

When only need to cut the outer contours of dress patterns, select the longest border sequence table corresponding to the sequence table that contains the points on the outermost broad outlines of the dress patterns as the original input data to generate a vector trajectory.

IV. Experiment and its conclusions

This subject mainly apply VC++6.0 (the programming software) to develop the software platform, and use this software directly gets acquisition of the processing materials with the CCD and edge tracking , extracting the edge contour and passing the vector coordinates to the laser cutting machine are fulfilled well. Figure 14 shows the experimental scene of cutting the dress patterns that the laser cutting machine controlled by vectors takes the flat predetermined motion.

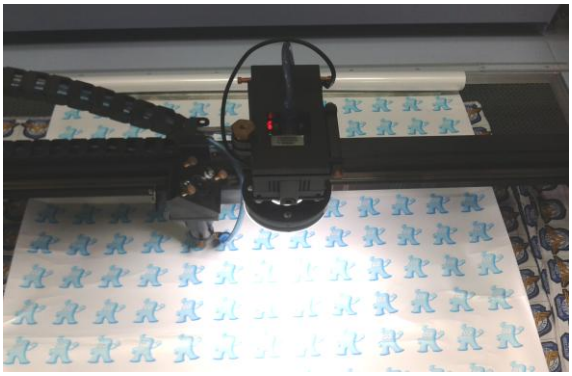


Fig 15 The scene of automatic cutting dress patterns with the laboratory equipment

With the VC programming of the integrated use of above algorithms, and the actually driving the cutting equipment, the experiment proves that this system is able to achieve the foreground objects with the specific outline-clear patterns, and whose profile does not exist fracture and distinguished obviously from the background. A good dress pattern cutting work can be got. The cutting result is shown in figure 15.

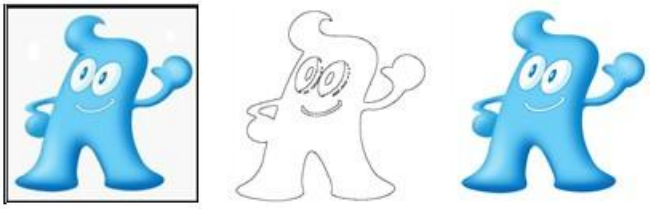


Fig 16 The cutting effect of the edge cutting system

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