Study on Processing for Seam Image Based on CCD Vision Sensing

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Abstract: - In automatically seam tracking system with structured light vision sensor in girth-welding of pipeline, there is a lot of noise in seam images. To extract seam information reliably, it is important to process the original images to eliminate influence of noise. A novel compounding process method is presented. Firstly, one dimension Laplacian of Gaussian filter was applied to transform noises whose width was larger than laser light stripe to isolated and small noise. Then the image was smoothed with neighborhood median filter. Due to gray distribution variety of seam image, binary image was created with maximal square difference adaptive threshold within selected section based on priori information. Acnode noise was cleared up by region labeling and selected threshold, consequently a binary image of seam is obtained. Finally, smooth and consecutive skeleton of seam is extracted with morphologic thinning method. Experiments indicate that this process method satisfies requirement of real-time seam tracking.

Key-words:- Vision sensor, Seam tracking, Filter, Image processing, CCD, Structured light

1 Introduction

The enormous separation between product and market requirement of oil and natural gas promotes the development of long distance pipeline transportation industry. Recently, the pipeline construction technology relies on manual welding or orbited-welding device manipulated by workman, which enormously restricts the development of pipeline construction technology. Therefore, development of intelligent seam tracking system for pipeline welding robot will enhance the efficiency and improve the quality of pipeline construction.

There are many seam detecting methods, such as mechanical sensing, electromagnetic sensing, arc sensing, ultrasonic sensing and optical sensing. Among all of these methods, structured light sensing method, one of optical sensing methods, can not only detect the center of a seam, but also detect the shape of a seam section. The image of vision sensor with structure light is strongly influenced by the arc light, spatter, fume, and vapor, repeated reflection of laser stripe specially in V-type seam [1-4] .An original image of seam is shown as Fig.1.

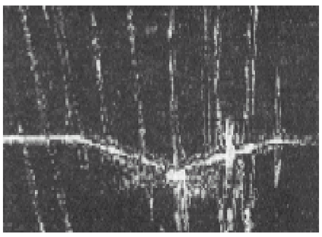


Fig.1 Original image of seam

Therefore, the key to achieve seam tracking reliably is how to release these noises to acquire high quality seam image quickly. Aim at the characteristic of seam image of structured light sensor, a novel compounding process method is put forward, and the process result is presented.

2 Image process method

In the seam image captured by structured light vision sensor, the laser stripe is structured, which allows to process the image with corresponding method for extracting characteristic information of welding seam. In this section, A novel compounding process method is developed, composed of LoG filtering, neighborhood smoothing process，image segmentation, individual pixels filtering and skeletonization.

2.1 LoG filtering

Analyzing the original seam image, the width of laser stripe of structured light is approximately constant, however, the width of arc light noise and repeated reflection of laser stripe is much bigger than that of laser stripe, and there is a angle between spatters and laser stripe. The selected filter should be able to release these noises. The LoG(Laplacian of Gaussian) filter is composed of the exciting centric zone and the restraining peripheral zone, so it gets the greatest response at the sectional center of laser stripe. Because the direction of laser stripe section is in parallel with row or column of seam image, one dimension LoG filter is applied to process image in order to reduce quantity of computation[5]. One dimension LoG filter can be expressed as follows:

$$G(x, y) = e^{-\frac{x^2}{2\sigma^2}} \qquad (1)$$

Where (x, y) is image coordinate, σ is standard difference of correlative probability distribution. After discretization Eq.(1) can be expressed as follows:

$$L(x) = \begin{cases} 1, & -\frac{w}{2} \le x \le \frac{w}{2} \\ -\frac{1}{2}, & -\frac{3w}{2} - 1 \le x \le -\frac{w}{2} - 1 \\ -\frac{1}{2}, & \frac{w}{2} + 1 \le x \le \frac{3w}{2} + 1 \\ 0, & \text{ZδΛó} \end{cases} \qquad (2)$$

where w is width of laser stripe. Function $L(x)$ acts on every column of input image $I(x, y)$, and the output image can be expressed as follows:

$$F(x, y) = \sum_{m=-\frac{3w}{2}-1}^{\frac{3w}{2}+1} A_m I(x, y+m) = -\frac{1}{2} I\left(x, y - \frac{3w}{2} - 1\right) - \frac{1}{2} I\left(x, y - \frac{3w}{2}\right) \cdots - \frac{1}{2} I\left(x, y + \frac{3w}{2} + 1\right) \qquad (3)$$

where A_m is weight. When $w = 2$，the template is expressed as follows.

$$\begin{bmatrix} -\frac{1}{2} & -\frac{1}{2} & -\frac{1}{2} & 1 & 1 & 1 & -\frac{1}{2} & -\frac{1}{2} & -\frac{1}{2} \end{bmatrix}^T \qquad (4)$$

Processed by LoG filter as template (4), the noise whose width along the columns is much larger or smaller than that of laser stripe has been filtered, but the noise whose width along the columns is approximately equal to that of laser stripe has been retained. As a result, the noises in seam image have been transformed into discrete, isolated blocks, whereas, laser stripe is not effected by the filter. The result is shown in Fig.2(a).

2.2 Neighborhood Smoothing Process

Processed by LoG filter, in the image of laser stripe amount of lacunas appear. To be convenient to following process, it is necessary to smooth the image. The smooth methods include neighborhood averaging filter, median filter, selective mask method, and so on. Comparing with the results of the smooth methods, we know that median filter is sensitive to the noise although the edge of laser stripe image is sharp, that the selective mask method with large amount of computation debases the contrast of seam image although the details of the edge of laser stripe image is not been destroyed, and, that using the neighborhood averaging filter to smooth seam image has better result although it make the edge blurry in some extent. Moreover, the process period of the selective mask method is approximately five times to that of the neighborhood averaging filter. Therefore, synthetically considering the process effect and period, the neighborhood averaging filter is used to smooth the seam image.

The neighborhood averaging filtering is that the average of pixels gray levels in selective window replaces the gray level of the discussional pixel. If the gray level of input image is $F(j, k)$ and neighborhood A is of size L, processed by neighborhood averaging filtering the center pixel $G(j, k)$ is as follows:

$$G(j,k)=\frac{1}{L}\sum_{(x,y)\in A}F(j,k) \tag{5}$$

For a neighborhood of size 3×3, the template is expressed as follows:

$$\frac{1}{9}\begin{bmatrix}1 & 1 & 1\\ 1 & 1 & 1\\ 1 & 1 & 1\end{bmatrix} \tag{6}$$

The smoothing result is shown as Fig.2(b).

2.3 Image Segmentation

To get a clear image of laser stripe, it is necessary to segment seam image to subdivide the laser stripe from background. Thresholding is a fundamental approach to segmentation that enjoys a significant degree of popularity, especially in applications where speed is an important factor.

In different welding seam image, arc noise makes the gray distribution fluctuant. Processing a series of images, fixed segmenting threshold is unsuited. Therefore it is necessary to select adaptive threshold to improve segmentation results [6][7]. Automatically thresholding includes difference histogram algorithm, iterative threshold algorithm, maximal square difference algorithm, etc. Among these methods the executing speed of maximal square difference algorithm is the fastest, and in the segmented binary image the edge between objects and background is reliable.

The maximal square difference algorithm is that a gray level is selected as the threshold value to divide image into two groups which histogram has the maximal square difference. Supposed that in an image the gray level is 0~m, and the amount of pixels gray level is i says n_i. With a gray value, $k\in(0, m]$, dividing image into two groups: C_0={0~k} and C_1={ k+1~m}, the square difference between two groups is given by

$$\begin{aligned}\sigma^2(k) &= w_0(\mu_0-\mu)^2+w_1(\mu_1-\mu)^2\\ &= w_0w_1(\mu_1-\mu_0)^2=\frac{[\mu\times w(k)-\mu(k)]^2}{w(k)[1-w(k)]}\end{aligned} \tag{7}$$

where $\mu=\sum_{i=0}^{m}ip_i$ is mean of all pixels gray value in whole image, $\mu(k)=\sum_{i=0}^{k}ip_i$ is mean of all pixels gray value when shreshold is k, $w(k)=\sum_{i=0}^{k}p_i$ is probability of C_0.

Changing k from 0 to m, calculate the value of $\sigma^2(k)$ using Eq.(7) . k* corresponding to $\max\sigma^2(k)$ is desired threshold value. $\sigma^2(k)$ defined by Eq.(7) is the threshold choosing function.

The maximal square difference threshold k* is used to segment the smoothing processed image to binary image.

In every period segmenting processing requires to change k from 0 to m for choosing threshold k*, the amount of computation is still very large, which debase real-time of whole system. In actual pipeline girth welding seam tracking, the gray level of seam image with 1 byte per element ranges from 0 to 255. Experimental statistics shows $k^*\in[35,90]$. So in actual choosing maximal square difference threshold k*, the range of k is limited 30~100. As a result, the amount of computation for image segmentation is cut down. The result of segmentation is shown as Fig.2(c).

2.4 Individual Pixels Filtering

Some individual pixels and small isolated regions in binary image are usually noise for the whole image and should be filtered. In this paper, labeling method is adopted to filter the individual pixels in seam image. Each threshholding segmentation image maybe has many adjacent regions, and each adjacent region corresponds with a target pixel region. Different labels are assigned for different target pixel region[8]. We use 8-adjacence to label the individual pixels in the segmented binary image.

The total number of pixels in each labeled region will be computed after labeling. The regions in which the total number of pixels is less than a given threshold value T will be regarded as noises and will be cleared up. On the contrary, the regions are regarded as valid data and will be hold. After many repeated experimentations, we find that the threshold value T is not less than 800. So, we regard 800 as T for labeling the individual pixels and isolated regions for V-type seam image in our research work.

The Individual pixels and their immediate neighbors in preprocessed binary image will be removed using labeling method process, and the distinct seam image can be obtained. The result is shown as Fig.2(c).

2.5 Seam Image Skeletonization

At present, skeleton is usually used to express object's shape in the researches on pattern identification, image processing and computer vision. Skeletonization is a way to reduce binary image objects to a set of thin strokes that retain important information about the shapes of the original objects.

In discrete space, the basic algorithm for skeletonization has two ways. One is the thinning operation [9]. In this method, a set of adjacent pixels can be obtained by repeatedly separating pixels from the boardline of the shape of the original object on the condition of invariable topology and geometry restriction, and the obtained set is regarded as skeleton. This operation can obtain consecutive skeleton which retain main topology structure of the original object. Another skeletonization algorithm is based on distance transform. It creates skeleton from the ridge line formed by distance curved surface in one higher dimension. It's main characteristic is that the skeleton has a exact position and a smooth shape. It's shortcoming is that the operation is easy to be interfered by the noise on the boardline of the original shape, and is hard to ensure the consistency of the obtained skeleton. Furthermore, the algorithm based on field transform is induced from the concept of distance transform.

According as the feature of seam image and the real-time performance of image processing, the algorithm for skeletonization must fulfill the following qualification:

1) The skeleton must retain the consistency and topology structure of the shape of the original image.

2) The skeleton should be the central line of the shape of the original image as possible.

3) The skeleton should be a single pixel wide.

4) The algorithm should have a rapid operation speed.

5) The algorithm should be provided with high performance of interference rejecting.

The skeletonization algorithm based on distance transform or field transform. Therefore, we employ thinning operation to obtain the skeleton of the seam.

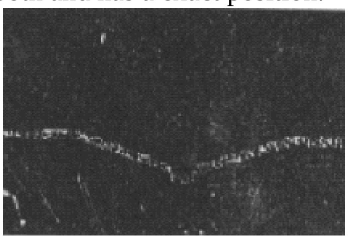
Before thinning operation is employed, the binary image should have a inversion process for that the foreground pixels value of seam image are '1', and background pixels value are '0'. The result is shown in Fig.2(e).

The rules used in thinning operation for determining a pixel to be removed or retained are as follows:

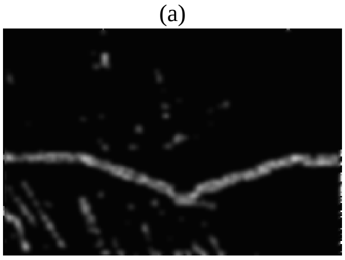
- $2 \le NZ(P_1) \le 6$□
- $ZO(P_1)$□1□
- $P_2 * P_4 * P_8$□0 or $ZO(P_2) \neq 1$□
- $P_2 * P_4 * P_6$□0 or $ZO(P_4) \neq 1$□

where $NZ(P_1)$ is the total number of target pixels in 8-neighbors of P_1. $ZO(P_i)$ is the alternately changing times of pixel value '0' and '1' in 8-neighbors of P_i.

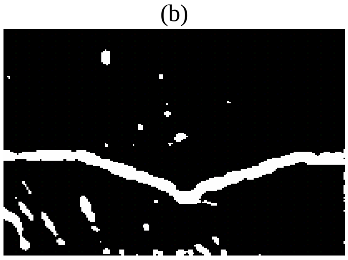
The pixels fulfilled the above rules should be removed. The algorithm for thinning operation employed to pick up the characteristic curve of seam possesses a rapid speed, and the obtained skeleton image is smooth and has a exact position.



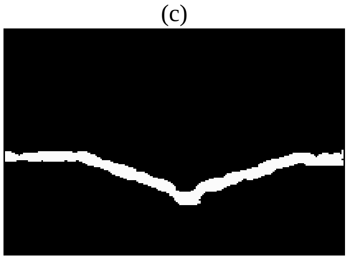
(a)



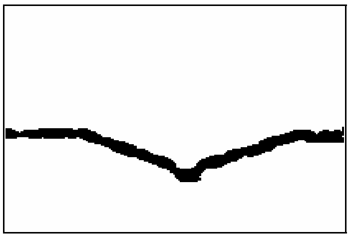
(b)



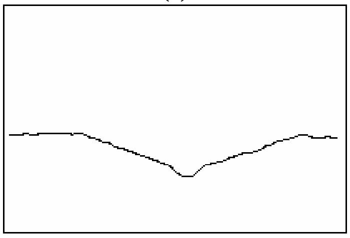
(c)



(d)



(e)



(f)

Fig.2 Sequential results of image Processing

3 Conclusion

In seam tracking system based on vision sensor, seam image processing is the key step that straightly influences precision, rapidity and stability. A compounding processing method is presented, which includes one dimension discrete LoG(Laplacian of Gaussian) filtering, neighborhood averaging, adaptive threshold segmentation used maximal square difference, labeling small dollops removal and morphological thinning. As a result, the characteristic information is extracted rapidly and stably. Experiments show that by using this compounding processing, the seam tracking system acquires powerful anti-jamming ability. Within 0.08s, an image of size 400×300 pixels can be processed, so it can meet the requirement of field welding.

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