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# Uneven Illumination Image Segmentation Based on Multi-threshold S-F

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**Abstract**：For the problem that image segmentation link of steel tube recognition and counting system is affected easily by uneven illumination, and deficiency that some objects' mistaken segmentation is caused by segmentation after image's enhancing, a multi-threshold S-F (Segmentation-Fusion) image segmentation method is proposed. According to improved Otsu multi-threshold method, the morphology algorithm and image fusion technology are applied to extract steel tube objects. Experimental results show that the steel tube image segmentation effect of this method is obviously superior to traditional methods' under uneven illumination circumstance, the proposed method is free of the effect of illumination quality and well-adapted, which can be applied in objects recognition of the machine vision field.

**Key words**：multi-threshold; image segmentation; improved Otsu method; image fusion

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## 0 Introduction

Recognition and statistics of steel pipes, that is, counting the number of steel pipes stored in warehouses or production plants, one of the indispensable links in the production and management of steel pipe manufacturers. Image recognition technology has the advantages of high precision, strong flexibility, which makes the recognition statistical system of steel pipes based on image processing into the mainstream [1], however, the preprocessing of image segmentation is the key step, its drawback is that image quality is affected by light, the segmentation effect of the traditional global method is not ideal [2-3], and it is difficult to meet the actual needs.

In order to overcome such problems, the images of steel tube are often enhanced then segmented [4-5], which is to improve the contrast and clarity of interested objects without considering the degradation of part of the image quality. Therefore, while enhancing contrast, it also brings noise, blurs details and easily loses important information, leading to the phenomenon of wrong segmentation. It can be seen that there is a certain correlation between enhancement and segmentation. How to improve local illumination without affecting global segmentation seems to be difficult to solve. In view of the above problems, a large number of scholars have studied. Liu yi [6] etc. enhanced the uneven illumination images to improve the influence of uneven illumination on image by improving the homomorphic filtering method; WEI Weiyi[7] etc. proposed a robust fuzzy c-mean method, which has a good segmentation effect on uneven illumination images; Chen hua etc. [8] realized image segmentation in pulverized coal area by using the c-means clustering method of adaptive illumination compensation and fuzzy enhancement; Long jianwu etc. [9] proposed an interactive threshold segmentation method of image region segmentation, which realized interactive segmentation by users through block image information. The segmentation effect of uneven illumination images was good, but it could not be automated.

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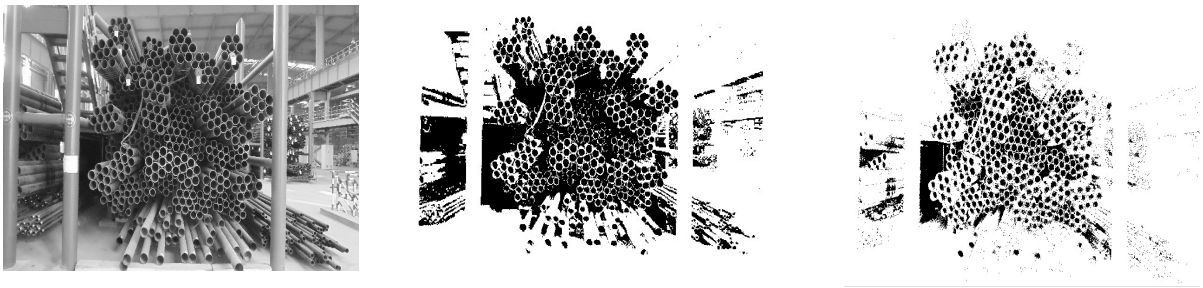
In order to improve the defects of traditional segmentation methods which are easily affected by the light, this paper proposed a kind of multiple threshold segmentation method, which combines image segmentation with image fusion technology, according to the image characteristics of the steel tube image under uneven illumination, the modified Otsu method is guided by the twin-peak method after transformation, multiple thresholds are set and morphological operations are combined to achieve the extraction of steel pipe targets. This algorithm is insensitive to light and has strong adaptability, which can coordinate the compromise between image enhancement and segmentation.

# 1 Traditional segmentation method of uneven illumination images

It is necessary to enhance the image of uneven illumination before segmentation, which could improve the definition of local areas. Based on it, the traditional segmentation methods can be divided into two steps: image enhancement and image segmentation. The effect of former plays a decisive role to the latter.

## 1.1 The analysis of image enhancement and segmentation effect

Typical image enhancement methods include: Gray transformation, Histogram correction [10], Image sharpening, Homomorphic filtering, etc. Threshold segmentation methods include: Bimodal method, Otsu method, Gray histogram method, Maximum entropy method, Interactive segmentation method, etc. [11].First of all, this paper adopts homomorphism filtering and histogram specification to enhance the steel pipes image of uneven illumination, then compares the Segmentation results by Otsu segmentation, as shown in figure 1.



(a) 原图 (a) The original image

(b) 同态滤波增强后 Otsu 法分割 (b) Otsu segmentation after homomorphic filter enhancement

(c) 直方图规定化增强后 Otsu 法分割 (c) Otsu segmentation after histogram specification enhancement

图 1 传统的图像增强后分割效果

Fig.1 The effect of traditional segmentation after image's enhancing

In the figure, histogram normalization has a better segmentation effect on the enhanced uneven illumination image, and can obtain the texture of concave region with fuzzy details. However compared with the segmentation image after enhanced homomorphic filtering, it is found that misclassification is more obvious because it destroys the surrounding area of the targets. Therefore, regarding the uneven illumination image, there is a certain correlation between enhancement and segmentation, that's called compromise problem.

## 1.2 The compromise between image enhancement and segmentation

The steel tube image affected by uneven illumination presents multiple concave (relative to the whole into the concave) or convex areas, which are greatly different from the target's overall gray scale, making the enhancement of this area while destructing the overall pixel. This paper adopts the improved Otsu multi-threshold method to determine multiple thresholds; the final segmentation image is resulted by the combination of local and the whole segmentation information, which can coordinate the compromise between enhancement and segmentation.

### 1.3 Traditional Otsu algorithm

Otsu method takes a certain gray level as the threshold, divides the image into two parts and calculates their variances, when the variance becomes maximum between the two groups the gray value is used as the best threshold to realize segmentation. The selection function of largest inter-class difference $\delta^2(T)$ is

$$\delta^2(T) = \omega_0(\mu_0 - \mu)^2 + \omega_1(\mu_1 - \mu)^2 = \frac{[\mu\omega(T) - \mu(T)]^2}{\omega(T)[1 - \omega(T)]} \tag{1}$$

Where $C_0$、$C_1$ respectively represent the partial grayscale range of target and background; $\omega_0$ represents the probability of $C_0$; $\omega_1$ represents the probability of $C_1$; $\mu_0$、$\mu_1$ is respectively the average of $C_0$ and $C_1$; $\mu$ represents whole image average, T is the threshold value. The inter-class difference selection function of Otsu multi-threshold algorithm $\delta_B{}^2(k)$ is

$$\delta_B{}^2(k) = \sum_{j=0}^{M-1}\sum_{k=j+1}^{M}\omega_j\omega_k(\mu_j - \mu_k)^2 \tag{2}$$

Where $\omega_j$、$\omega_k$ respectively represents the probability of two classes to be segment in [0 ~ $M$], M is the number of segmentation.

## 2 The description of Improved Otsu multi-threshold S-F algorithm

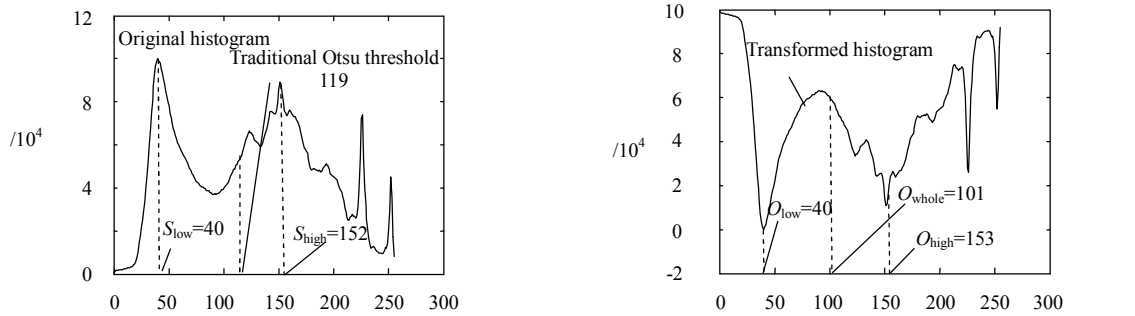
On the basis of obtaining multiple thresholds by improved Otsu method, the S-F algorithm is used to segment the multi-target images with uneven illumination. This paper is used to extract multiple steel pipe targets, cross sections are elliptic. The algorithm is divided into two steps:

### 2.1 Step 1: improve Otsu method to determine multiple thresholds

1) The determination of segmentation number M. As equation(2), The traditional Otsu multi-threshold method uses the separation factor measuring the degree of separability between classes as the recursive judgment condition, and determine the segmentation number, which has a large number of cycles, resulting in low operation efficiency. Therefore, according to the feature of steel pipe image characteristics with uneven illumination, the segmentation number M is determined according to the local single peak phenomenon of histogram caused by concave and convex phenomena. The histogram curve is drawn according to the grayscale image of steel tube in FIG. 1(a) as shown in FIG. 2(a). In the global scope, the gray level of about [40,152, 230] presents a single peak, while [40,152] obviously occupies most pixels. After observation on many experiments, it was observed that the gray scale of about [40,152] corresponds to the gray scale range of concave and convex phenomena. Therefore, with the bond of the global threshold $O_{\text{whole}}$, the image can be divided into two categories, and then local classification is carried out respectively, obtaining low threshold $O_{\text{low}}$ and high threshold $O_{\text{high}}$ to be the local segmentation points corresponding to the concave and convex phenomena. Therefore, the segmentation number M is settled as 3 to meet the requirements of uneven illumination images studied in this paper without affecting the segmentation accuracy. This greatly reduces the number of cycles and improves the operation speed.

2) The description of Improved Otsu method and determination of its margin. ① After analysis of traditional Otsu method, if the histogram peak and valley are not obvious, it will cause bad segmentation quality. The uneven illumination results in unimodal shape histogram of the local category, and there is no obvious "two-peak and one-valley" feature. Therefore, subtracting the number of grayscale pixels from the total number of pixels inversing shape of the unimodal histogram can be obtained, and the two-peak feature also can be obtained, the transformation result is given in FIG. 2(b); ② Before segmentation, the high threshold value $S_{\text{high}}$ and low

threshold value $S_{\text{low}}$ of rough segmentation were obtained by using the two-peak method, a small range of grayscale can be determined in its neighborhood, as the initial searching range (i.e. margin T) of Otsu threshold. The conventional Otsu method is based on the method with the minimum misclassification probability, which is relatively conservative in segmentation, and the threshold value is always ahead of the position of the valley bottom of the bimodal method. In order to easily do not cause the target to miss, the margin T is set as $T=-10+t$, that is, t is set on the basis of both the coarse threshold values of the bimodal method and the best threshold values of the Otsu method, which all lag 10 grayscale.




(a) 原始直方图，Otsu 法阈值[119]，双峰法阈值[40,152]

(a) Original histogram Otsu threshold [119]

Two-peak method threshold [40,152]

(b) 变换直方图 改进 Otsu 法阈值[40,101,153] 变量 $t=8$

(b) Transformed histogram improved Otsu

threshold [40,101,153] variable $t=8$

图 2 传统 Otsu 算法与本文算法搜索阈值对比

Fig.2 Traditional Otsu algorithm's searching thresholds compares with our algorithms'

3) Based on the determination of the segmentation number M and transforming of the histogram in figure 2, the segmentation accuracy discriminant (3) and the constraint expression (4) of the variable t can be given. Firstly, the global threshold $O_{\text{whole}}$ is obtained by using the selection function in equation (1), then calculate the below thresholds $S_{\text{low}}$ and high thresholds $S_{\text{high}}$ by using equation (2). The high thresholds $S_{\text{high}}$ and low thresholds $S_{\text{low}}$ are obtained by using two peak method, the local high threshold $O_{\text{high}}$ and the local low threshold $O_{\text{low}}$ are obtained by using improved Otsu multiple threshold method, then the $S_{\text{high}}$ and $O_{\text{high}}$, $S_{\text{low}}$ and $O_{\text{low}}$ are compared, a measure value $\Delta M$ is set as the difference between the two values. If $\Delta M \le KM$ ($KM$ is the constraint value as matter of fact), the variable $t$ is calculated and adjusted by equation (4), then fill the advance or delay grayscale caused by the improved algorithm until $t \le \Delta t$. $\Delta t$ is set as the small amount of grayscale not less than 1 pixel, as the perfect goodness of fit, which matchs with the high threshold and low threshold to achieve the optimization of threshold; If the $\Delta M > KM$, then the segmentation quality is not guaranteed and the initial parameters of the algorithm need to be adjusted.

$$\Delta M = \max\left|(O_{\text{high}} - S_{\text{high}}),(O_{\text{low}} - S_{\text{low}})\right| \le KM \tag{3}$$

$$t = ((O_{\text{low}} - S_{\text{low}}) + (O_{\text{high}} - S_{\text{high}}))/2 \le \Delta t \tag{4}$$

Since the two-peak method and Otsu method are complementary in mechanism, the prediction of

segmentation quality is obtained through mutual verification, which also needs to be carried out on the basis of setting T. As shown in figure 2(b), after histogram transformation, the improved Otsu multi-threshold guided by the dual-peak method is significantly better than the searching threshold by the traditional Otsu method.

### 2.2 Step 2: achievement of S-F algorithm and re-segmentation

In the first step, after calculating the multiple thresholds by the improved Otsu algorithm, combining with the characteristics of steel tube images with uneven illumination, the first corrosion then open operation and area marking filtration method in morphological operations to remove the obvious interference areas, then the processed images are fused, namely S-F algorithm. Finally, the fused image is segmented again. Since the image at this time has very obvious grayscale characteristics and is different from the background, conventional Otsu method is used to complete the segmentation.

### 2.3 The process of segmentation algorithm

The algorithm flow is shown in figure 3. The steps are as follows:

1) Input steel tube image $f(x,y)$ ，by processing of graying and median filtering，obtain the image $g(x,y)$.

2) Image $g(x,y)$ is initialized，each threshold value is calculated by the improved Otsu multiple threshold method.

3) Calculate $\Delta M$ ，judged by(3).If $\Delta M \le KM$ ，step into 4)，Otherwise adjust parameters to return to 2).

4) Calculate $t$ ，judged by (4). If $t \le \Delta t$ ，then segmentation，and step into 5)，Otherwise adjust t to return to 2)。

5) Morphological operations were carried out on each sub-image after segmentation，first corrosion then open operation，and the sub-images are subtracted by the original image after area marking filtration to remove the interference connected domain.

6) The sub-images are operated by fusion (5) after morphological operations to realize the information fusion of images and obtain image $h(x,y)$.

$$h(x,y) = w_1 g_1(x,y) + w_2 g_2(x,y) + w_3 g_3(x,y) \tag{5}$$

Where: $W_k$ (K = 1, 2, 3) represent multiple thresholds calculated by improved Otsu method, which set parameters of morphological operations for each sub-images, $g_k(x,y)$ represents each sub-image.

7) The fusion image $h(x,y)$ is segmented by the traditional Otsu method again.

8) After repeated recursive operation, the segmentation is completed until condition satisfied and the segmentation image is displayed.

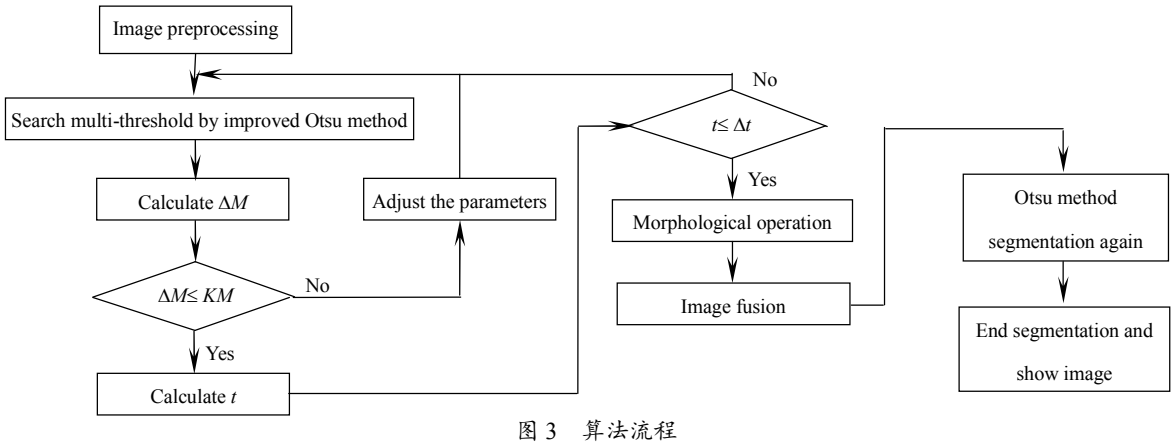



图 3 算法流程

Fig.3 Algorithm process

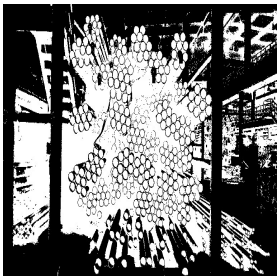
## 3 The experimental analysis

The experimental figure was taken from a steel pipe factory warehouse with a digital camera, and each image size was 4608×2592, in which the steel pipe radius occupies about 50 pixels. Therefore, when conducting morphological operations, the weighted average method was used to obtain circular structural elements, and the radius should be restricted within 10×5 for global sliding to ensure reliability. The experiment is based on MATLAB R2010a, Visual C++ 6.0 software and opencv-1.0.0 library platform.

To test the algorithm performance of this paper, respectively using the traditional Otsu segmentation method (Otsu), literature [6] improvement homomorphic filtering to enhance the Otsu segmentation method (IFHO), literature [9] block interactive image segmentation method (BIS) and the algorithm of uneven illumination of steel tube image segmentation in this paper, and the different segmentation results and performance of the algorithm are compared, as shown in figure 4 and are shown in table 1.

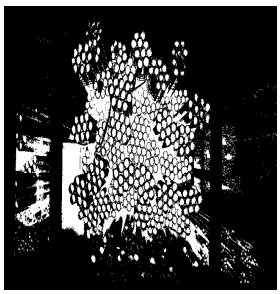
(a) 原图

(a) The original image



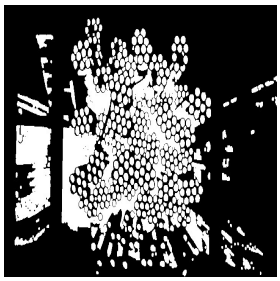
(b) 传统 Otsu 分割法

(b) Traditional Otsu method



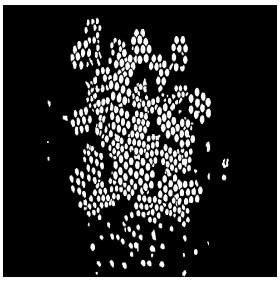
(c) 改进同态滤波增强后的 Otsu 分割法

(c) Otsu Segmentation method after improved homomorphic filter enhancement



(d) 分块图像交互式分割法

(d) Segmented image interactive Segmentation method



(e) 本文算法

(e) Our algorithm

图 4　四种分割算法效果对比

Fig.4　The effect comparison of four kinds of segmentation algorithms

表 1　4 种算法的主要性能对比

Table 1　The main performance comparison of 4 kinds of algorithms

| Segmentation algorithm | Otsu | IHFO | BIS | Our algorithm |
|---|---|---|---|---|
| Threshold | [119] | [108] | Each Sub-block threshold | [40，101，153] |
| Toc/s | 1.107 | 2.461 | 3.905 | 2.580 |

The traditional Otsu method has the advantages of simple calculation, strong robustness and minimal time consumption, but obviously it doesn't work very well here; IHFO method leads to the loss of the target part of steel pipe, increase the noise and make the wrong classification seriously; segmentation time of BIS method is random records, the segmentation effect is obviously better than the first two, but because of interactive segmentation, it can not achieve automation; by comparison, the algorithm in this paper is better than the former three in terms of the integrity and thoroughness of segmentation, and is not easily affected by the quality of illumination. Meanwhile, it can improve the compromise between enhancement and segmentation, and has a strong adaptability. However the time cost is also relatively long and still need to be further optimized. The optimal Threshold value and time consumption Toc of the four algorithms were calculated and shown in table 1. The speed test was performed on the platform of an Intel(R) Core(TM) i3 CPU, 2.67 GHz main frequency, and 2.00 GB of ram.

In order to further verify the superiority of this algorithm over traditional methods under the influence of uneven illumination, the segmentation experiment results of the other two images A and B under this algorithm are presented. In order to illustrate the adaptability of this algorithm to illumination, histogram analysis of these two images is presented. At the same time, the corresponding Threshold value and time consumption Toc list were given.

表 2　A、B 图像的本文算法性能参数

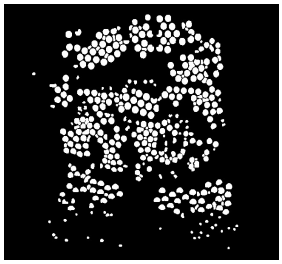
Table 2　Our algorithm performance parameter of the A、B images

| Image | Threshold | Toc/s | Segmentation algorithm |
|---|---|---|---|
| A image | [50,87,205] | 2.573 | Our algorithm |
| B image | [26,127,252] | 2.587 | Our algorithm |

As shown in figure 5, 6 and table 2, the superiority of this algorithm over the traditional segmentation algorithm in the case of uneven illumination and its adaptability to illumination were verified.

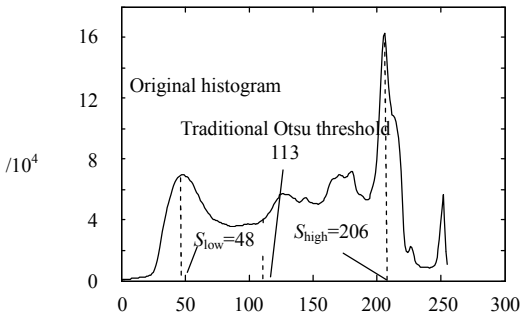
(a) 原图

(a) The original image



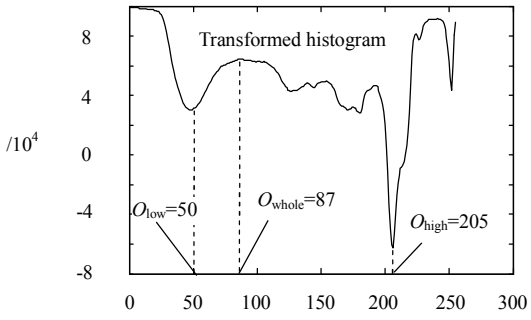
(b) 本文算法分割

(b) Our algorithm segmentation




(c) 原始直方图、Otsu 法阈值[113]、双峰法阈值[48,206]

(c) Original histogram Otsu threshold [113] Two-peak method threshold [48,206]

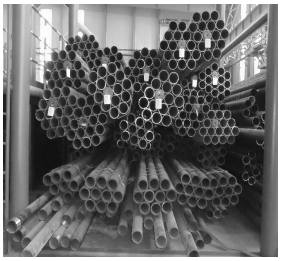



(d) 变换直方图、改进 Otsu 法阈值[50,87,205]变量 $t$ = 5

(d) Transformed histogram improved Otsu threshold [50,87,205] variable $t$ = 5

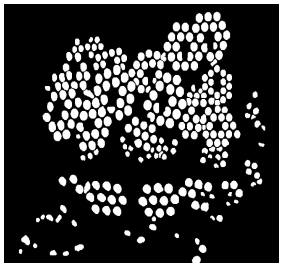
图 5 A 图本文算法分割结果及对应直方图分析

Fig.5 Otsu Algorithm's Segmentation result and histogram's analysis of the A image



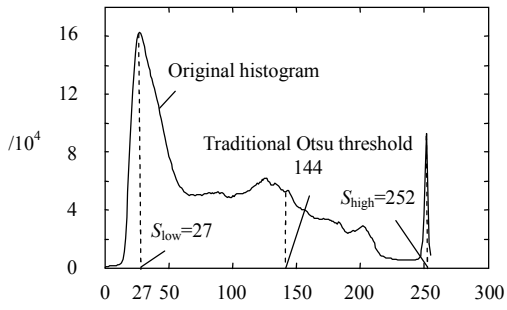
(a) 原图

(a) The original image



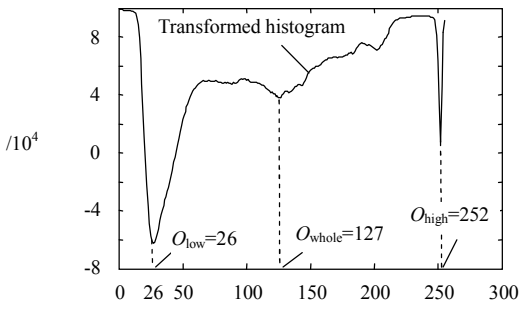
(b) 本文算法分割

(b) Our algorithm segmentation




(c) 原始直方图、Otsu 法阈值[144]、双峰法阈值[27,252]

(c) Original histogram、 Otsu threshold [144]、 Two-peak method threshold [27,252]




(d) 变换直方图、改进 Otsu 法阈值[26,127,252] 变量 $t$ = 7

(d) Transformed histogram improved Otsu threshold [26,127,252] variable t = 7

图 6 B 图本文算法分割结果及对应直方图分析

Fig.6 Otsu Algorithm's Segmentation result and histogram's analysis of the B image

# 4 Conclusion

In this paper, an image segmentation algorithm based on multi-threshold S-F method is proposed to solve the problem that traditional image segmentation methods are easily affected by uneven illumination. This method improves the traditional Otsu multi-threshold method, and uses the transformed histogram by two-peak method to obtain rough segmentation threshold, which serves as guidance and verification, and by recursion search to carry out segmentation after obtaining each segmentation thresholds, and the information of each sub-images are fused to achieve the segmentation after morphological operations. This paper verifies the algorithm by using the steel pipe image taken by a steel pipe factory, and compares the experimental results of this algorithm with traditional Otsu segmentation method, improved homomorphic filtering enhanced segmentation method and block image interactive segmentation method. Experimental results show that the proposed algorithm is stable, accurate and insensitive to light intensity.

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