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## Research of Image Contour Extraction Method of Coal Mining Image Based on OTSU

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**Abstract:** Image segmentation and contour extraction are key techniques in the computer vision technology. Due for the environmental impact of the coal mine, most of the image are vague and mixed with a large amount of image noise which brought many difficulties to the image contour extraction. Traditional image feature extraction techniques applied directly to the image can not get a satisfied effect. Aiming at the shortcomings of traditional image contour extraction, a practical contour extraction method is introduced. The method combines the characteristics of computer vision technology, based on the improved OTSU image segmentation method, using morphological methods to extract the outline of the binary image characteristics. Experimental results show that the method of processing the image contours have the advantages of strong anti-interference and high accuracy etc. which can meet the needs of practical application.

**Key words:** Coal mining, image, threshold segmentation, computer vision, contour extraction

### INTRODUCTION

With the application of virtual reality and image positioning to underground coal mining, the requirements of real-time image processing, such as equipment health status perception, underground staff environmental perception and mine disasters perception are increasing. Image contour is not only a very important foundation in the field of image analysis such as image segmentation, identification of the target area and regional shape extraction, but also an important attribute used to extract image features in image recognition research. However, in harsh coal mine subsurface environment, underground images are very vulnerable to the interference of the dark, damp, coal dust and other unfavorable factors which makes the acquired image becomes blurred and mixed with a lot of noise, thus affecting the image contour extraction (Gong *et al.*, 2007).

For the existing problems in the traditional image contour extraction methods, combined with the characteristics of computer vision technology, this study presents a practical method of contour extraction that is, to adopt the improved threshold segmentation method which is based on OTSU to realize image segmentation (Lin *et al.*, 2005) and to use morphological binary image filtering to extract image contour characteristics. Compared with classic edge detection methods, this method has the following advantages: (1) He

improved image segmentation method based on OTSU theory makes the best segmentation threshold immune to noise and the contour feature is completely determined by the gray value of the image itself, (2) Complete image contour can be extracted and continuous image edge can be detected after image segmentation by the improved threshold segmentation method and (3) Calculation amount is small, simple and easy to implement.

### OTSU PRINCIPLE

OTSU is the optimal method among automatic threshold selection methods (Otsu, 1979). The basic idea of the method is to divide the image into two groups by taking a certain gray value of the histogram as threshold value and then calculate the variance of the two groups. When the variance between the divided two groups reaches the maximum, take that gray value as threshold to realize image segmentation (Qi *et al.*, 2006; Sun and Chen, 2008; Sun *et al.*, 2009). Let the gray value  $k$  of a gray-scale image with a size of  $M \times N$  be  $(0, 1, \dots, L-1)$  and let  $f(x, y)$  be the gray value of image point  $(i, j)$ , then the basic steps of the OTSU algorithm are as follows:

**Step 1:** Calculate statistic result of the image histogram, obtaining the frequency of the gray value  $PHK(k)$ :

$$PHK(k) = \frac{1}{M \times N} \sum_{f(i,j)=k} 1 \quad (1)$$

**Step 2:** Calculate the gray value average of the image:

$$\mu_T = \sum_{k=0}^{L-1} k \times PHK(k) \quad (2)$$

**Step 3:** Calculate the gray class mean  $\mu(s)$  and the sum of class histogram  $\omega(s)$ :

$$\mu(s) = \sum_{k=0}^s k \times PHK(k) \quad (3)$$

$$\omega(s) = \sum_{k=0}^s PHK(k) \quad (4)$$

**Step 4:** Calculate class separation index  $s_B$ :

$$\sigma_B = \frac{[\mu_T \cdot \omega(s) - \mu(s)]^2}{\omega(s)[1 - \omega(s)]} \quad (5)$$

Finally, determine  $s_B$ , reaching the maximum  $s$ , then the optimal threshold  $T = s$ .

### IMPROVED IMAGE CONTOUR EXTRACTION METHOD BASED ON OTSU THEORY

The task of Contour extraction is to extract the outline contour of the target from a single image or sequence images for subsequent processing. Effective image contour extraction is very important for Subsequent tasks such as underground image target perception and real-time positioning. One important part in Contour extraction is the threshold segmentation (Wang *et al.*, 2008) which is applied to separate the image target from background. The thoroughness of background removal as well as the integrity of retained information of the target image directly determines whether the next task can be completed normally, therefore, this article will adopt a new shareholding method, on the one hand, to reduce the amount of computation and on the other hand, to maintain the continuity of image contour as far as possible. Figure 1 shows the flow of contour extraction.

**Image enhancement:** Due to light, dust, humidity and other environmental factors, images are always seriously polluted. Images transmitted by underground suffer poor resolution as well as quality. And image processing exert a direct impact on the accuracy of the follow-up image segmentation and contour extraction; Therefore, in order

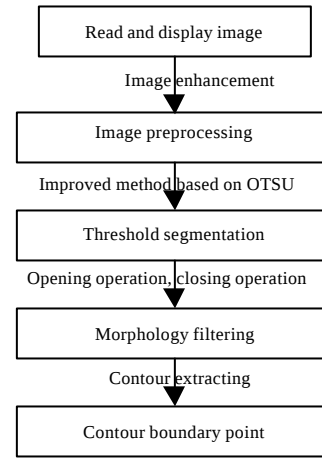


Fig. 1: Flow of contour extraction proposed in this study

to improve the quality of the image, to facilitate the detection, image enhancement becomes an essential part. The major goal of image enhancement is to improve the image quality, to extrude the prominent image edge information, to better the contrast, to enhance contour feature so as to ensure the detection accuracy. Image enhancement includes gradation and contrast processing, noise cancellation, the edge protuberance and sharpening, filtering, interpolation and amplification, as well as pseudo-color processing, etc. Active enhancement techniques can be divided into two parts, namely, airspace image enhancement method and frequency-domain image enhancement. The former directly focuses on the image-pixel processing and the latter first conducts image Fourier transform before processing. In order to simplify the calculation amount, this article employs airspace enhancement method for image processing. Airspace Enhancement includes gray transformation, histogram transformation, image impulse noise model, neighborhood averaging, median filtering and image sharpening, etc. (Li and Zhang, 2010; Li *et al.*, 2012).

According to different processing basis (each processing of the image is by a single pixel or by a small sub-picture), Airspace enhancement method can be divided into two groups: Pixel-based (dots) and template-based. In the pixel-based processing, the process of the processing of each pixel is independent from the other pixel and template processing means every processing operation is based on a small region of the image. Airspace Enhancement method can be expressed as:

$$G(x, y) = EH[f(x, y)]$$

where,  $f(.)$  and  $g(.)$  are images before and after the enhancement, respectively; EH means to enhance the operation. If EH is defined at each  $(x, y)$ , then is the operation point; if EH is defined at a certain neighborhood of  $(x, y)$ , then EH is called template operation. EH works not only for one image  $f(.)$ , but also for a series images  $\{f_1(.), f_2(.), \dots, f_2(.)\}$ .

#### Improved threshold segmentation based on OTSU:

Traditional OTSU method searches the threshold on the entire gray scale (Jin *et al.*, 2005) which asks to calculate the interclass variance for each gray value, the computation is huge and this method is not ideal for complex background image segmentation. In order to improve underground image real-time location and the contour extraction effect, on the basis of keeping the standard of judging the optimal threshold the same, this study puts forward a new threshold segmentation method based on OTSU theory, the specific process is as shown in Fig. 2:

- **Initial threshold segmentation:** The initial threshold segmentation is done with use of the average gray value of the whole image. This selection bases on a simple image statistics process, avoiding the analysis of complex image gradation histogram. Let the gray value of a gray-scale image with a size of  $M \times N$  be  $(0, 1, \dots, L-1)$ , then the initial threshold value is:

$$T_0 = \frac{\sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x, y)}{M \times N} \quad (6)$$

- **Calculate the target mean:** The initial threshold value  $T_0$  divides the image into two parts, let the region that is smaller than  $T_0$  be target area  $C_0$  and that that is larger than  $T_0$  be target area  $C_1$  that is:

$$C_0 = \{f_{C_0}(x, y) | 0 \leq f(x, y) \leq T_0\} \quad (7)$$

$$C_1 = \{f_{C_1}(x, y) | L-1 \geq f(x, y) > T_0\} \quad (8)$$

The mean gray value calculation equation of  $C_0$ ,  $C_1$ , respectively as shown in Eq. 9 and 10:

$$T1 = \frac{\sum_{i=0}^{T_0} f_{C_0}(x, y) \times i}{\sum_{i=0}^{T_0} f_{C_0}(x, y)} \quad (9)$$

$$T2 = \frac{\sum_{i=T_0+1}^{L-1} f_{C_1}(x, y) \times i}{\sum_{i=T_0+1}^{L-1} f_{C_1}(x, y)} \quad (10)$$

- **To determine the optimal threshold:** In the interval  $[T_1, T_2]$ , the optimum threshold value  $T$  is obtained by using the OTSU method, thereby avoiding the search for the optimum threshold value in the entire gradation level which greatly reduces the amount of computation and the subsequent experimental results show that the improved method is also more efficient in target segmentation and maintaining the continuity of the target image contour

**Morphological filtering:** The binary image obtained in section 3.2 has a prominent problem that some parts suffer discontinuity which makes the objects that originally belong to the same target be divided into different parts and this will result in discontinuity in the extracted contours, affecting the final effects. Therefore, some methods need to be adopted to eliminate these defects.

Mathematical morphology (Maragos, 2005) is a nonlinear filtering method and the basic idea is to use the structural elements with a certain shape to measure and extract the corresponding form in the image objects so as to achieve the purpose of image analysis and identification. There are four fundamental operations in mathematical morphology, namely, erosion, dilation, opening operation and closing operation:

- Erosion is a process that eliminates the boundary points and makes the boundary shrink into the internal. Erosion operation is quite useful for eliminating meaningless burr in images and it can eliminate the boundary point and salient point. If erosion operation is repeatedly conducted app: Addword:repeatedly or the structural elements are large enough, the thin connected part can completely be separated. Let a binary image function be  $A(x, y)$ , structural element be  $B(x, y)$  and define erosion as:

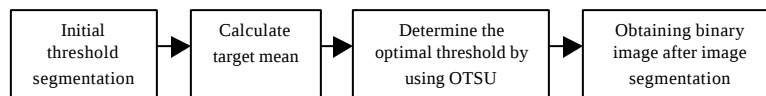


Fig. 2: Flow of improved method based on OTSU

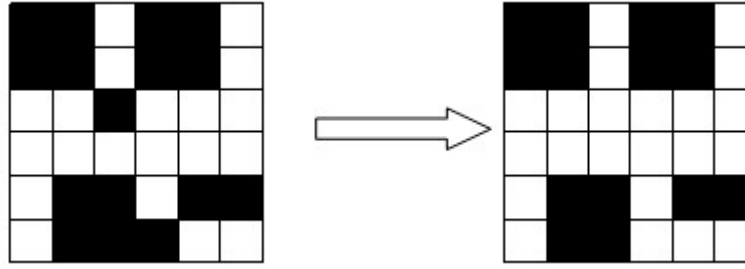


Fig. 3: Schematic diagram of erosion processing

$$E = A \otimes B = \{x, y | B_{xy} \subseteq A\} \quad (11)$$

The erosion algorithm implementation in this study is as follows:

```
void Erodeable(BYTE *image_in, BYTE *image_out, int xsize, int ysize)
{
    int i, j;
    for (j=1; j<ysize-1; j++)
    {
        for (i=1; i<xsize-1; i++)
        {
            *(image_out+j*xsize+i) = *(image_in+j*xsize+i);
            if (*(image_in+(j-1)*xsize+i-1) == LOW)
                *(image_out+j*xsize+i) = LOW;
            if (*(image_in+(j-1)*xsize+i) == LOW)
                *(image_out+j*xsize+i) = LOW;
            if (*(image_in+(j-1)*xsize+i+1) == LOW)
                *(image_out+j*xsize+i) = LOW;
            if (*(image_in+j*xsize+i-1) == LOW)
                *(image_out+j*xsize+i) = LOW;
            if (*(image_in+j*xsize+i) == LOW)
                *(image_out+j*xsize+i) = LOW;
            if (*(image_in+j*xsize+i+1) == LOW)
                *(image_out+j*xsize+i) = LOW;
            if (*(image_in+(j+1)*xsize+i-1) == LOW)
                *(image_out+j*xsize+i) = LOW;
            if (*(image_in+(j+1)*xsize+i) == LOW)
                *(image_out+j*xsize+i) = LOW;
            if (*(image_in+(j+1)*xsize+i+1) == LOW)
                *(image_out+j*xsize+i) = LOW;
        }
    }
}
```

- Dilation is processes that merges the entire background point tangent with the object to the object and make the boundary expand into the external. Dilation operation has the function of expanding the input image and it can fill holes with relative smaller structural element in the image and small hollow part in the image edge. Dilation is defined as:

$$D = A \oplus B = \{x, y | B_{xy} \cap A \neq \Phi\} \quad (12)$$

The dilation algorithm implementation in this study is as follows:

```
void Dilation(BYTE *image_in, BYTE *image_out, int xsize, int ysize)
{
    int i, j;
    for (j=1; j<ysize-1; j++)
    {
        for (i=1; i<xsize-1; i++)
        {
            *(image_out+j*xsize+i) = *(image_in+j*xsize+i);
            if (*(image_in+(j-1)*xsize+i-1) == HIGH)
                *(image_out+j*xsize+i) = HIGH;
            if (*(image_in+(j-1)*xsize+i) == HIGH)
                *(image_out+j*xsize+i) = HIGH;
            if (*(image_in+(j-1)*xsize+i+1) == HIGH)
                *(image_out+j*xsize+i) = HIGH;
            if (*(image_in+j*xsize+i-1) == HIGH)
                *(image_out+j*xsize+i) = HIGH;
            if (*(image_in+j*xsize+i) == HIGH)
                *(image_out+j*xsize+i) = HIGH;
            if (*(image_in+j*xsize+i+1) == HIGH)
                *(image_out+j*xsize+i) = HIGH;
            if (*(image_in+(j+1)*xsize+i-1) == HIGH)
                *(image_out+j*xsize+i) = HIGH;
            if (*(image_in+(j+1)*xsize+i) == HIGH)
                *(image_out+j*xsize+i) = HIGH;
            if (*(image_in+(j+1)*xsize+i+1) == HIGH)
                *(image_out+j*xsize+i) = HIGH;
        }
    }
}
```

- The process that erosion comes before dilation is called opening operation and that that dilation works before erosion is called closing operation. Let  $A \circ B$  represent the opening operation in which A operates on B and  $A \bullet B$  represent the closing operation in which A operates on B, so their definitions are:

$$A \circ B = (A \otimes B) \oplus B \quad (13)$$

$$A \bullet B = (A \oplus B) \otimes B \quad (14)$$

where,  $A \circ B$  can be regarded as recovering corrosion image  $A \otimes B$  by dilation and  $A \bullet B$  can be regarded as recovering dilation image  $A \oplus B$  by erosion. Opening operation can eliminate discrete point and burr that is, conduct smooth onapp: addword: smooth binary image and connect two adjacent targets through closing operation which is convenient for further extracting complete contour app: addword: burr.

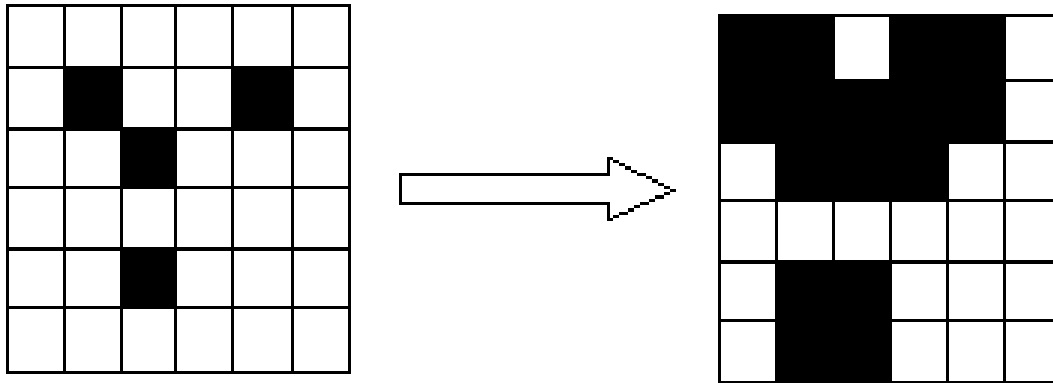


Fig. 4: Schematic diagram of dilation processing

Both opening operation and closing operation have function of denoising and both of them can eliminate specific image details, meanwhile ensuring that it does not cause a global geometric distortion, but they have different emphasis on the elimination of noise. The Open computing is mainly to remove tiny connection isolated points and the salient part of the image and to cut lathy lap joint which plays a role of separating and makes the image smoother. The closing operation is to remove the foraminule and the concave portion of the image, to fill the small gaps or holes in the target internal and to lap short intermittent, thus, playing a connecting role. Therefore, the opening operation is chosen in this study to eliminate discrete points and burr in the image.

**Image contour extraction and tracking:** The purpose of image contour extraction is to obtain the external contour feature from binary image after morphological filtering. The idea of image contour extraction is to use a structural element with nine points to corrode image and then let the original image minus the corrosion image. The theory of the algorithm is that if one point of the original image is black and its eight adjacent points are all black, then the change point is thought to be the internal point, delete it. The contour extraction rules are as follows:

- If the center pixel value is 0 and no matter what the remaining 8 pixel values are, retain the central pixel value be 0
- If the center pixel value is 1 and the remaining 8 pixels values are all 1, then change the center pixel value to 0
- In addition, all of the center pixel value is set to 1

The contour extraction algorithm implementation in this study is as follows:

---

```

BOOL FindContours(unsigned char *pImageData, int nWidth, int nHeight,
int nWidthStep)
{
    int i=0, j=0;
    unsigned char *pLine[3] = { NULL, NULL, NULL };
    for (j=1; j<nHeight-1; j++)
    {
        pLine[0] = pImageData + nWidthStep * (j-1);
        pLine[1] = pImageData + nWidthStep * j;
        pLine[2] = pImageData + nWidthStep * (j+1);
        for (i=1; i<nWidth-1; i++)
        {
            if (pLine[0][i-1] == 0xFF andand
                pLine[0][i] == 0xFF andand
                pLine[0][i+1] == 0xFF andand
                pLine[1][i-1] == 0xFF andand
                pLine[1][i] == 0xFF andand
                pLine[1][i+1] == 0xFF andand
                pLine[2][i-1] == 0xFF andand
                pLine[2][i] == 0xFF andand
                pLine[2][i+1] == 0xFF)
            {
                pLine[0][i-1] = 0;
            }
            else
            {
                pLine[0][i-1] = pLine[1][i];
            }
        }
    }
    return TRUE;
}
    
```

---

where, the pointer pImageData points at the image data in the memory, nWidth and nHeight, respectively denotes the width and height of the image, nWidthStep means the number of bytes an image needs to store a row of pixels, usually in multiples of 4.

Image contour tracking is to find out the edge points by sequence to track beyond the boundary. The basic method of contour tracking is to firstly find out the pixels of target object contour according to some strict “detection criteria”, then find out other pixels of the target object contour based on characteristics of these pixels in line with certain “tracking criteria”. The contour tracking algorithm in this study is described as follows:

- First, search in the order of top-to-bottom and left-to-right. And the first non-foreground point to be

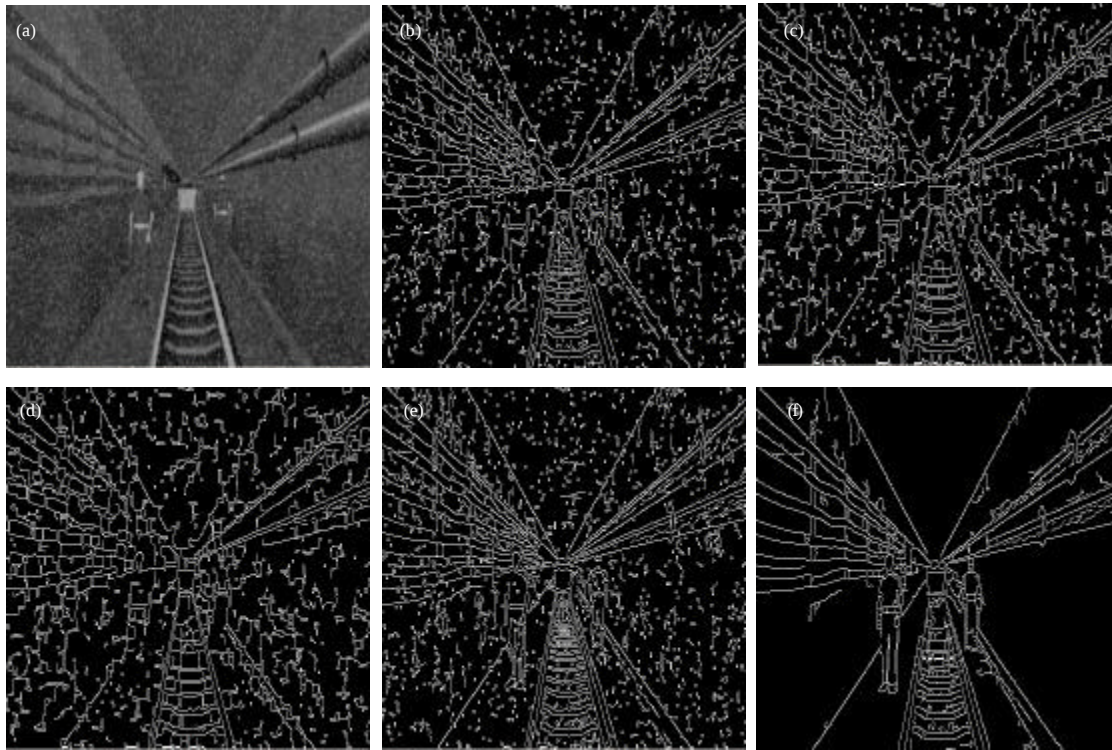


Fig. 5(a-f): Comparison of the extracted contours (a) Underground image with noise, (b) Contour extracted by Roberts operator, (c) Contour extracted by Laplace operator, (d) Contour extracted by Sobel operator, (e) Contour extracted by Prewitt operator and (f) Contour extracted by the method proposed in this study

found must be the upper left boundary point which can be denoted by A. Among the four adjacent points at its right, lower right, lower, lower left, there is at least one boundary point which is referred to as B

- Starting from the beginning B, search boundary point C in the adjacent points in the order of right, upper right, upper, upper left, left, lower left, lower and lower right
- If C is point A, it shows that the process has gone through a circle and it is the end of the program. Otherwise, keep looking from point C until A is found

## EXPERIMENTAL RESULTS

In order to test the effect of contour extraction method proposed in this study, an underground image with noise was selected and comparisons have been made with traditional Roberts operator, Laplace operator, Sobel operator and Prewitt operator. The experimental results are as shown in Fig. 5. Figure 5a is the original extracted image. From the figure it can be seen that due to the influence of factors such as lighting and coal dust, the image appears fuzzy and is mixed with a large amount of

noise. Figure 5b-e are extracted image contours by Roberts operator, Laplace operator, Sobel operator and Prewitt operator. It shows that Sobel operator is the only one that can detect a rough contour. The detected contours by other operators are not obvious with a lot of noise and the disconnection is serious. It almost could not tell the difference between the object contours of the image. A common problem of the detected results of these operators is that the extracted image contours are seriously affected by image noise which significantly affects the outline features of the image. Figure 5f is the image contour extracted by adopting the proposed method in this study. From the figure it can be seen, the proposed method can extract the image contour well. In the contour, the edge of the target object in the image is very obvious, maintaining a good continuity and the contour also possess good noise immunity, receiving very mild influence:

## CONCLUSION

The underground positioning and sensing technology is more and more widely used in coal industry and image contour extraction is usually an essential part.

Selecting the appropriate image contour extraction method is very important to ensure the accuracy of positioning. Against the existing problems of the traditional edge detection methods, combining with characteristics of computer vision technology, an image contour extraction method which is applicable to coal mine underground has been put forward. This method uses gray threshold to realize image segmentation and mend binary image's imperfection by employing mathematical morphology which has achieved rapid contour extraction. The experiments show that, compared with the classic edge detection methods, the extracted contour adopting the proposed method has a strong anti-interference, high accuracy, good practicality and is able to meet the needs of the practical underground work in coal industry.

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