A Fast Algorithm of Extracting Rail Profile Base on the Structured Light

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Abstract

This paper analyzes the theory of extracting rail profile based on the structured light and proposes a fast algorithm of extracting rail profile. The precise profile of rail section is obtained by extracting R color feature component in the RGB image. This algorithm, which has been proved in the experiment, has features, such as robust anti-noise capacity, fast calculation, high accuracy and etc. It's used in non-contact inspecting rail gauge whose inspecting accuracy is 0.01mm and maximum deviation is 0.2mm.

Keywords: image segmentation, structured light, background remove, contour extraction

Introduction

With the rapid development of high-speed railway, track inspection technology has become an important prerequisite to guarantee the safety of high-speed rail transport operation.

The track detection (CHEN dong-sheng, 2008) technology mainly includes two aspects: the track geometry detection and rail wear detection. The track used to be inspected by manual sampling, which was inefficient and was incapable to dynamically inspect objects with considerable manpower and resources. At the same time, this manual sampling measurement was inevitably interfered by human factors, which undermined accuracy and reliability of measurement results.

With the development of machine vision technology (Zhang Zheng-you, 2000; WANG Chun-lei, ZHU Jin. 2008), the three-dimensional visual measurement technology, such as structured light, has been widely applied due to its non-contact, high speed, high accuracy, and strong real-time characteristics. The key of machine vision technology in track detection is to quickly and accurately extract the rail profile information. The detection accuracy depends on the extracting speed and precision.

Extracting System Design

The rail profile extracting system includes linear laser, high-speed camera, high-speed visual image collecting system, software and its related mechanical structure and etc.

System design is shown in Figure1.The high-speed camera is installed between the rails and put underneath the train. The laser is perpendicularly projected to the rail surface in longitudinal direction, the rail intersection profile produced by the light plane and rail is obtained using rail profile imaging system in the same side. The information of the rail profile image will be extracted in real time after image processing and visualization measurement.

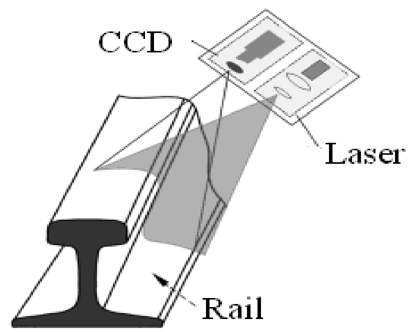


Figure 1: System Principle

The traditional image extracting algorithms are based on the grayscale image, such as color image segmentation using histogram threshold methods, region growing and merging methods (A. Tremeau, and N. Borel,1997), edge extracting and tracing methods (Nevatia,1977), clustering algorithms such as k-means methods (R. J. Schalkoff, 1992) or mixture of principal components methods (S.Wesolkowski, M.E.Jernigan, R.D.Dony,1999). Most of the methods use color similarity to do color segmentations. These methods are easy to implement, while the accuracy is usually not high.

Since the rail acquisition image background noise is complex, it is difficult to achieve online rapid extraction of the optical information. The traditional segmentation method based on gray image is insufficient, and the edge detection algorithm is slow. So, in this paper, a fast rail profile algorithm is proposed based on the structured light.

Algorithm Theory

As we have mentioned above, many segmentation algorithms for color image were grown from segmentation algorithms for gray-scale images. Many of them treated RGB components of a color image separately or even just treated them as three gray-scale images, which may not fully use the information offered by these three color-components. This algorithm is featured by a single structured light color, and the large contrast of the rail section contour image formation.

The algorithm is deduced in the following procedures.

- Step 1、Extract the red component in the rail RGB image I(M*N). Assume I(M*N) to be a RGB color Image. I_R is the red component of the image I. It is clear that I_R image has the same size as I has.
- Step 2、Create a mask image M from I . T and I have the same size. The Mask image M has to meet the following condition:

$$R(i, j) = \frac{\sum_{m=1}^{M}\sum_{n=1}^{N} S_{ij}(m,n) \times T(m,n)}{\sqrt{\sum_{m=1}^{M}\sum_{n=1}^{N}[S_{ij}(m,n)]^2}\sqrt{\sum_{m=1}^{M}\sum_{n=1}^{N}[T(m.n)]^2}} \quad (1)$$

When R(i,j)=1, these two images are completely same. Otherwise, When R(i, j)<1, the larger correlation coefficient is, the better result will be obtained. The gray-scale images in the primary image I is extracted by the theory of the maximum similarity as the mask image M;

- Step 3、difference image methods

$$C(x, y) = A(x, y) - B(x, y) \quad (2)$$

In the formula (2), A(x, y) is current image, B(x, y) is fixed background image (match template) and C(x, y) is the output image. The I_R image obtained in the first step is A(x,y) and the mask image obtained in the second step is B(x, y),M= B(x, y).

But their values could be negatives. To remove the negative values, we could have redefine I'_R. Assume I is a RGB color Image, and I_R, I_G, and I_B are three color-components of image I. I'R could be defined as $I'_R = I_R + Amax$.

Amax is a constant matrix image of A. And Amax is the maximum value of I_R, I_G and I_B. Then Amax = max(I_R(i, j), I_G(i, j), I_B(i, j)).

To simplify the calculations of Amax = max(I_R(i, j), I_G(i, j), I_B(i, j)), Amax could be defined as a constant matrix image with the value 255 or what you need, or I'_R is A(x,y)。C(x,y)= I'_R – M.

- Step 4、Binaryzation

To satisfy the speed requirement of real-time dynamic image processing, the binaryzation is realized by adopting overall threshold method on the base of the pixel.

T in the image C (x, y) is the segmentation threshold of foreground and background. The foreground pixels are w_0 percent of image and the average gray scale is u_0; the background pixels are w_1 percent of image and the average gray scale is u_1. The total average of image gray scale is as following:

$$u_T = w_0 \times u_0 + w_1 \times u_1 \tag{3}$$

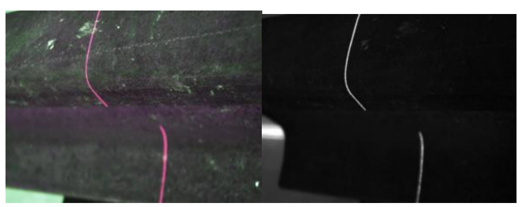
The value T goes through from the minimum gray value to the maximum gray value when T is square deviation.

$$\delta^2 = w_0 \times (u_0 - u_T)^2 + w_1 \times (u_1 - u_T)^2 \tag{4}$$

The value of T is optimal dividing value when δ^2 is maximum.

Testing Results

The AVT CCD camera, which is used in experiment, has 1280×960 pixels and use the sector structured light of red with 635nm output wavelength.



(a) Original image (b) R component image

(c) Binary image (d) Contour

Figure 2: Images Processing Result

This algorithm is applied in contactless rail gauge measuring system. The system, which satisfies the railway operation safe standard, can run on the rail of the standard gauge 1435mm with the maximum speed 45km/h. The data in table 1 illustrates one spot measured by multiple times. As we know according to the measuring result, this gauge measuring system can effectively obtain the variation data, which the maximum deviation is smaller than 0.2mm and the precise reaches 0.001mm, which satisfies the high-precise measuring requirement in the experiment. The data in the experiment is obtained by Leica TDA 5005.

Table 1: Gauge Measuring Data (unit: mm)

No.	Spot 1	Spot 2	Spot 3	Spot 4
1	1438.749	1437.336	1434.214	1434.156
2	1438.636	1437.491	1434.234	1434.012
3	1438.639	1437.407	1434.114	1434.056
4	1438.667	1437.323	1434.133	1434.13
5	1438.784	1437.439	1434.051	1434.087
Average	1438.695	1437.399	1434.149	1434.08
Standard value	1438.650	1437.442	1434.125	1434.102
Deviation	0.045	-0.043	0.024	-0.014

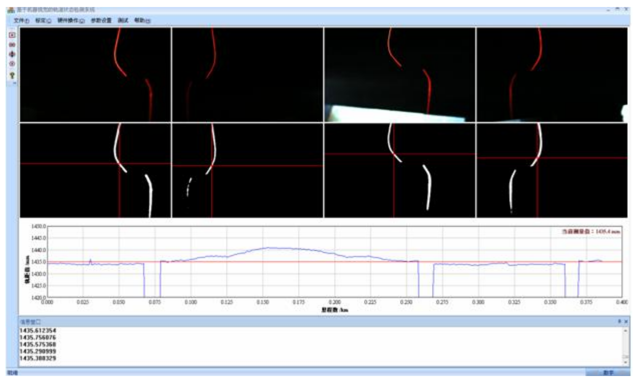


Figure 3: Gauge Detection

Discussion and Conclusions

According to the testing results, the new algorithm shows the following advantages:

(1) Robust in system color intensity error: the system error in colors intensity will not affect the result as the new algorithm uses the differences of original colors. To verify this strongpoint, two cryosection images have been selected for testing as below. The color of one selected image (the right side below) is much darker than the color in the other one (the left side below). The new algorithm worked well on both images without changing any parameters.

Figure 4: Contour Extraction under Different Illumination

(2)Faster and efficient: They come from the simplified algorithm and the fact of "all operators used by the new algorithm are simple".

(3)The speed, precise and reliability of extracting the rail profile image is improved and can satisfy the real-time extracting requirement. The gauge deviation is smaller than 0.2mm and the precise reaches 0.001mm in the real-time gauge measuring system.

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