Rail Surface Area Localization Based on Vertical Projection

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Abstract. In order to shorten the time-consuming of the image preprocessing stage and improve the accuracy of the rail area positioning, a new method is proposed. First, the image is converted into a binary image, then the image is divided into the same distance in a horizontal direction, and finally the rail boundary is determined based on the abrupt change of the gray value on the bisector. Compared with horizontal projection method, searching for the H value mutation method, Prewitt operator and other algorithms, the new method has obvious improvement in time and precision.

Introduction

Rails are the main components of railway tracks, and their quality directly affects the safety of railway operations [1]. Rail positioning and segmentation is the fundamental component in the track defect detection system. Image segmentation is to divide the image into some non-intersecting interconnected sub-regions with similar features [2]. The original orbit images include noise, rails, sleepers, fasteners, ballast, and garbage. If the whole track image is processed directly, the workload of subsequent processing will be increased, so it is necessary to locate the rail surface. The surface of the rail is regarded as the foreground area, and the other parts are regarded as the background area [3]. Aiming at the segmentation and extraction of the foreground region of orbital images, there have been some researches and analysis at home and abroad, and specific methods have been proposed. In [4,5], the vertical direction of the original image is divided into several bisectors. From these bisectors, the mutation of the hue is searched. The upper and lower boundaries of the orbit are located according to the position of the mutation. If the mutation point is not found, the step length needs to be re-determined. In [6], the vertical edge of the measured image is enhanced by using a horizontal gradient operator, then the image is projected in the horizontal direction, the number of pixels of each row of pixels equal to 255 is counted, and finally the position of the two peaks can be judged to be the approximate position of the upper and lower orbit edges, but the use of the horizontal gradient operator is relatively time-consuming. The literature [7,8] first converts the image into a binary image, then counts the value of each row with a gray value of 1 and finds the row with the largest mean to distinguish the boundaries of the track. Considering that to count the value of each row needs to traverse the entire image, it still takes a certain amount of time. In this paper, the image is converted into a binary image, and the image is divided into the same distance in the horizontal direction. Then the search for the mutation point is started on the bisector in the vertical direction, the upper and lower boundary coordinates are recorded, and the image is segmented according to the coordinates. Since the vertical projection only needs to traverse the values of several bisectors, the running time will be reduced.

Vertical Projection Method

On the basis of searching for the H value mutation method [9,10], the H value of the original image is not directly searched for the boundary of the track, but the original image is first converted into a binary image, and then to draw a projection of a vertical pixel at a certain interval to determine the upper and lower boundaries. First, select the bottom of the binary image as the x-axis, and the left end of the image as the y-axis. Let the size of the image be $u \times v$, the range of the detected image is $\{x|0 \leq x \leq u, x \in N\}$, $\{y|0 \leq y \leq v, y \in N\}$, as shown in Figure 1.
Divide the image into \( n \) equal parts. The point on the \( p \)-th bisector is \( (x_p, y_p) \), the value of each point is \( h(x_p, y_p) \), and \( \{ p \mid 0 < p \leq n - 1, p \in \mathbb{N} \} \), \( \{ i \mid 0 \leq i \leq u, i \in \mathbb{N} \} \). Draw vertical projection on the \( p \)-th bisector, as shown in Figure 2.

The position of the two mutation points can be clearly seen from Figure 2. In order to conveniently record the coordinates of the mutation points on the \( p \) bisector, set the mutated region to \( d \), and the method for determining the upper boundary \( L_u \) is as shown in Eq. 1:

\[
L_u = \begin{cases} 
    h(x_p, y_i) = 0 \\
    h(x_p, y_{i+1}) = 1 \\
    j = i + 1 \\
    h(x_p, y_j) = 1, i + 1 \leq j \leq d + i + 1
\end{cases}
\]  

(1)

The gradation value of the \( i \)-th coordinate point is 0, and the gradation value of the \( i+1 \)-th coordinate point is 1. Record the current coordinate with \( j \). If the gray value is always 1 in the \( d \) region of the current coordinate, then the point is the coordinate of the upper boundary. The method for determining the lower boundary \( L_l \) is as shown in Eq. 2:

\[
L_l = \begin{cases} 
    h(x_p, y_i) = 1 \\
    h(x_p, y_{i+1}) = 0 \\
    j = i + 1 \\
    h(x_p, y_j) = 1, i + 1 - d \leq j \leq i + 1
\end{cases}
\]  

(2)

The change of a certain coordinate point is from 1 to 0 and the value of \( h \) in the \( d \) region before the point is always 1, and the point is the coordinate of the lower boundary. This is the result of the first bisector, and then count the coordinates of the mutation point of the \( n \) bisectors. The upper boundary takes the minimum value and the lower boundary takes the maximum value in the \( n \) bisectors. The final segmentation result is shown in Figure 3:

Figure 1. Binary image coordinate diagram. Figure 2. Gray value in vertical direction.

Figure 3. Segmentation result graph.
Experimental Results and Analysis

In order to evaluate the effectiveness of the proposed algorithm, the same rail image was used for image segmentation experiments. The experiments were all programmed in the MATLAB language and ran in the same environment. Three kinds of rail positioning methods are selected for comparison such as searching for the H value mutation method, binary image plus horizontal projection method and Prewitt operator plus horizontal projection method. The H value mutation is to map the RGB color space to the HSL color space, and the visual detection system can easily realize the extraction of the H value. The threshold is set to 0.5 when the original image is converted to a binary image. The experimental results are shown in Figure 4 and Figure 5.

**Figure 4. Projections of different algorithms.**

(a) H value mutation  
(b) Binary image plus horizontal projection  
(c) Prewitt operator plus horizontal projection  
(d) Binary image plus vertical projection

**Figure 5. Different algorithms to obtain the results of the rail surface.**

(a) H value mutation  
(b) Binary image plus horizontal projection  
(c) Prewitt operator plus horizontal projection  
(d) Binary image plus vertical projection
It can be seen from the comparison in Figure 4 that the H value mutation method affects the selection of the mutation point when there is a certain noise. The effect of the binary image plus the horizontal projection method is obvious, and the boundary of the rail area can be clearly distinguished, but it is need to calculate the number of white pixels in each row and traverse the entire picture. The Prewitt operator plus horizontal projection method has some noise near the upper boundary, which has a certain influence on the selection of the upper and lower boundaries. The effect of the method in this paper is obvious. The rail area is obviously separated from other areas, and the coordinates of the upper and lower boundaries can be easily located.

The average running time of the above four algorithms is shown in Table 1:

| Algorithm                               | H value mutation | Binary image plus horizontal projection | Prewitt operator plus horizontal projection | Binary image plus vertical projection |
|-----------------------------------------|------------------|----------------------------------------|-------------------------------------------|--------------------------------------|
| average time (s)                        | 0.9359           | 0.7912                                 | 0.5457                                    | 0.5194                               |

It can be seen from Table 1 that the H value mutation method has the longest average running time, and the average running time of the binary image plus vertical projection method is the shortest. The running time of the binary image plus horizontal projection method is longer than that of the binary image plus the vertical projection method. This is because the horizontal projection needs to traverse the entire image, while the vertical projection only needs to traverse the values of several bisectors in the horizontal direction.

**Summary**

The method of this paper is based on the characteristics that the upper and lower boundaries of the rail are basically parallel. First, the original image is converted into a binary image, then the horizontal bisector is drawn at a certain interval, and the upper and lower boundaries are determined according to the mutation of the pixel points in the vertical direction of the bisector. Compared with the other three methods, the binary image plus vertical projection method proposed in this paper has a shorter running time, the difference of the location of the mutation points is more obvious, and the segmentation of the rail region is more accurate.

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