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Speed Measurement Algorithm for Subway Entering Station Based on Light Reflection

Ruiqi Liu, Duozhi Qin, Bo Hu*

College of Electrical and Information Engineering, Guangxi University of Science and Technology, Liuzhou 545006, China
**Corresponding author e-mail: 443722152@qq.com*

ABSTRACT. *The monitoring of subway entry speed is mainly done by subway hardware equipment such as transponders in the existing subway control system. In order to establish external feedback that does not rely on subway hardware equipment, a visual measurement algorithm of subway entry speed based on light reflection is proposed based on the video of entering subway on the platform. After converting the subway entry video into an image sequence, firstly use the reflection phenomenon of the fixed light source on the subway compartment to segment each frame of image. Then, according to the different changes of the reflective pixel area in the door and window of the subway subway, the door frame and the window frame are detected in the image sequence. Finally, the length of the carriage and the number of frames that the carriage passes through the fixed light source are used to determine the subway's entry speed. This method is used to conduct experiments for the network acquisition of video. Through analysis and calculation, the average speed of the subway when the first to sixth carriages pass the light reflection position are 36.6m/s, 33m/s, 31.4m/s, 26.4m/ s, 20.6m/s, 9.6m/s. This shows that this method can realize the detection of subway entry speed, thereby establishing closed-loop feedback outside the subway hardware.*

KEYWORDS: *Subway Entering Station, Light Reflection, Speed Measurement*

1. Introduction

With the rapid development of urban rail transit in China, subway speed measurement as an important information acquisition method for subway safety control has received more and more attention. Speed is an important information for subway operation. The traditional speed measurement is to use sensors, radars, and tacho-generators to measure the subway speed. These speed measurement methods strongly rely on subway hardware equipment such as transponders [1-3]. Therefore the subway hardware failure may have a greater impact on the measurement accuracy, and the application of image processing technology for measurement of speed measurement has been widely used [4-6]. On the other hand, there are more and more applications of image processing technology in rail transit[7-9]. At the same time, there are many researches on vehicle speed measurement in tunnels and

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other similar lighting environments as subway platforms [10, 11]. Therefore, we can consider introducing image processing technology for visual measurement to reduce the dependence of speed measurement on hardware equipment.

2. Video and Images of Subway Entering

The ambient brightness of the tunnel in the subway section is poor, and a lighting system needs to be added in the tunnel section. On the one hand, it provides driving lighting for the subway driver to facilitate the subway driver to observe the situation of the track area. On the other hand, it provides operation lighting for subway track, communication, power supply, traffic inspection, construction, emergency maintenance and other fields, which is an important guarantee for the normal operation of the subway.

In the subway tunnel, some lights of lighting system are installed on the inner wall of the tunnel, and the lights are reflected on both sides of the outer wall of the carriage, which can determine the shooting position of the camera and install it in the lateral position of the subway. The camera shooting direction is facing the direction of the subway. In order to observe the multiple reflected lights of the subway entering the station, the shooting angle is the sharp angles formed with the inner wall of the tunnel.

After the video is collected, the collected subway entry video needs to be converted into an image. The video can be converted into an image sequence with different frames per second. Through many experiments, it is found that if use an image sequence of about 10 frames/s, fewer images are obtained, the subway moves too fast in the sequence of images, and part of the image reflected by the light to the vehicle connection is missing. Use the image sequence of about 30 frames/s to get more images. The images are played and observed in an orderly manner. The observation is that the movement of the subway is slow, the reflection of the light on the carriage is relatively comprehensive, and the light is reflected at the junction of the carriage. The image is also completely decomposed, which is a more appropriate choice of frame number. While using an image sequence of about 50 frames/s, although a lot of images are obtained, the movement of the subway in the image sequence is very slow, the processing is slow, and the difference in light reflection between frames is not much changed compared with the image sequence of 30 frames/s . Therefore, according to the speed of the entering subway, 30 frames/s can be considered to convert the subway entering video into an image sequence.

After the video is converted into the image sequence, due to the changing speed of entering subway, the number of reflected lights in adjacent frames will cause different reflection phenomena due to the difference of the landing points, mainly the position of the car skin, the window and the junction of the carriage. Under the condition of sufficient light brightness, the camera will get a good shooting environment, and the light reflected on the subway will also get a better brightness display. Under normal circumstances, it can be observed that the display of the reflected light on the surface is relatively clear, and the restoration of the light form

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is relatively high, and it will not be disturbed by the lights from the carriage. Take the second reflection light in Figure 1 as the observation object, as shown in 1(a). The phenomenon of reflection lights on the carriage windows is poor. The glass material of the carriage windows is easy to transmit light and is easily affected by the lights in the carriage, but there are also light reflections, as shown in Figure 1(b). When the light is reflected to the carriage junction, because there is a gap in the junction, there is no reflected surface, and the reflected light disappears, as shown in Figure 1(c).

(a) *(b)* *(c)*

(a) Light reflected on the carriage surface

(b) Light reflected on the carriage window surface

(c) Light reflected on the carriage junction

Figure. 1 The image of the subway entering the station

3. Use Light Reflection to Visually Measure the Speed of Subway Entering

According to the existing vehicle speed image processing algorithm, vehicle speed measurement is divided into three links: region of interesting extraction, image segmentation, and speed calculation.

3.1 Extraction of the Region of Interest

In image processing technology, it is generally necessary to first extract the region of interest from the image. Since the reflection of light is different in different positions of the subway, in the visual measurement of the speed of the subway entering the station, the region of interest in the image is the region corresponding to the light reflection position in each frame of the image. Generally speaking, because the light reflection area at the of the carriage window and the carriage junction is not obvious enough; the light reflection area on the carriage surface is selected to determine the region of interest.

At the same time, since the position of the light source in the tunnel is fixed, the shooting angle of the camera is relatively fixed, and the light reflection region can also be considered fixed in the image. The image area corresponding to the

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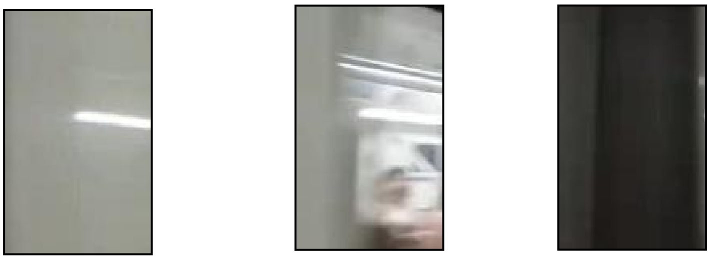
reflection area of the light on the carriage surface in any image in the video can be selected as the region of interest. Figure 2 shows the results of the regions of interesting extraction of the three images in Figure 1.



(a) (b) (c)

(a) The light is reflected on the carriage surface

(b) The light is reflected on the window surface

(c) The light is reflected on the carriage junction

Figure. 2 The region of interest in the image of the subway entering the station

3.2 Image Segmentation

After selecting the region of interest, image segmentation is performed on the image of the region of interest. Image segmentation is to convert an image into a binary image, where there are only two values, 0 and 1. Generally, 1 means white and 0 means black. Since the area corresponding to the light is relatively bright in the image, the brightness feature is selected and the threshold segmentation algorithm is applied for image segmentation. At present, the most common color space for digital images is the RGB color space, that is, each pixel uses three values of R, G, and B to indicate the degree of red, green, and blue. The brightness feature can be obtained by the weighted summation of the three values through the brightness conversion formula. Then, set a threshold, and the pixels larger than the threshold are 1 in the segmentation result, indicating the light reflection area, and the pixels less than or equal to the threshold are 0 in the segmentation result, indicating the background area.

After segmenting the regions of interest in the three images shown in Figure 2 using the brightness feature, the results of the segmentation are shown in Figure 3. The white area in the figure represents the light reflection area, and the black area represents the background. Obviously, due to the obvious light reflection at the carriage surface, a relatively regular reflection band appears, as shown in Figure 3(a). The reflected lights on the windows are interfered by the lights in the carriage, and although there are reflections, they are relatively irregular, as shown in Figure 3(b). When the light is reflected to the carriage junction, because there is a gap in the

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junction, there is no reflective surface, and there is no obvious white area in the image, as shown in Figure 3(c).

(a) *(b)* *(c)*

(a) Light reflected on the carriage surface

(b) Light reflected on the carriage window surface

(c) Light reflected on the carriage junction

Figure. 3 Image segmentation results

3.3 Speed Calculation

The last step is to calculate the speed of the entering subway. The image sequence corresponding to the subway entering video can detect the light reflection state on the subway in real time. The length of the subway is fixed. Combining the time for each carriage to pass through the fixed light source, the speed of the subway entering the station can be calculated.

Taking a carriage as a unit of length, the length of the carriage is related to the type of carriage, and L is determined according to the type of carriage. Every 30 frames in the image sequence represents 1s, and the time of two adjacent frames of images is 1/30s. According to the number of images reflected by the light in a carriage, the reflection time of the light on each car can be known. Under normal circumstances, when the reflected light is transferred to the next carriage, the reflection will pass through the junction between the two carriages. The junction is discontinuous and spaced, and the reflected light has incompleteness in the form of performance, so that the average speed of the subway is calculated. The ratio of the length L of a carriage to the time t of light reflection on this carriage is the average speed of the subway, that is:

$$\bar{v} = \frac{\Delta L}{\Delta t}$$

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4. Experimental Results and Analysis

The video used in the experiment is a video of the entering subway of Wuhan Metro Line 6 obtained from the Internet. From the time the subway enters the camera's field of view to monitor it until it stops, the video time is 32s. The complete entering is taken into the station and the video in a bright manner. The phenomenon observed in the video is good, and the running of the subway can be clearly observed, and the subway to which it runs can be distinguished. The position and reflection form of the reflected light are also relatively clear. The reflected brightness of the reflected light on the carriage is sufficient. The reflection of the light on the windows and the carriage surface is different, and because of the speed the reflection is not too obvious at the junction of the carriage.

Wuhan Metro Line 6 is an A-type car with a length of about 22m and a total of 6 carriages observed in the video. The time for each carriage to reflect the light is determined by the connection between the two sides of the car. If the light does not reflect at the connection, the number of white pixels in the binary image is 0 (all black), and if the light reflects in the carriage, then the binary image has white pixels. Figure 4 shows the number of white pixels. The abscissa in the figure represents the number of each frame of the image sequence, and the ordinate represents the number of white pixels in the segmentation result of the region of interest of each frame of image.

It can be seen from Figure 4 that the light starts to reflect on the 135th image, and the image at the connection between the first carriage and the second carriage is the 153th, which means that the number of pictures of the first carriage through the reflected light is 153. The number of frames is 30, that is, an image is 1/30s.

Therefore

$$\Delta t_1 = (153 - 135) \times \frac{1}{30} = \frac{3}{5}(s)$$

Then

$$\bar{v}_1 = \frac{\Delta L}{\Delta t_1} = \frac{22}{\left(\frac{3}{5}\right)} = 36.6(m/s)$$

The average speed of the subway is 36.6m/s when the position where the first carriage passes the light reflection completely. In the same way, the average speed of the subway when each carriage is reflected by the light can be calculated. The average subway speed when the second carriage, the third carriage, the fourth carriage, the fifth carriage, and the sixth carriage completely pass the light reflection position, their speeds are 33m/s, 31.4m/s, 26.4m/s, 20.6m/s, 9.6m/s.

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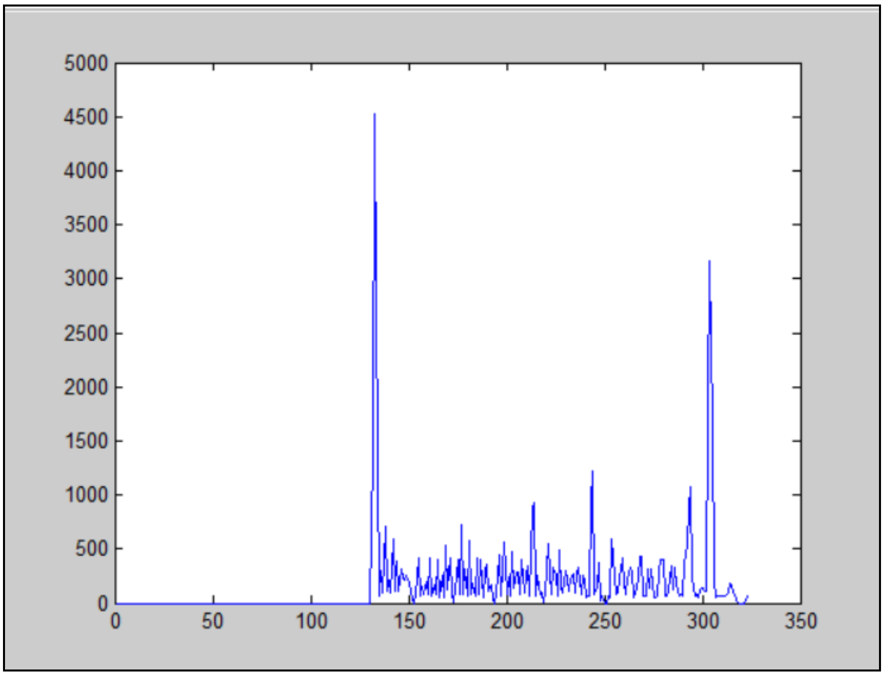

Figure. 4 Number of white pixels

5. Conclusion

With the rapid development of digital image technology, the technology based on video speed measurement has now been more used in highway traffic. In order to establish a speed measurement feedback that does not rely on subway hardware equipment, from the analysis of the target image of the light reflection, a method of calculating subway entering station speed based on the light reflection is proposed. This will provide a theoretical basis for the development of visual measurement equipment for subway inbound speed.

References

[1] Kouroussis Georges, Kinet Damien, Moeyaert Veronique, Dupuy Julien and Caucheter Christophe (2016). Rail-way structure monitoring solutions using fibre Bragg grating sensors. International Journal of Rail Transportation, vol.4, no.3, p. 135-150.

[2] Wang Qiang (2019). Application of auxiliary speed measurement and positioning technology of LKJ-15 Train operation monitoring system. Electric Drive For Locomotives, no.1, p.126-128+133.

ISSN 2706-655X Vol.2, Issue 3: 55-62, DOI: 10.25236/IJFET.2020.020306

[3] Tong Xinglin, Wei Jingchuang, Deng Chengwei, Zhang Cui, Mao Yan, Xu Ouyang and Yin Renjie (2014). Research progress on speed measurement and positioning technology of high-speed maglev train. Laser Journal, vol.41, no.3, p.1-5.
[4] Bjorn Lidestam, Lars Eriksson and Olle Eriksson (2019). Speed perception affected by field of view: Energy-based versus rhythm-based processing. Transportation Research Part F: Traffic Psychology and Behaviour, vol.65, no.8, p.227-241.
[5] Saleh Javadi, Mattias Dahl and Mats I (2019). Vehicle speed measurement model for video-based systems. Computers & Electrical Engineering, vol.76, no.6, p.238-248.
[6] Gustavo A.P. de Morais, Lucas B. Marcos, Joes Nuno A.D. Bueno, Nilo F. de Resende, Marco Henrique Terra and Valdir Grassi Jr (2020). Vision-based robust control framework based on deep reinforcement learning applied to autonomous ground vehicles. Control Engineering Practice, vol.104, no.4, p.1-14.
[7] Yu Zhou and Ronggang Cao (2019). The artificial neural network prediction algorithm research of rail-gun current and armature speed based on B-dot probes array. Measurement, vol.133, no.2, p.47-55.
[8] Hou Wenjun, Huang Wei and Fumamulin (2019). A study of subway vehicle image detection system based on pattern recognition technology. Railway Quality Control, no.5, p.44-47+51.
[9] Sun Pei and Hu Xiaomin (2020). Metro passenger flow statistics system based on image feature extraction. Machinery & Electronics, no.10, p.17-20.
[10] Zhou Lixue and Ma Chengqian (2019). Real time detection and simulation of urban road tunnel object. Computer Simulation, no.1, p.192-196.
[11] Zhao Wengeng, Zhang Xu and Shao Qingqing (2020). Automatic point cloud registration method of subway tunnels based on reflection intensity images. Bulletin of Surveying and Mapping, no.9, p.38-41.