Intelligent Detection and Early Warning System of Railway Track

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Abstract. Rail trains are an indispensable part of the transportation, so technological innovations such as artificial intelligence will inevitably promote the overall development of unmanned driving technology in this field, how to ensure the safety of unmanned trains is related to intelligent rail detection technology is very important, such as the detection of foreign body intrusion on rails, turnouts, curved rails, etc. These technologies have become the basic technology of rail train automatic driving technology. This paper divides the key technology of rail intelligent detection into three parts, and conducts in-depth analysis and research from these three aspects: curved track detection and warning module, turnout detection and warning module, obstacle detection and warning module, and combined with the actual needs of each module, Continuously through experiments, choose more suitable and optimal algorithms to achieve and then integrate the module algorithms to achieve the synchronization of the work between each module without interfering with each other, and design and implement the intelligent rail detection and early warning system to enhance the interactive experience. According to the functional requirements of different modules of the system, this paper selects core algorithms such as curvature radius, Hough transforms and frame difference method to improve each module, and verifies the feasibility of the selected algorithm.

Keywords: Curvature radius · Hough probability transformation · Frame difference method

1 Introduction

The traditional railway system includes an intelligent flaw detection system of railway track, foreign matter intrusion detection system of railway train, etc. The obstacle recognition system of the train based on video image recognition technology can realize the automatic detection of obstacles in the track of the direction of the man-less driving [1–3]. For the railway intelligent detection and warning system, several aspects of the technology should be integrated, such as track bending detection, switch detection, obstacle detection, track tracking, and critical warning. This technique depends on the image recognition processing technology, the realization of synchronous detection and warning of train operation process, namely in the procession of the train, the system can

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real-time detect the status of the current train lines on the road ahead, if there are any curved rail line, the front rail or obstacles ahead, pay timely treatment and early warning system. Of course, this technology requires a fixed HD camera installed in front of the train to obtain real-time data. The image processing technology is targeted at the acquired image data set for batch processing to achieve fast and accurate results.

The intelligent railway detection and warning technology firstly capture the railway image of the road in front of the train, that is, the track where the train is located, through the high-definition camera in front of the train [4–7]. The captured images are transmitted to the system in real time, through the intelligent detection warning system tracks in recognition of the front rails in the captured image information and extract tracks, and then through the steel rail has been extracted from the point of equal extract, a fitting method for quadratic fitting after they conform to the curvature of the two tracks curve, and then use curvature radius calculation method to calculate two curve radius of curvature, within the scope of a value, not curved track, beyond count curved track; Based on the two curves, Hough transform method is used to detect all the lines outside a certain slope range, to judge whether there is a switch. For the detection of obstacles, the frame difference method is used to detect whether there is an obstacle contour, and the area ratio method is used to judge whether there is an obstacle.

The core modules are as follows:

(1) Curved track detection and warning module
This process is only given the current train tracks recognition, so the interested region is obtained by image segmentation image, through the perspective transformation image correction, after using Sobel gradient operator combination of adaptive threshold method in orbit, extraction pixel through sliding window technology, according to these pixels are quadratic fitting, finally calculate the radius of curvature of the fitted curve, according to the radius of curvature threshold relation judgment curved track, then the warning.
(2) Switch detection and warning module
The process is the switch testing process, because only need to consider the train's rail switch, so we want to is obtained by image segmentation of interested area, and then through the Hough way detection probability, transform interested area exists Hough line, calculation of the detected line slope, after many tests to get a range of slope, filtered according to the size of the slope, screening to within the range of straight line is the switch.
(3) Obstacle detection and warning module

First of all, the obstacles that a train can encounter are much less diverse than those that a car can encounter, and the probability of encountering them is also quite small. Therefore, the detection of obstacles in front of the train is not very difficult. With the development of video monitoring, the intelligent monitoring algorithm has been gradually improved [8]. The moving target detection algorithm is mainly used in intelligent monitoring. In the moving target detection algorithm, the traditional algorithm has disadvantages such as inaccurate detection results and low anti-interference performance [9]. Moving target detection is one of the emphases and difficulties in the field of computer vision and image processing. It is the foundation of moving target tracking and behavior recognition. Frame difference method, background difference method, and the optical flow method are several common methods for moving target detection [9]. In this module, the frame difference method, a commonly used and easy to use an algorithm, is used to detect the obstacle, and then the contour area of the obstacle in the image is calculated through contour detection, and then the ratio of the contour area to the image area is obtained. Based on this ratio, whether the existing obstacle will affect the train can be judged, and then an early warning is issued. The flow chart of railway intelligent detection and warning technology is shown in Fig. 1.

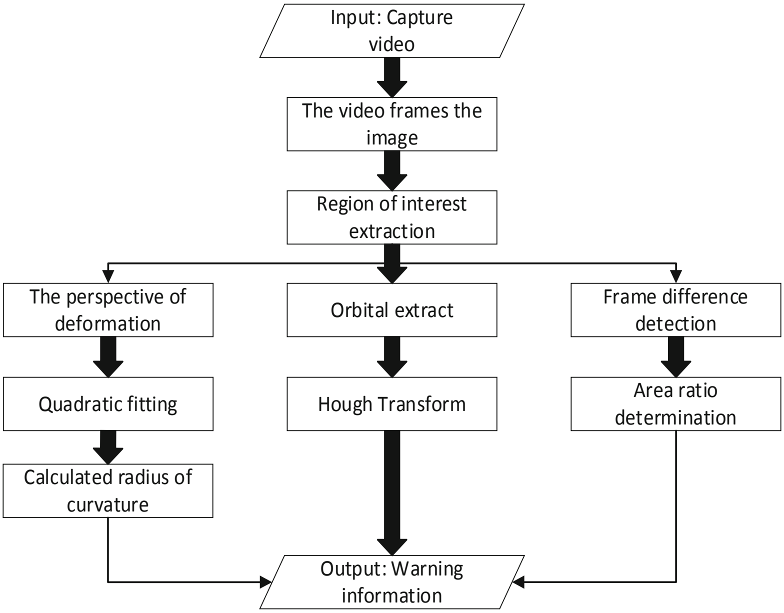

Fig. 1. Flow chart of railway intelligent detection and early warning technology

2 Intelligent Detection Technology

2.1 Perspective Transform

Perspective transformation is the process of projecting an image onto the original plane and mapping it to the desired visual plane. The principle of perspective transformation is to transform the three-dimensional model of an image in the three-dimensional space [10–13]. Because the train track to be tested in this paper is on the track plane, and the camera captured images in the three dimensional approximate horizontal and vertical plane, then on the research content of this article, for a rail line detection especially curved track rail will there is a certain error or mistake, so this article will need to track image perspective transformation, projection mapping to the camera to capture images of 3D plane, can be roughly understanding to the rail line formed in the form of a bird's eye view, thus processing rail have many conveniences.

2.2 Region of Interest Extraction

The region of interest (ROI) of the image is extracted through a mask, which is actually a binary image [14], with a maximum value of 255 and a minimum value of 0. In this paper, the mask value of the region of interest is set as the maximum value, and the mask value of the non-region of interest is set as the minimum value, then the region of interest is extracted. Define the interested region we usually adopt is to draw the rectangle, which we will in advance, we want to interested in the area of four coordinates, according to the coordinates at four, after the mask with matrix, surrounded by four coordinate areas is set to the minimum, other is set to the maximum, so interested area is extracted.

2.3 Sobel Algorithm

The region of interest (ROI) of the image is extracted through a mask, which is actually a b Sobel operator is an important processing method in the computer field, which has two detection templates: horizontal detection and vertical detection. Although the Sobel operator is very convenient to operate and the detected edges are all continuous and smooth, the detected edges will present coarse results and false edges will appear. If A represents the original image and G_x and G_y represent the images detected by horizontal and vertical edges respectively [7], the formula is as follows:

$$G_X = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} + A \tag{1}$$

$$G_Y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} + A \tag{2}$$

The approximate value of the horizontal and vertical gradient of each pixel of the image is calculated as follows.

$$G = \sqrt{G_X^2 + G_Y^2} \tag{3}$$

Finally, the direction of the gradient is calculated.

$$\theta = \tan^{-1}\left(\frac{G_X}{G_Y}\right) \tag{4}$$

3 Bend Detection

3.1 Quadratic Fit

Curve fitting is essentially the dynamic approximation of data points, that is, the trajectory modeling of logarithmic data points. With this fitting function, future trend prediction and system performance analysis can be carried out on the data. Suppose the fitting equation is a quadratic curve: y = ax + bx + c, the data point (x_i, y_i) is known, I = 1,2…N. The mean square error of the approximate fitting curve is

$$Q(a, b, c) = \sum_{i=1}^{n} \left(ax_i^2 + bx_i + c - y_i\right)^2 \tag{5}$$

Take the derivative of the above equation and you get the coefficients of the quadratic fitting curve equation,

$$\begin{cases} \mathrm{a} = \frac{D_a}{D} \\ \mathrm{b} = \frac{D_b}{D} \\ \mathrm{c} = \frac{D_c}{D} \end{cases} \tag{6}$$

When you figure out the coefficients of the quadratic function you get the quadratic function. In the above paper, the data set of orbital line points has been obtained. Then, the data can be fitted into a quadratic curve. Do the same for each frame, and you get a quadratic fitting of a continuous trajectory.

3.2 Calculate Radius of Curvature

Through the study of on-board video images, the track detection template is constructed, and the calculation of the curvature of the track is realized through regional growth and curve fitting, which can automatically detect the minimum radius of curvature of the track in front of the train and provide the driver with early warning function to ensure the safe operation of the train [15]. If we know the quadratic fitting equation y $= a*y*y+b*y+c$ of the orbital line, then at y meters away, the radius of curvature is calculated as follows:

$$R = \frac{\left(1 + (x')^2\right)^{1.5}}{x''} = \frac{\left(1 + (2ay + b)^2\right)^{1.5}}{2a} \tag{7}$$

4 Detect Fork in the Road

4.1 Hough Probability Transformation

Probabilistic Hough transformation is an updated version of Hoff linear transformation, which has good experimental results and is relatively simple to use [9]. Probabilistic Hough transform with past Hoff differed from the linear transformation, Hoff linear transformation will detect all lines in the image are extracted, no matter how long is the line, just as a straight line will reveal it, and there will be a threshold limit Hoff probability transformation, if detection lines will there be greater than the threshold line exists, so will the linear filter do not say, but only for those who are less than the threshold of the straight line segment is used to identify the corresponding logo, only record the start and endpoints of these segments. As long as the above steps are repeated in this article, all line segments that meet the requirements in an image can be identified.

5 Obstacle Detection

5.1 Frame Difference Method

The video stream captured by the camera must be continuous. If there is no moving target in a particular scene, then there will be very subtle changes between successive frames in the video stream. If there is a moving target, then the chances of successive frames in the video stream will be obvious. Frame difference method, namely the frame difference method, takes advantage of this feature and subtracts the pixels corresponding to different frames to obtain the absolute value of gray difference [16–18]. When this gray value is greater than the given threshold value, this paper can regard it as a moving target, so as to realize the function of detecting moving targets.

On the train track video sequence, this paper use of frame differential method, although the scene is a moment transformation rather than a fixed, because this article will extract the interested region video sequences, and for the tracks, change between consecutive frames is not very big, in this paper, by setting the threshold to filter out these changes, so when foreign invasion on the track, the algorithm can be detected quickly.

5.2 Set the Area Ratio T Threshold

Obstacle detection and the warning is ultimately to achieve the purpose of the warning. There should be no false alarms. Unlike the warning of curved rails and switches, the warning of obstacles means that there may be danger ahead, so false alarms should be avoided as far as possible. As mentioned above, in the process of detecting foreign bodies by frame difference method, there is slight noise caused by orbital changes. However, after setting a threshold value in this paper, these noises can be ignored without false positives.

6 Experiment

6.1 The Design of Experimental

According to the functional architecture requirements of the system, different modules of the system have strong independence. Except that the video frame conversion module is the basis of other modules, the remaining three modules can run independently without interference. According to this characteristic, this article uses the multi-threaded way of working. The system can be divided into four threads.

Since each module of the system has its own independence, the integrated system can not cause great conflicts between modules, and each module should be run at the same time. Therefore, it is necessary to establish a good thread relationship between each module of the system. The details are as follows:

(1) Storage and reading threads of files: including the access to intermediate processing results of programs such as curved rail detection, switch detection and obstacle detection, and the reading of image files generated and processed finally;
(2) Curved track detection thread: including sliding window detection, quadratic fitting, and calculation of the radius of curvature after track extraction;
(3) Switch detection thread: it includes the function of extracting the region of interest in the image frame and Hough probability transformation to detect the existence of line segments in the image frame.
(4) Obstacle detection thread: including the function of detecting the frame difference method of the continuous frame image extracted from the track and determining the obstacle by the area ratio of the detection results;

The multi-threaded workflow of the system is shown in Fig. 2.

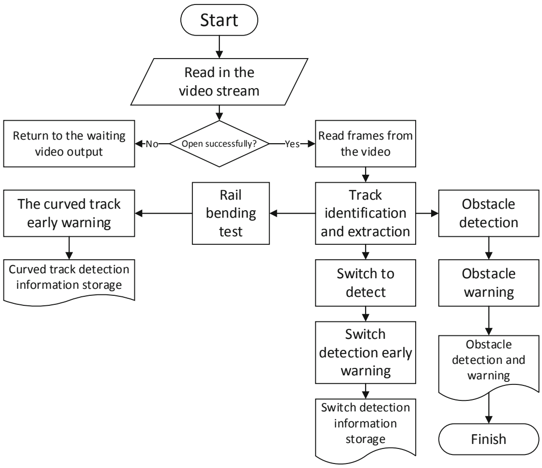

Fig. 2. The system flow chart

6.2 The Experimental Results and Analysis

In this paper, the research and experiment of intelligent railway identification and detection and early warning technology are carried out, and a detection and early warning system is designed through the research and experiment. According to the actual needs of system design and combining with the reality, the framework of railway intelligent detection technology is formulated, and appropriate methods and technologies are selected to realize the included functional modules, so as to achieve the expected effect as far as possible. The work described in this article is as follows:

(1) Intelligence advanced research analyzes the track key technology required for the detection of early warning as well as the basic framework, realizes the intelligent detection of the tracks, each module detailed research and analysis of methods and

techniques, including rail bending test, switch the key techniques and algorithms needed for the detection and obstacle detection, and through continuous experiments verify the feasibility of the algorithm.

(2) According to the specific requirements of railway intelligent detection and warning system design, the overall framework and modules of the system are designed linearly, and then the railway intelligent detection and warning system is implemented based on Python and PYQT to give users an intuitive experience.

In the main interface, through the button operating system-related functions, the start button operates the entire system to start operation, that is, to read in the image data captured by the camera, and the system curved track, turnout, obstacle detection function multi-threaded execution, real-time display; The stop button controls the entire system to stop working; The button of curved track detection data and other detection data is available only if the start button is pressed, otherwise, these two buttons are not available. The curved track detection data button displays the curved track detection data in the form of a line graph, while other detection data are displayed in the form of picture processing data. The status bar displays the warning status, and the light is on. Yellow lights are used for the detection and warning of curved rails and switches, and red lights are used for the warning of obstacles.

The curved track detection data interface, as the name implies, is to facilitate us to check all real-time data of curved track detection in the curved track detection module. Of course, this data refers to the curvature radius data of curved track detection. We can observe the change of curvature radius in the whole process by using the line graph of the upper part of the interface.

Figure 3 shows the working state of the system, that is, the system shows the working state after the start button is pressed.

Fig. 3. The system work

Under the working state of the system, the working conditions of each detection and warning module are as follows: track warning, switch warning and obstacle warning indicator light is displayed as shown in Fig. 4, 5, and 6.

Fig. 4. The curved track early warning

Fig. 5. The turnout detection early warning

Fig. 6. The obstacle detection early warning

7 Conclusion

In this paper, the intelligent identification and detection of railway track and the related technology of early warning are studied, and the detection of curved track, switch, and the obstacle is realized. In this method, the core algorithms such as radius of curvature, Hough transform, and frame difference method are selected to experiment with each module.

However, this method still has the following problems:

(1) In this paper, the method of Hough probability transformation is applied for the detection of the turnout. Although the identification and detection results after the region of interest are extracted and satisfactory, it is unavoidable to calculate some orbits with small curvature, which will produce errors and disturb the occurrence of early warning behavior. The obstacle detection algorithm still needs to be improved in the later stage, because the difficulty in collecting data sets brings great inconvenience and the experimental data is still few, so it is difficult to improve the robustness of the program.
(2) The experimental data used in the research process of this paper have some regularity. Because the system in this paper is track detection, the Angle of video stream acquisition is fixed. Therefore, when the system in this paper is applied to some other special scenes, its robustness will be very low.

The next research direction is to optimize the algorithm and apply the method to more complex scenes to improve the accuracy and reliability of the system.

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