Research of Real Time Video Monitoring and Remote Control System of Escalators

Yantai Luo

Shanghai Mitsubishi Elevator Corporation, Japan

Key Words: video monitoring; detection; functional safety; remote control

Abstract. An escalator is a safe related, heavy-duty special equipment. It is a big challenge for escalator manufacturers to detect a dangerous state or the behaviour of passengers on an escalator by using real-time video monitoring thereby helping the administrators in a security monitoring room to control the escalator remotely at the emergent moment. This hasn't been solved effectively since the escalator was invented 120 years ago. This paper presents some practical methods to overcome the difficulties, which includes following two aspects:

1) Detect a dangerous state or the behaviour of passengers, such as accidental falling down, walking in the reversal direction, based on real-time video analysis. To improve the accuracy of detection, this article introduces the method of real-time video analysis which combines optical flow algorithm and image deep learning algorithm.

2) Based on functional safety technology, use only one emergency stop button in the security monitoring room to control any of the escalators on which the dangerous state or behaviour of passengers is detected remotely.

The actual run of the system in metro stations demonstrates it can detect a dangerous state or the behaviour of passengers accurately and stably and administrators in security monitoring room can stop the escalator in a safer and more convenient manner. The application result shows that the proposed system has a significant value in lift industry.

1. INTRODUCTION

An escalator is a safe related, heavy-duty special equipment, which is widely used in the vertical transportation of subway, light rail, station, airport, wharf, and shopping mall.

In China, with the rapid development of urban subways, the use of escalators for subways has increased rapidly. Taking Shanghai Metro, the largest urban rail transit network in China, as an example, at the end of 2018, the total length of the whole network operation line of Shanghai urban rail transit reached 705km, ranking first in the world, with 2.038 billion passenger trips in the whole year, ranking third in the world[1]. The Shanghai Metro has more than 4,000 escalators, which carry more than 30 million passengers a day and bear more than 50% of Shanghai's public transport capacity [2].

Due to the inevitable contact of moving parts with passengers, passenger injuries on escalators account for more than 60% of the total number of rail transit passenger injuries, up to 70 to 80 per month [3]. According to statistics, falls account for about 75% of all types of escalator passenger injuries [4]. Therefore, how to detect the fall on the escalator as it happens and stop the escalator remotely and safely by the staff of the control room to prevent major personal injury occurring because of continuous rolling of the fallen passengers is an urgent problem to be solved in the daily operation management of the escalator.

2. METHODS

2.1 Real-time video analysis

The existing escalator detection system can only detect the operation of traditional machinery, and the monitoring of passenger behaviour mainly depends by way of video surveillance and manual real-time viewing. Due to the wide distribution of escalators, the large number of monitoring, the lack of a large number of human resources to implement real-time monitoring, video surveillance systems can usually only play the role of passive tracing after the accident.

With the development of artificial intelligence image recognition technology, the real-time video analysis related research of escalator passenger behaviour is booming. For example, based on the Openpose[5] key point detection algorithm to obtain the human body structure, and the use of the SVM (the Support Vector Machine) classifier to realize the detection and alarm of the pedestrian fall phenomenon in the picture [6], the defect of the algorithm is that it is necessary to detect the key point of the human body, which is easily blocked by the rear passenger or object, and when classifying the human body posture by the SVM, it is difficult to complete the accurate discrimination. The algorithm is based on the human skeleton sequence of the escalator abnormal behavior recognition algorithm. The algorithm firstly detects the passenger face by using the support vector machine which combines the features of the deformable component model and tracks the passenger's motion in the escalator with the improved kernel correlation filter. Then, the human skeleton sequence of the passenger is extracted by using the convolution neural network, and the abnormal behaviour sequence is detected from the passenger skeleton sequence by template matching. Finally, the algorithm uses the dynamic time-regularization to identify the abnormal behaviour sequence based on the five-nearest neighbour method. The optical flow tracking algorithm, and the human object is tracked to define the related abnormal behaviour, and the abnormal behaviour detection is carried out [7]. This algorithm only determines the fall through the optical flow tracking, and the misjudgment rate is high.

To achieve a high accuracy, low misjudgment rate, and low cost real-time video method to detect passenger falls on the escalator, this paper proposes a method to first extract the direction of passenger motion based on the dense optical flow method, then group the information eigenvalues of each sub-block motion direction, speed, acceleration and so on in the block which accords with the pixel points in the direction of motion, and then use the SVM classifier to classify the eigenvalues of the matrix in the continuous 1-2 seconds to determine whether the pedestrian in the picture is normal, reverse walking or falling.

The calculation process is as follows:

1. Obtain the first frame image detected by optical flow method
2. Get the second frame image as the current frame image detected by optical flow method
3. The motion direction and displacement of each pixel in the image are calculated by dense optical flow method.

4. Calculate the area of the moving block and the speed of the moving block with the escalator in the third step optical flow diagram displacement distance, mean velocity and variance.
5. Cache the calculated results of step 4 as the feature vector of this frame.
6. Repeat 2,3,4,5 steps using the current frame as the first frame for detection
7. To judge the number of frames with the current pre-frame N frame motion block area > MIN_S, when the number of frames > K, the preliminary judgment is suspected to fall or reverse walking.
8. The feature matrix composed of n frames was input into the SVM classifier for classification to determine whether it was fall, reverse walking or false alarm.

Feature generation and training specific algorithms:

1) Single frame feature generation:

1. According to the optical flow calculation, the displacement maps of the x-direction and y-direction of the image are obtained respectively:

$$\begin{bmatrix} x_{00} & x_{01} & x_{02} & \cdots & x_{0j} \\ x_{10} & x_{11} & x_{12} & \cdots & x_{1j} \\ x_{20} & x_{21} & x_{22} & \cdots & x_{2j} \\ M & M & M & M & M \\ x_{i0} & x_{i1} & x_{i2} & \cdots & x_{ij} \end{bmatrix} \begin{bmatrix} y_{00} & y_{01} & y_{02} & \cdots & y_{0j} \\ y_{10} & y_{11} & y_{12} & \cdots & y_{1j} \\ y_{20} & y_{21} & y_{22} & \cdots & y_{2j} \\ M & M & M & M & M \\ y_{i0} & y_{i1} & y_{i2} & \cdots & y_{ij} \end{bmatrix}$$

The downward displacement should be greater than the left and right displacement according to the retrograde and fall movement characteristics of the escalator. Obtain the motion block mask image from the above displacement map:

$$Mask = \begin{bmatrix} m_{00} & m_{01} & m_{02} & \cdots & m_{0j} \\ m_{10} & m_{11} & m_{12} & \cdots & m_{1j} \\ m_{20} & m_{21} & m_{22} & \cdots & m_{2j} \\ M & M & M & M & M \\ m_{i0} & m_{i1} & m_{i2} & \cdots & m_{ij} \end{bmatrix}$$

When $y_{ij} \le 0$ When $m_{ij} = 0$; when $y_{ij} > 0$; when $x_{ij} < y_{ij}$ In which $m_{ij} = 0$ Otherwise $m_{ij} = 1$.

2. Area extraction of moving blocks

Open operation of mask image; calculate mask image in mask $m_{ij} = 1$, calculate the area of the connected domain as S;

3. CALCULATION OF AVERAGE VERTICAL DISPLACEMENT VELOCITY

Calculate the average velocity of the moving block according to the motion block mask map Mask, displacement map in the y direction.

$$v = \sum_{i=0;j=0}^{i<H;j<W} y_{ij} \bullet m_{ij} \Big/ \sum_{i=0;j=0}^{i<H;j<W} m_{ij}$$

3. Velocity variance calculation, based on the average velocity calculated in step 3 to obtain velocity variance:

$$s^2 = \frac{\sum_{i=0;j=0;m_{ij}!=0}^{i<H;j<H} (y_{ij} - v)^2}{\sum_{i=0;j=0}^{i<H;j<H} m_{ij}}$$

2) Combination of 25 frame single frame features:

4. The feature vector of 25 consecutive frames is 25*3=75 eigenvalues

$$F = \left[[S_0, S_1..S_k],[v_0, v_1..., v_k],[s_0^2, s_1^2, ..., s_k^2]\right]$$

5. The elements in the three groups of vectors in F are arranged in ascending order respectively to get F';

6. Collect feature vectors F' in each case for SVM classifier training.

7. Save the classifier's training results for subsequent classification use.

3.2 Stop Escalator Remotely

Since it was invented more than 120 years ago, the operation mode of escalators are all local operation, and the practice of attempting remote operation by subway companies all over the world has not been successful for many years. When there is an emergency at the scene (passenger falls on the escalator, congestion at the escalator exit, etc.), it can only rely on the scene personnel to happen to find, on-site emergency operation. In order to ensure the safety of operation, some subway operation companies send more personnel on duty during the peak period and emergency intervention.

- In Moscow Subway, at the side of the escalators, a guard box and an operator on duty is set up. The operator observes the escalators and pushes the emergency stop switch immediately in case of an emergency. The following figure shows:

- Domestic portion MTR Corporation In the peak hour of danger Temporary to be on duty Occurs Emergency Immediate in case of situation Emergency Stop the intervention.

Figure 1 Moscow Subway, long-term duty personnel

Figure 2 Temporary personnel watching escalators at the peak time in China

If we can realize remote control of escalators in the security monitoring room, especially intelligent awareness and safe and remote control of emergency events, which will greatly accelerate emergency response, and reduce personal injury. But as a specialty equipment, remote control of escalators must be strictly compliant to security standards and regulations, otherwise, if there is a software defect, component failure or EMC defect, it will fail to implement an emergency stop correctly or cause an incorrect emergency stop, which will lead to a more dangerous situation. The emergency stop device shall be an electrical safety device (electric safety device) compliant with EN115-1:2008+A1:2010 5.12.1.2, i.e.: may consist of A) either one or more safety switches, or B) safety circuit (fail-safe circuit), or C) programmable electronic safety related system (PESSRAE).

Currently the world's response strategy is like type A, with a physical emergency stop button for each escalator that conforms to the electrical safety device (EN115-1:2008+A1:2010 5.12.1.2). Operators manually press the corresponding physical emergency stop button to stop the escalator remotely in the event of a passenger fall occuring, as shown in Figure 3:

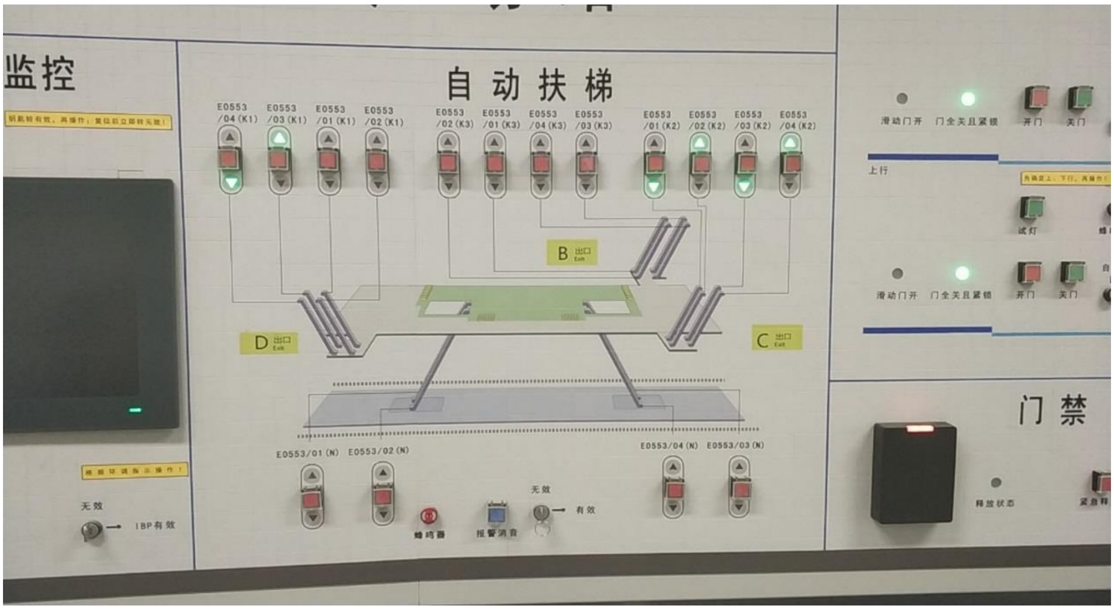

Figure 3 One actual stop button for each escalator

This approach has the following disadvantages:

- It's not easy to find accurate buttons when an emergency occurs;
- When the operation error causes further injury, the operator should bear the corresponding safety responsibility, so the operator is not willing to use it, nor dare to use it [8].

This paper proposes a safe and convenient way to stop escalators remotely (i.e. mode C), Operators press only one actual stop button to cut off the safety circuit to stop the escalator on which the dangerous event occurs, through the control of video analysis server and remote control components (which Pass PESSRAE safety certification and obtain type test certificate). As shown in Figure 4:

Figure 4. Monitor screen and the actual stop button

The operating procedures are as follows:

1. Video analysis server and remote control components preserves the escalator information when detecting that a passenger is in a dangerous condition on an escalator;
2. Monitor in the security monitoring room display corresponding real-time video according to the information preserved in video analysis server and remote control components;
3. The operator manually confirms that the escalator information is consistent and presses the actual stop button if there are dangerous conditions on the escalator in the video;
4. Video analysis server and remote control device components cut off the corresponding safety circuit of the escalator to stop the escalator.

4. RESULTS

The system which includes a total of 8 cameras corresponding to 19 escalators, runs from August 2018 to October 2019 In Shanghai Metro Hanzhong Road Station.

1）Successfully capture:

- 32 passenger falls (all passenger falls were successfully captured);
- 738 passenger reverse walking events;

2）Realize safely remote control:

The further personal injury of the passenger is effectively prevented, and the safety is greatly improved.

Take the case that happened at 15:20 on August 17, 2018 as an example, on an up running escalator in Shanghai Metro Hanzhong Road Station, an old lady falls down because of not grasping the handrail, the operator in the security monitoring room is informed by the monitor, then he presses the actual emergency button to stop the escalator immediately, as shown in figure 5 and figure 6.The time is 14 seconds since the fall happened until the escalator stopped, the time is 26 seconds since the fall happened until the counsel in the station arrived at the escalator.

Figure 5 Passenger fall detection and remote stop of escalator

Figure 6 The counsel in the station arrived at the escalator

The results show that the system has high accuracy and low misjudgment rate, and the remote stopping escalator is safe and convenient. It has a wide application prospect in the lift industry all over the world.

REFERENCES

[1] Liu Chunjie. Research and Practice of Shanghai Smart Subway [J]. Urban Rail Transit Research,2019(6):1-6.

[2] Liu Chunjie. Innovation and Practice of Intelligent Control of Shanghai Rail Transit Escalator [J]. China Municipal Engineering,2019(06):1-3+100.

[3] Long, Sijin,Lu, Jian,Xing, Yingying, et al. An analysis of escalator-related injuries in metro stations in China, 2013-2015[J].Accident Analysis and Prevention,2019,122(Jan.):332-341.

[4] Filippone, J., Feldman, J. D., Schloss, R. D. and Cooper, D. A.(2002). Elevator and Escalator Accident Reconstruction and Litigation, Lawyers & Judges Publishing Company, Inc.

[5] M. Andriluka, S. Roth, and B. Schiele. Monocular 3D pose estimation and tracking by detection. In CVPR, 2010.

[6] Chen Dong. Software development of pedestrian safety monitoring system for electric escalators based on video analysis [D]. Zhejiang University,2019.

[7] Tian Lianfang, Wu Qichao, du Qiliang, Huang Liguang, Li Miao, Zhang Daming. Identification of the abnormal behavior of walking elevator passengers based on human skeleton sequence [J]. Journal of South China University of Technology (Natural Science),2019,47(04):10-19.

[8] Yang Guanbao. Escalator energy saving and intelligent monitoring system based on panoramic vision [D]. Zhejiang University of Technology,2011.

[9] He Cheng. AI Image Recognition and Functional Safety Based Escalator Supervisory and Control System and Related Safety Regulations[J]. China Elevator, 2019,(15):6-8.