METHODS FOR DETECTION OF OBSTACLES ON THE RAILWAY LEVEL CROSSING

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Abstract – Railway level crossing is one of the most dangerous parts of the railway traffic. There, railway and road infrastructure are intersected at the same level, thus it becomes a weak safety point with very often terrible accidents. In addition to motor vehicles, the crossings are not rarely used by pedestrians who are also participants in traffic exposed to the risk. Accidents can happen due to malfunctioning of warning system (flashing lights, warning tones and boom gates) which informs traffic participants that a train is coming. However, even in the case of complete regularity of the warning system, very often fatal accidents happen due to not possessing enough awareness of traffic safety and "traffic culture". Because of that, drivers, cyclists and pedestrians, despite the activated warning system, use the railway crossing. This behaviour leads to the violating of the law, endangering traffic participants and accidents with material damage and possible fatal outcomes. This paper presents actual solutions in the field of detection of obstacles on the railway crossing. The aim of those systems is to monitor the railway crossing with the goal to inform the train driver about possible obstacles existence, and timely response for preventing an accident.

Keywords – Railway crossing, safety, detection, obstacle, monitoring.

1. INTRODUCTION

The railway is a very important type of transport because of its capacity and infrastructure. However, railway infrastructure is very complex itself, so intersection with another type of traffic (road, marine, pedestrian) additionally complicates traffic flow. In case of intersection of railway and road infrastructure, dependent on the way of the intersection, there are more or less possibilities for accidents. If is an intersection on the same level, known as railway level crossing, that is a weak safety point with very often terrible accidents, because there is an intersection between three types of traffic – railway, road and pedestrian. In addition, many of railway crossings do not have separated parts for road vehicles and pedestrians, which have an effect on increasing of accidents with fatal end.

Railway level crossing accidents and fatalities represents more than one quarter of all railway accidents on European Union railways [1]. So, in the EU, in recent years, on average, every day, beside big material damages (approximately one hundred million euro per year in the EU for all level crossing accidents), one person has been killed and close to one seriously injured on the level crossings in Europe. Pedestrians represent about 40 % of the people killed on the railway level crossings. In the EU, in 2009, there were 641 accidents on the railway level crossings with 411 serious injuries and 332 fatalities, while in 2012, there were 555 with 364 serious injuries and 322 fatalities [1, 2]. Therefore, there is certainly decreasing of the number of accidents, but data about accidents with injuries and fatalities is still alarming.

Generally, cause of the accident can be malfunction of train or/and railway infrastructure, staff incompetence, etc. Furthermore, fault of the warning system (flashing lights, warning tones and boom gates) on railway level crossings, which has a task to inform traffic participants that the train is coming, and human mistakes in terms of using of the railway level crossing despite the activated warning system, significantly increase risk for accident. However, the existence of any physical object (vehicle, pedestrian, animal, rock, etc.), represents obstacle on the railway, and can cause an accident because, in most cases, it cannot be avoided. This problem can be solved with some system with ability to monitor railway infrastructure and, in case of existence any obstacles that can have an effect on

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railway traffic, inform the train driver about that. Therefore, based on that information, train driver can stop the train on the time and avoid any accident. Monitoring systems, which are using the object recognition principle as infrared, embedded system, multiple lasers, etc., can be installed anywhere on the railway infrastructure and/or train [3-7].

In this paper, some of the actual solutions in the field of detection of obstacles on the railway level crossing are presented. The task of those systems is to monitor the railway crossing with the goal to inform the train driver about possible obstacles existence, and timely decrease possibilities for an accident.

2. CONVENTIONAL METHODS

The most effective solution for decreasing the risk of an accident on the railway level crossing is those that can totally provide safe railway crossing. However, all systems have advantages and disadvantages, so its effectiveness depends on the level crossing construction, the method used by the installed system, weather conditions, costs, etc. Nowadays, there are many conventional methods, based on optical principles, with purpose to detect moving object-obstacle when passing at a particular point on the railway level crossing. Some of them are optical beam, ultrasonic detectors and 3D laser radar.

2.1 Optical beam

Method with optical beam (Fig 1.) is based on several optical emitters that are placed on the one part of the crossing (marked with A in Fig. 1). All emitters emit a directed optical beam, but each one with a defined field of emission. At the other part of the crossing (marked with B in Fig. 1), there are receivers which detect the optical beam from the emitters. If the some beam is intersected (marked with red colour at Fig 1.), there is no beam detection by the receiver, so it means there is some obstacle. Based on field of emission of intersected beam, it is known in which zone is obstacle – away, close or on the railway crossing [8].

Advantages of this method are easy installation and relatively inexpensive equipment (dependent on the number of emitters and detectors, and compared to the other methods). However, the disadvantages are: it is required to install several emitters and detectors along the crossing for increased safety, traffic needs to be stopped for installation and maintaining, it is weather dependent – unusable in periods of heavy snow, and the most important – optical beam cannot detect pedestrians without the large number of emitters and detectors.

2.2 Ultrasonic detectors

Method, which uses ultrasonic detectors, is based on measuring the time between sent and received ultrasonic signal. This type of system transmits ultrasonic signal towards the roadway. When there is no any obstacle, the signal is reflected from roadway and detected by the system in certain time (marked with green colour in Fig. 2). However, if there is any obstacle, signal is reflected from obstacle and detected by the system in shorter time (marked with red colour in Fig. 2), compared to the case without obstacle [8].

![Fig. 2. Ultrasonic detector method [8]](image)

Accuracy and determination of vehicle size are dependent on the number of installed systems. The advantage of this method is that system can detect both stationary and moving vehicles. As in the case of optical beam, pedestrians can be detected only in case that there are a large number of installed systems. Disadvantages of this system are equipment and installation costs because of the need for additional supporting structure and extremely sensitivity to environmental conditions.

2.3 3D Laser radar

This method is based on the emitting of a laser pulse to an object by 3D laser and measuring the time that it takes for reflected laser to return to the radar (time-of-flight method), in order to acquire a distance to that object [9]. A laser pulse is emitted so that scans the whole area of railway level crossing in two directions – horizontal and vertical (Fig 3). Based on
the laser reflected and returning to the 3D laser radar, 3D coordinate values of each point of the area are measured. The coordinates which is higher than the road surface are extracted, based on the coordinate values of each point. Points which are distributed in close proximity to each other are identified as one group of points. The close proximity of points indicates that there is some object which is a potential obstacle. In order to calculate the positions and sizes of objects, data of these groups of points are processed and analysed (Fig 4). Moving direction and speed of the objects are calculated based on the amount of changes in their positions. Because of pre-defined area, obstacle detection and alarm conditions, etc., if the system detects an object on railway crossing, it generates an alarm.

Advantages of 3D Laser radar method are that operation of this system is relatively independent of the weather conditions (rain, snow, etc.). In addition, it is enough to install only one system for one side of the level crossing, so there is no need for a large number of additional equipment. However, disadvantages are reflected in the operating conditions of the system (vibration, strong wind, etc.) because for system operation, rotation of the 3D laser radar is required. This problem can be solved with high quality equipment, but that effect on increasing on total costs of system installation.

### 3. IMAGE PROCESSING METHODS

The obstacle detection system on the railway level crossing can use, beside previous named methods, image processing method which is based on cameras. Objects can be detected and tracked in space and time, which enable modelling of behaviour from image sequences. Tracking of the detected objects can provide more relevant information, such as the type of the object (pedestrian, vehicle, animal, paper), and activate alarm in case of potential accident.

#### 3.1 One single camera method

The obstacle detection system on railway level crossing that uses one single camera method has one single camera, which is placed on a certain construction in a corner of the crossing. Objects are detected by image processing, based on the difference between current and background images (Fig 6). Then, 3D positions of the different found objects are computed with knowledge of intrinsic camera parameters, calibration matrix and ground place hypothesis. After that, objects are tracked with an Extended Kalman Filter, and object classification is performed to determine objects as a car, truck, pedestrian, animal, paper, etc. [8, 10].

This method shows good results in different positions of camera, bad weather and environmental conditions. However, it is limited in low illumination, because the presence of shadows on railway crossing that come from objects, can activate an alarm although that objects are not obstacles on the crossing.

#### 3.2 Stereo camera method

This method uses stereo camera, which represents, in fact, two cameras placed in one housing. The aim of this method is to determine the 3D shape of the object and the distance between camera and the object. In order to detect an object with a stereo camera, first, the object is projected on each screen with a disparity (Fig. 7) [10].
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Fig. 7. Stereo camera method [10]

Suppose two cameras are placed under a parallel optical axis, consistent horizontal axis and baseline length b, the distance z between the stereo camera and the object can be calculated by the next formula:

\[
z = \frac{b \cdot f}{d} = \frac{b \cdot f}{x_2 - x_1}
\]

After finishing above processing, a 3D shape of the whole scene is extracted and compared with the background shape. Finally, the 3D shape of the object is obtained as well as distance between stereo camera and object, and can be used in further information processing.

The main advantage of this method is reducing of detection of shadows as objects. That has very big effect on the accuracy of the object recognition on railway level crossings because decreased number of false alarms. Furthermore, a system that uses the stereo camera method, showed the correct results in detection of the object during the day and night under general weather conditions. In addition, this system detected the pedestrians and two wheel vehicles without problems. However, system is extremely sensitive in bad weather conditions, like heavy rain, fog or snow, because a large drop of rain or snowflake can be detected as an object.

4. CONCLUSION

Nowadays, the railway is an irreplaceable type of transport in certain fields, so any interruption of railway traffic has a large effect on people’s everyday life and the economy. However, railway infrastructure is often intersected with road infrastructure, which causes occurrence of the railway level crossings. Those crossings are safety weak places with terrible accidents. Cause of accidents and then interruption of traffic can be malfunction of rail, train, warning system, incompetence of staff and using of the crossing despite the activated warning system. Any object, which is on crossing at the moment when train coming, is obstacle and may cause a collision and accident with possible fatal end.

In this paper, the actual methods for object detection on railway level crossings are presented. There are conventional methods, which include use of optical beam, ultrasonic and 3D laser radar. One of the main problems in those systems is operation in different weather conditions and the detection of the pedestrians. However, in presented image processing methods – one single camera and stereo camera method, there are no problems with detection of pedestrians. Disadvantage of one single camera method is false alarms caused by shadows, while a stereo camera method is very sensitive in bad weather conditions, so a large drop of rain or snowflake can be detected as an object. The improvement of all presented systems or designing of some kind of multi-method system should be very important because of increasing of safety on railway level crossings, as well as their integration in autonomous railway that very clearly coming soon.

REFERENCES