Customize techniques and operational rules to improve level crossings by means of imaging methods

Markus Pelz[1], Matthias Grimm, Michael Meyer zu Hörste, Karsten Lemmer

[1]*German Aerospace Center, Braunschweig, Germany*

Abstract

A significant part of the existing level crossings were built for cart-tracks or streets with few traffic in the near of crossroads of main streets. The characteristic of most of these level crossings is laying in the orthogonal adjustment to the main street. The operationally most efficient alternative is the use of an on-call barrier. But this technology can only be realized with cost-intensive common of the shelf components.

To show the possibilities to automate an on-call barrier system to reduce costs without neglecting safety, the Institute of Transportation Systems (ITS) of the German Aerospace Center (DLR) will build up a demonstration system to analyze the alternatives in realizing technical protection of level crossings in economically efficient ways without reducing the safety. In addition to the on-call barrier function different other functions, like danger zone supervision, will be developed. Therefore the ITS will build up customized techniques, and operational rules to improve level crossings by means of imaging methods will be analyzed.

Introduction

The Institute of Transportation Systems (ITS) of the German Aerospace Center (DLR) in Braunschweig investigates the situation of secondary lines in present and future in Germany. This project is funded by the Ministry of Economics in Lower Saxony. In particular, technical and operational solutions, which result in cost reducing improvements for the operating company, will be analyzed. One approach to increase the economical situation without neglecting safety aspects is found in the adoption of imaging methods for safety relevant applications in railways.

In the past, several approaches were carried out to build up automated railway operations using imaging methods. Most approaches were using video based camera technologies within optical systems. However, none of these approaches were implemented in practice. On the contrary, imaging methods for applications to assist the operations of the German railways are in use since a longer period of time. As an example may be named that the Hamburg commuter railway system is using video technology for the dispatching of the trains in stations by the train driver. Further applications for imaging methods for example are the track surveying and the level crossing monitoring. The video based level crossing monitoring is only used as a technical aided system for the signal man to observe a distant level crossing. The protection of the level crossing against unauthorized crossing is still not implemented using imaging methods.

In Germany, a significant part of the existing level crossings were built for cart-tracks or streets with few traffic in the near of crossroads of main streets. The characteristic of most of these level crossings is laying in the orthogonal adjustment to the main street. The operationally most efficient alternative is the use of an on-call barrier. But this technology can only be realized with cost-intensive common of the shelf components (see fig. 1).

A high number of not technically protected level crossings exist today worldwide without any obstacle detection in different structural and operational constellations. Therefore the Institute of Transportation Systems of the DLR investigates the options for technically realized vacancy detection for the danger zone of level crossings by a cost efficient way.

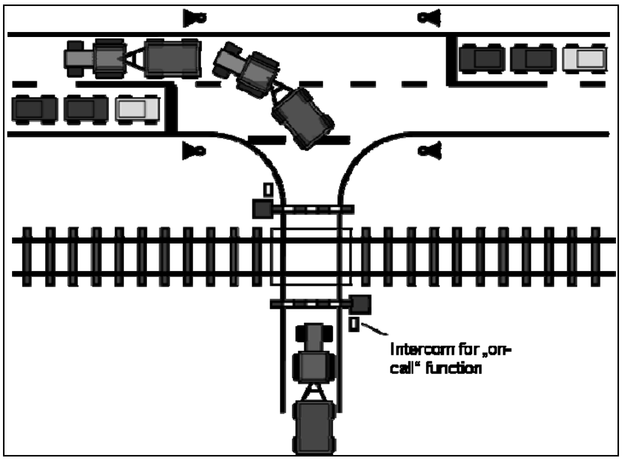

Fig.1. typical constellation of an on-call barrier at cart-tracks

With this vacancy detection it will be shown, how it is possible to close gaps in today's safety concepts of the level crossing system by an efficient way. The goal is to improve the safety at level crossings. Because of this case, a start will be made by analyzing accidents at level crossing to find out the root causes. Within the knowledge of what the root causes are, we are able to eliminate these things by interposing new technologies, e.g. by means of imaging methods in combination with operating rules.

To reach this goal, the ITS started by a progressive step-by-step development of functions at the level crossing system. These functions will be realized by optical sensors and image processing (optical systems) in combination with operational rules:

- „Unclosing barrier“: automatic opening of the barriers at full-barrier level crossing with on-call functionality. The barriers will open only when traffic wants to cross the railroad.
- „Observe closing barriers“: to avoid closing of barriers when obstacles like trucks are beneath the barriers at the same time (see fig. 2)
- „Real-time photo telegraphy to the train driver“: transmission of the situation at the level crossing to the train drivers desk. The train driver is able to see what is happening at the time when he is going to reach the danger zone.
- „Real-time photo telegraphy to the operator“: transmission of the situation at the level crossing to the operator. The operator sees the danger zone and its surroundings. Now he is able to, e.g. warn the train driver.
- „Obstacle detection“: to inform, to warn, to brake the train when any obstacle is between the half barriers.
- „Danger zone supervision“: to make sure that no obstacle is inside the danger zone between the full-barriers. This is a safety critical function and should provide a safety integrity level (SIL) of 2 or even higher.


Fig.2. collision of truck with a barrier

To show the possibilities of a technology based on optical sensors, the ITS of the DLR will build up a demonstration system to analyze the alternatives in realizing technical protection of level crossings in economical efficient ways without reducing the safety.

Motivation

All over Europe there is a multiplicity of technically secured level crossings (see fig. 3). Though the chance of an accident at a level crossing (LX) according to other accident hotspots is very low, there are numerous incidents at LX with very high measures of damages [1]. Furthermore, it can be said that as a result of different appearances of the LX road securing system the car driver is confronted with a system at LX with very high complexity where it is not relevant whether the LX is equipped with semi-barrier or only secured by flash lights, because the car driver will ride over a secured LX anyway without any attention to the trackside of the LX.

In this contribution it will be shown how a LX can be designed with more performance for the LX securing system, when the roadside is included in the whole system design.

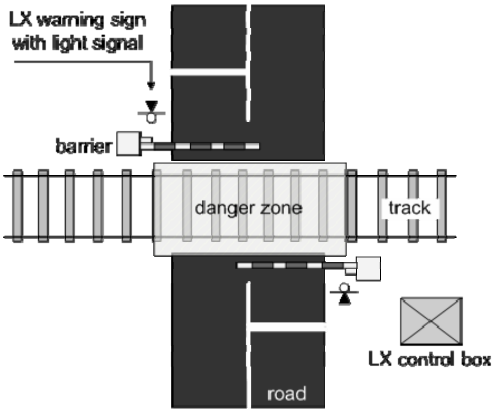

Fig.3. Level crossing with half barrier and light signal

Performance vs. safety

In many countries, LX on less important roads and railway lines are often open or uncontrolled, sometimes they are equipped with warning lights or bells to warn the car driver of approaching trains. LX without barriers represent a safety issue. Many accidents have occurred due to failure to notice or obey the warning.

In the German Allgemeines Eisenbahn Gesetz (AEG) it is said that "Railways in Germany are obliged to build their vehicles and infrastructures in a safe way and to keep them in a safe state." [2]

To reach this requirement, it is common practice to learn out of dangerous situations, incidents and accidents to identify weak spots of a system and eliminate them. This contribution shows how the system safety of a complex structure like that of a LX can be increased by the use of non-common methods. This could in future lead to the development of a new LX securing system.

In rail traffic it is necessary to take special technical and operational measures for realising reliable and safe rail operations because of the longer braking distances in comparison to rail traffic and the missing possibility of a train to avoid. Such measures are resulting in higher operational costs although the railway operators are under increasing cost pressures.

In Europe a lot of LX systems are secured for the road traffic only by a LX warning sign (see fig. 4). This is not really performed to the operation and to the safety in railways. Additionally there is no system, which allowes the train driver to react in urgent cases of a dangerous situation.

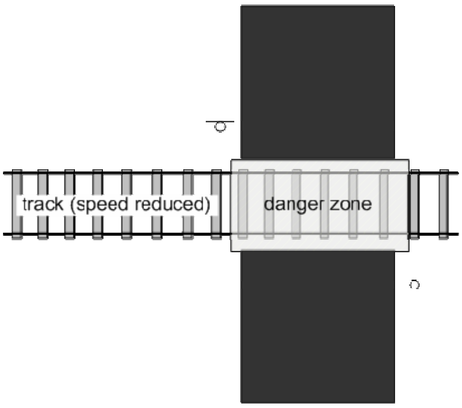

Fig.4. Level crossing without barrier and light signal

Expensive technology vs. Economic interests

Because of system inherent features of the railway, trackside equipment is exposed to high stress resulting out of climate, vibration and electromagnetic radiation. Thereby, maintenance works with high financial and personnel efforts are resulting. The initial costs of a system that resists these circumstances are very high at the moment, so that the investor avoids such a capital expenditure for LX systems.

One step for lowering the costs is the reduction of cabling. Furthermore it is to check, whether highly available low-cost technology can lead to a reduction of existing safety components, like expensive vacancy proving system for the danger zone of a LX, or not. The relocation of technology from the track to the on-board side can be seen as one possible way to get a cost minimisation, because special maintenance services do not need to take place, due to periodic vehicle maintenance and to reach a adaptively of the equipment to the volume of traffic.

State of the art

Today, some technical systems based on video technology are involved in the operational process of the German railway system, e.g. for the operator to watch the danger zone (see fig. 5 a).

In Hamburg, Germany, a video based system is in use by the Hamburg commuter railway system. The train driver obtains part of the information required for the train dispatching procedure by means of wireless video transmission. Information about what is happening on the platform is transmitted from the cameras installed on the platform to the monitors in the driver cab (see fig. 5 b) [3].

Fig.5. a. Video system at level crossing with full barrier and
b. Driver-dispatch system of the Hamburg commuter railway system

Innovative approach

In general, special signals are given to the train driver by the interlocking if a LX flash light system is faulty. This linking between interlocking and train is highly expensive and forms the main part of the total costs of a LX, though used only a few times in a year. This is why infrastructural technology should be turned down, especially on low frequented lines.

Therefore, in the Switzerland an innovative system is under test, which secures a LX only by flash light in combination with a dynamic road sign instead of expensive barriers (see fig. 6). The road sign will flash yellow in case of a fault in the flash lights of the LX and the crossing of the tracks is on own risk because the train driver does not know if the LX flash light is in operation or if it is faulty.

Fig.6. An innovative LX system with light signal at Emmental [4]

Range for methods of resolutions

The answer of the above mentioned problem could be seen in low cost technologies like imaging methods. For realising a LX securing system, modern imaging methods by using optical sensors (e.g. cameras in visible an infrared range) are investigated. These optical sensors will be installed in such a way that an automatically detection of the road traffic (e.g. pedestrians, bicycles, cars, etc.) and by this an activation of the LX control can be realised. This method of resolution and a lot of other ones can be situated in the range that figure 7 shows.

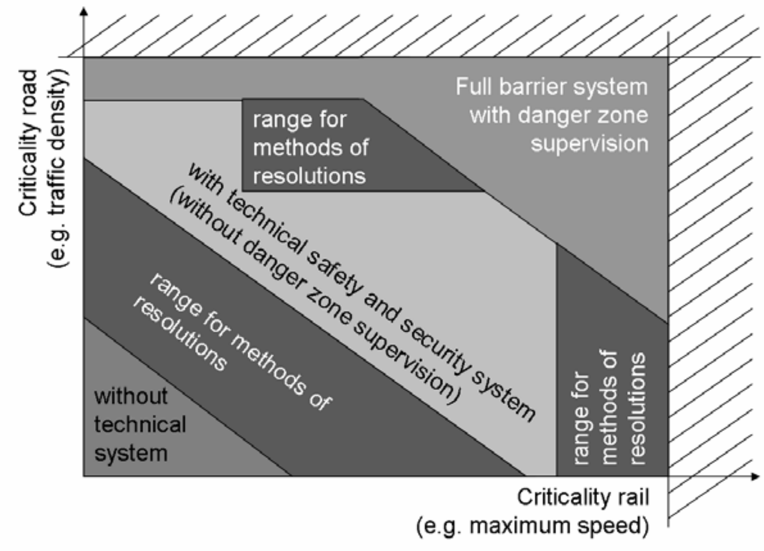

Fig.7. range for methods of resolution for customize technique

The following functions shall be achieved by such a method of resolution to implement efficient and cost optimised rail operations, especially on secondary lines:

- safe technology with higher efficiency
- extension of existing safety concepts and technology to reach better performance
- safety optimisation
- minimisation of harms
- cabling reduction
- safe low cost vacancy proving of LX danger zone

Several applications can be found in the field of railways and especially in the area of level crossings, e.g. the vacancy proving of the danger zone or the transmission of live video streams from the LX to the rail vehicle. Regarding to this contribution, only the methods of resolution for performing a vacancy proving of the danger zone of a LX is shown in detail.

The Janus Head algorithm

The optical sensors (e.g. cameras) are mounted at the LX warning sign (see fig. 8). They reduce the costs by disclaiming earth moving. The construction is called Janus Head, which means that a optical system, consisting of two optical sensors, is able to view in two different directions. One optical system means two optical sensors (camera in visible and infrared range) and computers for image processing. A Janus Head system itself consists of two optical systems (see fig. 8).

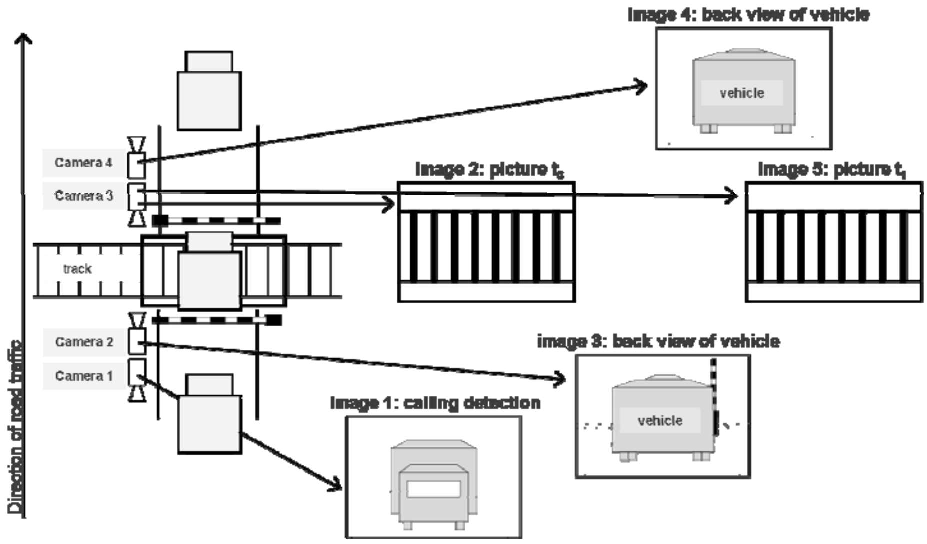

Fig.8. Example of operation of the Janus Head algorithm

To perform a vacancy proving of the LX danger zone, a safe detection of every obstacle in the danger zone is required. The Janus Head system uses the fact that an obstacle like a vehicle first has to approach the LX from the road side before it can enter the danger zone. The approaching traffic can be detected by the used method. In a next step an algorithm can perform a vacancy proving for the danger zone by generating expectation values, which were communicated between the sensor systems and the system algorithms respectively.

The example which is discussed in this contribution can include the following action sequence (or see also fig. 9):

- Camera 1 detects a vehicle and safes a picture (image 1) of the front side of the vehicle (see fig. 8) and sends a message to the LX safety system that a vehicle is approaching.
- When image 1 is send, an expectation value will be send to camera 3.
- Camera 3 makes a picture at t_0 of the free danger zone (image 2) and safes it.
- When the barriers are open camera 2 will be activated and has to expect a vehicle.
- Camera 2 detects a vehicle and safes a picture (image 3) of the backside of the vehicle (see fig. 8) and sends a warning to the LX that the danger zone is blocked by a vehicle.
- Camera 4 detects a vehicle with the expected value (see fig. 8) and sends a message to the LX that the obstacle has left the danger zone and that the LX is free again.
- Camera 3 detects the danger zone and makes a picture at t_1 (image 5). If there is no difference between image 2 and image 5, the danger zone is free of obstacles.
- The barriers can be closed.

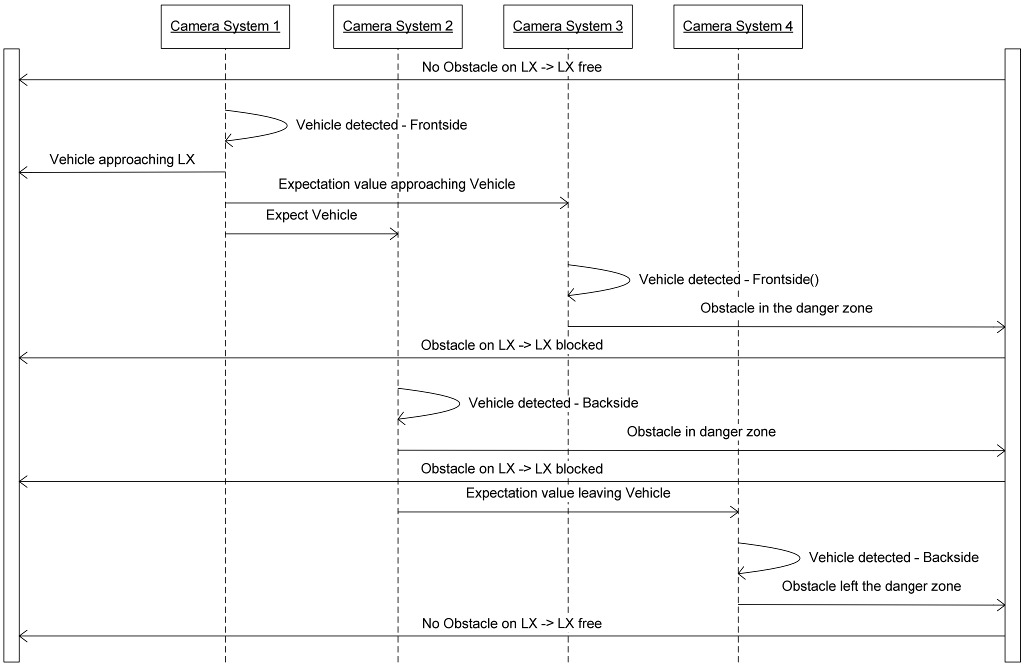

Fig.9. Sequence of obstacle detection in the LX danger zone

If the system is not able to generate a doubtless vacancy proving detection of the danger zone, the LX will be signalled as not secured. By this a misleadingly as free signalled LX can be avoided.

Demonstration

Because of a wide operational area of such a method, it is necessary to perform realistic tests. Especially with regards to the safety criticality of such an application, first tests will be done in a non-public area where only a SIL 2 (SIL = “Safety Integrity Level”) system is required. For the field tests, a road-rail vehicle and a minivan will be used in the first steps. After an initial phase of tests, a demonstration unit will be developed that can be mounted at a LX in the above mentioned non-public area.

Conclusion

The implementation of imaging methods using camera based technology can help increasing the safety of railways especially at level crossings. To implement such an innovative system, intensive test campaigns are necessary in which the multiple requirements regarding safety targets, availability, maintainability and security can be evaluated. Innovative systems using camera based technology form an economical advantageous alternative to existing track-fixed monitoring units still reaching the required safety regulations formulated by standard books, laws or other official documents all over Europe. The Institute of Transportation Systems of the German Aerospace Center in Braunschweig develops such a system and will evaluates it in different field tests. First results are expected in 2009

References

[1] Dieter Ellinghaus, Jürgen Steinbrecher: Das Kreuz mit dem Andreakreuz, Continental AG, Hannover, 2006
[2] Allgemeines Eisenbahn Gesetz (AEG)
[3] Bernhard Mrochen: Zugselbstabfertigung durch den Triebwagenführer bei der Hamburger S-Bahn, SIGNAL + DRAHT, 4/2002
[4] Bruno Zürcher: Ungesicherte Bahnübergänge mit wenig Geld verbessern, www.Wochen-Zeitung.ch, 05.10.2006