Development of an imaging based gang protection system

[1]M. Grimm, [1]M. Pelz
German Aerospace Center, Institute of Transportation Systems, Braunschweig, Germany[1]

Abstract

During maintenance or construction works in or at the tracks of railways, high risks for passengers and railway staff, especially for the workers on the construction site exist. The high risks result out of the movement of rail vehicles, like trains or construction vehicles, which must be faced by using any available technical and operational technologies for securing them against the environment. Therefore, it is necessary to evaluate the level of protection continuously and to identify new and innovative methods and technologies for the protection of the gang (construction worker, machines and material).

Especially on construction sites at line sections with two or more parallel tracks but also with single tracks, there are still a lot of incidents and accidents mostly with seriously injured persons or fatalities. These were mainly gang members that breach the railway-loading gage. By using proper warning or protection systems, the avoidance of such accidents must be achieved.

The latest developments in gang protection systems concern on the one hand fixed barriers in the middle between the construction site and the operated track and on the other hand construction vehicles equipped with automatic warning systems.
The disadvantage of such protection methods is that the gang can be warned against an approaching train but a monitoring of the gang members cannot be performed. Only one part of a potential dangerous situation will be detected. If the gang members will overhear the acoustic warning signal of the security staff and the workers will not leave the danger zone in the track, the driver of the approaching train had no chance to react to the dangerous situation. An accident is often inevitable.

While the detection of acoustic warning signals by the gang members working on a construction site is very difficult, the acoustical planning of an automatic warning system has to be designed for an acoustic short range level of one meter besides the construction vehicle.

The decision about the use of today's technical warning system (fixed systems, automatic warning systems, etc.) must be geared to the technical feasibility and the level of safety which is needed. Criteria for decision guidance to block a track should be developed by danger estimation and economical variables.
To realize the actual jurisdiction and to minimize the hazards of railway operations by the use of construction vehicles near the tracks further developments are needed. This means, that the warning systems have to be enhanced to systems for protection, which monitor the realization of the warning signal as a precondition for giving a movement authority to a train. This method can protect against accidents caused by predictable wrongdoing.

The actual state of the art technique of using a collective warning combined with additional security staff is no longer acceptable. Therefore, the Institute of Transportation System of the German Aerospace Center in Braunschweig (Germany) will develop a gang warning and protection system based upon imaging methods, with optical sensors such as video in visible and invisible ranges, radar, laser, and other.

The advantage of such a system based on the possibility to monitor both the gang itself and the railway-loading gauge either of the parallel track or of the same track still in use. By monitoring both situations, the system will be able to generate a warning message for the approaching train,

that there are obstacles in the track, so that the train can be stopped to prevent an accident. And also the gang workers will be warned, while they breach their area.

Introduction

The rough environmental conditions and the high dynamical impacts on the infrastructure of railway networks, make continuous maintenance works necessary. Those works mostly takes place while the normal traffic on the track is rolling as scheduled.

During maintenance at the tracks high risks for passengers and railway staff – especially gang workers – exist. The danger based on moving vehicles on such a construction site, both normal trains and construction vehicles. The protection of all involved parties has to be guaranteed by exploitation of every technical and organizational protection measurements possible. The outcome of this requirement is a continuous improvement process regarding the identification of new and more effective protection techniques and methods.

Figure 2: Working situation of gang workers on a railway construction site [1]

Especially on lines with two or more parallel tracks, deathly incidents occur. Here, mostly gang workers endanger themselves by violating the railway-loading gauge of the neighbor track (see figure 1 and also figure 2 right-hand picture) or passing by trains were hit and damaged by construction vehicles, such as excavators like shown in figure 2 on the left-hand side. Those are examples for several situations, which has to be avoided by the use of adequate warning and protection systems.

Figure 2: Working gang with heavy construction machine on a two-track line while the traffic regularly goes on [2]

State of the Art

Today there are several possibilities for gang protection in use at the railways in Germany. In general they could be categorized in the following four groups:

- Signal interlocked protection of the construction site
- Automatically working warning systems [4]
- Gang warning by means of operational methods [5]
- Warning by security staff (see figure 3, also [5])

Figure 3: Security staff for the warning of gang workers in front or in the rear of the construction site [3]

The latest developments of protection systems concern both fixed barriers between the track still in operation and the track under construction (see figure 4) and the equipment of track-side construction machines with automatic warning systems.

Figure 4: Fixed barrier between the track in operation and the construction site [2]

Today's systems only give gang workers warning of approaching trains without monitoring, that they clear the railway-loading gauge. So only a partial detection of a potential danger is provided.

The warning systems mostly work with acoustic signs, whose perception is very critical because of high noise level of the construction machines. To warn workers, deployed directly beside a track laying machine, of approaching trains the acoustic planning of the automatic warning

system has to be very detailed. The underlying acoustic level for the distance between worker and machine has to be about one meter.

If the acoustic warning signs, against the planning, will be overheard by the workers and therefore the gang has not cleared the hazardous area of the tracks, a reaction of the approaching is not possible anymore. An accident cannot be avoided. The installation of a fixed barrier system is recommended in such a situation.

The decision regarding the use of technical state of the art systems – fixed barrier system or automatic warning systems with acoustic and/or optical warning – depends on the technical feasibility of the chosen system and on the safety level needed at the certain construction site. Not only technical reasons have to be taken into account but also economical criteria will play a much more important role.

Today's realization in using a collective warning either by an automatic system or security staff in combination with additional security staff close to construction vehicles as it could be seen in figure 1 can no longer be accepted.

The protection system based on imaging methods

To fulfill the actual legal requirements and to avoid hazardous situations in the operation of the railway by construction vehicles, a further development of automatic warning systems away from just the functionality "warning" and towards the functionality "protection" is necessary. Such a development can help to minimize incidents caused by foreseeable errors of the gang workers. In addition to that, the monitoring of giving a movement authority only if warning information for the gang is sent can be provided.

Picking up the described requirements and the mentioned disadvantages of the state of the art, the Institute of Transportation Systems has developed a concept for an innovative gang protection system.

The system concept will provide an automated method to warn a gang when a train is approaching the construction site and to give an all-clear signal, when the hazard has left the danger zone. The innovation in this concept can be seen in the used technical equipment. The monitoring will be managed by imaging methods, like video based technologies, Laser-scanner or Radar. The concept can be used both to protect gang of stationary and moving construction sites. The system architecture for the protection of a moving construction site can be seen in figure 5, the system architecture for a stationary construction site in figure 6.

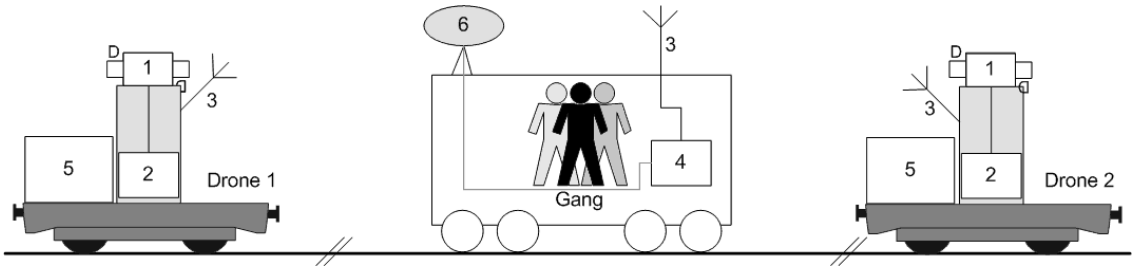

Figure 5: System architecture of the gang protection system

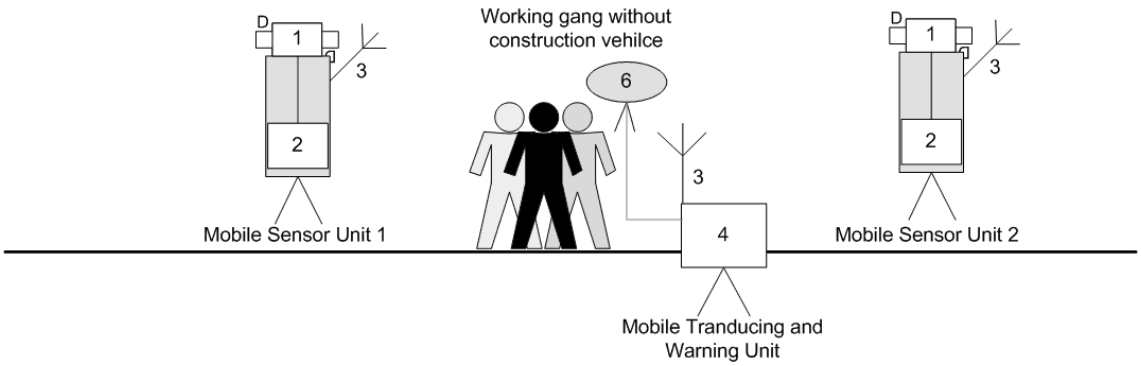

Figure 6: System architecture of the gang protection system in a schematic view

The numbers in the figures 5 and 6 have the following meanings:

1 – Optical sensor system

2 – Evaluation Unit including an image recognition algorithm

3 – Data transmission and receiving unit

4 – Transducer for the „WARNING“ and „ALL-CLEAR“ messages

5 – Propelling unit for the self-sustaining movement for moving construction sites

6 – Output-Unit for the „WARNING“ and „ALL-CLEAR“ messages

By using optical sensor systems it is possible to monitor the movements of the gang and the construction vehicles, especially according the railway loading gauge of the parallel track in case of an approaching train. When the system detects a violation of the loading gauge, it has the ability to decide if the situation can become hazardous for the workers or the approaching train. A schematically illustration of the monitored area is shown in figure 7.

The red line in the left part of the figure describes the boundary of the loading gauge of the right track, the track under construction. In the right part of the figure the hazardous area of the line is shown by the red box. If a worker or a construction vehicle is totally or partly within this box an incident is highly possible when a train approaches on the left track, the track still under operation. This situation must lead to a warning of the gang workers and/or the approaching train.

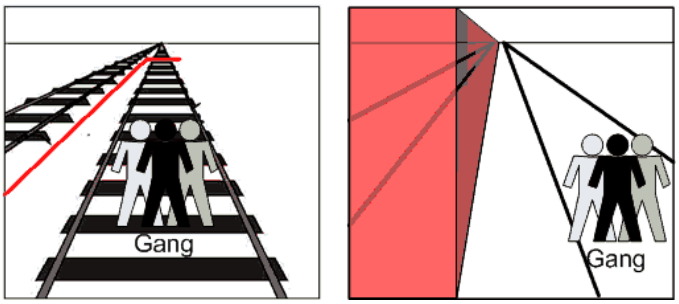

Figure 7: Schematically illustration of the monitored area

In general it is possible to support three different parts of a construction site with this system:

- The front end of the construction site
- The construction site itself
- The rear end of the construction site

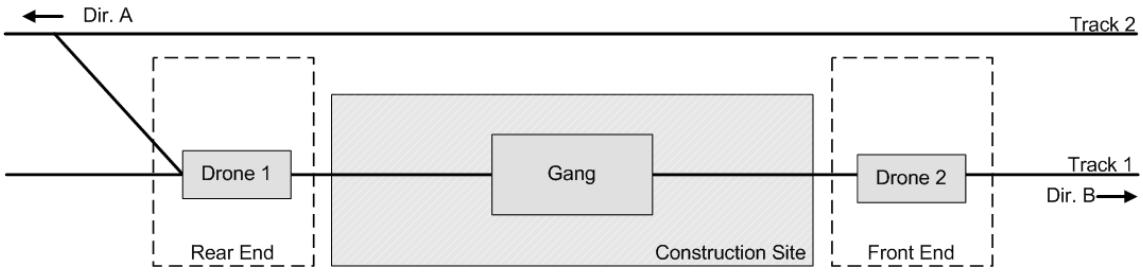

Figure 7: Parts of the construction site for the equipment with the protection system

The front and rear end of the construction site

Both the front end and the rear end of the construction site are protected by the drones included in figure 5. The drones are self-sustaining units, equipped with a motor and a sensor system combined with the needed evaluation unit. The communication to the protection system of the construction site itself is provided by radio transmission.

By using the motor unit of the drones a constant distance between the protection equipment at the two ends and the construction site itself can be provided. This will guarantee a sufficient long warning time before the hazardous situation by the approaching train starts. The needed distance of the drones results from the allowed track speed in combination with the required transmission time for the data from the drone to the construction site.

The construction site itself

Close by the construction site itself, Mobile-Sensor-Units are used (see figure 6). The demanded number of mobile sensor unit depends on the special situation and could be chosen without any restrictions.

The main task of the Mobile-Sensor-Unit is to monitor the gang and the approaching trains. Therefore the units are equipped with a sensor system and the needed evaluation unit, like describes above for the drones.

In addition to the Mobile-Sensor-Unit, each gang has its own Transducer-Unit, so that the signals, sent by the drones or the Mobile-Sensor-Units, can lead to an acoustic and/or optical warning. The output of the warning signal is done by the different Output-Unit for the „WARNING“ and „ALL-CLEAR“ messages.

The place where the Mobile-Sensor-Unit is stationed depends one more time on the special situation on the construction site. On site with construction vehicles, each vehicle must be equipped with a transducer; on sites where only gang workers are in action handheld or other mobile transducer were needed.

Each unit of the protection system has to be equipped with a radio device, which enable a wireless communication, e.g. broadcast between each unit.

The Advantage of the new gang protection system

The advantage of the gang protection system developed by the Institute of Transportation Systems of the German Aerospace Center in Braunschweig is an automatic monitoring of the gang and the adherence of the railway loading gauge of the construction site by the gang and construction vehicles. A warning can be generated and sent automatically by the system to the approaching train, if the railway loading gauge is violated by a worker, a construction vehicle or a machine.

Furthermore, the traffic approaching the construction site can be monitored and here as well a warning of the gang can be generated automatically. The automation of the gang warning will decrease suspicious actions in identifying of a hazardous situation by man.

Besides these technical improvements and the increasing of the safety, a reduction of costs will take place because security personal will be needed only in few situations.

Example for an implementation

To give a better understanding of the implementation and functionalities of the protection system, it will be described with an example construction site. The situation can be seen in figure 8.

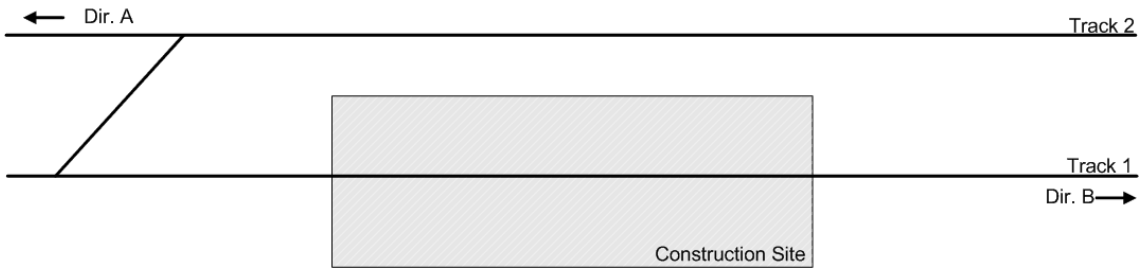

Figure 8: Example construction site without equipment

In the example, there is a line with two parallel tracks, where the operation on the track 1 goes from the left to the right side (direction B) and vice versa on track 2 (direction A). The construction site will be installed on track 1, so that the whole traffic operates on track 2 in both directions. The construction site itself is moving continuously in direction B.

The main task of the system is the prevention of damages, caused by the gang on the construction site on track 1 and/or a moving train or vehicle on track 2. Those damages can occur by violation of the loading gauge of track 2.

The system therefore monitors via the optical sensors the line in the in figure 9 shown angels of view. An automated image recognition algorithm in the Evaluation Unit analyzes the images and decides if a train approaches the construction site and/or a worker or a construction machine violates the loading gauge of the parallel track. In this case, the Evaluation Unit sends these information to the Transducer in the near of the gang. Here, a warning message is generated, that will be displayed to the workers. The Output-Unit can generate both the warning-signal, when a train or another rail vehicle approaches and the all-clear-signal when the vehicle has left the danger zone.

To generate the all-clear-message, the information about the approaching vehicle is sent to the optical sensor system on the other end of the construction site. The information, especially the images will be used an expectation values to detect the departing vehicle. The detection will be carried out by image comparison.

If the construction site is situated on a single track line, the whole line will be blocked for operation or the gang consists only out of workers without vehicles, so that they can leave the track if a train approaches. The warning and all-clear procedure is similar to the procedure described above. Only the two drones can not be used here. They are displaced by Mobile Transducing and Warning Units.

Detailed description of the protection system functionalities

The construction site as shown in figure 8 will be equipped with the following modules to implement a sufficient protection for the gang (see figure 9):

- Two Drones (D1 and D2) equipped with an optical sensor system, including Evaluation Unit and image recognition algorithm (1) as a self-sustaining propelled unit. The two Drones will monitor the line in front (Direction B – view angel D2-b) and behind (Direction A – view angel D1-a) of the site. Approaching trains or rail vehicles were detected by the optical sensors. The optical sensors of the Drones also monitor the parallel track still in operation (view angels D1-b and D2-a) to get an image of the moving vehicle for the usage as expectation value for the respectively other Drone.
- Two Mobile Transducing and Warning Units (M1 and M2) positioned directly at the construction site. The Units are equipped also the optical sensor system and the Evaluation Unit (1) as mentioned above. The optical sensors monitors on the one hand the track under operation to identify approaching vehicles which were detected by the drones (view angels M1-a and M2-b) and on the other hand the gang itself to identify any violation of the loading gauge by workers. If the construction site has a long extension, it could be reasonable to install more than two Mobile Transducing and Warning Units to provide a seamless monitoring of the loading gauge.
- The gang itself is equipped with a Transducer Unit (2) that will receive the wireless messages sent by the Drones or the Mobile Units when either a vehicle approaches the site or a worker is violating the loading gauge of the track that is still und operation (track 2). The two Drones also send a message, when the vehicle has left the danger zone of the site, so that an all-clear signal can be given.
- In addition to the Transducer Unit, in the near of the gang an Output-Unit is installed, which receives the signals from the Transducer Unit and controls the optical and/or acoustic “WARNING” and “ALL-CLEAR” signals. In parallel to the Mobile Units, it is recommended to equip a long extended construction site with several Output-Units. This will guarantee a seamless chain of warning signals.

In the example given, the gang works with a construction vehicle on a mobile work zone that moves continuously on track 1 in direction B. On board of the construction vehicle the modules 2 and 3 were installed.

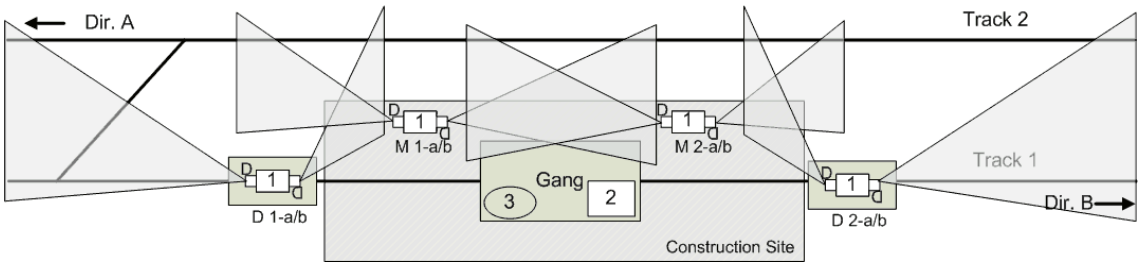

Figure 9: Example construction site with equipment and the angel of view of the cameras

The numbers of the modules in the figure 9 have the following meanings:

1 – Optical sensor system, including Evaluation Unit and image recognition algorithm installed on a self-sustaining propelled drone (D1 and D2) or on Mobile Transducing and Warning Units (M1 and M2)

2 – Transducer for the „WARNING“ and „ALL-CLEAR“ messages

3 – Output-Unit for the „WARNING“ and „ALL-CLEAR“ messages

From the left hand side of the example construction site, a train approaches on track 2. The sensor D1-a detects the train and takes an image of the view (see figure 10-B). The detection of the vehicle based on a comparison between the taken and a reference image (see figure 10-A). If there is a difference in the two images, which means that a vehicle appears, it will be captured and marked (see figure 10-C). A tracing of the vehicle is possible.

The task sequence during the warning phase of the protection system is displayed in figure 11.

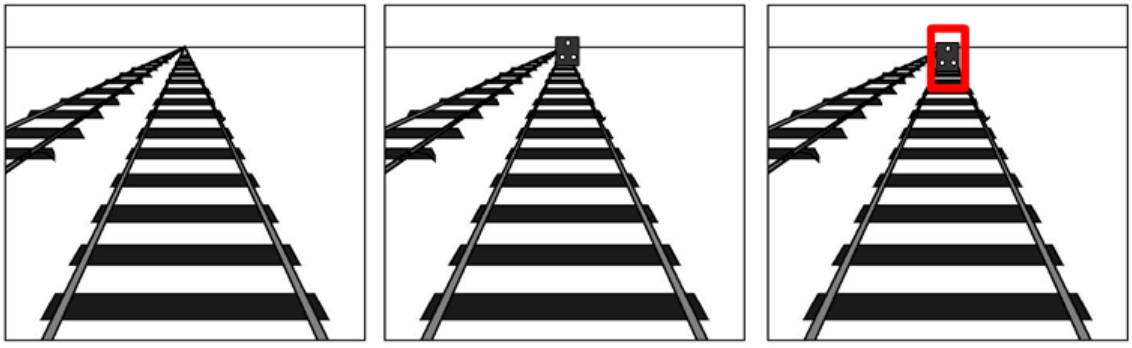

Figure 10: Detection sequence of a vehicle by image comparison

In that moment, D1-a detects an object that approaches the construction site, an information is generated and sent to the Transducer Unit in the construction vehicle. By receiving the approaching train information, the Transducer Unit forwards this three times:

1. The information of an approaching train is moved to the Output-Unit.
2. The information is given to the sensor D1-b.
3. The information is sent to the sensor D2-b.

The Output-Unit onboard of the construction vehicle receives the information from the Transducer Unit and generates a “WARNING” signal, both optical and acoustical. This is the message for the workers to pay attention while the train on track 2 passes the construction site. The “WARNING” signal is active as long as the Transducer Unit has not received the information that the train has left the danger zone.

When the sensor D1-b gets the information of the detected approaching train, it becomes ready to take a fixed-image of the end of the train. This is managed by another image comparison of the actual sight with the typical end of train sign, each train has to carry. If the sensor D1-b identifies such an end of train sign, an image will be taken and sent to the sensor D2-b as a reference value.

The sensor D2-b was informed by the Transducer Unit, to get ready to receive a fixed-image from the sensor D1-b and save this as reference value. By receiving and saving the fixed-image, the sensor D2-b monitors the tracks and compares the actual view with the reference value. When the train has left the danger zone of the construction site, the sensor D2-b onboard of the Drone 2 will detect the end of train sign. This sign will be compared with the reference value. If the two images are similar, information will be sent to the Transducer Unit, that the danger zone is free.

The Transducer Unit forwards this to the Output-Unit and an “ALL-CLEAR” signal is generated and the hazardous phase for the workers ends.

During the warning phase, further functionalities of the protection system on the construction site itself have to be fulfilled. The Mobile Transducing and Warning Units monitor the lauding gauge of the two tracks. To provide a seamless monitoring, a sufficient number of Mobile Units, depending on the extension of the site, have to be stationed.

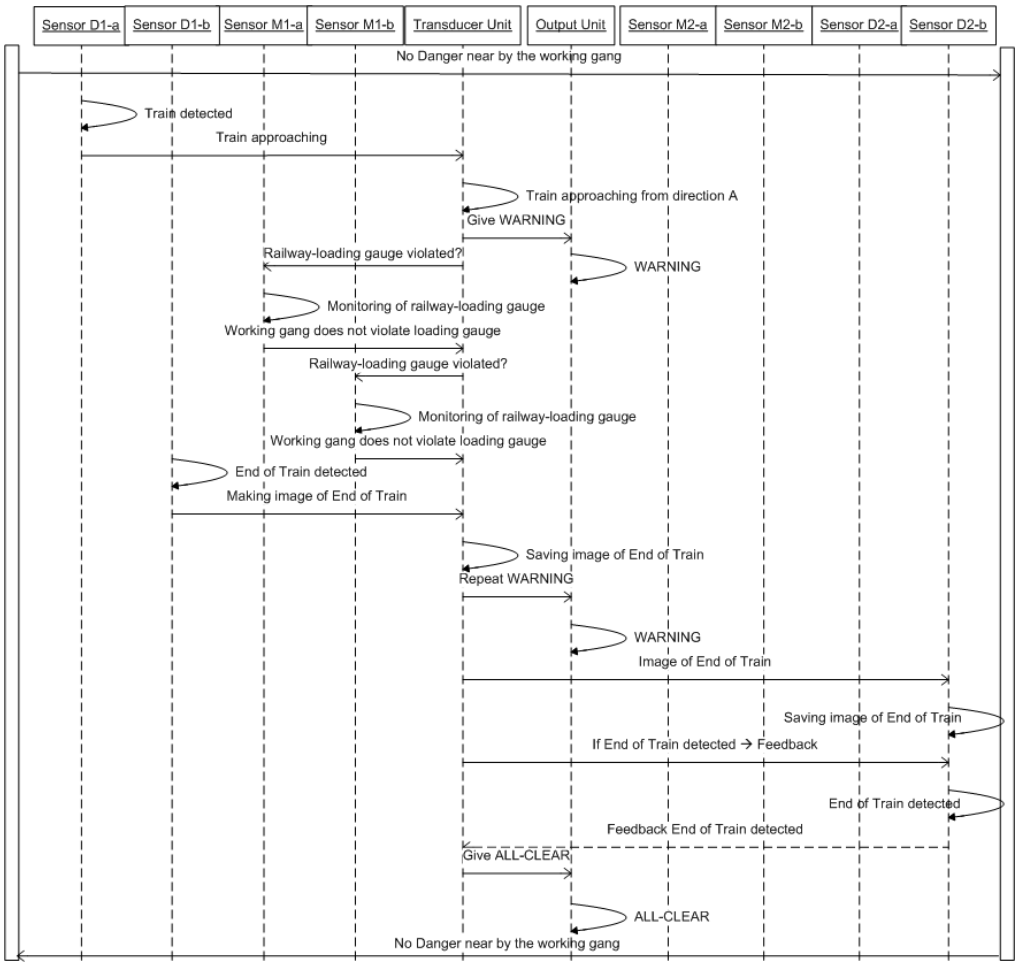

Figure 11: Actions of the protection system during gang warning

The position of the Mobile Units and the view angels of the sensors for the example construction site can be seen in figure 9. The sensors are monitoring continuously the loading gauge of track 2. This will be done any time, also without a train approaching the construction site.

If a worker or a construction vehicle left the loading gauge of the site and gets into the loading gauge of the parallel track, a signal is sent to the Transducer Unit onboard of the construction

vehicle. Immediately, a “WARNNG” signal is generated to inform the worker about the hazard. The worker has to react at once and leave the danger zone on track 2.

When the violation of the loading gauge of track 2 continues despite the warning of the protection system, a message will be sent by the Transducer Unit via Radio to the next interlocking. The signaller can then give the stop order to all trains which approach the construction site.

It is also possible to send the emergency message directly to approaching trains. This message can be displayed on a screen in the driver’s cab to give the order to stop the train before reaching the construction site.

Conclusion

The implementation of imaging methods using optical sensors can help increasing the safety of railways. 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 e.g. state of the art optical sensor technology form an economical advantageous alternative to existing gang warning units and methods still reaching the required safety regulations formulated by standard books, laws or other official documents. The Institute of Transportation Systems of the German Aerospace Center in Braunschweig will develop such a system and evaluates it.

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