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Integration of rail vehicle devices into one module in order to increase passenger safety and comfort

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ABSTRACT
This paper presents an overview of collision and other threats (like e.g. rail crossing accidents) detection methods in railway passenger traffic. This overview leads to concept of Integrated System of Supporting Information Management in Passenger Traffic (the polish acronym of the system is ZSIKRP Demonstrator+). Currently on the polish and, as far as we know, international market such integrated solution is not developed and proposed. In this concept the final customer, e.g. the manufacturer or carrier company, will install one complete solution instead of multiple different installations that are usually difficult or even impossible to integrate. In our opinion the integration leads to increase in safety level of public transport and to improvement the quality of services offered. The novelty of the system is to provide collision, threats detection and fire alarm system integrated into a single coherent solution.

KEYWORDS: safety in passenger railway traffic, collision detection module, fire alarm module, rail crossing monitoring, ultrasonic methods, radars

1. Introduction

Ensuring passenger safety is the most important objective for operators and providers of railway services, manufacturers and carriers. Safety of rail transport is therefore a basic criterion for assessing its performance and determines its efficiency, as well as the broader criterion of transport service quality [1].

Monitoring the state of rail safety in Poland is maintained by the Office of Rail Transport, Chalubinskiego Street 4, 00-928 Warsaw. Within the framework of the statutory tasks the office prepares quarterly reports summarizing the state of rail safety. Last analysis show (see Table 1) that the number of three types of events is growing:

1. collisions of trains,
2. the derailment of trains,
3. fires of railway vehicles.

Table 1. Comparison of train accidents in time I-IX-2012 and I-IX 2013 r. [2]

Accident	I-IX 2012		I-IX 2013		Change
	Number	%	Number	%	
Train collisions	30	5,4	31	5,4	+3,3%
Train derailments	101	18,2	117	20,6	+15,8%
Accidents on rail crossing	208	37,4	206	36,2	-0,9%
Accidents with humans participation caused by rail vehicles in motion	210	37,7	210	36,8	0 %
Rail vehicle fire	1	0,2	3	0,5	+200%
Other	6	1,1	3	0,5	-50%
Total	556	100	570	100	-2,5%

These conditions justify starting work on a system which helps to reduce the negative effects of railway incidents. Design experience of ENTE company indicates that it is possible to develop an integrated system focused on the following aspects:

1. detection of collisions of trains,
2. monitoring the work of the driver,
3. detection of fires and potential causes of fires (overload circuits, overheating systems, etc.)

Currently on the Polish market there is no offer of an integrated system that performs assumed in the design functionality in such a wide range. Moreover, development of driver monitoring module will be worldwide innovation work. Polish producers of systems are specialized in the production and development of devices, which are parts of the proposed system. Potential customers under the trade talks clearly indicate the need to develop an integrated system joining:

- the traffic data taken from a railway vehicle,
- warnings of possible dangers during the journey,
- transmission the data in case of disasters.

There is therefore a need to develop an integrated system connecting the data from vehicle and rail signaling of dangers and the transmission of data on the parameters of disasters. The project of implementation of ZSIKRP system indicates the validity of the continuation of industrial research and development works on this innovative solution and verification of its products on a demonstration scale will be an indication for the production on an industrial scale to meet market needs.

The need for the model and implementation in the framework of the project modules are confirmed by the tragic consequences of disasters in Baby and Szczekociny, Poland. In the event of a disaster train collision detection module and risks will significantly minimize its negative effects by providing immediate information to the competent services of the nature, geographic location and sizes disaster occurred and the number of passengers. This information will allow for more effective planning and carrying out rescue and help in the search for its causes.

2. Analysis of existing methods and solutions

The following chapter will focus on a review of methods of obstacles detecting on the way of a rail vehicle and hazard detection [3].

2.1 Method 1 – ultrasonic obstacles detection

One method of detecting obstacles is the use of ultrasonic sensors. It uses ultrasounds in the form of longitudinal waves in the frequency range from about 20 to 250 kHz. In this type of sensor the source of vibration is a vibrating system excited to vibrate by variable magnetic fields of electric or electromagnetic type. Typically, due to the variable voltage with high frequency, membrane excitation occurs and short pulse is generated and sent within a time of 100 ms to 1 ms consisting of the sequence of vibrations. When the pulse hits an obstacle it bounces back to the transducer as a pulse echo. By measuring the time at which the beam travels sensor – object – sensor way it is possible to determine the distance to the object from the sensor. Ultrasonic waves are sent in the area called ultrasonic field. Ultrasonic sensors are used to detect the moving objects (proximity sensors) and to measure the distance (up to 12 m). Modern ultrasonic sensors contain professional electronics in a common housing, including a microcontroller, precisely control the entire process generation, detection and measurement. The distance of up to 12 m disqualify this solution due to too short driver reaction time required.

2.2 Method 2 – radar detection

Another method is a solution that uses a radar sensor to detect objects in the contour gauge track at a distance of about 100 m before the train. Compared to ultrasound technology and photoelectric detection radar solutions are resistant to rain, snow, wind, fog, ambient temperature, humidity, and exterior lighting. The devices operate on a general ISM band (no need for a special license). Radar sensors are used to detect objects and determine the distance by means of microwave radiation (electromagnetic radiation of a wavelength of from 1 mm to 300 mm and a frequency of 1-30GHz). Active radars send signals and receive the signal reflected from the obstacle.

2.3 Method 3 – infrared detection

Infrared sensors can be used to detect objects in the contour gauge track to a distance of about 40 meters before the train. Unfortunately, this method also has its drawbacks as, for example, the worst performance during the haze. LIDAR, or Light Detection and Ranging, is one of the most modern techniques of gathering data for digital terrain model. The principle of operation is based on the phenomenon of reflection of light waves from the obstacle. The basic kit includes a LIDAR laser rangefinder that emits laser radiation on the rotating mirror. The beam from the mirror is directed to the surrounding space, and scans the system angular. It leads to possibility to determine the tracking angle. After reflection from obstacles beam returns to the CCD transducer (cooled digital camera), and is converted to information about the distances from obstacles. Scanning the environment may be realized with a particular (assumed) angular resolution – not in continuous way. It allows to pre-determine the size of the obstacles that detection system have to react. An important advantage of the solution is independence of the lighting conditions and of the weather with the exception of fog and high clouds. The method is characterized by high accuracy of 0.15-0.25 meters and a short time of analysis the data. As each method also has its drawbacks, such as: absorption laser pulses through the mist, water, asphalt and tar, large volume data sets. As an alternative method of tracking "continuity" of the track a stereoscopic camera can be used. It is a system of two cameras, with optical axes parallel positioned, that is directly used for collecting data about the environment in visible light or infrared band. This second solution will be preferable in case of driving in the dark.

2.4 Method 4 – detection of obstacles using laser triangulation system

Laser Detection Module may be realized by a set of sensors. Several sensors can create a measuring grid mounted in the front of the locomotive. This system is able to detect obstacles but only within sensors range. The advantage of module implemented on the basis of this type of sensors is the lack of elements before the locomotive. Unfortunately disadvantage is too small range of such system which practically eliminate this method from practical implementation.

2.5 Method 5 – detection of obstacles by electronic measurement of acceleration

In the collision detection module there is a need to apply devices that are resistant to physical disturbances, such as vibrations or strong fluctuations in temperature. One can either use the sensors made in MEMS technology (Micro-called Electro-Mechanical-Systems or micro-electromechanical) or other solutions made in the form of a monolithic integrated system in a standardized enclosure adopted to SMD mounting standard. A practical example of such a sensor is a new digital accelerometers that have a large measurement range (from + / - 120 g to + / - 480 g), and the choice of communication. The implementation of the collision detection module will be in this case associated with the implementation based on a monolithic integrated system. The concept of such solution is presented in the next point.

2.6 Conclusion - the concept of collision and threats detection module using an electronic measuring acceleration

In the project it is assumed to construct of collision and threats detection module. Its main task will be to obtain information about the strength of impact and tilt the vehicle after a collision or shortly before the collision.

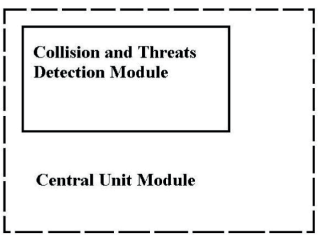

Fig. 1. Location of collision and threats detection module in the CPU [8]

Based on the foregoing review of the methods and assumptions, it was found that acceleration sensors are of crucial importance in the design phase of the module. Acceleration sensor are performed as capacitive sensors in the technology of micro-motor systems, and as a piezoelectric sensor. The capacitive sensors in a special circuit capacitor includes a comb fixed and mobile plates, which under the action of acceleration are deviated from a neutral position, and change of capacity is proportional to the acceleration or delay. The piezoelectric sensors are based on the piezoelectric effect. The measure of the acceleration is the voltage generated in the sensor that is proportional to the force on the piezoelectric crystal. In the case of capacitive sensors, three-axis sensors integrated in a single electronic component can be. The collision and threats detection module requires devices resistant to physical disturbances, such as vibrations or strong fluctuations in temperature. Therefore, the proposed solution is based on a monolithic integrated system in a standardized enclosure for SMD mounting.

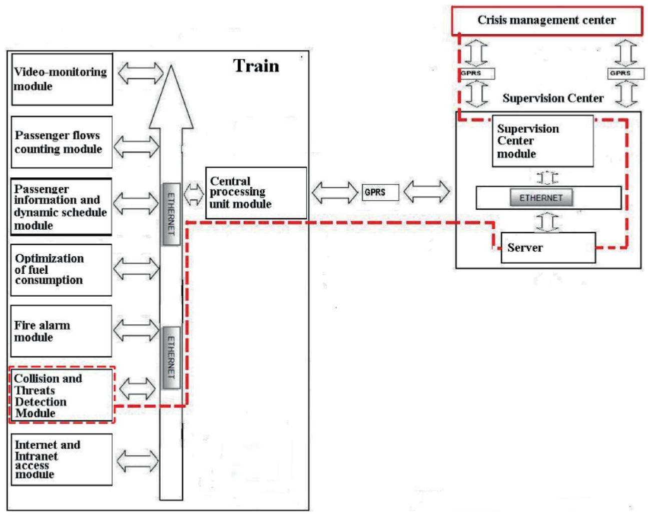

Fig. 2. Signal path in collision and threats detection module [8]

It was assumed that the collision and threats detection module will be both part of the CPU module as well as the autonomous element beyond the central unit, which enables the transmission of information about the collision and rail vehicle state parameters roll through the GSM network to the Surveillance Centre module. After analyzing the data information will be sent to Command Support System (SWD) in the Crisis Management Center. Figure 2 shows the signal path when it detects a collision / hazard.

3. Concept of integrated system supporting information management of railway passenger traffic

In the project the concept of a prototype of Integrated System Supporting Information Management of Railway Passenger Traffic (polish acronym is ZSIKRP, also "Demonstrator+" short name is used) has been proposed [6]. The concept is presented in Fig.3.

The project uses a multilayer distributed architecture, which provides the expected scalability of the whole solution. In fact Demonstrator + will be powered by data from the following modules:

- Video-monitoring.
- Counting passenger flows.
- Information passenger on the train.
- The central processing unit.
- Surveillance center.
- Fire alarm.
- Collision and threats detection.
- Access to the Internet and Intranet.
- Optimization of fuel consumption [4].
- Rail crossings monitoring.

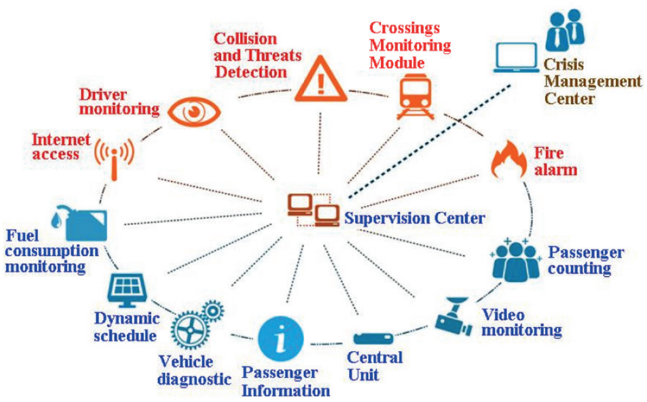

Fig. 3. Concept of integrated system supporting information management of railway passenger traffic [8]

The following are the basic features and functionality of the recommended solutions for each module Demonstrator + [8].

Video-monitoring module will enable video recording taken from: inside the vehicle with cameras in passenger spaces, the rail trail and behind the vehicle in front of the cameras of track, and cameras operating as side mirrors and the registration of the camera that monitors pantographs for diagnostic purposes. The driver will have complete freedom to manually select a camera or camera group, which wants to see on the monitor. Switching sequence between internal and external cameras displayed on the monitors will be controlled automatically or by GPS, for example, at the entrance of the train to the train station (the image is displayed with the side camera). After leaving the station, the monitor will display images from cameras in the passenger sections. The system will be based on digital cameras using IP technology. It will be possible to sound recording in vehicle cabins and integration it with fire alarm system. Activation of the fire sensor will automatically switch the monitor image to the scene. The image will be sent to the Control Centre. Collision detection, thanks to the integration with collision and threats detection will automatically transfer recorded scenes to the Surveillance Centre and conversations with the driver cab just before the event.

Passenger Flows Counting Module will work on the basis of data from the sensors (cameras stereoscopic 3D) located above each door. It will calculate the number of passengers being on and off for each station along the route. Data will be sent in real time to the Surveillance Centre and archived on the server. It will be possible to display information about the vehicle fulfillment on panels in the cabin of the vehicle operator and presentation of data in the Surveillance Centre: for example, statistics in the form of reports and charts (number of inputs and outputs on the station, the total number of passengers carried on a given day etc.).

Passenger Information and Dynamic Timetable Module will enable to display information about the position and route of the vehicle on information boards placed inside the vehicle. Information about the current and the next stop will be administered in the form of voice announcements. The driver will have the possibility to give special messages and have access to information on the current journey. The module will enable the issuance of promotional materials for internal boards. The driver will have the possibility of obtaining the Surveillance Centre updates information on travel routes, text messages, displayed on bulletin boards, message for voice announcements, timetables. Expansion functionality will be to display on notice boards located inside the LCD information about delays and possible transits available. On the terminals with LCD monitors installed in driver's desktops, there will be displayed current train schedule in the form of PDF reports that will be automatically positioned basing on GPS data. The primary purpose of being placed in the passenger information and dynamic timetable module is to increase the comfort of the passengers through dynamic information about the current situation, and also to facilitate the work of drivers with dynamic information about the current position of the vehicle, current observations, warnings and speed limits on the trail, located in one place, i.e. driver LCD terminals. Thanks to the official timetable in PDF format driver will have access to electronic documents that are identical and consistent with their paper counterparts, such as a paper notebook timetable. For this purpose, it is planned to use the WebService interface and integration with Polish Rails (PLK) servers, as well as carriers and owners of trains. On external boards there will be displayed the number and type of train, on side boards: train number, type of train, train route, and intermediate stations. It is also planned to expand the module for LED interior panels, installed in the vehicles. For internal tables will be displayed on the train number, train name (if defined), current date and time, initial and final station, the rest to go along with the planned route, also arrivals downloaded from the official timetable of the driver and the distance to the next station.

Fuel Consumption Optimization Module will allow to precise control of the technical condition of the vehicle during long-term operation and basing on this optimization of fuel consumption by appropriate control procedures and by the evaluation of the effectiveness of particular drivers. Operating parameters of the vehicle will be taken without interfering with the action of the vehicle controller. Integration will take place via CAN and CANopen protocol. Parameters of the controller will be send via the GSM network to keep to the center of Supervisors. Application module will enable the Centre Supervision instant access to current and historical values of the operating parameters of the vehicle. This will carry out a full diagnostic work vehicle and supervision of the operation of the vehicle by the driver, and also generate graphs and reports [4].

Central Module will act as the master controller of the system in the vehicle. It will be equipped with GSM modules [7] and

GPS, digital inputs and outputs, and analog and digital interfaces [5]. The central unit will be equipped with high-performance processor which will initiate operation of the unit, assign tasks, communicate with external devices, collect all the data from measurement systems and regulations, process them, archive and send data to a server in the Control Centre. The module will be developed in the operation of individual modules within the system and will have the following characteristics:

- CPU using the collision and threats detection module will detect the event and obtain current information about the position of the vehicle, number of passengers in the vehicle during the event, traffic parameters at the time of the event, the speed at the moment of impact, as well as directly from the module detection of accidents and threats of force impact and tilting (eg, rollover) of the vehicle and transfer them all to the Control Centre, where Crisis Management Centre will be notified immediately,
- CPU will obtain information about events (fire, accident) and then monitoring module to share video recordings from cameras installed on the vehicle, which will be forwarded to the departments responsible for ensuring security.

Fire Alarm Module will enable the transmission of information taken from vehicle fire alarms to the Control Centre. Activation of the fire sensor will automatically result in a change of preview of the monitoring system in the driver cabin and immediately send information and photos of the danger zone to the center of Supervisors.

In the event of a disaster, collision and risks detection module will significantly minimize its negative effects by providing immediate information to the competent services of the nature, geographic location and size of the disaster. This information will include: data on the speed of the vehicle at the time of the crash, the data on the number of passengers in the vehicle at the time of the crash, the exact geographical location of the vehicle at the time of the crash, recording of cameras and conversations in the cab driver just before the crash. They will allow for more effective planning and carrying out rescue and help in the search for its causes. The module will detect the force of impact and tilt (eg, rollover) of the vehicle. Upon detection of the vehicle accident will be immediately sent event information to the Control Centre.

Control Centre Module will be responsible for archiving and visualization of data received from the central units of vehicles.

Access to the Internet and Intranet Module will allow to use of free Internet and Intranet sites, which will increase the comfort of passengers. To achieve access to the Internet and Intranet WI-FI, 3G, LTE technologies will be used. Train facilities in internal wireless InterMedia technology enable travelers accessing the data of all kinds, periodically updated content such as movies, music, magazines, etc. In order to ensure uniform signal level throughout the vehicle, leaky cable technology is planned to be use.

Crossings Monitoring Module will allow for the automatic detection of improper behavior of drivers at railroad crossings through continuous image analysis and recording of abnormal situations. Information about the event will be sent immediately to the Control Centre. Surveillance Centre will also be sent via the GSM network footage. The module will be able to achieve error-free identification of vehicles in different weather conditions. With its innovative software module will not require any connection to the traffic light controller.

4. Conclusion

In the event of a collision and derailment ZSIKRP System (Demonstrator +) will be relieving the effects of the event, by sending all the information to the Center of Supervision and quick to inform the staff at the Center for Emergency Notification. Are also important safety issues and accidents at level crossings, mainly caused by the improper behavior of the drivers [9]. According to the statistics a man is still the most unreliable link in the security system.

Using solutions proposed in this work it is possible to use the Demonstrator + system in electric (EMU - type) and diesel (PCS - type) vehicles. Currently, a prototype system is being prepared for testing by Mazovia and Wielkopolska Railways.

Acknowledgments

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Bibliography

[1] SITARZ M., CHRUZIK K., MAŃKA I.: Zintegrowany System Zarządzania Bezpieczeństwem Transportu Kolejowego w Polsce, Czasopismo Techniczne Politechniki Krakowskiej, Mechanika, Zeszyt 14, (2012)

[2] Raport za III kwartały 2013 r. Podsumowanie stanu bezpieczeństwa transportu kolejowego. Urząd Transportu Kolejowego, Warszawa, (2013)

[3] HEJCZYK T., ALEKSANDER L., WILCZEK M.: System perymetryczny do wizualizacji dynamicznych zmian na terenie lotniska, Wydawnictwo Pomiary Automatyka Kontrola, vol. 59, nr 12 (2013)

[4] KOWALIK L., CHMIELEWSKI W., SZASTOK, A.: Wykorzystanie systemu METRONIX do pomiaru zużycia paliwa oraz detekcji pozaeksploatracyjnych ubytków paliwa w lokomotywach spalinowych, INSTYTUT NAUKOWO WYDAWNICZY TTS nr 9 (2008)

[5] MŁYŃCZAK J.: Telematyka w transporcie kolejowym, Infrastruktura Transportu (2012)

[6] MŁYŃCZAK J.: Analysis of intelligent transport systems (ITS) in public transport of upper Silesia. In: Mikulski J.: CCIS 239, Springer Heidelberg (2011)

[7] MIKULSKI J., MŁYŃCZAK J.: Wykorzystanie systemu monitoringu GPS do oceny parametrów energetycznych lokomotyw spalinowych, Przegląd Elektrotechniczny, Tom 85 (2009)

[8] Projekt nr UOD-DEM-1-243/001, pt. „Zintegrowany System Wspomagający Zarządzanie Informacją o Kolejowym Ruchu Pasażerskim".

[9] K. DYL.: Ocena Funkcjonowania Transportu Kolejowego i Stanu Bezpieczeństwa Ruchu Kolejowego w 2012 roku, Urząd Transportu Kolejowego (2012)