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SATELLITE BASED LOCALISATION SYSTEM FOR SECONDARY RAILWAYS LINES

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Abstract: *The presented paper shows an innovative approach to a vehicle autonomous localisation system for railways, providing cost-efficient position information for various safety- or non-safety-related systems especially for protection systems on non-equipped secondary lines in a cost efficient way. This is the main focus of a project called "DemoOrt" which consists of developing a platform with an onboard, vehicle autonomous technology, a reference measuring platform and a safety analysis methodology. This approach integrates and uses available as well as innovative technologies with the focus on satellite based positioning (GPS, GALILEO and EGNOS)*

Key words: *Localisation System, Railways, GALILEO, DemoOrt*

INTRODUCTION

Present positioning methods in railway systems are based on trackside located technical equipment, i.e. axle counters, track circuits, etc. At best this equipment provides train position information with an accuracy of several hundred meters, which is indeed sufficient for existing protection systems but reduces the performance with respect to track capacity. Furthermore these devices require enormous maintenance efforts and exhibit a poor adaptability towards innovation or changing operational requirements. For modern railway operation as for example the ERTMS/ETCS (European Rail Traffic Management System/ European Train Control System) a vehicle-autarkic and continuous positioning as well as a train integrity validation with high accuracy, availability and safety are required in order to provide a modern and flexible train operation also in the future. But also in order to increase the track capacity and safety on non-equipped secondary lines with in general low traffic, a vehicle autarkic positioning is necessary to assure train protection at low costs [11].

DEMOORT PROJECT OBJECTIVE

The basic idea of the project called "DemoOrt" consists of developing a platform with an onboard autonomous and vehicle autarkic technology which also integrates and uses available as well as innovative technologies with the main focus on satellite based positioning (GPS, GALILEO and EGNOS).

The project is a part of the research program "System Schiene 2010" which translates into "Railway systems in 2010". The basic concept is to design homogeneous, standardised systems (e.g. onboard stand-alone positioning systems for trains in safety critical applications). Thereby the global market can be envisaged in combination with a simultaneous reduction of system costs as shown in Fig. 1.

Present processes of positioning in railway applications are trackside-based. The use of trackside equipment has the following consequences

- High maintenance cost
- Insufficiently adaptive towards modifications and changing operational requirements

For modern operational processes as ERTMS/ETCS etc. a train-based, continuous positioning system and verification of integrity with high accuracy, availability and safety is needed.

The advantages of autarkic are reductions of cost and complexity.

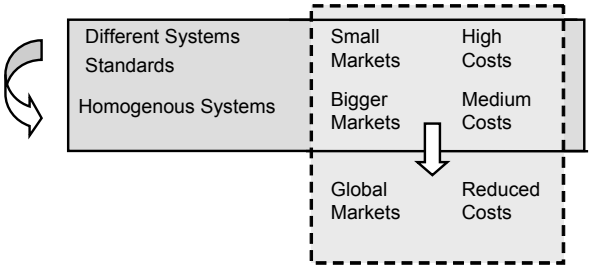

Fig.1. The economic aim of Project DemoOrt

This project is funded by the German Federal Ministry of Education and Research (BMBF). The consortium comprises

- The Institute of Transportation Systems of the German Aerospace Centre (DLR), Braunschweig
- The Institute for Traffic Safety and Automation Engineering of the Technical University of Braunschweig,
- Institut für Mess- und Regelungstechnik of the University of Karlsruhe
- Bombardier Transportation Rail Control Solutions (BT RCS) in Ulm,

and among of the subcontractors.

REQUIREMENTS ANALYSIS

In the first step of the project work it was necessary to specify the operational, constructional and safety-relevant requirements. The experiences from the projects [1, 2, 3] from this domains showed, that it is very useful to use for these purposes a requirements engineering tool, Figure 2 shows a screenshot for the requirements provided by the software tool "DOORS".

Fig.2. Requirement analysis (screenshot)

In this work package, all project partners specified the users' requirements specification (URS), system requirements specification (SRS), subsystems requirements specification (SSRS) as well as the form-fit functional interface specification (FFFIS). These specification documents were reviewed in two distinct review steps.

DEMOORT SYSTEM OVERVIEW

The system is designed to be highly available and will be deployed for applications bearing safety responsibility. In order to fulfil the requirements the fusion of diverse position information is necessary as shown in Fig. 3 [10].

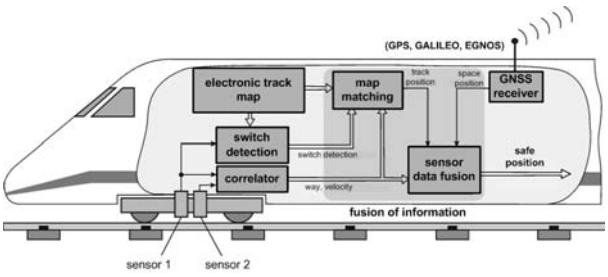

Fig.3. DemoOrt locator principle

The main idea is to use different sensors with different principles of measurement. In particular, three basically different sensors are used for one highly available and safe system. These are

- GNSS based receiver
- Eddy current sensor
- Map matching.

The use of satellite based positioning is utilised in many applications for air, maritime and land transport. In all of these cases, at least four satellites are used to get a four dimensional position, consisting of three coordinates in space and the time (fourth coordinate). This position can be (almost) anywhere on the surface of the earth or the airspace above it [12].

When used on the surface of the earth, the reception of the necessary amount of satellites (namely four) can be difficult due to environmental barriers (buildings, trees, etc.) in close range of the object to be localised. This problem arises, because quasi-optical wave propagation occurs in the frequency range used for satellite positioning. If an object obstructs the necessary direct line of sight to the satellite, no signal can be received [5]. This fact reduces the availability of satellite based positioning in places surrounded by high objects, which cannot be extended in railway environment.

For the usage in railway systems, a high reliability is necessary for the use in safety related functions (e.g. the train control system). On the other hand, in railway systems, the special constraint exists, that the vehicle cannot leave the track. Thus the degree of freedom of a train is reduced to one in space, which means it can only move along its track [5]. This prerequisite provides a vehicle-mounted device for track features.

The onboard eddy current sensor detects inhomogeneities between the primary and secondary coil like clamping and switches [10].

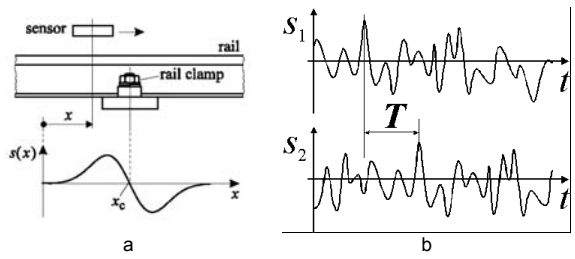

Fig.4. a: Sensor Signal, b: Signals from both sensors

The typical output signal is shown in Fig. 4. The signal from both sensors is correlated and the time T can be derived [9].

$$v = \frac{l}{T} \quad (1)$$

From the time T and travelled distance l between the sensors, one can derive the velocity v by correlation methods. The eddy current sensor provides a high accuracy of velocity as well as of position and the direction information of passed over switches.

The digital Route map provides high accuracy data about the track, position of (virtual) balises as well as about specific switch properties.

After the data fusion from all sensors it is possible to calculate an exact position and output this in the ETCS data format [8] with high reliability and a qualified confidence and uncertainty.

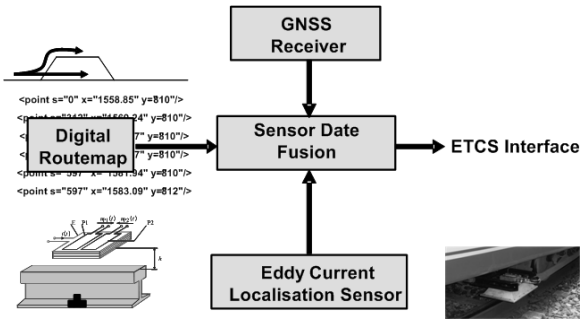

Fig.5. Multi sensor system for autarkic localization

Identification of the position is more accurate using multiple sensors together with sensor data fusion than using a single sensor. The robustness of the system is higher and continuous identification of the position of trains is possible. The position accuracy requirement for the ERTMS/ETCS specifications is about +/-5m + 2% of the driven distance [8]. This can be fulfilled by the system described above.

SAFETY ANALYSIS

In particular the possible fields of application for the DemoOrt system shall be

safety relevant systems. In this manner the system can be used as a positioning system for protection purposes of secondary lines. For approval purposes the basic proof of availability has to be enhanced by a safety case. For this reason and based on a comprehensive inquiry of legal aspects, standards and regulations this project shall face an integrated method on providing a proof of safety. The method shall be developed in order to be practically used for an exemplary system.

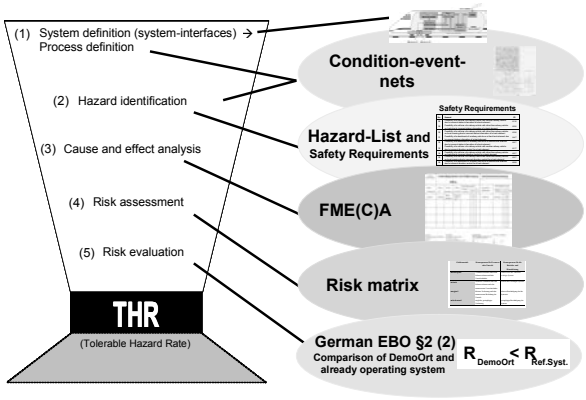

Fig.6. Methodology (based on EN 50126)

Based on the CENELEC-standards [13] the procedure for system certification as shown in Fig. 6 has been developed. After closing the selection process for the system components and therefore the identification of partial systems the definition of the complete system referring to EN 50126 will follow. Using condition-event-nets the system processes are defined afterwards. For this no separate tool will be necessary, since this task can be done using standard office software. The defined processes will be used for the hazard identification process. As a reference a general hazard list for railways will be used and adapted with the outcome of safety relevant requirements. The extracted hazards will be analysed using the Failure-Mode-and-Effect-(and-Critically)-Analysis (FME(C)A) methods for qualitative and quantitative results. A quantitative risk estimation under consideration of the risk matrix ref. to EN 50126 will also be done using the FME(C)A method. The finishing safety comparison with a reference system will lead to the risk evaluation. For that purpose the DemoOrt system will be compared with an already approved and operating safety relevant system.

APPLICATION: TRAIN PROTECTION SYSTEM

As initially mentioned, a large potential for the vehicle autarkic localisation systems with safety-relevant applications is to be seen with a protection system in the "Low Cost" range. In particular for the secondary lines, which - at least in Europe - constitute a predominant part of the railway lines in operation, such an economical system would particularly contribute to increase safety. Today only a few courses per day are in operation on these lines, so that a track equipment with an expensive signalling system could not be presented – would not be economically applicable. It is state of the art that the courses on these lines are in operation without any protection equipment. The basis of the operation is only the communication by means of arrangements between the driver and the course manager (in German: “Zugleiter”). In the following, we will refer to this as “telephone supervision operation”. As soon as more than one train is on the line, a potential risk for a collision of the trains arises, which is not reduced by any protection system. Here the presented "DemoOrt" system should step in and transfer the continuous positions of all courses on the line to the “Low-Cost-Protection System”, which is located at the course manager. The task of the protection system is to compare the received position data of the courses with a route map. In case of a fatal (collision) course of two trains, the system shall send relevant data to the trains that activate directly an emergency braking.

The present procedure of the “telephone supervision operation” should not be changed so that for the personnel no additional and cost-intensive training courses are necessary. The operational staff should not notice the application of the protection system in normal operational situations. It serves only as a protection and fallback solution, if a dangerous action of the personnel could lead to fatal consequences like train collisions etc.

A further advantage of the continuous position transmission of the positioning data of the trains to the course centre is among other things the supply of the information on a display for the course leader, who is better and more accurately informed about the situation on the

line. Thus fast solutions to problem situations can be found more quickly, what contributes to the cost reduction again.

An example test track (located near Braunschweig) was selected and the protection and operation system were investigated in detail. A feasibility study was conducted at the Institute for Traffic Safety and Automation Engineering of the migration from a common to an ETCS or a DemoOrt based protection system. The preliminary results show, that the break-even point will be reached after approximately 30 months.

CONCLUSION

The achieved system redundancy of the train localisation system assures the required high level of system safety, accuracy and availability. Concerning these parameters the realisation of a basic train protection system becomes possible.

In Europe a large number of non-equipped secondary lines for basic train operations are in service mostly using telephone block system; due to costs protection systems exist rather barely or even not at all. Telephone block train operations use telephone messages between train dispatcher and train driver in order to issue movement authorities, which can easily lead to misunderstandings followed by accidents. This goes along with poor traffic densities on secondary lines. In the course of a railway modernisation and the accompanying increase of traffic on secondary lines an innovative cost-efficient protection solution for train operation is obligatory. A basis for this is presented by the vehicle-autarkic positioning for a train protection system developed inside the “DemoOrt” project, which operates in the background and in case of emergency immediately stops all trains on track.

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ЛОКАЛИЗИРАЩА СИСТЕМА ЗА ВТОРОСТЕПЕННИ ЖЕЛЕЗОПЪТНИ ЛИНИИ НА ОСНОВАТА НА САТЕЛИТ

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ГЕРМАНИЯ

Резюме: *Докладът представя иновационен подход към автономна локализираща система за железопътни возила, която осигурява икономически ефективна информация за местоположението на различни системи, свързани и несвързани с безопасността, специално за защита по икономически изгоден начин на системи при второстепенни линии. Това е основният фокус на проекта, наречен DemoOr, който е за разработване на платформа за автономна технология във возилата,еталонна измерителна платформа и методология за анализ на безопасността. Този подход интегрира и използва съществуващи, както и иновационни технологии, насочени към позициониране на базата на сателит (GPS, GALILEO and EGNOS).*

Ключови думи: *локализираща система, GALILEO, DemoOrt.*