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Enabling Certification of Satellite Based Localization in Railways by Combination of Redundant Sensors and Map Matching

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Abstract: With the proven general applicability of satellite based localization systems (GNSS) and satellite based augmentation systems (SBAS) the way is paved for safety relevant applications in railways. Secondary lines currently equipped with no or only a not up-to-date train control system as well as the currently introduced European train control system (ETCS) can benefit from satellite based train localization. Thus the efficiency of operation can be increased including the reduction of costs for infrastructure equipment.

Keywords: Railway, GNSS, Safety, Certification

1. INTRODUCTION

Satellite based localization systems are currently applied in various domains in transportation for information purposes. In railways, they are used for passenger information and in automotive for navigation. These applications are non-safety relevant because of a missing certification. In this paper a development strategy towards the certification of safety relevant applications in transportation with the example of railways is shown.

1.1 Targets of this paper

The intended safety relevant application of GNSS in railways leads to the targets of this paper summarized in this section. The focus is on the architecture, the safe functionality, the safety assessment and the broad applicability of the achieved results.

The system architecture of the localization unit to be developed needs to be railway specific to consider the specific safety requirements and conditions. The architecture shall be regarded from the technical and functional perspective as well as by the process cycles it shall fulfil.

The safe functionality of the localization unit shall contain procedures to control system malfunctions or failures including the construction of the safe system architecture based on the required functions.

To enable the safety assessment of the localization unit, a safety and reliability analysis of the system, its requirements and specifications is necessary. Furthermore, non-operational and operational tests have to be included to proof the functionality of the system under real conditions.

With an applicability for various purposes, the development with its according costs and efforts enables further benefits. This supports the financial viability of the introduced approach. By designing a modular structure, the localization unit shall be applicable in other domains as well.

1.2 Applied normative background and responsibilities

The introduced approach is only feasible if the normative background of all domains involved – in this case railways and satellite based localization – is considered. This includes national and international (European) laws and regulations as well as technical norms and standards, specifications as well as documents of the operators and manufacturers. The normative background can be summarized as the relevant input documents for the development and certification of the localization unit. It has to be considered that the legal documents in Europe have changed during the last two decades from national documents to a European framework with the target to achieve interoperability of European railways. These European normative documents, especially the Technical Specifications for Interoperability (TSI), are primary applied for cross-border transportation of persons and goods in the European Union on the Trans-European Network (TEN).

As part of the TSI, the responsibilities in the certification process were newly defined [EC/2011/217]. The new established institutions are the notified body (NoBo), the designated body (DeBo) as well as the Assessment Body (AssBo). Their expertise and participation is necessary as part of the certification to put a train or other railway equipment into service. The NoBo analyses and verifies the conformity of the system to be approved with the relevant TSI according to a European procedure concluding with an according certificate. Additionally the interfaces of the system to be approved with other systems are checked [EC/2008/57]. The designated bodies (DeBo) have the task to assess the Notified National Technical Rules (NNTR), therefore they have to come from the member state where the assessment takes place. The assessment of the risk evaluation done on the base of the common safety methods (CSM) is done by the

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assessment body (AssBo). On the basis of the evaluation and assessment of the NoBo, DeBo and AssBo, the national safety authority (NSA) has the task to issue a safety certificate valid on the whole railway network of the European Union [Sciutto et al. 2010]. It coordinates and supervises the effort of all involved institutions and includes the resulting technical properties of the system and procedures of the safety management system into its considerations.

1.3 Applied approach

Based on the normative background analyzed in section 1.3, a process for the development of a satellite based localization unit to be certified for safety relevant applications is suggested in this paper. Therefore, results of previous projects which have confirmed the general applicability of satellite based solutions in railways are used. The approach presented in this paper consists of a developed methodology deriving the system architecture of the localization unit out of the required functions where it shall be applied for. This leads to the presented system architecture whose safety needs to be assessed. This is done by an innovative safety case combining the traditional railway requirements with the necessary integration of COTS.

2. DEVELOPMENT OF LOCALIZATION UNIT

The localization unit shall be developed for safety relevant applications in railways, e.g. to localize trains as part of a train control system. Therefore components not developed according to the requirements of railway standardisation need to be included into the safety relevant certification process of railways. In this chapter, the state of the art of this approach is described in section 2.1. In section 2.2, the potential sensor to be implemented into railways as components-off-the-shelf (COTS) are introduced with a focus on satellite based localization. In section 2.3, the GNSS sensor as most important sensor in this paper is introduced. Section 2.4 explains details of the digital map, section 2.5 outline different odometry sensors.

2.1 State of the art

Currently, safe localization in railways is carried out by track side equipment, which is partially supported by vehicle based equipment. The replacement of these components like axle counters, balises and looped circuits by satellite based solutions has been discussed in several research projects in the past [Alcouffe/Barbu 2001; DemoOrt 2009; Manz et al. 2014]. However the qualification of the localization solution has not been carried out yet because the used sensors are not qualified and certified.

2.2 Introduction of sensors

For the localization of any object in transportation, sensors are necessary. In railways, the train control system requires position information to guide the trains according the safety requirements. It has to be guaranteed that sensors deliver the according information in the requested quality. They can be positioned at the transportation object (person/ good), at the transportation infrastructure, in the traffic-control system and on the means of transportation. In this work, the sensors shall be solely located at the means of transportation because of the various disadvantages of the other options. A sensor at the transportation object would always need to be carried with the object, even if it is not in traffic. Sensors at the transportation infrastructure are exposed to environment and require a huge amount of cabling especially in remote areas. The same applies to sensors in the traffic control system which is currently only installed at a part of the network.

Sensors on the means of transportation enable an autonomous self-localization of the vehicle. The sensor outputs have to be used and combined leading to a level of safety requested by railway standardization. As potential sensors for the satellite based localization unit, three categories are available and useful. These are sensors for satellite-based localization, a digital map and additional sensors.

2.3 GNSS sensors

The sensor for satellite-based localization can use one or several satellite based localization systems (GNSS) as signal input to calculate the position of the antenna and accordingly of the vehicle. As GNSS, the US-American system GPS and the Russian system GLONASS are currently available. The European system Galileo and the Chinese system COMPASS are currently under construction. GNSS generally consist of a control segment, a space segment and a user segment. GPS, GLONASS and COMPASS offer as guaranteed signals only military signals, the open available signals are not guaranteed. Galileo is the only GNSS which intends to offer a civil guaranteed service with its safety of life service.

The accuracy of satellite based localization can be additionally increased by using augmentation systems. This can be ground based augmentation systems (GBAS) and space based augmentation systems (SBAS). GBAS are for example DGPS (Differential GPS), SBAS are e.g. the European EGNOS (European Geostationary Navigation Overlay Service) or the American WAAS (Wide Area Augmentation System). These systems use ground based monitoring stations to evaluate the accuracy of the received satellite signals and send the resulting necessary correction signals to the satellite. The user can receive the augmentation information from the satellite if their receiver is accordingly enabled.

2.4 Digital map

The digital map should comply with domain specific requirements. For railways, it should be designed based on the railML standard. It has to be compiled separately for each used railway line, therefore a convenient and smooth algorithm is desirable. Same applies to the permanent improvement of the digital map by a special algorithm to be developed and implemented.