Cooperative Situation Awareness for a Railway Collision Avoidance System (RCAS)

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Abstract. This paper introduces a new approach addressing the problem of colliding trains. As opposed to "traditional" technical train safety systems, the approach does not require any technology in the infrastructure, i.e. along the railway track, but entirely relies on pervasive information and communication technology in the trains. The approach combines three core technologies: a direct train-to-train communication system, an accurate localization system and a cooperative situation analysis and decision support system. The system has been implemented and demonstrated with real trains, showing the huge potential for saving lives and avoiding damages.

1 Introduction

Trains are considered to be a safe mode of transport. Nevertheless, even if comprehensive and complex technology is extensively deployed in the infrastructure which should help to avoid collisions, they do occur occasionally. Experiences from the aeronautical Traffic Alert and Collision Avoidance System (TCAS) and its successor the Automatic Dependent Surveillance Broadcast (ADS-B), as well as the maritime Automatic Identification System (AIS) have shown that the probability of collisions can be significantly reduced with collision avoidance support systems, which do hardly require infrastructure components.

This paper is about a Railway Collision Avoidance System (RCAS) [9] which uses this independency from components in the infrastructure as a guiding principle, which is an innovative approach for the railway domain. It is obvious that there are similarities as well as differences in the requirements if the railway domain is compared to the aeronautics and the maritime domain. [5] addresses them in detail.

The system uses the latest communication and sensor technologies. The trains exchange information about their geographical and topological position, speed, loading gauge and the planned route using direct train-to-train communication as soon as they are within radio range of one another. If the system detects an imminent collision, it warns each train driver and assists them with a pre-assessment of the current situation and how it may evolve in the next few seconds.

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Fig. 1. Providing information to the driver about the situation as assessed by RCAS.

2 Main Components

RCAS uses in many ways concepts researched on in the pervasive computing domain. This is already reflected in the following overview of the three main components of the system.

The first main component of RCAS is a short range communication system dedicated for being used in a railway environment with its particular characteristics (shadowing but also signal guidance in tunnels, many metallic reflectors etc.). It started with a careful selection of the most suitable frequency band (460-480 MHz) and proper signal propagation channel modeling, given the identified frequency band and a set of distinguished scenarios (train station, shunting yard, regional network etc.) [4]. The communication system is designed to work without any specific addressing and works in an ad-hoc, self-management way. As such it adopts concepts from organic and pervasive computing. The protocols (e.g. on Medium Access Control) have been designed and validated with simulations. The prototype system was then implemented based on an existing similar, but not fully equivalent off-the-shelf communication system named TETRA, which was adapted to the needs for the demonstration and modified to come as close to the RCAS system design as possible.

The second important component of RCAS is its localization system. Accurate positioning is very important for RCAS, as the position of each train on the track network is an essential information for the situation analysis, i.e. whether there is a high potential for a collision or not. In particular, a sensor fusion approach is used, not relying on a single sensor but a set of several, functional complementary position sensors. This includes GPS, cameras, odometer, RADAR, eddy current sensors etc. The information from all these sensors are evaluated in a joint way, taking into consideration also any knowledge about the quality of information any sensor is able to deliver at any time and in the current environment. Following a proper context modeling approach [8] as suitable in this pervasive computing environment, methods of context inference [2] and quality of context [1] have been successfully adopted.

The third most important component of the RCAS technology is its internal situation estimation and analysis algorithm, which is explained more in the next section.

3 Cooperative Situation Awareness

As the core philosophy of RCAS is to not rely on anything in the infrastructure but only on components which can be made available on board of a train, there is no central component providing data about other trains in the network. Thus, each train has to rely on the information about other trains received by the train-to-train communication together with the information about the own train as perceived through the on-board sensors and a track map. This track map can be provided by an authorized source, but even can be learned or updated with another algorithm [6]. A probabilistic situation estimation algorithm has been used, taking into account all information about the trains in an area of at least 10 km in diameter, and their possible movements along the track topology [7] in the next minutes. The algorithm raises an alarm level depending on the probability of a collision and the remaining time to this event [3].

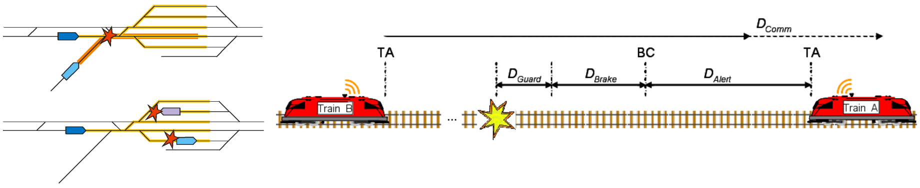

Fig. 2. Potential flank and head-on collisions situations on the left, 2-stage alert concept on the right.

4 The demonstration

A prototype of the system has been demonstrated on board of real trains on a railway test track in Wegberg near Duesseldorf, Germany, in May 2010. At the demonstration only a subset of the sensor fusion approach as been shown, i.e. a combination of GPS with a special camera (see Fig. 3 middle) were already sufficient to fulfil the positioning accuracy requirements of the track network of the demo track. For more challenging track topologies and environments, our comprehensive sensor fusion approach will provide the necessary robustness for a safe and reliable operation.

A video has been produced on the occasion of the demonstration, illustrating the challenges and the solution as a prototype implementation installed in real trains. The video of the RCAS prototype in operation is available at `http://www.youtube.com/watch?v=SBOwswFuFoU`. More information about the project and all related aspects is available at `http://www.collision-avoidance.org/rcas`.

Fig. 3. BOB Integral and RailDriVE approaching the same switch in a flank collision situation on the left, special camera for optical switch stand detection mounted on the coupling of the train in the middle, QR code of the link to the video on the right.

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