Infrared-based position determination for augmented cognition utilization in miniaturized traffic test facilities

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Abstract

New infrastructure-less traffic collision avoidance systems are currently developed for road and railway transportation. Similar to maritime and air transport a significant increase in safety is expected by exploiting direct vehicle-to-vehicle communication to detect possible collision threats and to immediately warn the driver. Augmented cognition is a key feature to expand the driver's "view" or to support the self awareness of intelligent onboard units in such critical situations. To design new control and collision avoidance systems and to assess their performance, it is essential to emulate the interaction of centralized traffic management components with partly autonomous vehicles or their drivers. For this purpose test facilities can be operated, e.g. in case of railway transportation using train models to reduce costs and to avoid substantial damage. Concomitant with this approach, a millimetre level localisation of vehicle models is required for small-scale indoor test environments. In this paper we present an infrared based positioning concept that allows simulation of the vehicle's and driver's access to additional traffic relevant information like position or velocity of vehicles in the vicinity.

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1. Introduction

So far small-scale traffic control test facilities for railway transportation feature fully equipped control centres, which can be operated by humans in order to investigate and improve safety and economy relevant operation mechanisms. Train models are typically steered from a central unit and their position is detected by sensors in the tracks. Alike, in reality train positions are determined using transponders at decisive points in the railway network.
The historically grown centralized traffic control in real railway transportation still suffers three significant train accidents in Europe every day [1]. The concept of direct vehicle-to-vehicle communication adds here substantial benefit by providing the most relevant traffic information very fast directly to the driver. Moreover in numerous cases such a safety overlay service can prevent collisions with obstacles that cannot be sensed by the control centre, such as construction vehicles, construction workers or pedestrians and vehicles on level crossings, if they are equipped with transceivers. Another important feature in the context of pervasive computing is the general possibility to collect and distribute information about hindrances or damages, but also about delays, weather conditions, or numbers of passengers.
The basis for such an infrastructure-less collision avoidance system in real, as well as in a small-scale model testbed, is the precise position determination of vehicles and the transmission of this information to other vehicles in the vicinity. In this way a joint situation awareness is established and each vehicle is able to detect a collision threat and advise the driver in how to resolve the critical situation. As described in [2], a reliable and accurate position solution for real railway vehicles can be achieved by fusion of multiple sensors, e.g. a GNSS (Global Navigation Satellite System) receiver, an odometer and an eddy current sensor. While GNSS provides reasonable absolute position information with high long term stability, the combination with the short term stable odometer allows very accurate position determination along the track. In order to resolve the track on multi track lines with high reliability the eddy current sensor is used to detect which branch is taken when the train passes a switch.
In the next section we will explain how the functionality of existing miniaturized traffic control test facilities [3] can be expanded to integrate autonomous collision avoidance systems in the individual vehicles. For a close to reality approach, this can be achieved by accurate determination of the position on board of the models and transmission of the data to other intelligent vehicles.

2. System architecture

Standard position determination in test facilities is realized infrastructure based. That means the position information of vehicles is e.g. collected by sensors on the tracks and analyzed by a central control unit. Our concept provides the information onboard the models, as it will be done in future vehicle-to-vehicle communication systems, including rail-based systems.

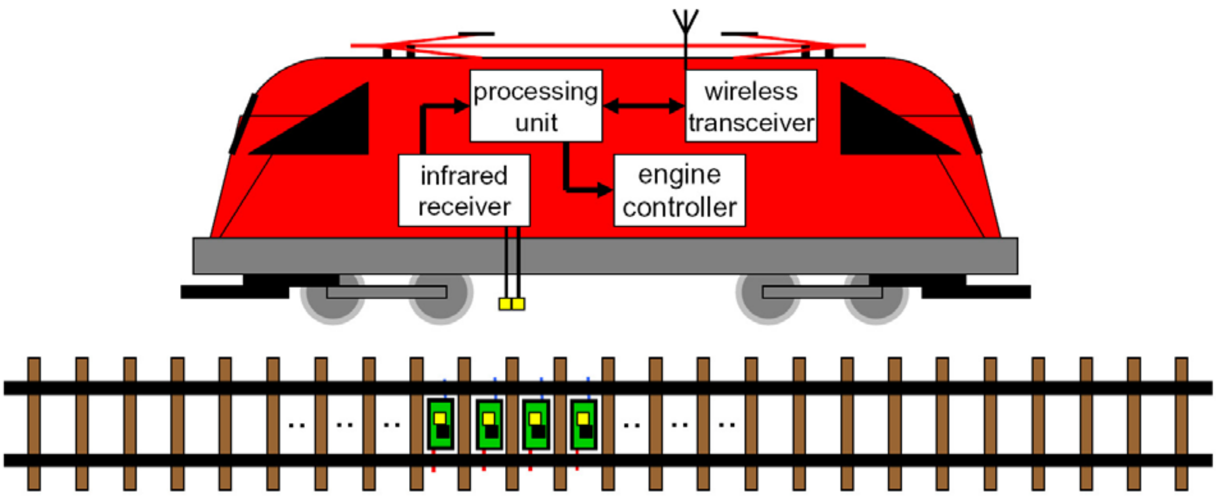

Figure 1.
Railway Collision Avoidance System (RCAS) testbed with a tiny vehicle model acquiring position information through infrared sensors.

Figure 1 illustrates the system setup for our Railway Collision Avoidance System (RCAS) testbed with tiny vehicle models exploiting ad-hoc vehicle-to-vehicle communication. For position determination a series of infrared transmitters is integrated in the tracks. Each transmitter broadcasts a specific address that is assigned to a predefined location on the track map, which is known by the processing unit on the vehicle. To precisely determine position, each vehicle is equipped with a row of infrared sensors. By appropriate selection of the transmitter diode beam width and the distances between transmitters and sensors, respectively, an accuracy down to millimetre range can be achieved. Besides providing the position information directly to the model train, one of the main advantages of this approach is, that this millimetre precision on the small model railways allows emulation of accurate GNSS based positioning that shall be used for the real anti-collision systems in the future. Moreover, as each infrared transmitter address can be mapped to a known WGS84 coordinate on the track map, it is also possible to apply error models for reproduction of characteristic degradation of position accuracy by shadowing effects or multipath. For example, if the model train enters a tunnel, the variance of the error model can be increased when mapping the corresponding addresses to WGS84 coordinates. On the other hand, a very precise rail selective position information can be passed to the train, if a certain address is specified to model a location-transponder on the track.
Another important property of the selected infrared-based positioning solution is the provided absolute position information. In contrast to distance measurement techniques like e.g. wheel sensors, the absolute position information is available under all circumstances, even if a vehicle derails and is placed anywhere else on the test platform.
Existing infrared hardware e.g. by [4] can be adapted to realize the depicted miniaturized positioning system. For cost efficient solutions fully integrated transmitters can be build into the track and can be directly powered through the rails.

In order to run and test collision avoidance algorithms, the position data is read by an onboard processing unit and broadcasted to other vehicles on the test facility using WiFi transceivers. Together with the received information from other vehicles, the processing unit detects potential collision threats, warns the driver or even takes over control to stop the vehicle.
Figure 2 illustrates the collision avoidance test facility with a selected scenario setup for railway transportation. In addition to existing facilities the RCAS system approach is fully reproducible. The collective interaction of the centralized control mechanisms and the onboard collision avoidance strategies, including the human interfaces to the control centre staff and the train drivers, can be tested, analysed and improved. In order to emulate a realistic environment for the train driver, the image of a miniaturized camera (onboard the model) can be visualized in the rebuilt driver's cabin, where he can access all instruments and remotely steers the model.

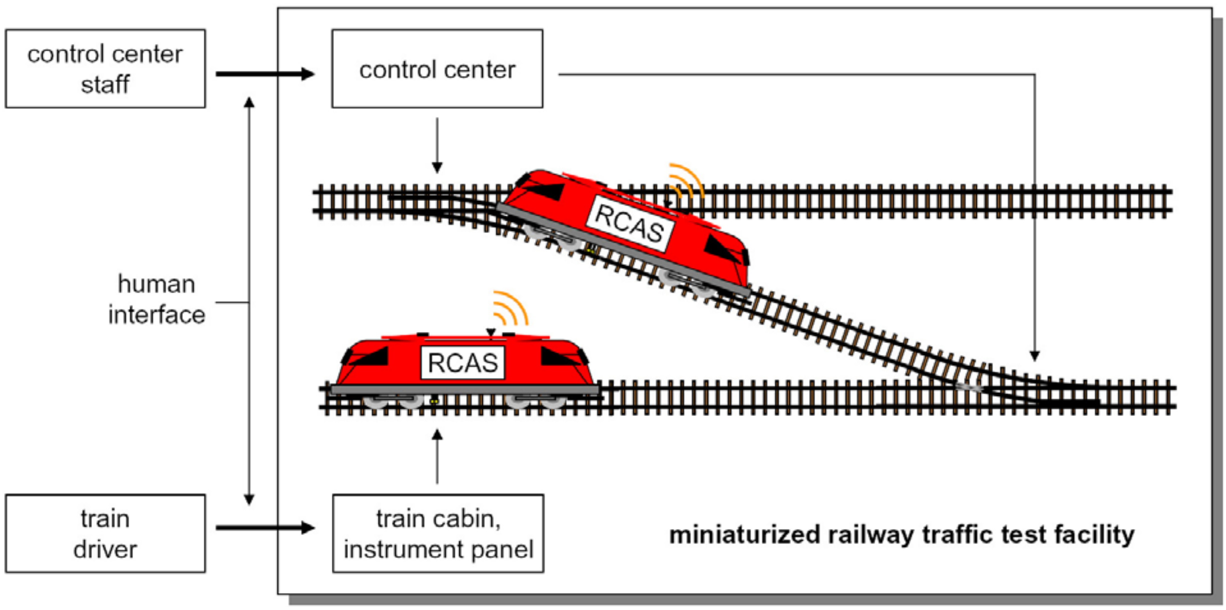

Figure 2.
System architecture of the collision avoidance test facility with a selected scenario setup for railway transportation.

3. Related work

A wide range of positioning technologies is available for various industrial, safety of life, or location based service applications in indoor environments. Just as well different types of sensors are in use to determine the position of vehicles on model railways, but normally this position information is quite rough and it is only provided to the central control unit. Rail occupation sensors or reed contacts only allow replay of railway operation as practised today.

More sophisticated position detection approaches make use of camera systems that track reflective markers on moving objects like the motion capture system from [5]. Similar if velocity information of objects is available in a network and the position of static reflective markers on a test facility are known, these objects can be virtually mapped to the tracks and their location can be further processed or visualized as demonstrated in [6]. Again the positions are determined on the infrastructure side and not on the vehicles' as aimed for.

Wide area inertial-optical motion tracking systems with integrated image processing abilities [7] are typically used in mobile augmented reality applications. Nevertheless, compared to the proposed infrared-based approach the complexity and costs are much higher, and the larger size limits the applicability to large vehicle models. Augmented reality solutions also require steady lightning conditions and do not scale well enough when it comes to test a large number of trains. Occlusion as in tunnels is problematic for vision-based approaches, too.

Advantageous when considering positioning by RFID technology, is the fact that passive tags can be integrated into tracks. On the other hand position accuracy is some orders lower than for the proposed infrared concept, just as it is the case for ultra wide band (UWB) sensors [8], which are limited to decimetres. This would result in a loss of compatibility and thus would not allow transferring results from the model system to real railway systems.

4. Conclusions and outlook

Precise onboard knowledge of position, and the distribution of this information through inter-vehicle communication networks, is the cornerstone to increased safety. At the same time efficiency can be increased by minimizing follow up distances. But also inter-connections to other train control systems and to travel information systems offer new services.

To develop and test new collision avoidance systems, taking interaction with operation centres, controllers and drivers into account, miniaturized test facilities can be equipped with wireless communicating vehicles. A precise, low cost infrared sensor based system can be used to reproduce the great position accuracy of real world multi-sensor-fusion positioning systems. By applying error models different position accuracies can be reproduced to investigate the influence on the system performance.

Currently a test platform is under construction (see Figure 3) which shall demonstrate the functionality of collision avoidance in railway transportation. This miniaturized railway traffic testbed will be operational in autumn 2008 and will allow to test and develop collision avoidance algorithms that augment the train driver's cognition by warning him from dangers he cannot see.

Figure 3.
Platform for the demonstration and test of collision avoidance in railway transportation with an integrated infrared sensor based positioning system.

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