Siemens is developing a Collision Warning Assistant for Mainline

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Abstract
Siemens has been equipping its trams with a collision warning system, the Siemens Tram Assistant, at the customer's request since 2017. The Siemens Tram Assistant reliably detects collision risks, warns the driver, or brakes the vehicle if the driver can no longer react. Thus, hazards to people as well as damage to the vehicles and therefore downtimes during repairs are reduced every day. The Tram Assistant in Siemens trams makes an important contribution to road safety in our cities. The possibilities of the system can also be transferred to mainline trains, i.e. for S-Bahn, regional and long-distance traffic as well as freight traffic: Siemens is developing a collision warning system for mainline, the Siemens Mainline Assistant, which can be gradually expanded to support higher automation levels. The system complements the range of Siemens assistance systems, for example for energy-optimized driving or automation systems for automatic train operation.

1 Higher collision risk at low speeds up to 45 km/h

In 2016, as an early demonstration of the collision warning system, a Siemens Desiro was equipped with multiple sensors and the necessary software. Without any driver intervention, the train was prevented from colliding with a buffer stop at a test facility in Berlin. This system was also used at Innotrans 2016 on daily demonstration runs as a way of engaging with customers about the requirements of an assistance system. There is a constant risk of collision in tram operations due to the complex traffic conditions in urban areas, but not normally in mainline operation thanks to automatic train protection and sections without mixed traffic.
According to feedback from rail operators and drivers, however, there are possible accident hotspots in those areas where driving still takes place on sight or without full train protection. The main operational scenarios are shunting, parking and preparing trains, and entering the station. The Mainline Assistant is therefore primarily configured to prevent typical accidents at speeds up to 45 km/h, such as running into buffer stops or other vehicles and colliding with people, thereby protecting the surroundings, operations, the vehicle, the personnel and the passengers.

2 Basis of the collision warning system: Sensor fusion and extremely accurate localization based on a digital map

The collision warning system uses its sensors to capture the surroundings and generate a virtual image of reality. Armed with the position of the vehicle to the nearest centimeter, knowledge of the track layout and measurements of the size, position and distance of the object, the system decides whether there is a collision risk and whether to trigger a warning (*figure* 1).
Sensor fusion is a key technology in the collision warning system. Depending on the development stage of the system, the data from different specialized sensors such as radar, lidar or camera are fused. This makes it possible to generate an accurate virtual representation of the surroundings of the rail vehicle in real time and in all weather conditions. In the next step, objects are identified and classified, and a prediction is made about their next movements.
Like artificial intelligence, sensor fusion has other industrial uses beyond the railways, for example in the smart factory. That is why Siemens has concentrated fundamental development in a single Core Technology Competence Center. This benefits the Siemens Mainline Assistant because the development process can build on the latest technologies and the basic algorithms and frameworks created there.
Another key technology is the digital map. Alongside commercially available GNSS systems, the collision warning system uses an extremely accurate digital map, enhanced with sensor data, in order to improve the accuracy of position determination of the vehicle. This allows landmarks in the surroundings and the railway infrastructure to be used for orientation, making up for missing or inaccurate GNSS information. Siemens Mobility will present early demonstrators of this technology in 2021 at the ITS World Congress in partnership with DB in the innovation project

called Sensor4Rail, part of the Digitale Schiene Hamburg project [1].
But the digital map generated by the sensors is used for more than just the algorithms of the collision warning system. Siemens Mobility Customer Service uses special sensors to discover, analyze and report changes to the railway infrastructure in a highly automated process [2]. In future, the sensors of the collision warning system will be able to send information about the surroundings to the digital map in real time, introducing a new level of quality in railway infrastructure monitoring.

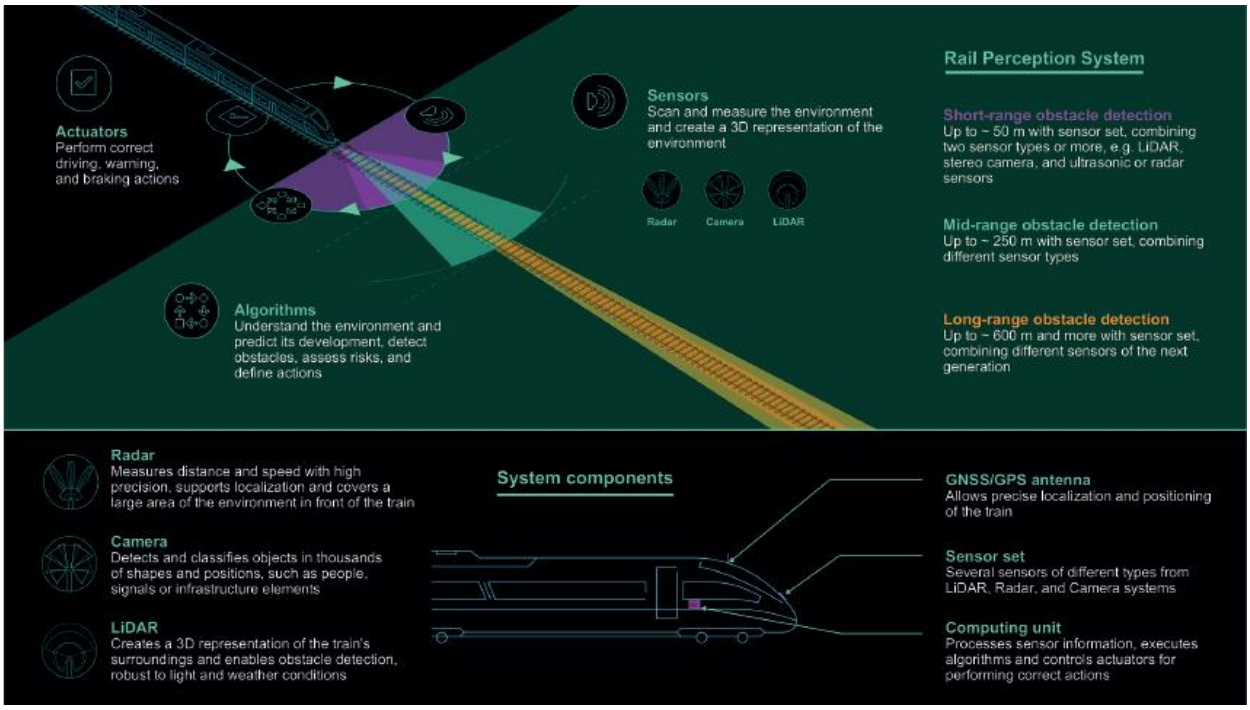

Figure 1: General operating principle of the Rail Perception System on which the Siemens Mainline Assistant is based

3 Simulate and test, test, test

Updated versions of the collision warning system are first simulated as an overall system and validated in a three-stage test procedure: first in the laboratory, then at a test facility close to the development site, and finally on board a vehicle in productive (test) operation. The Advanced TrainLab, an ICE TD Class 605 [3], is used as a test vehicle and also a presentation platform for obstacle detection. The Advanced TrainLab is operated by DB and allows new technologies to be trialed on the operating railway. Siemens has installed sensor technology in the front of the vehicle for this purpose. With special mounts and covers, the sensor set has been fully integrated in the ICE TD. It meets the railway standard and can also be used at high speeds *(figure* 2).
Systematic test procedures have been developed for trial operation and to prove that the Siemens Mainline Assistant works properly. They were partly based on the guidelines for acceptance of collision warning systems for trams formulated by the VDV (Association of German Transport Companies) in conjunction with manufacturers and tram operators. As yet there are no specifications and acceptance guidelines for collision warning systems within the scope of the EBO railway regulations. That is why Siemens is seeking a partnership with DB to jointly develop proposals for standardized test and acceptance procedures. The intention is to submit them to the working groups of the VDB (German Railway Industry Association). They may even be incorporated into the next railway standard (TSI).

4 Practical test with the ICE TD in the DB Digital Test Panel in the Erzgebirge mountains

One of the building blocks for trialing the technology is the DB Digital Test Panel in the Erzgebirge mountains [4]. Here, without disrupting the operating railway, it is possible to test whether the perception and recognition of obstacles on the track work reliably. Siemens has set itself the goal of detecting the objects most commonly involved in accidents at speeds up to 45 km/h: people, buffer stops, other vehicles/parts of vehicles, and road traffic objects. The system will also issue warnings about closed shed doors in the depot. The tests will use standardized Euro NCAP test objects that are moved on and onto the track in various scenarios. But the aim in future is also to detect special objects such as shopping carts (a particular problem in Berlin) or large branches on the track *(figure 3*).
Thanks to its location and the climate there, the Digital Test Panel in the Erzgebirge mountains can also provide us

with useful insights into the impact of weather and dirt accumulation. These insights are used as input when tests are prepared in day-to-day operation. The aim is to collect and analyze test data for a large fleet of vehicles in all seasons, and improve the system incrementally.

5 New (smart) sensors

The latest developments in sensor technology are regularly evaluated and analyzed by an in-house team. Manufacturers are investing heavily in lidar in particular, opening up new potential applications in terms of accuracy of detection and achievable ranges. In the core sensor technologies, Siemens is working with internal research departments, for example a special department for high frequency technologies, and with various startups on the basis of dedicated partner management. In-house test labs check sensors thoroughly to ensure they meet railway standards. If necessary, Siemens engineers develop mechanical and mechatronic solutions to enable promising and innovative sensors to be used on the operating railway in accordance with the standards.

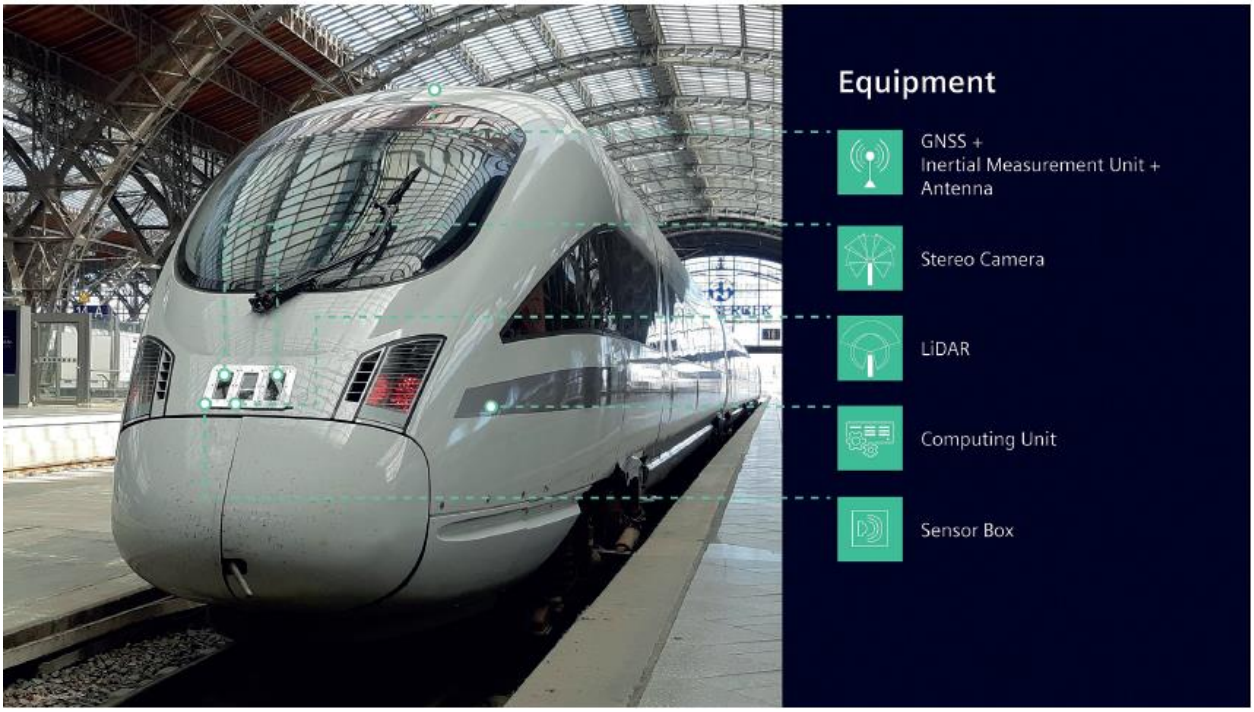

Figure 2: The front of the Advanced TrainLab was equipped with sensor technology for obstacle detection

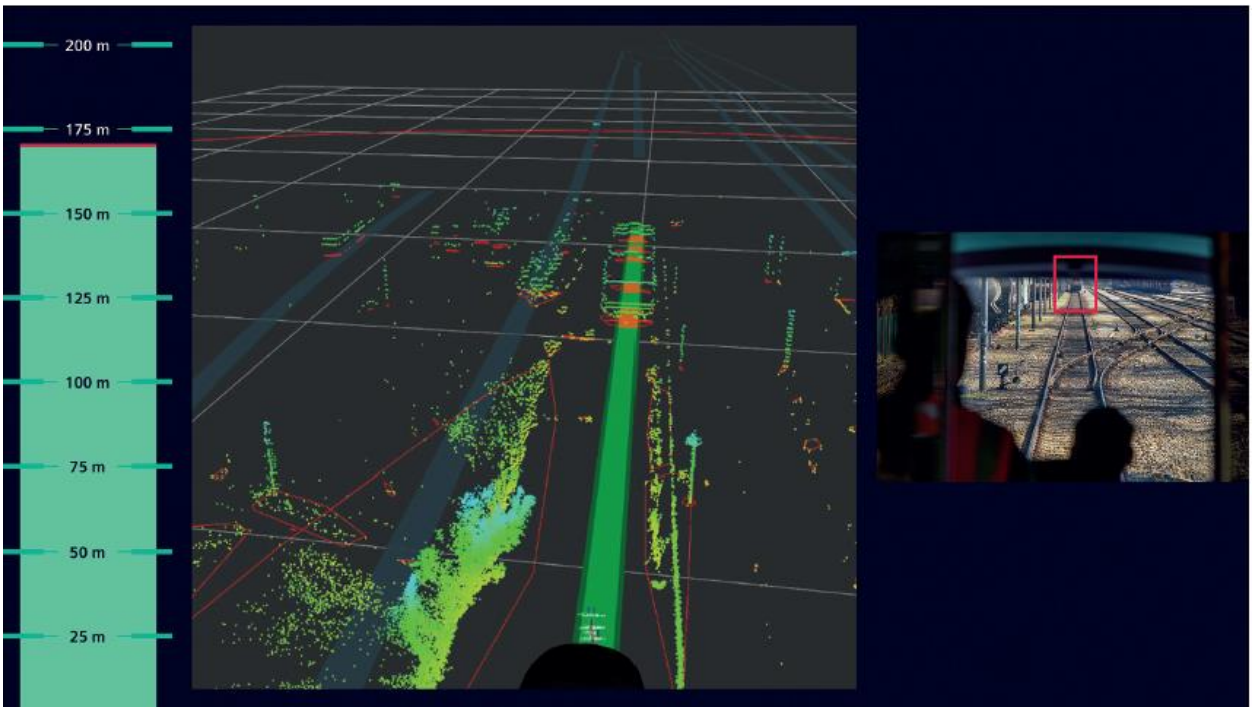

Figure 3: The lidar of the assistance system detects another vehicle on the track

6 Full mechanical/electrical integration on board and 100% Railigent

The aim is to achieve full mechanical/electrical integration of the Mainline Assistant sensor system in the vehicle. The necessary space was made available and specialist equipment was provided to stabilize, clean and protect the sensor from dirt accumulation. The system is an integral part of the energy, weight and vehicle status management system and also the vehicle diagnostic system. The Railigent platform [5] is used to analyze system events and to check that the system is working correctly. The Siemens vehicle architecture is being prepared incrementally for integration of the Mainline Assistant.

7 Included in the update program and extendable for the future

Inclusion in the vehicle IT software update program is planned so that Siemens customers can benefit from future advances in development, for example better detection performance and fewer false alarms. It is also possible to take customer-specific or line-specific factors into account. The new software versions are activated in consultation with the customer and automatically transmitted to the vehicle.
As Siemens vehicles are developed and improved, the planning process includes mechanical, electrical and software integration of additional sensors for fully automated driving *(figure* 4).

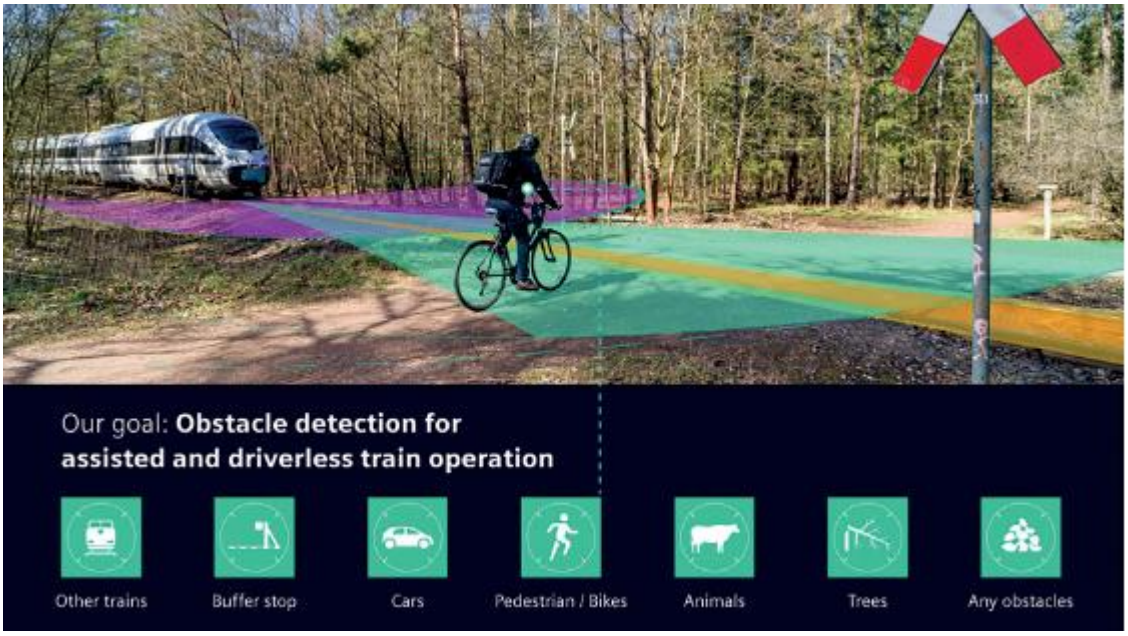

Figure 4: The system will detect all objects on the track that could cause accidents

8 Looking ahead: laying the foundations for approval of fully automated systems

Siemens will use the obstacle detection function to enable other applications in an incremental approach. The next application level could involve fully automated train parking and preparation, or driverless movements on operating sites and in the depot. Siemens Mobility is laying the foundations for approval of systems like this by developing driverless reversal, which will enter passenger service in 2021 as part of the Digitale Schiene Hamburg project [6].
A project called AStriD (Autonomous Siemens Tram in the Depot), funded by the Federal Ministry of Transport and Digital Infrastructure, demonstrates how automated depot operations can be made possible with a driverless tram. The project includes preparing the legal basis for approval and operation of driverless systems in the depot [7, 9].
To further prepare the ground for approval, Siemens is working with the German Center for Rail Traffic Research (DZSF)/the Federal Railway Authority and other partners on two research projects lasting until 2023: risk acceptance criteria for fully automated systems (ATO Risk) and automated system sensor technology and sensor requirements (ATO Sense) [8]. The ATO Sense project aims to develop a method of comparing human performance and the errors that can be expected. This will be crucial in defining the fundamental requirements of a future obstacle detection system for driverless operation. At the European level, Siemens is taking its observations from the developments and the research projects and using them in the European Rail Joint Undertaking/Shift2Rail project to speed up the introduction of new technologies and improve investment security through industry-wide standardization.

(Picture credits: 1 to 4, Siemens)

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