Automatic Train Operation on conventional railway lines

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Why is it that automatic train operation (ATO) has until now reached only a rudimentary level in terms of its development and introduction on conventional railway lines (these include neither light rail vehicles nor self-contained underground rapid transit systems)?

The 'Autoferrivia' interest group comprises experienced railway specialists from the fields of infrastructure, operations and rolling stock, and was created in order to demonstrate the feasibility of an inexpensive driver assistance system, GoA 2 (Grade of Automation Level 2) ATO, which is simple to operate. Autoferrivia is not part of the Smart Rail 4.0 programme.

Autoferrivia's ATO solution allows a simple, non-reactive expansion of an existing conventional railway system with optical signalling and a traditional train control system. Technologically speaking, the ATO concept proposed by Autoferrivia is largely independent of the vehicle and infrastructure.

A field trial conducted by the Oensingen – Balsthal Railway (OeBB) in Switzerland has shown that ATO is possible and could be introduced quickly and with minimal effort on railway lines with simple operational conditions.

Introduction

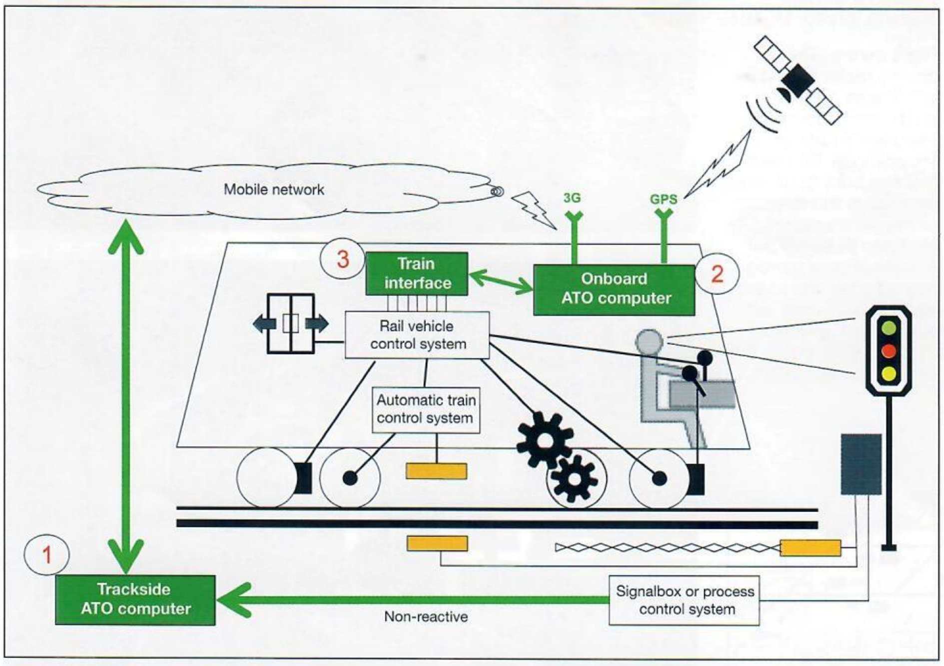
The railway is predestined for automated operation given the fact that trains are rail-bound vehicles. In contrast to road, water or air transport, it is – due to its two-dimensional movement (distance and time) – comparatively simple to monitor and control.

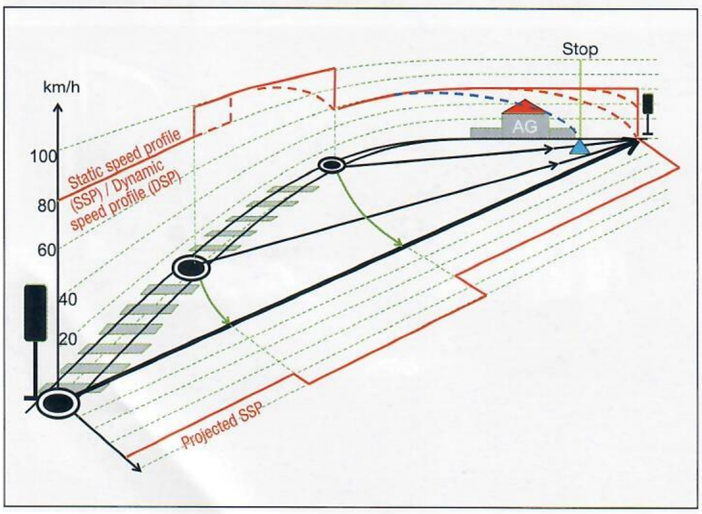
Having said that, automated driving on conventional railway lines has until now hardly been used. The first ATO runs using the continuous automatic train control system, LZB, took place on the Gotthard-Südrampe (southern ramp) as long ago as the 1980s and 1990s. Whilst LZB was widely used, particularly in Germany but also in Austria and Spain, the development of LZB in Switzerland was discontinued on cost-saving grounds and due to the introduction of ETCS (European Train Control System).

Time and time again railway and industry experts insist that ATO can be introduced only in connection with cutting-edge technology with regard to infrastructure and rolling stock. Most railways, however, cannot renew infrastructure and rolling stock in one fell swoop owing to the different life cycles.

The Autoferrivia interest group chooses to pursue an approach to ATO which can be implemented on already existing infrastructure and available rolling stock, and which is particularly suited to railways with simpler operating conditions.

Shortly before Christmas in 2019 the proof of concept stage was reached by using an OeBB prototype construction in the form of a conventional train supplied by the Koblenz Depot and Rail Vehicle Association (DSF). The proof of concept testified that the proposed solution works in practice and has potential for further development.





Above: The architecture for the ATO test setup, including track-side ATO computer ①, on-board ATO computer ② and train interface ③ (drawing: Autoferrivia).

Left: The principle of the route profile calculation (drawing: Autoferrivia).

Below: Route information derived from the status of the signals (drawing: Autoferrivia).

Autoferrivia's understanding of ATO

Autoferrivia sees ATO as a form of supporting the train driver in his or her train operation duties.

GoA 2 ATO is a driver assistance system and allows the train driver to hand over routine actions (such as cruise control, acceleration and braking due to speed thresholds and approaching stops) to the system. ATO allows for operationally optimised driving.

The train driver is in the position to take over control of the train at any time and disable ATO.

The train is monitored by the existing train control system which works in the background and intervenes when the permissible speed is exceeded by means of automatically initiated braking. Existing train control systems are designed to offer a high level of reliability. This ensures that movements

Above: The ATO test train, previously a TRN shuttle train, made up of the RBDe 567 184 motor coach and the ABt 205 driving trailer, in Oensingen. Since 2018 the train has been owned by the Depot and Rail Vehicle Association (DSF) located in Koblenz. As part of the Smart Rail 4.0 programme, this train is to be deployed for ATO testing on the SOB as well (photo: Ph. Wyss).

Centre: Visualisation on the laptop during the test runs (drawing: Autoferrivia).

beyond the permissible speed or the (geographical) end of the train movement authorisation are not possible.

The proposed ATO system under GoA 2 (whereby the train driver is responsible) does not need to be constructed with a fail-safe design like a signalbox or a modern train control system (such as ETCS Level 2), but can be understood as an automation or telematics application. This simplifies the approval process, enhances flexibility and cuts costs.

Another approach, for instance, would be to merge ATO with the train control system, which would have a significant effect on complexity and a negative one on flexibility (in the light of time and costs of safety verification and certification).

Design and functionality

If the ATO system is to support the train driver, all the information necessary for operating the train properly must be at his or her disposal.

The dynamic information about all train journeys (that is, the status of the signals and position of the trains) is recorded and updated in a database via a non-reactive capturing device of the signal or process control system data.

Similarly, a route atlas is stored in this database with the static route data (for instance, fixed speeds on the line, in the station and speed curves as well as stopping points) in a one-dimensional form as a direct distance to the target signal (reference point).

The conditions and information relevant to the train are periodically queried by the onboard ATO computer via a 3G or 4G internet connection. This information is used by the ATO computer to calculate the static speed profile (SSP) and – with the help of the train's characteristics, such as length and braking ratio – the dynamic speed profile (DSP).

Determining the location of a train is carried out by means of GPS. When using GPS, one challenge is the lack of reception in covered sections of the track. Since trains are rail-bound, it is relatively straightforward to determine the distance travelled, since a GPS signal loss can be intercepted relatively easily via the already existing wheel rotation sensors.

The onboard ATO computer continually determines the distance between its position and the reference point and in this way can derive the permissible speed in each case from the DSP.

The target speed is transmitted to the vehicle control via a special interface, which itself is subject to the vehicle type and becomes more complex the older the vehicle's technology is.

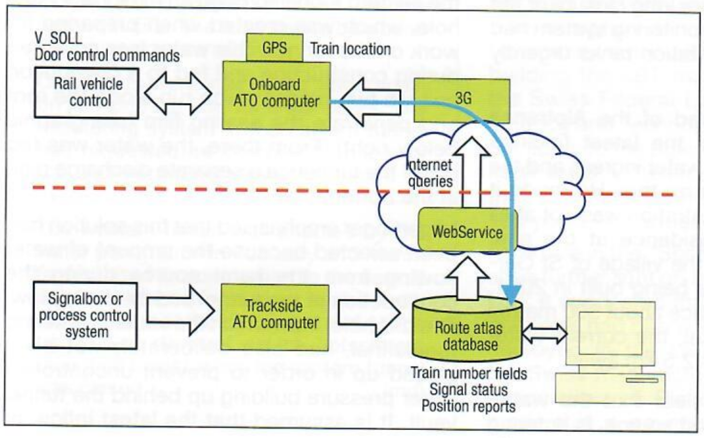
OeBB test runs

The OeBB's infrastructure proves to be ideal in various ways for the ATO test runs:

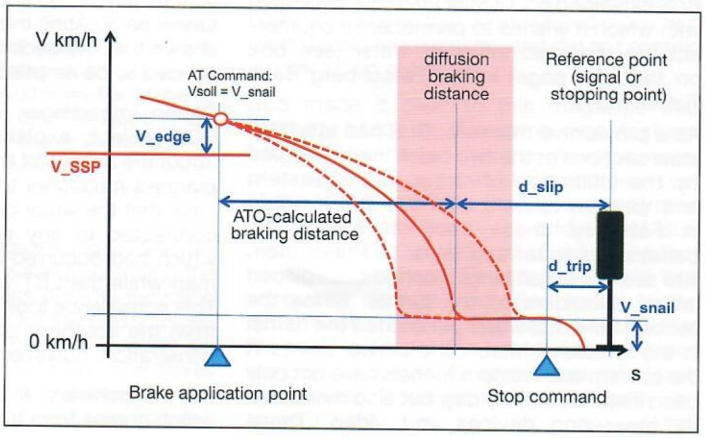
- simple operating conditions where there are no conflicts with other train journeys,
- a pre-existing train control system: ZUB 121 / ETM P44 / ETCS Level 1 Limited Supervision, – relay-based signalbox technology widespread in Switzerland,
- long time slots for testing (starting at 20:00).

The OeBB signalbox is based on Domino relay technology. A capturing device similar to a vehicle control system was superimposed onto this technology by means of a trackside ATO computer. This processes the non-reactively captured states of the signals (stop or proceed) as part of the route information

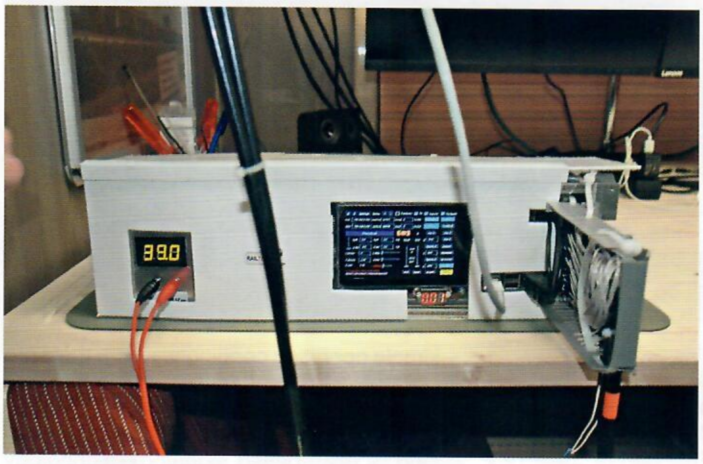
ATO system's function (drawing: Autoferrivia).



The electric brake is used to decelerate the test train during the stopping process and the electro-pneumatic brake for the final stopping procedure (drawing: Autoferrivia).



Above: View inside the driver's cab of the test train (photo: Ph. Wyss).



Left: The on-board ATO computer (photo: Ph. Wyss).

and assigns them to train numbers by means of a timetable.

Following this principle, all relay signalboxes can be connected to an ATO system. In Switzerland most safety systems are to this very day still based on such technology. If available, the data required by ATO can, however, also be taken from an electronic signalbox or a control system, as long as the corresponding interface is known.

The train deployed for the test runs, which is owned by the Koblenz Depot and Rail Vehicle Association (DSF) and Rail Systems Engineering, has reached middle age and dates back to the year 1985. Retrofitting it with ATO is complex when compared with a modern train. A special interface had to be developed which converts the ATO commands into digital and analogue signals that the vehicle can understand.

With regard to onboard train systems, the test runs were conducted using a laptop as the onboard ATO computer. The ATO test software, which contains all the necessary functions, is installed on this laptop, to which a GPS sensor and a webcam are also connected.

It was on 17 December 2019 when the first integral test runs between Oensingen and Balsthal took place. The transmission of data from the signalbox to the vehicle functioned perfectly. Likewise, the GPS location proved to be very stable and reliable. The specifications for the vehicle control provided by the ATO computer were implemented correctly by the interface and, all in all, resulted in a satisfactory, yet still optimisable test run. Especially a pinpoint stopping manoeuvre is demanding, and parameters have to be set by using numerous settings.

Nevertheless, after a few fine adjustments, autonomous trips were carried out in both directions without intervention from the driver (with the exception of the route request demands via radio). The system is even responsible for taking over control of the doors. The latter are released for a pre-set time at every stop. After feedback from the door lock, the train proceeds automatically when the signal is set.

Summary and conclusion

The test run shows that with relatively simple means automated driving is possible on conventional railway lines.

The proposed ATO solution can be superimposed onto both the existing infrastructure and train systems. This allows for maximum protection of investment and rapid migration, even with signalbox and train technologies, the majority of which are ageing.

Autoferrivia's ATO approach is an inexpensive platform that addresses the issue of autonomous driving.

Only extensive practical experience will be able to show whether and where automatic train operation has its advantages and disadvantages and, if need be, its justification.