AUTOMATED DOCKING OF TRACTOR SEMITRAILER WITH DRIVER IN THE LOOP VIA 5G TELEOPERATION

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Introduction

The logistics sector is constantly looking for innovations that can help improve the service productivity level and profitability of the freight transport. These innovations have led to reduced fuel consumption and emissions in recent decades, and the automatization inside the warehouses, among other things. Yet, road transport sector in Europe nowadays faces new challenges such as dynamically growing shortage of drivers, unused road capacity during the night, wasted terminal time due to paperwork and poor digital insight into total incoming and outgoing traffic. Digitalization and enhanced telecommunication offer concrete options for improvement. Where fully autonomous transport is not yet feasible under all operational condition’s teleoperation can add to the next level in road transport.

In teleoperation, humans still monitor and operate the vehicles but from the distant control center, shown in Figure 1. To make this work, communication between vehicles and control centers needs to be fast, secure, widely available and reliable at all times, being exactly the promise of 5G network connectivity. This significantly changes the work of drivers while offering more comfort, but most of it makes it more efficient. Instead of waiting for cargo at terminal and adding avoidable costs an operator can take remotely switch control between several different vehicles. Moreover, additional automated functionalities can be accommodated by teleoperation such as Cooperative Adaptive Cruise Control (CACC) for Truck Platooning or Automated Docking of the vehicle combination when the operator has purely supervisory role. In this paper the latter functionality is presented, starting with functional architecture, controller design, integration, and testing on the scaled vehicle platform, and finally integration and testing of the full-scale pilot.

Figure 1. Teleoperation visualization [1]

Research Method

To explain the functionality of teleoperation high-level architecture is shown in Figure 2. Herewith, can be seen that teleoperator is sitting in cockpit where video stream from the cameras based in vehicle is shown along with secondary screen where the relevant information from so called enabling functions is presented, which leads to enhanced performance of the teleoperator in terms of safety, productivity, and situational awareness. The teleoperator actuates the vehicle by steering wheel, pedals, and gear shift based in cockpit and the signal is being carried by 5G network to the vehicle which has 5G on board unit and teleoperation interface enabling actuation on remote basis (x-by wire). The vehicle is also equipped sensorics cluster which provides the vehicle states data to autodocking control unit through the 5G network. When actuated the autodocking control unit takes over the control from the teleoperator plans the optimal path between the current location and loading dock position (obtained through enabling function), and subsequently starts to calculate required steering angle and speed to keep the vehicle combination on the optimal path. These signals are being send to vehicle teleoperation interface which executes them is same spirit as if the driver would be in control. During the automated docking the driver is provided with real time tracking error, so he has the monitoring role and the possibility to intervene if necessary.

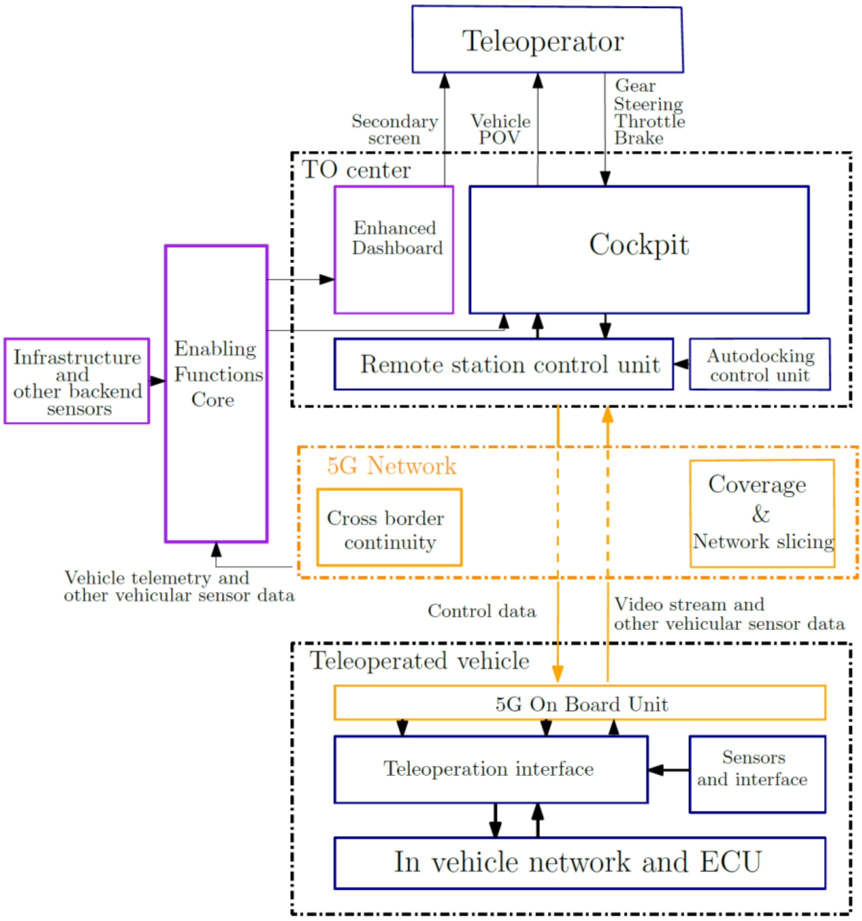

Figure 2. Functional architecture of the teleoperation.

The functionality of the controller and the path planner has been verified in a real-life experiment using the scaled vehicle model (1:3) of tractor-semitrailer shown in Figure 3. The tractor's first axle is only steerable, the second axle is rigid and driven, and the last axle is only solid. The semitrailer has solid tridem axle group.

Figure 3. Scaled model of Tractor-semitrailer 1:3

All the rubber tyres are inflatable, and given the fact the suspension is not pneumatic, an equal load distribution cannot be guaranteed. The weight of the vehicle combination is approximately 290 kg. The tractor can be teleoperated, in terms steering and driving speed in both forward and reverse direction. The localization of the vehicle combination is ensured by two high-accuracy RTK-GPS systems which enable to measure position and orientation of both tractor and trailer independently in the local coordinate system centred at the final destination point, representing the loading dock. The experimental manoeuvre is bidirectional docking with the reference path produced by the path planner whilst respecting the real dimensions of the vehicle combination. The longitudinal speed of the tractor is approximately 0.7 m/s forward and 0.5 m/s in reverse direction.

The results displayed in Figure 4. show that controller can navigate the scaled vehicle combination along the reference path while maintaining tracking error at an acceptable level during the manoeuvre. One can notice slightly oscillatory behaviour of the steering angle which can be explained by the accuracy of the RTK-GPS which fluctuated during the tests in the range of ±4 cm. The biggest error (~15 cm) occurs due to irregularity of the terrain when the vehicle approached the steep slope. The final docking error is 2 cm which meets the positional tolerances even though the kinematic model has been employed to model the vehicle behaviour.

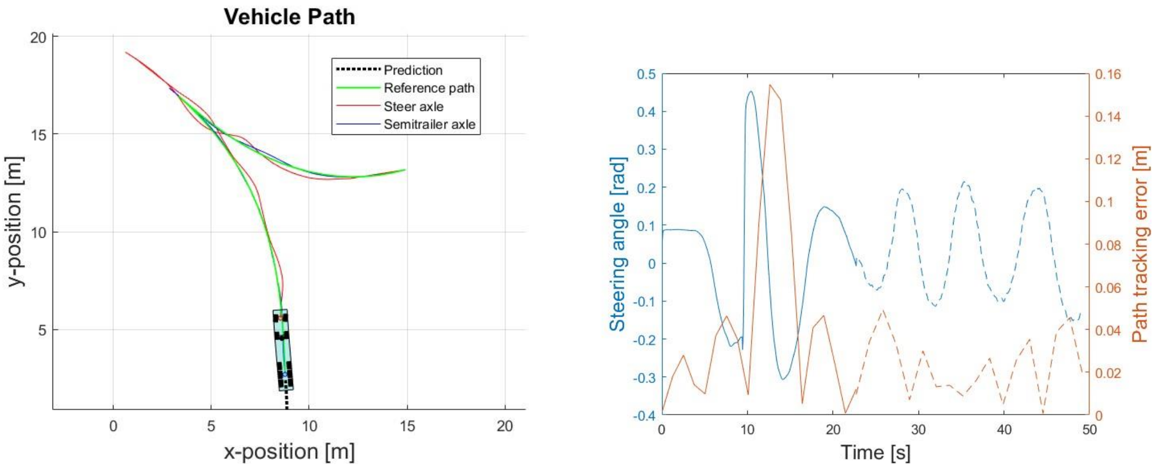

Figure 4. Results from the testing with scaled model of Tractor-semitrailer 1:3

Outlook

In the full paper, the autodocking controller and path planner will me explained more thoroughly, and the results from the full-scale experiment will be provided.