Automated driving and HMI design for city bus and truck with professional drivers

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Abstract

When vehicles are getting more and more automated driving functions, it is essential that a driver understands what the vehicle can and cannot do. HMI design for automated driving has lacked general guidelines until the National Highway Traffic Safety Administration released their guidance for Level 2 and Level 3 Automated Driving concepts in August 2018. Once automated driving functions are started to be introduced to heavy vehicles such as city buses or trucks with professional drivers, the role between the driver and the automated systems must be clear. This paper provides early results of the HMI design for a city bus and truck scenarios from TrustVehicle project. The shared autonomy approach and driver monitoring are utilised and HMI design support to keep the driver in the loop. Trust building with open feedback about automated driving performance including possible limitations are studied in the project.

Keywords:

Automated driving, HMI, shared autonomy

1. Introduction

In recent years, the development of automated driving research has progressed rapidly, and the automotive industry has introduced gradually Automated Driving (AD) features to the market. The level of automation is increasing feature by feature. It will take long time before fully automated vehicles may provide significant traffic safety benefits. Before this, semi-automated vehicles will increase the traffic safety if drivers are able and willing to use the automated features as they are intended to be used. The Human Machine Interface (HMI) design is one of the key components that are needed to support the driver in semi-automated (SAE Level 2 and Level 3) vehicles.

In August 2018, The National Highway Traffic Safety Administration (NHTSA) published a Human Factors Design Guidance for Level 2 and Level 3 Automated Driving Concepts [1]. The guidance is intended to help HMI developers with the HMI design; human factors assessment of the driver performance and behaviour under Level 2 and Level 3 (L2, L3) automated driving. NHTSA guidance provides collection of research results, references to relevant standards and best practises in compact format. This kind of guidelines are needed as the existing automotive HMI guidelines, such as ESoP [2], have been only focused on manual driving and in-vehicle information systems. NHTSA guideline includes guidance for all HMI aspects such as visual, auditory and haptic interfaces, driver inputs and messages to the driver. It also focus on the designing of transfer of control from driver to automated system and vice versa. However, it does not include guidance how driver monitoring could be utilised in the HMI design.

The HMI is a critical component in L2 and L3 automation, since the driver is always the fallback if the automated system goes beyond its limits. Hence, the human centred approach is needed in the design from the very beginning. The role of the driver and the automated systems must be clear. Massachusetts Institute of Technology (MIT) has introduced a Human-centered Autonomous Vehicle (HCAV) concept that lists the principles of shared autonomy used for the design and development process [3]. The main idea of the HCAV concept is to remove the boundary between human and machine by getting humans and automated driving systems to collaborate effectively. The HMI concept in the TrustVehicle project has partly similar approach in HMI and automated driving design, and the role of the driver by utilising driver monitoring. Sensing the state of the driver is the first and most impactful step for building effective shared autonomy systems [3].

2. TrustVehicle HMI concept

The trustworthiness of the automated systems is one of the key aspects in the introduction of the first automated vehicle systems. The driver's perception towards automation is especially important during Level 3 automated driving, where the driver has to be able to resume vehicle control in limited time. One of the objectives of the TrustVehicle project is to develop and demonstrate intuitive HMIs for the safe management of the transition phases between automated and human driving. [4]

The general HMI concept in TrustVehicle is focusing on Linkker and Ford Otosan heavy vehicle demonstration scenarios, both of which are targeting on low-speed automated driving scenarios in pre-mapped urban areas. The HMI design is guided by the traffic safety as the first priority. The following main features can be listed for the TrustVehicle general HMI concept:

- HMI supports safe transition between manual and automated driving modes during low-speed manoeuvring in urban mixed traffic situation
- Adaptive HMI:
    - Measuring the driver state (e.g. fatigue, distraction and gaze direction);
    - Identifying risky traffic conditions by combining driver state estimators with the information about the environment and other road users around the vehicle;
    - Prioritizing and adapting the information given to the driver.

HMI concept in the TrustVehicle project is developed for the Linkker city bus and Ford Otosan truck automated driving scenarios. In both scenarios, the target is to automatically drive accurately a short distance in urban traffic environment. In that environment, other road users may exist and that can be a challenge for automated driving functions. In both scenarios, the driver in the vehicle is an experienced professional driver who is trained to use the systems. The driver uses in-vehicle systems daily in his/her work and is expected to learn how the system behaves in various conditions rather quickly. Therefore, the role of the driver and the automation system can be a bit different compared to a regular driver in a passenger car utilising L2 or L3 automated features occasionally. In general, with L3 automation the driver does not need to monitor the road when a vehicle is in automated mode. However, in these TrustVehicle scenarios the time for automated driving is quite short (< 60 seconds). The driver has been employed to drive the vehicle and there is no other task, which driver would need to carry out during the automated drive. Therefore, in these scenarios, the driver can take hands off the steering wheel but should monitor the automated driving. The collaboration between the professional driver and the system, and shared autonomy approach has been selected to be one of the key principles of the TrustVehicle HMI concept.

As discussed above, there are many similarities in the scenarios and HMI design principles for the truck and city bus scenarios in the TrustVehicle project. However, there are also some differences when designing the HMI. For example, the voice prompts or high volume warning chimes could be used in trucks but in city bus, where are passengers; it may not be preferred method.

3. Linkker city bus demonstration HMI design

In the TrustVehicle project, one of the demonstrations is with the Linkker electric bus, which drives in automated driving mode accurately under a charging point at the bus stop. The flowchart of the Linkker demonstration HMI (successful use case) is described in Figure 1. In this scenario, the bus is approaching the bus stop on manual driving mode, while the system provides driving instructions (e.g. speed and distance to area where automated driving is available). When the bus enters the "*Approaching area*" (around 100 meters before the bus stop; see Figure 2), the preconditions for automated driving are checked, e.g. current speed, lateral position, heading, safe distance to a leading vehicle and angle of the steering wheel as well as vehicle sensor condition and capabilities and possible weather restrictions. The automated driving system starts to calculate the driving path and detects possible obstacles in the background, but the vehicle stays in the manual driving mode.

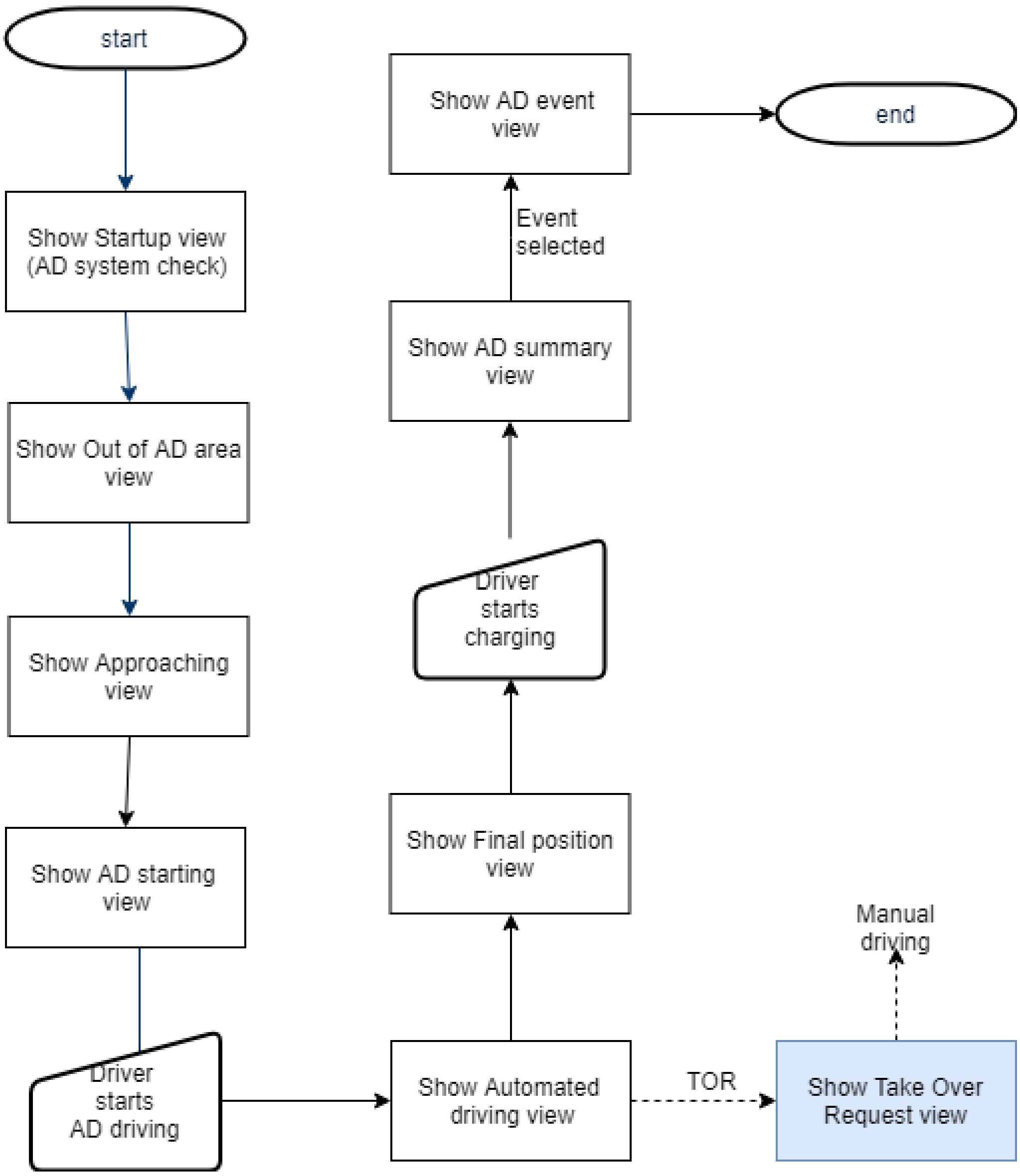

Figure 1. Flowchart of the Linkker HMI in the demonstration.

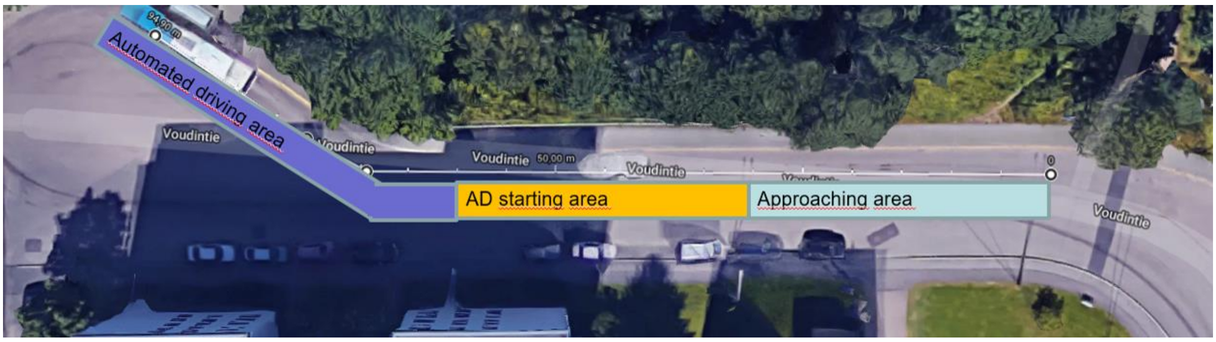

Figure 2. Linkker automated driving demonstration area (map data: Google Earth).

When the bus is in the “*AD starting area*” and all conditions for automated driving are met, the automated driving can be activated (see Figure 3). The driver turns ON the AD with steering wheel mounted paddle shifters (or alternatively with the Start AD button on the touch screen). While on automated driving mode, the system shows only the relevant information, e.g. the current location of the bus, planned driving path, and distance to the destination. The driver can take over the vehicle control at any time by turning the steering wheel or touching the brake pedal (or alternatively with the Cancel button on the touch screen). At the end of the automated drive when the charging point has been successfully reached, the system indicates to the driver when the bus has been parked and the charging can be activated. After the vehicle has reached the final position, stopped and the charging has been started, more detailed information about the automated driving is presented to the driver including possible events related to driver monitoring (e.g. detected distractions), obstacles, alerts with reasons, hand-overs, etc.

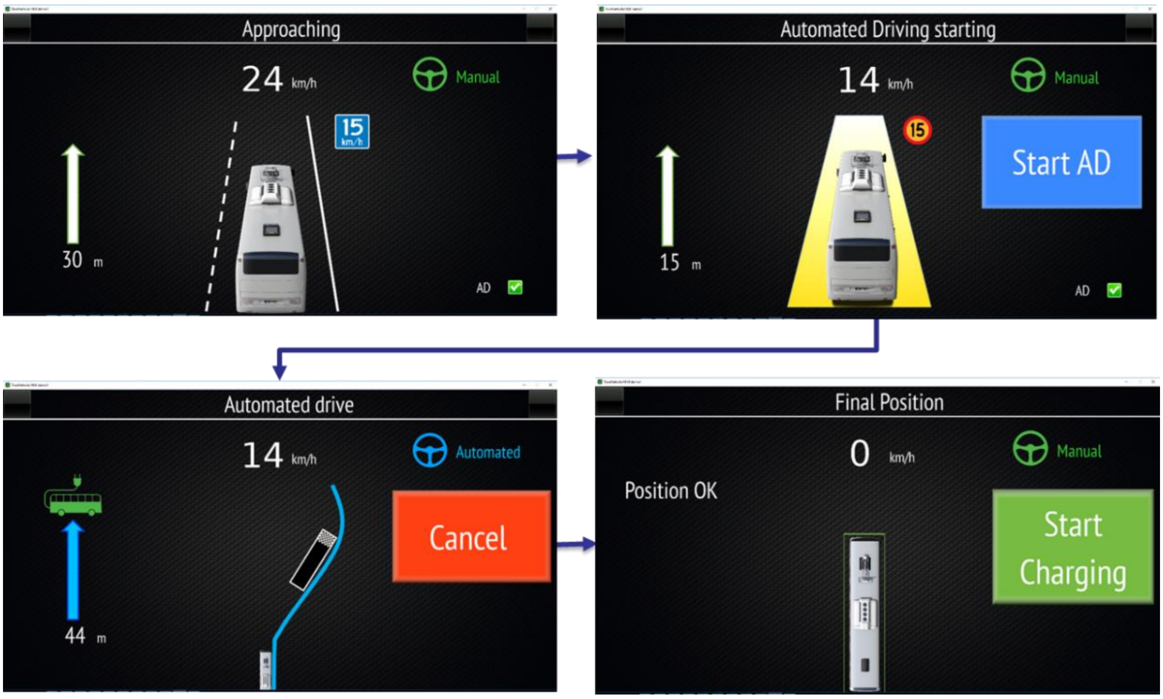

Figure 3. Linkker bus prototype HMI layouts: Approaching, Starting AD, AD and Final position.

[Stock media for Linkker HMI prototype provided by Pond5, www.pond5.com]

There are multiple exception use cases that are handled with various methods depending on the severity of the case. For example, if the automated driving system can no longer handle a situation and requires human takeover the system provides timely warning and provides a countdown to the required takeover. In more critical situation, the automated driving system is able to stop the vehicle on its own lane and request immediate takeover. However, the longitudinal deceleration limits for buses with possibly standing passengers must be taken into account. Both environment perception as well as driver monitoring are used to estimate the criticality of the situation.

The main design principle has been that the driver stays on the loop and actively monitors the vehicle surroundings. This is verified with driver monitoring and gaze direction measurements. The visual information on the screen is kept minimum to avoid distraction, and directional audio or voice prompts are used in order to guide the driver to look at the right direction. Alerts or messages that might seem annoying for the user can have undesirable safety outcomes wherein users are likely to disable the system [5]. This may happen even more with professional drivers who utilise the system all day long. However, when the driver uses the system in driver training and for the first times on the road the feedback (alerts and messages) could be more extensive (e.g. with more explanatory voice prompts) and reduced when the driver gets familiar with the system.

4. Ford Otosan Truck trailer back parking demonstration HMI design

One of the other demonstrations of the TrustVehicle project is Ford Otosan's truck – trailer back parking. Accomplishing a back-parking manoeuvre with an articulated heavy commercial vehicle requires a certain experience. For Ford Otosan's use case, there are two different environments; a docking area for a warehouse and a construction site within city boundaries. These areas will be replicated on Inonu Proving Ground, Ford Otosan's testing facility for demonstration of the AD functions. Similar to Linkker's approach, Ford Otosan scenario also defined three phases within the boundaries, for the AD manoeuvre, as shown in the Figure 4.

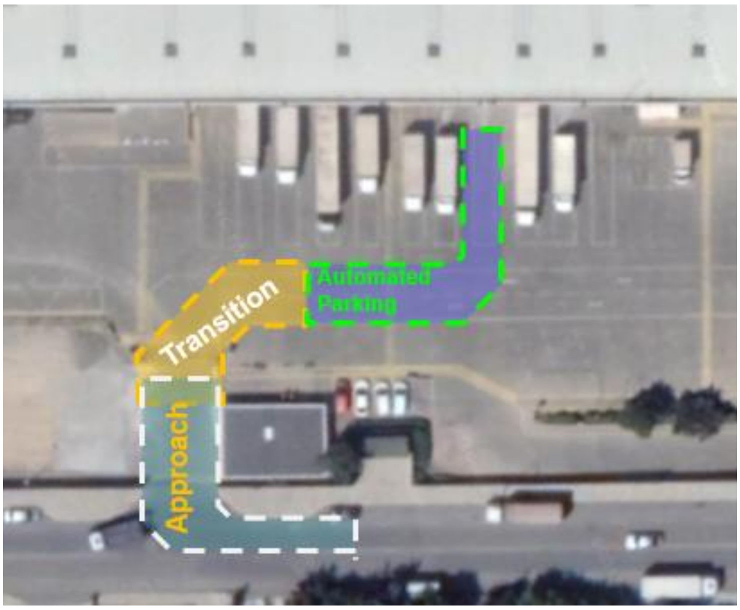

Figure 4. Simplified representation of AD phases of Ford Otosan scenario.

The flowchart of the Ford Otosan truck HMI is described in Figure 5. Within the approach boundaries, HMI will display the available parking slot and report the system status as "Approaching". For the successful case, driver will be in total control, only driver instructions will be shown on the HMI, such as speed limit for transition, vehicle position and vacancy of the approached parking slot.

During Approach, driver instructions will be displayed in a simplified way (e.g. Manual Control). For unsuccessful approaching case, system notifications such as errors and system unavailability will be displayed on the HMI screen. Since driver is in full control (manual driving mode), no action is required from HMI screen. After approach, system will switch to Transition phase, where the vehicle will be still under control of the driver and HMI will display the prerequisites for autonomous parking manoeuvre to start. After all requirements for AD are met, HMI will show "Release Brake Pedal" and the activation of the system will be done. For the successful case, driver will be able to press the Park button if the system requisites became available (green). For unsuccessful transition case, system notifications such as errors and system unavailability will be displayed in the HMI with combined audible and screen notifications.

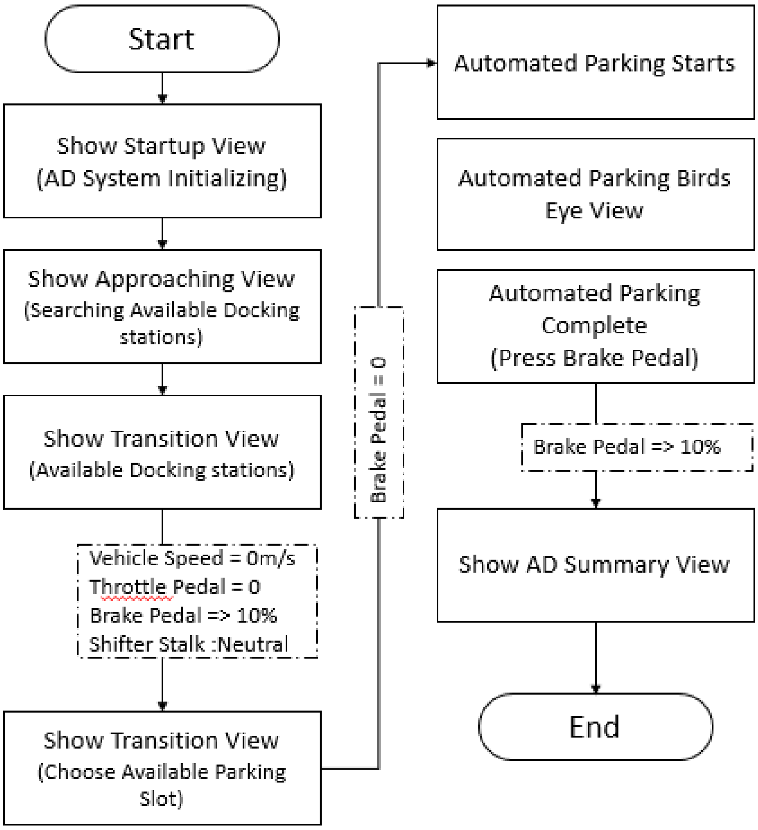

Figure 5. Flowchart of Ford Otosan Truck HMI.

If transition phase is successfully completed (with driver's activation of the Autonomous Parking), automated parking screen (a bird's eye view) will be shown to driver where driver instructions will switch to parking manoeuvre parameters since no action is awaited from driver. For successful case, only "Cancel Parking" button will be available on the HMI screen. However, cancellation can also be done if driver applies any pedal or steering wheel inputs. Different from the approach and transition phases, for an unsuccessful automated parking case, vehicle will stop its actuation and request from driver to take the control by using both HMI screen and audible notifications. If this occurs, driver can regain control via brake pedal or steering wheel input.

Strategy for the audible and visual notifications are not defined in certain terms in this phase of the project. However, similar to Linkker approach, utilizing lean and clear notifications is important to avoid annoying the driver during all phases of the autonomous back parking.

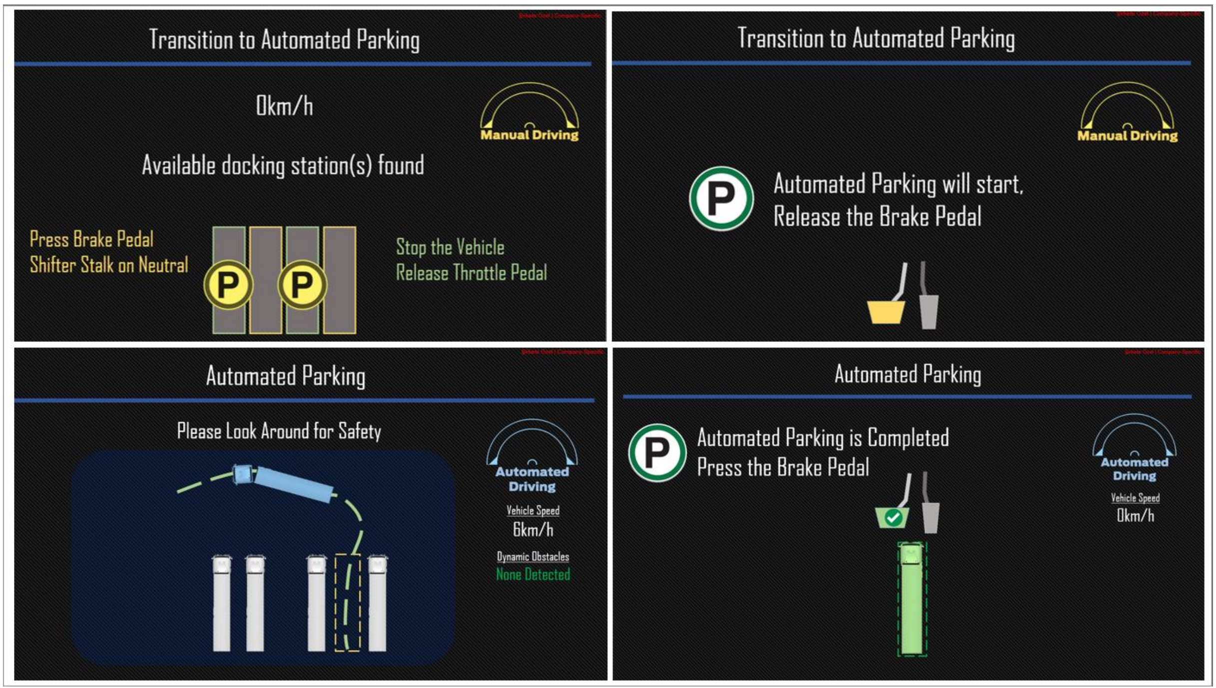

Figure 6. Ford Otosan Truck HMI layouts: Transition, Parking Start, Bird's Eye View and Completion.

After vehicle reaches its final position during automated parking phase, HMI screen will display selected KPIs of the automated back parking, such as lateral offset, manoeuvre completion time, in order to inform the driver about systems performance. By so, understanding the driver's expectancy from the system and showing system's capabilities to the driver will be easier.

5. Building the trust with feedback about AD

In the Linkker scenario, the feedback about automated driving will be provided in multiple levels. After the vehicle has reached the final position and the charging has been started, more detailed information about the automated driving can be presented to the driver. At this stage, the driver has most likely some time to view more visually rich information as the vehicle is standing still during charging. This information also includes the degree of uncertainty and possible limitations of the environment perception system during the automated drive if the driver wants to go deeper in the information provided or playback an event. The system imperfections or events are reported to the driver with textual and visual representations. For example, if there was a sudden braking during automated driving and the reason for that was unclear to the driver. The driver can easily check the event information of the situation or event, which includes for example a short video clip of the front view together with graphical illustration of the sensor output including degree of uncertainty of each detected obstacle. The situation could be e.g. a false-positive detection of an obstacle, which actually was chunks of snow falling from the trees, see Figure 7.

Figure 7. Draft of the AD event visual representation.

Professional drivers could also provide simple feedback about each case to the automated driving system developers. For example, the driver could verify possible false-positive detections and this information could be utilised to enhance the AD system, as presented in Figure 7. Furthermore, this open communication could build the trust and understanding of the AD capabilities with the driver. *Building the trust* is one of the key research questions that the TrustVehicle project is investigating.

6. Conclusions

TrustVehicle project studies trustworthiness of the Level 3 automated driving systems. During the first half of the project the HMI concept and the first prototypes of the HMIs for the city bus and truck scenarios have been developed, both following similar HMI design approach. The HMI concept focus on supporting the professional driver on safe automated driving and transitions between manual and automated driving modes during low-speed manoeuvring in urban mixed traffic scenario. The shared autonomy approach and driver monitoring are utilised. Fast HMI prototyping of HMI solutions has been evaluated in an expert evaluation. Next, the HMI prototypes go through final tests with professional drivers. The HMI development in TrustVehicle will follow a human-centric approach where the HMI concept is developed as an iterative process.

The final version of the HMI will be integrated to the test vehicles during 2019. The field-testing and evaluations of the scenarios as well as the HMI will be done in the end of the project in spring 2020.

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