Highway sensor system as enabler for autonomous driving

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Abstract
Partially automated vehicles require drivers to timely take over driving tasks, when the vehicle reaches its functional system boundaries. Optimized interfaces should ease the take-over by providing information about the current traffic situation. Intelligent transportation systems provide vehicles and drivers with information that exceed the individual vehicle's perception range and might facilitate driver take-overs. The collected data can complement the vehicle's sensor data and thus enable autonomous driving. The concept of this paper is based on the Providentia system, which combines vehicle and infrastructure perception to provide participants with a far-reaching view that can see over traffic far ahead. The Providentia system visualizes the highway in a simulated representation. That can help the situational understanding of the current traffic situation. Different interaction units within the cockpit like AR windshield display, tablet or speech assistant improve understanding and trust of the driver in autonomous systems.

Author Keywords
Take-over scenario, Highway driving, Highly automated vehicle

ACM Classification Keywords
CCS [Hardware]: Emerging technologies; CCS [Human-centered computing]: Visualization

Figure 1: Simulation of the digital twin of the highway.

Introduction

Highly automated vehicles will soon be more present in mixed traffic with human-operated vehicles on the road. Until fully autonomous vehicles are produced in series the task of driving will still at least partly depend on the driver. While regaining driving control the driver has to understand the current traffic situation and needs to take control in a timely manner. Therefore a safe take-over request needs to be implemented in the car. In order to do so the driver has to shift his attention from unrelated tasks to driving. Needed information for driver take-over, like the necessity for an emergency braking, has to be presented effectively. The driver needs to know why he has to take-over control and what he needs to focus on.

New perception and communication technologies can have significant impact on the information available to drivers in critical situations. Within the project Providentia [2], a sensor system is set up and implemented on poles along the highway. Thus it is possible to detect vehicles, turn signals, obstacles, construction sites as well as occurring traffic scenarios. This can be emergency braking or accidents. The projects' scope also includes predicting the immediate future development of traffic scenarios. All this information is used for a digital twin that simulates the traffic on the highway. It also informs the user of the processed information like future trajectories of the vehicles and the prediction of the traffic flow [2]. A picture of the simulation of a highway scene can be seen in figure 1.

Within the Providentia system data about the traffic along the highway is collected and analyzed. It is possible to provide highly automated vehicles with the resulting scenario classifications and the predicted traffic development.

The data that is provided by Providentia can not be captured by vehicle sensors alone. By providing information about the traffic behind or in front of the ego vehicle it can react better to for example high speed or obscured vehicles. Traffic flow can be predicted to ensure a smooth traffic flow. After the realization of this project, data can be collected to model realistic human driving behavior in traffic. This model can then be used to test automated vehicles and verify the autonomous driving algorithms.

Related Work

Many projects like AutoNet2030 researched the aspects of co-operative driving of automated vehicles [1]. Vehicle-2-X (V2X) is also investigated by Hobert et al. to identify poten-

tials and core functionalities for cooperative autonomous driving. Within the project vehicles cooperated with a V2X connection and infrastructure on intersections was taken into account [3]. The project Providentia in contrast implements a sensor system on the highway that measures data of the traffic. V2X communication and traffic infrastructure systems, which could extend the perception range of individual vehicles, have been studied in [4] [5]. Following, we present our approach to realize the full potential of far-reaching perception systems for an innovative and cooperative human-computer interaction interface.

Influences of scenario characteristics on user interfaces

In order to increase acceptance and security while driving highly automated vehicles, only necessary information to assess the driving situation must be available to the driver without causing information overload during take-overs. In future autonomous vehicles, the driver will be relieved of driving responsibilities but can use the time on the road for other tasks. Those tasks include work related and entertainment tasks. In case the driver needs to take over the driving task again, the driver needs all the information about what is happening on the road and what kind of traffic situation the vehicle is in. For example, if during a take-over scenario a fast car is approaching from behind it can be useful to warn the driver beforehand that it is not safe to overtake. Within the Providentia project [2] a Car-2-X infrastructure perception system combines vehicle and infrastructure sensor systems to provide vehicles with a far-reaching view. Combined with a prediction module in the system, it can alert drivers early on during occurring scenarios or even beforehand when certain traffic developments become very likely to happen.

Thus it is possible to prepare the driver of a take-over request in different manners, depending on the estimated time to the dangerous situation and drivers preferences facing a take-over request. The challenge of driving in a specific environment can be rated according to different traffic situations on the highway. For example depending on the traffic load on the highway, drivers can either feel more certain or uncertain in performing driving tasks. Some people tend to be more stressed by traffic jams than others. So the information about a traffic jam can be used to categorize the traffic situation as well. The traffic load, the current maneuver of the ego vehicle, the maneuvers of the neighboring cars and weather can be influencing factors on the rating of the environment and highway situation of the area in close vicinity to the vehicle. This information can be used to rate the take-over request depending on urgency and on the challenge of the take-over situation on the highway. In our opinion this rating can be advantageous to create a flexible take-over that considers the traffic situation on the highway. A new kind of user interface is developed that can utilize vehicle and infrastructure sensor information to ensure a safe and calm take-over scenario. Different technology concepts are examined to research the best visualization of the far-reaching view of the highway. Within the project innovative technology is considered, like AR windshield display, VR and AR glasses and haptic feedback with ultrasound. The advantage of Providentia is the realization of a take-over in a very timely manner. Thus the driver can be provided with further information about the traffic situation. This can be done by providing the driver with a 3D model of the vehicles involved in the possibly dangerous developing situation.

Virtual assistants within cars are also an emerging topic in the automotive industry. Those assistants are realized by speech output like Alexa or Siri. These assistants have a basic configuration like asking about the weather but can also offer special skills depending on the interest of the user. Those special skills are a personalization of the user,

for example managing the smart home with a virtual assistant. Within our project we develop a speech assistant that has the special skill for Providentia so users can receive information about the project or traffic scenarios while driving within the test bed.

Conclusion

Autonomous driving is a technology that will change the mobility of people in a fundamental way. There is already a lot of research on how to use the vehicles sensor system to realize an autonomous vehicle. Research is also considering Vehicle-to-vehicle (V2V) communication to enable autonomous driving. Very few research is concentrating on highway infrastructure to enable autonomous driving. This position paper states that an intelligent infrastructure system enables autonomous driving on the highway. This can achieved by enhancing the view of the highway to a multiple kilometer reaching view. Data on the highway is collected to get the vehicles attributes like velocity and position. With that data the traffic flow can be predicted and that information can be transmitted to autonomous vehicles. This additional data can be used to verify existing data with the vehicle's sensor system. Also it completes the information of the autonomous vehicle from its own sensor system. The time of the take-over request can be extended as the system analyzes data from traffic situations in several kilometers distance. Drivers can be provided with additional information concerning the reason why a take-over is necessary.

In addition, the advantage of the infrastructure sensors in comparison to the stand alone vehicle sensors is the redundancy of information. This is beneficial in case the vehicle's sensors break down or sensors fail in certain weather conditions. This redundancy of data can also replace additional redundant sensors of the autonomous vehicle. In conclusion it is convincing that an intelligent infrastructure system can enable autonomous driving on the highway.

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