Cooperatively Communicating Assistance Systems

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Abstract: In this paper we analyze the potential of communication for driver and driving assistance systems as extension of current systems and their potential for future systems. We discuss the relevance of cooperatively communicating assistance systems (CCAS) and their impact on the dimensions safety, efficiency and comfort. We present and discuss three examples that are enabled and supported by communication.

1 Introduction

Modern vehicles comprise a high number of communication and computing systems that are intended to increase the comfort, safety and efficiency of the driver. The systems can be classified into advanced driving assistance systems which, without human interaction, autonomously work in the background, such as the vehicle stability control (VSC) and into advanced driver assistance systems, such as a lane departure warning (LDW) system, which support the driver, but leaving control to the driver. These systems are currently not interconnected in a way that allows the coupling with other existing systems such as the navigation unit and thereby using all available information in a given traffic context.

In this paper we explore, on a conceptual level, the options and benefits of interconnecting driving and driver assistance systems with other systems to build a novel form of assistance systems which we call cooperatively communicating assistance systems (CCAS) to provide a better driving experiences with implications on comfort, safety and efficiency.

Cooperative communication in this context means the information exchange among in-vehicle systems, such as the CAN bus, and among external systems, such as other vehicles or infrastructure which can be subsumed under vehicle-to-x (V2X) communication, as under research by the Car-to-Car Communication Consortium [CAR07].

1.1 Motivation

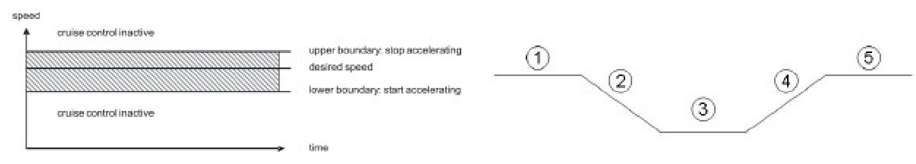
Vehicles are an interesting space for innovative applications, combining resources already available today.

- They can be host to mobile devices (e.g. PDAs, PNAs, mobile phones). Interaction with these devices in vehicular environments includes computer-computer interaction (e.g. exchanging data between vehicle and mobile device) and human-computer interaction involving voice, gesture and text input and output with their respective technologies.
- Vehicles themselves are mobile networked sensing systems. They have a significant number of intra-vehicle communication systems such as busses connecting hundreds of sensors and delivering information at high data rates, both to other digital systems and to the driver.

The sensor density in modern cars is comparable to ubiquitous computing environments. Interconnecting sensor-equipped vehicles enables novel types of applications. Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication provide vehicles with information about their vicinity, allowing vehicle systems to augment the driver's perception of the environment, thereby increasing road safety, traffic efficiency and comfort.

1.2 An Example for Improvements - Cruise Control

Cruise control (CC) allows the driver to select a preferred speed which the vehicle is supposed to maintain. As driver assistance system, the driver can always take over control, e.g. to brake if necessary. Depending on the implementation, the cruise control does not only control acceleration to maintain the desired speed, but also actively brakes. Usually though, the vehicle just stops accelerating if the vehicle is getting too fast, e.g. when driving down a hill. The algorithm for maintaining the speed can be compared to reactive control circuit e.g. of a heating system: if the speed falls below a preferred threshold, the vehicle is accelerated; if the speed reaches a threshold above the preferred speed, acceleration is stopped or the vehicle is actively slowed down (see. Fig. 1 (a)). While this is usually comfortable, there are situations where improvements using additional information, e.g. about road features, can improve the driving experience.



(a) Simplified Reactive Control Algorithm for Cruise Control

(b) Cruise Control phases in a hilly scenario

Figure 1: Cruise Control Driving Phases

In Fig. 1 we illustrate our example. In phase 1 the vehicle comfortably maintains the preferred speed. In phase 2, the vehicle stops accelerating. In phase 3, cruise control waits until the lower boundary of cruise control is reached. This results, in phase 4, in an uncomfortably result: the vehicle reaches the lower boundary. As the slope requires additional accelerating, which was not be anticipated by the vehicle due to the lack of knowledge of the road, the perceived driving experience suffers from the fast and high acceleration required to reach the desired speed again. This is also fuel inefficient. The example is not only limited to hilly environments, but is a common scenario e.g. at underpasses or overpasses in cities. By communication of the cruise control system with e.g. a navigation unit or road-side units (RSU) providing information about the road, or in more general, providing situated context information, the driving experience could have been improved by anticipating the uphill slope and adjusting the cruise control respectively.

1.3 Paper Outline

After the motivation for cooperatively communication assistance systems (CCAS), we discuss the potential of these systems with respect to their influence on the driving experience and provide examples for potential applications.

2 Cooperatively Communicating Assistance Systems

In this section we present our conceptual work on the implications of cooperatively communicating assistance systems. Communication can provide us with additional context information about the present situation, virtually increasing the number of sensors deployed in the car. Communication is treated as virtual additional sensor. Like that we can take advantage of enhanced, context aware vehicular environments.

2.1 Communication and Information in Vehicular Systems

Currently, fixed car navigation systems comprise online and offline map data with geo-coded information about persistent road features. Online services such as TMC (traffic management channel) augment these systems with one-way dynamic information. Though, the available bandwidth of TMC is rather limited to about 100 Bytes/s. Also, the available number of referencable positions is limited to about 65000 locations, which is insufficient for a complete street network. To overcome position accuracy deficiencies of the current GPS and future Galileo system as global navigation satellite systems (GNSS) the fixed navigation system is interconnected to car sensors such as the speed indicator.

In future, V2X systems will allow much more accurate position estimation by incorporation and fusion of further context information, e.g. by cooperatively exchanged pseudo-range information of the GNSS. This will not as much be used to improve the absolute position accuracy (e.g. GPS coordinate), as to determine the relative distance information of the individual vehicles which is more important in real traffic situations than the absolute position.

We elaborate on the dynamical adaption of vehicle parameters (see also [MFSS05]), such as drive train management, and their impact on the vehicle's performance and/or the driving experience. We continue to distil an initial list of scenarios along with involved parameters for dynamic adaption.

While persistent features can be integrated in navigation systems, the accuracy of the GNSS receiver alone might not be sufficient to actually trigger an adaption process. V2X communication helps to reduce this ambiguity giving the current context. The information on changeable and semi-persistent features is enabled by up-to-date V2X communication, but needs GNSS data at least as reference information. Finally, in-vehicle- (e.g. number of passengers) and vehicle-context information (e.g. horizontal acceleration), merged with V2X information, e.g. about road conditions, can be combined to adapt vehicle parameters for CCAS.

2.2 Application Potentials of Cooperative Communication

Two types of applications are enabled by the adaption of vehicle parameters based on V2X communication:

- the vehicle's perceivable performance is maintained while the vehicle's experience is changed
- the vehicle occupants' experience is maintained while the vehicle's performance is changed

In the following, we provide examples for each of these applications to illustrate the potential.

2.2.1 Example 1: Smart Navigation and Performance Adaptation

Navigation systems comprise map data with in-detail information about road type, e.g. "highway", "rural road" or "city road" and altitude information. Usually this information is either not given to the vehicle's systems or not fully exploited, e.g. by suggesting different tracks depending on the vehicle type. With V2X and associated context processing systems, or in more general, cooperatively communicating assistance systems, geographic data can be augmented to enable novel applications. This adds an additional benefit to future systems. A hybrid drive vehicle fuses GNSS with V2X information and precisely determines its position in the city. High buildings or the geographic context do not allow precise position estimation alone, e.g. due to GPS signal shadowing or multipath signal propagation.

Other vehicles or a road side unit can provide the required information. The system determines that the current road is a residency road. The vehicle's system time indicates that it is late at night. CAN bus data is used for comparing the range of the high voltage electric drive battery, given the current speed and traffic conditions, to the length of the residency road. The car finally switches the drive train automatically to its electric engine to minimize noise. The parameter adapted in this example is the drive train. The inputs are V2X-enabled contextual information, such as enhanced geographic position, orientation and map information. The perceived performance of the vehicle in Example 1 is maintained, while the perceived experience (in the car and outside) is changed depending on the context.

2.2.2 Example 2: Enhanced Braking Systems

Heavy load trucks do have several braking systems, such as motor brake or air brake systems on the axes. All can be used to slow down the truck. The combination currently is chosen solely by the driver. Often, the chosen combination is not optimal given the actual situation resulting in increased brake usage and earlier brake degeneration. For our example 2, a heavy truck with a certain load on the main truck and on its trailer is driving down a steep mountain road. In a cooperatively communicating assistance system scenario, a RSU or other vehicles would broadcast context information e.g. on their altitude and vertical acceleration (e.g. using the built-in VSC acceleration sensors) and thus allowing the truck to improve the current vertical dilution of precision (VDOP) of its GPS and their brake usage at this position. Based on this additional communicated context information, the optimal combination of motor brake, air pressure brake, and trailer brake can be selected and optimized. The parameters adapted are the brake levels of the three brake systems. The inputs are road condition, temperature, friction coefficients, and traffic situation. The perceived performance of the vehicle is improved, while the perceived experience of the truck driver is maintained - the vehicle is slowed down, but more efficient by using this context information.

2.2.3 Example 3: Adaptive Perceived Experience

A last example illustrates how dynamic adaption as discussed above relates to comfort issues where the performance is maintained, but the perceived experience is significantly changed. There are conditions where a modification of e.g. the gas pedal results in a dramatic increase of the experience. While for normal driving conditions, a 20% press of the gas pedal is linearly mapped to a 20% opened throttle, under certain conditions this mapping might be altered to map to a 40% opened throttle. Use cases are emergency situations to prevent an accident, but also normal situations when the vehicle is stopped at a red traffic light. This adoption is similar to sports cars allowing the driver to change the suspension from comfort to sports mode which is already available from some manufacturers.

In this section we provided an initial list of scenarios along with the respective input and output parameters within a given V2X context. This allows stating and measuring the benefits of the adaption compared to a non-V2X setting.

3 Conclusions and Outlook

We intend do conduct initial studies on real systems using a V2X platform interconnected to a hybrid drive car CAN interface such as a Toyota Prius as for this vehicle CAN codes are available [Vas08]. This will include:

- car dynamics features, such as motor management, chassis suspension, throttle pedal reaction, or drive train management and selection
- safety features, such as pre-crash actuators, VSC, emergency tensioning retractor, or throttle amplifier
- comfort features, such as audio volume, mobile phone communication, direction and amount of air conditioning or radio frequency

We currently investigate the adaption of several parameters by using the Controller Area Network (CAN) bus [Rob91] partially accessible via the On-Board Diagnostic (OBD) interface. Based on the scenario and the context, there can be automatism e.g. based on rules or preferences. We are also investigating the impact of silently adapting the involved systems versus an explicitly announced (optional) change from the driver's perspective which concerns the adaption and acceptance of the vehicle-driver interface. This further takes into account legal issues involved.

4 References

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