“A CLASSIFICATION OF DRIVER ASSISTANCE SYSTEMS”

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Abstract

The objective of this work is to examine advanced driver assistance systems (ADAS), with notable potential for road safety and traffic efficiency improvement, and to propose an impact oriented classification of these systems. Based on the traffic and safety features analysis, the distinct phases in the accident process are often used for the classification of the driver assistance systems. On the other hand when functional analyses of the driver assistance systems characteristics are addressed, these systems are classified based on the supported levels of driver tasks. The results of this work might be used to support decisions related to the adoption and market penetration of the most promising ADAS systems.

Introduction

Driver assistance systems seem to have a considerable potential for road safety and traffic efficiency improvement. At present the use of driver assistance systems presents a rapidly growing industry as these systems are expected to improve road safety, increase road capacity and attenuate the environmental impacts of traffic. The advent of new technologies supporting vehicle intelligence (e.g. sensors, transmitters, communications and computers) makes the use of driver assistance systems less unapproachable to the wide public, allowing for safer and more efficient driver experiences.

Driver assistance systems support the modification of the driving task by providing information, advice, and assistance, they influence directly and indirectly the behaviour of users of both equipped and non-equipped vehicles and alleviate accident consequences by in-vehicle intelligent injury reducing systems (Naniopoulos, 2000). According to the literature, the classification of such systems follows either a system oriented approach or a user oriented approach, fully responding to the increasing complexity of driver assistance functions.

Based on the road safety features examination, the distinct phases in the accident process are often used for the classification of the driver assistance systems (Heijer et al 2000).

On the other hand when functional analysis of the driver assistance systems characteristics is attempted, these systems are initially classified according to the type of user (individual driver, professional driver, fleet owner, elderly drivers, etc.). Inevitably these systems are classified according to the levels of driver tasks they are supporting.

Although these kinds of classification fail to provide answers on the usefulness of driver assistance systems, as the impact to traffic efficiency and road safety is not taken into consideration, the present paper aims to outline these two different approaches on driver assistance systems where priorities for future developments can better be identified.

1. Classification of driver assistance systems based on the distinct phases in the accident process

Driver assistance systems have the potential to improve road safety by influencing traffic exposure, by reducing the probability of crashes and by reducing injury consequences. Towards this direction, a fundamental classification of these systems consists of certain advances during the following accident phases:

- pre-crash
- crash
- post-crash

1.1. Pre-crash phase

During the pre-crash phase, the driver assistance systems are mainly focused in the support provided to the driver in terms of information, perception, convenience, and (driver – vehicle) monitoring.

The classic systems for driver information are those related to **navigation routing**, which provide location and route guidance input to the driver (Srinivasan and Jovanis 1997). A number of **integrated navigation systems** have emerged in the past years, supporting the driver through a variety of additional services, such as signing, warning or even intervening in the driving process (e.g. by temporarily taking control of the vehicle), in the event of unsafe driving conditions, such as unsafe travel speed for the geometry ahead. No significant traffic efficiency impact is anticipated from these systems as speed and headway benefits are not expected to be considerable. **Real time traffic and traveler information** systems combine the information available to users of traditional navigation systems with real time travel-related information, which they receive from the infrastructure (e.g. through dedicated radio channels, roadside beacons or wide-area transmissions). Real time traffic and traveler information systems can exploit information such as vehicle location, previous route guidance instructions, safety and advisory information, and other real-time updates on conditions such as congestion, work zones, environmental, and road surface conditions (Davison et al 1997). Nevertheless, significant headway improvements are not anticipated, as real time traffic and traveler information systems do not assist vehicle control. It should be stressed that negative safety consequences from the above driver information systems are possible, as they require in-vehicle screens, which may distract the driver attention from his primary driving task.

The driver convenience during the pre-crash phase is closely related to the elimination of unnecessary and sometimes dangerous deceleration and acceleration areas. **Automated transaction systems**, such as electronic toll collection, facilitate such transactions and at the same time make possible for the vehicles to sustain their speed.

The driver's performance for potential signs that may lead to safety violations such as drowsiness as a consequence of fatigue (Sugasawa et al 1996), alcohol abuse, medication, etc., or lack of attention, e.g. due to stress (Boverie et al 2000) may be monitored through vigilance monitoring systems. **Driver health monitoring** systems take driver monitoring a step further by monitoring several parameters of the driver's health conditions and combining the results to estimate the current health level of the driver. From this information the system assesses the condition of the driver and if it appears to be below certain pre-selected "safe" levels then the driver and possibly some external entity, e.g. a doctor or the police, are notified (Hernandez et al 1998). A simple system for vehicle status monitoring is the **tachograph** recording equipment which can record, store, display, print, and output data related to driver activity, as well as log information describing the beginning and end of each trip, control activities performed during the trip, e.g. by the police, etc. Furthermore, **vehicle diagnostic** information systems are an extension of current vehicle monitoring and self-diagnostic capabilities, offering elaborate engine condition information services such as oil pressure, coolant temperature gauges, etc..

1.2. Crash phase

During the crash phase the recent developments in the vehicle restraint systems (EN1317), such as crush cushions etc., as well as the passive safety of support structures for road equipment (EN 12767) contribute in reducing accident effects.

1.3. Post-crash phase

A large number of alerting systems have been developed aimed at alerting the emergency services (e.g. police, ambulance, fire brigades, highway patrols) in case of a traffic incident. Furthermore, some of these systems offer also dedicated support services, to which the troubled drivers get connected automatically. Most of the systems feature either a cell-phone technology connection or satellite-based communications.

2. Classification of driver assistance systems based on the supported levels of driver tasks

The supported levels of driver tasks are either tactical or operational (Michon 1985). The tactical levels of driver tasks consist of the following support systems:

- longitudinal control

The most well-known longitudinal control system is the **intelligent speed adaptation (ISA)**. Different implementations range from external speed recommendations to an automatic speed reduction function. The latter may be imposed directly to all (equipped) vehicles within the control area, e.g. through a communication centre, or indirectly, e.g. by managing the local traffic lights accordingly. **Adaptive cruise control** (ACC) is a more elaborate longitudinal control system which adjusts vehicle speed to maintain a safe separation with the preceding vehicle (Martin 1993, Winner et al 1996). Adaptive cruise control senses the presence and relative velocity of moving vehicles ahead of the equipped vehicle and adjusts the speed of travel accordingly (Hayward et al 2000).

- lateral control

Road and lane departure collision avoidance is a lateral control system providing warning and control assistance to the driver through lane or road edge tracking and by determining the safe speed for road geometry in front of the vehicle (Pomerleau et al 1997). The system continuously calculates the vehicle's optimal position and compares it with the actual vehicle position. If the system detects deviations exceeding the defined safety thresholds, then it creates audio-visual warnings for the driver. **Lane change and merge collision avoidance** systems are another type of lateral control systems providing various levels of support for detecting and warning the driver of vehicles and objects in adjacent lanes. While this information can be useful during normal driving conditions, it is particular valuable during lane change or merging maneuvers. Systems in this category track vehicles in adjacent lanes and use this information to warn the driver when their position and/or speed make the planned lane change/merge maneuver unsafe.

- general vehicle control

Automatic stop-and-go systems allow vehicles to automatically stop when this is necessary, e.g. the preceding vehicle has stopped, and starts again when the conditions allow it (Carrea 1993). Such systems could offer significant safety benefits in hazardous situations and in situations where frequent stop-and-go is required, such as congested conditions. Another system in this category, albeit with a lower level of maturity is **platooning**, a situation where each vehicle travels keeping a constant headway from the preceding one, either through external speed control or through electronic speed control by the vehicle itself. A special case of this function is the tow-bar application, where the vehicles (usually trucks) are electronically coupled and each follows the preceding one. Platooning application areas are usually restricted to highway and motorway network sections with a reduced speed limit (usually up to 85 km/h).

- collision avoidance

Rear end collision avoidance systems sense the presence and speed of vehicles and objects in the vehicle's lane of travel and provide to minimise the risk of collisions with vehicles and objects found in front of the equipped vehicle (Ganci et al 1995, Woll 1995). **Obstacle and pedestrian detection** systems offer similar services by warning the driver when pedestrians, vehicles, or obstacles are in close proximity to the driver's intended path (Butsuen et al 1996, Kamiya et al 1996, Sugasawa et al 1996, Papageorgiou et al. 1998). Most accidents happen at intersections. **Intersection collision warning** systems utilize a cooperation of vehicle and infrastructure systems to provide warning to the driver for potential collision at an intersection (Lloyd et al 1996). A special category of intersection collision avoidance systems is railroad crossing collision avoidance systems, which provide in-vehicle warnings to drivers approaching railroad crossings when a train is approaching (Luedeke 1997, Polk 1997).

The operational levels of driver tasks consist of the following support systems:

- Aiming to augment driver's perception certain systems have been released or are under development. Such systems are focused on the **vision enhancement** of the driver and vary from specially designed headlights to infrared and radar sensors (e.g. blind spot detection, electronic mirrors, parking aid, etc.). A promising category of driver information systems refers to systems collecting and analyzing information on the **road surface conditions** using vehicle-mounted or fixed infrastructure road sensors (Cremona et al 1994).
- **Driver convenience** is a key factor determining their performance. Systems already commercially available offer the capability to identify the driver (from a choice set of a few pre-configured drivers) and automatically adjust the seat, the steering wheel, the rear and side mirrors, the temperature, etc. to the particular driver's pre-set preferences. Also in this category fall various **hands-free interfaces and remote control** units located on the

steering wheel The impact of **driver identification** systems on driver awareness can be significant, as the driver is not distracted by trying to adjust the driving environment (seat, steering wheel, rear and side mirrors).

3. Conclusions

The specific contribution of driver assistance systems on road safety and traffic efficiency is something still under consideration and research. However, several attempts already revealed basic trends. Some systems present a net potential for road safety improvement, while some others have an effect mainly on traffic efficiency improvement.

The individual systems can benefit from the combination of more integrated systems. On the other hand there is a need for "intelligent" roads that will support and cooperate with the "intelligent" vehicles.

More and more systems tend to connect and collaborate with external systems.

In every case the safety of the driver as well as the vehicle passengers is the overall goal.

The results of this work might be used to support decisions related to the adoption and market penetration of the most promising ADAS systems.

4. References

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