Advanced Safety Issues in the Car and Human Interface Implications

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ABSTRACT
In this presentation we shall discuss present and future information and control issues related to safety within the car. We shall be especially considering problems at the border of warning, to driver-aid, to full automation. We shall review the communication and sensing needs. Each one of these examples will have implications regarding the human interface required.

We shall view a series of examples both from the technology viewpoint and the user viewpoint.

INTRODUCTION

The trend in modern car technology has been towards more automation, with the car "taking over" a series of driving related tasks, participating in decision making and providing warnings to the inattentive, incapacitated or unaware driver.

One could claim that the autonomy trend started with "cruise control" and "anti-lock brake systems". In each case, the car was allowed some limited authority to do the driving, with the driver also having ultimate intervention capability and hence responsibility. With advanced cruise control, the authority of the car has increased.

Various warning devices have been added to the car. Included are back-up warnings, possibly using ultrasonics, radar or laser, checking for small obstacles (tricycles, toys, little children in the driveway) below the field of view of the rear-view mirror;, and possibly providing audible warning to oncoming cars or pedestrians as we back out of driveways and blind alleys.

Driving (motion) related warning devices are somewhat recent and are definitely related to sensor technology. The simplest would be "curb feelers", then other tactile warnings (ultrasonic or radar) usually providing a sound alarm, indicating an obstacle.

More recently we have seen "blind spot detectors". The blind spot detectors have ranged in capabilities and sophistication, depending on technology used and affecting, ultimately, the price for the customer.

As we move to more recent systems, for example automated lane following systems for the highway, providing steering assistance (and in fact, fully automated driving), we see the car as gradually assuming more authority.

Full obstacle avoidance for the highway driver, is in the very near future, as field tests have been performed by different manufacturers.

In all cases above, the car has provided information related to its activity to the driver.

The progress in wireless technologies has both provided opportunities and increased expectations. We shall provide some review of the use of wireless technologies for safety issues first, then discuss the presentation of such information to the driver.

INFORMATION

TRANSMITTED INFORMATION CONTENT: We classify the wireless interaction that occurs among cars or between the cars and the infrastructure, based on their *current driving related information content.*

As we have indicated in [1] we have developed a list of possible message types that could be exchanged. The existence of such a list makes the reaction of the Intelligent Vehicle simpler. It can decide on whether this is a message to the passenger, to be shown on rear-seat monitors, a warning to be sent to the driver display, together with emergency bells and instructional voices, or some information that the Intelligent Vehicle needs to quickly use itself.

Table 1 provides such a list and also indicates whether each piece of communicated information will be going to a nearby or remote car.

INFO TRANSMITTED	CLOSE/ REMOTE
1. Brake deployed	C
2. Air-bag deployed	C, R
3. Tire burst	C
4. ABS deployed	C
5. Turn signal (R)	C
6. Turn signal (L)	C
7. Steer (L)	C
8. Steer (R)	C
9. Backup	C
10. Accelerate	C
11. Obstacle	C, R
12. Road Closed	R
13. Detour	R
14. Slippery surface	C, R
15. Low visibility	R
16. Off road	C, R
17. Distress	R
18.Audio Chat	R
19.Written Chat	R
20.Message relaying	C, R

Table 1. A list of information broadcast by car.

One issue of concern is the actual data to be transmitted. Some of this may be available using present sensors on the car, some may definitely be coming (for example GPS), and some may rely on the acceptance of certain sensors in future cars. A list of possible local measurements/data that could conceivably be broadcast, is provided in Table 2.

Local info	Remark
1. Speed	Also from GPS
2. Brake	
3. Turn left	Signal
4. Turn right	Signal
5. GPS (m)	Multiple data
6. Radar (m)	Mult, loc, mult. Data
7. Camera (m)	Mult loc., mult. Data
8. Suround (m)	Mukt. near sensors
9. Steer	Angle, force
10. Gear	

Table 2. List of possible local measurements..

At this point, we shall not dwell on whether all of this data will be broadcast, or selectively sent or a mixture of both.

SHORT DISTANCE INFORMATION: We consider the case of wireless information where receiving the information causes the driver to take immediate action. This action would probably be hitting the brakes.

A number of examples can be provided, we choose to outline an Intersection Collision Warning System.

In a vehicle based Intersection Collision Warning System, each vehicle approaching the intersection generates a message. The message includes the vehicle's location, direction of travel and the intersection location. This information is based on the car's GPS and available map data base. If there is an intent to turn, established by the turn signal, that too is broadcast. Any other vehicle approaching the intersection can calculate the possibility of a collision and will generate a warning for its driver. One possible collision is shown in Figure 1. Other possibilities can also be detailed.

The warning to the driver needs to be provided through the driver display or using voice. Or an automated response directly from the car can be considered.

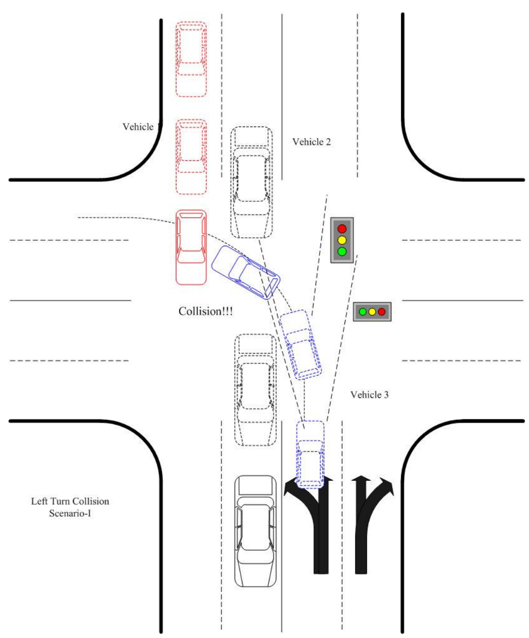

Figure 1. Intersection collisions, left-turn case.

LONG DISTANCE INFORMATION: A Long-Distance Information System will provide information to a driver on road conditions on the designated route or desirable destinations or stops.

Possibilities with such systems are numerous. They can provide information on gas stations, restaurants, hotels or tourist areas. Gas station info can be interconnected with the car's fuel gauge to tell the driver the distance to different brand offerings, and if the car has enough remaining fuel to reach each.

Ads are possible suggesting stopovers to the travelers. Standard local road and weather condition info is expected.

Here we specifically consider an Alternate Route Suggesting System. A standard congestion displaying system could be like that in Figure 2, where estimated delays in traversing routes can be indicated. This type of display is updated with wireless data provided from a central source which collects all traffic information from all city arteries.

An Alternate Route Suggesting System would have to have local knowledge of the intended destination and primary route of the driver. Such information could be provided by voice input to the car. The system in the car would then have to calculate time-to-destination along several alternate routes. If, due to congestion on the current route, the system discovers routes which will take less time to traverse, it will provide this information to the driver.

WIRELESS TRANSMITTAL

BROAD BAND: A number of applications imagined for the car using wireless technologies require broad band access. One can count the transmission of pictures, videos, full interaction with other vehicles as examples requiring broad band capability. Here we mention our experience in car-to-car transmission of individual pictures.

One aspect of our effort at the Ohio State University involved the transmission of JPEG images between vehicles using a Short Distance Communication (SDC) radios. These images consisted both of camera images from an on-vehicle CCD web-cam camera, which could be positioned by the passenger to point either out the front or side window of the vehicle or to view inside the vehicle, and stored images, for example maps, routes, announcements, or advertisements.

Several potential uses of this technology are envisioned, including driver information (communication of traffic accidents or congestion using a picture of the scene ahead of a lead vehicle), driver planning (communication of new routes or plans using an image), or "info-tainment" types of applications, including exchanging pictures along with text messages.

In Figure 2. below we illustrate a configuration where a camera looking out from the car can transmit road related information through the SDC link. Such a link could broadcast this data to other cars, creating an ad-hoc network in which this data is passed on, or to a roadside antenna, implying the need for additional infrastructure.

The issues related to data being handed over through an ad-hoc network creates a series of problems that need to be addressed.

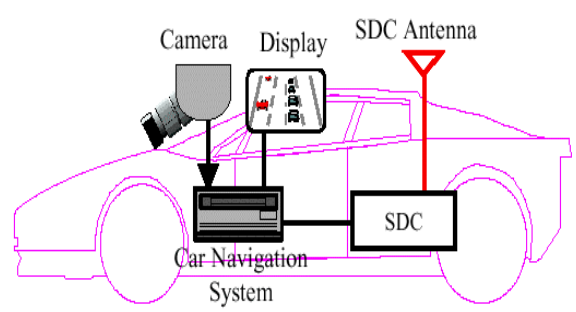

Figure 2. Roadway related picture transmission with SDC capability.

In Figure 3. we show the case of car-to-car picture transmission for social interaction purposes. Even if technologically possible, a number of issues need to be resolved for such an application. Specifically, the problem of how such a linkage can be established, needs to be addressed.

NARROW BAND: The amount of entertainment that can be provided within the constraints of a narrow-band communication channel is somewhat limited. One can consider, preset possibilities being triggered with a predefined set of codes.

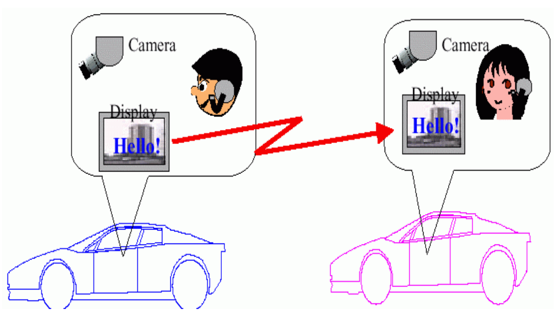

Figure 3. CAR-to-car chat with picture transmission.

During 2000-2003 at Ohio State University, we have investigated the scope of a narrow-band link at 220 MHz [1]. In fact, Table 1 was developed within this system. As can be understood from the table, the system could provide travel related information within a predefined set. For example 16 messages, like the ones above, can be predefined, with options for entering some numbers. Voice input can be used and at the receiving side, voice output (maybe with a choice of male or female) can be provided. Although having possible information value, we consider this basically an entertainment system.

OTHER SAFETY RELATED PROBLEMS

We have been alluding to a number of safety related driving situation up to this point, but have not considered one in detail except the intersection collision scenario. We provide first an incomplete list of **full speed** driving situations where warning systems or vehicle intervention is in the realm of possibility:

1. Obstacle avoidance by stopping
2. Obstacle avoidance by swerving
3. Obstacle avoidance by early lane change
4. Blind spot detection/lane change warning
5. Fast vehicle approaching/lane change warning
6. Vehicle catching up/lane change warning
7. Merging vehicle warning

Below we review the last one on the list: merging.

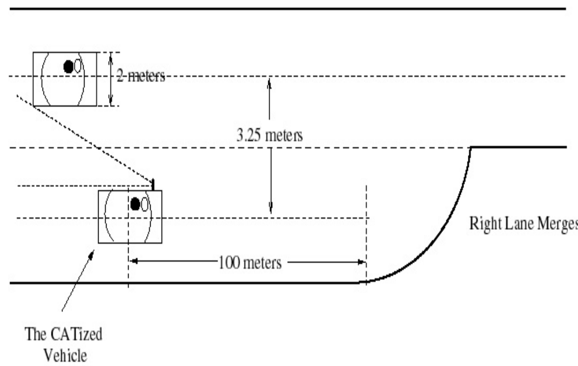

Figure 4. The merging situation.

The merging car possibility is an interesting problem, since it provides specific design decisions for Advanced Cruise Control Systems. As cars merge in front of the car with ACC, it may start falling behind, so as to retain a certain headway. The true danger is the following: If the ACC car is already following a slower car, and that car changes lanes (disappears), the inclination may be to speed up, to attain the pre-set speed. Yet the car ahead may have changed lanes to make way for a merging car, as shown in Figure 4. In this situation, speeding up is absolutely the wrong thing to do. The present solution to this dilemma is slowing down the response of the ACC car, so that if there is a possibility of a merging car, it has plenty of time to do it. On the other hand, if a wireless link is available, either through the infrastructure, or car-to-car, then the merging car may be able to warn the ACC car of a possible merge, simply getting it not to speed up. This is a more natural procedure, similar to how the human driver would have done it.

In either of the above cases, one could also provide a warning to the driver. However, with ACC on, the driver may not be attentive enough to show the needed reaction.

PRESENTATION OF SAFETY INFORMATION

In the preceding sections we have discussed a number of different safety related situations. One of the issues of concern is how these systems will interface with the driver and/or the passengers in the car.

Within the context of a project named "The Intelligent Cockpit" we have been investigating the design of the shape and functionality of the interior of a future car. The target date for such a car is important since one has to consider the technological developments, the acceptability and the infrastructure investments. Considering a target date of 50 years from the present would make a number of issues easy and one could be as "visionary" as desired. However, the sponsor has selected a target date of 2015, which makes guesswork harder and analysis of trends more serious. In fact, the technological issues have to be within the present realm of possibility.

Within the context of this project, we have listed the following functionalities as relevant:

- Vehicle operation and control
- Safety and security
- Trip navigation and information
- Interior comfort and well being
- Inter-person communication
- On-board business activities
- Leisure and entertainment amenities

One can see the relation of each and every one of the example systems I have described, to the functionalities listed above.

The question then, is how these functionalities can be reflected in the layout and design of, for example, the front display panel.

What we have not yet dwelt on in this presentation are the issues related to cognition. The driver will have to see (or hear) the warning, understand the warning select the correct reaction to the warning, and finally, physically perform the correct reaction (hit the brakes, or sharp steer left, for example).

It is possible (as shown in above mentioned project) to analyze personality and age based characteristics of the drivers and location, distance and shape of the displays, and even the color and shape of icons used for warnings, to come up with possible human reaction times.

Finally, a suggested set of modules is shown in Figure 6. One can understand how each display module (possibly arranged horizontally) can be used as visual displays for the example systems described.

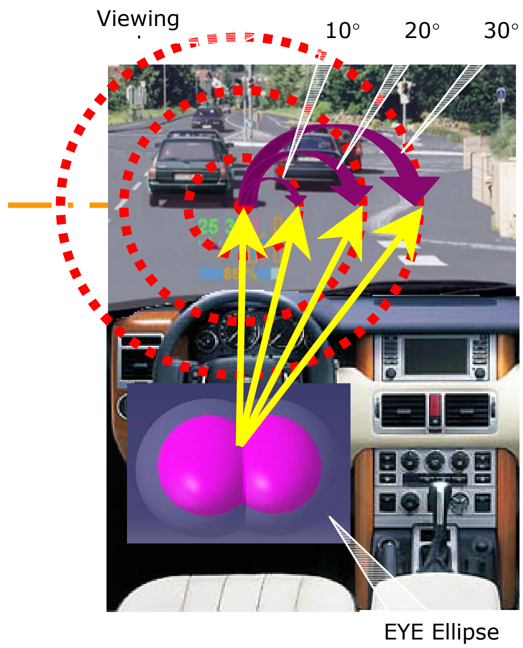

Figure 5. Analysis of attention focus.

CONCLUSION

We have described applications based on new technologies in the car related to safety. Each one of these require developments beyond the wireless technologies themselves. Common and universal data bases, various standards, general acceptance, human interface, a level of quick market penetration, infrastructure investment and development are all issues that have a bearing on the deployment of such systems.

ACKNOWLEDGEMENT

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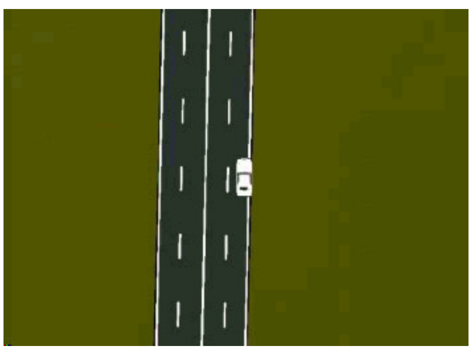

Figure 6(a). Module for top down look.

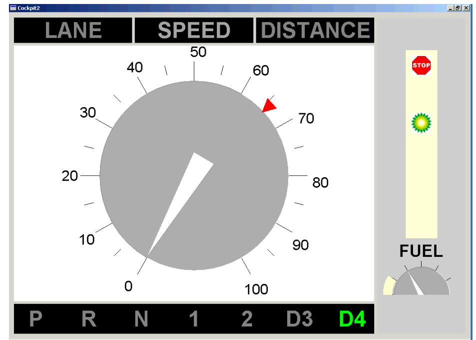

Figure 6(b). Module for speed, fuel and status.

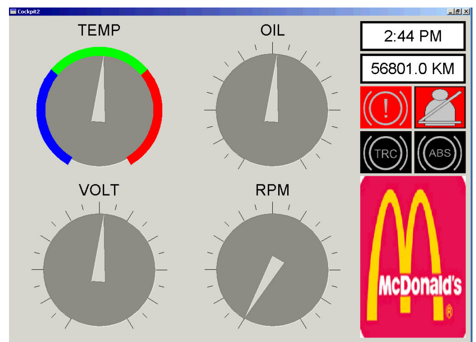

Figure 6(c). Engine info and external info module