Three generations of on board signing systems

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ABSTRACT

Advanced Drivers Assistance Systems use more and more on board visual, audio and haptic advertising interface devices. Exploiting ten years of research works and using a large set of live demonstrations, we proposed a typology analysis of on board signing systems and a classification in three generations.

Key-words: Traffic safety, data fusion, communication, on board signing, real time processing

INTRODUCTION

The Robotics Center of the Ecole des Mines de Paris pays a great attention to the road safety applications. We are involved in the design of new techniques dedicated to intelligent vehicles. Recently, to push the research in the collaborative ADAS system, we decided to increase our fleet from one to six test vehicles equipped with perception and positioning sensors as well as communication media.

Fig. 1 shows the first of our LARA prototypes[1] equipped with 4 cameras, an inertial measurement unit, a GPS receiver, a laser scanner, a radar, as well as a Real Time Multisensor Advanced Prototyping Software developed by our team [1],[2]and now commercialised by INTEMPORA Company [3].

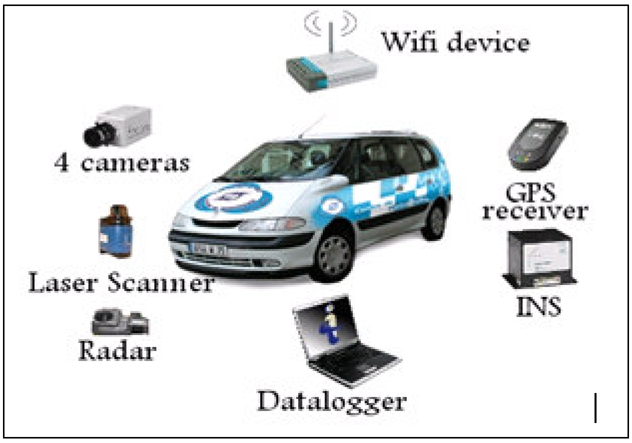

Figure 1: The first Lara prototype (Renault Espace car) with its sensors.

Figure 2 shows the new LARA fleet. The four "Citroen C3" are equipped with vision sensors, GPS and communication devices.

[1] LARA is the name of a Joint Research Unit between INRIA and Ecole des Mines de Paris.

Figure 2: The LARA fleet of the Robotics Center.

DATA FUSION AND SMART ON BOARD SIGNING

We can establish a parallel way on the evolution of navigation and on board signing.

If we observe navigation technology which is now largely deployed in Japan, US and now in Europe. Five millions of navigation devices have been sold in Europe in 2005.Navigation results of the fusion between a precise localization system using GPS and odometers and a map matching operation which position the vehicle on a digital map. The digital map is in fact a graph and navigation use a routing algorithm between the start point and the arrival point similar to those used for electronic circuits. This is what we call, the first generation of navigation or static navigation since we take into account the geometry of the road network but not the traffic density. If we can measure the density of the traffic on the different segment of the road network, we can modify the impedance of the network and the routing algorithm will take into account the traffic and deliver to the driver an optimum path…this is what we can call, dynamic or contextual navigation. This is the second generation of navigation systems.

We define "On board signing" as the technology which allows presenting to the driver, smart messages about the traffic signs. We can use also the term of electronic co-pilot.

The first generation of on board signing, results of an enhancement of the geographic information system in which we add the horizontal and vertical signs to the digital map. This necessitates a visual or vocal man machine interface to inform the driver of the presence of signs. This on board signing is redundant with the real signs on the road, but in certain cases it can help the driver when the signs are hidden by the vegetation for example.

	Navigation	On board signing
First generation: static	Routing according the geometry of the network	On board copy of road-signs on the dash board
Second generation : Dynamic or contextual	Dynamic routing	Data fusion and smart messages on the dash board
Third generation : Interaction and communication	V2V and V2I communication contributing to safety and fluidity: "Sensing traffic together"	

The second generation of on board signing is not a simple copy of the existing signs, but takes into account the traffic context, the weather or other observable parameters. The resulting smart on board signing system presents to the driver contextual information resulting of real time data processing of different sensors. This second generation will be illustrated with two different scenarios: approaching a cross road, and approaching an intersection with a stop sign

The second generation exploits the perception system of each vehicle; it can be seen as a passive system and has an autonomous behavior. The third generation corresponds to collaborative and autonomous robotics systems, using the communication media to exchange information between vehicles (V2V) and between vehicles and infrastructure (V2I). At a first glance, we can point three significant contributions:

- Extending the sensing capability to the communication coverage area (which will be more and more increased with the improvement of technologies),
- Delivering a valid and exact information about neighbor vehicles (other perception tools can only "estimate" the features of the detected vehicles)
- Making possible the exchange of none measurable data by an autonomous system (i.e. the driver intentions).

If we assume that all vehicles are equipped in localization and communication devices, each vehicle can reconstructed a local map of its surrounding (a bubble of its environment). This small data structure can be broadcasted and catched by other vehicles creating a collaborative community of vehicles. This is a distributed intelligent system which can contribute to safety and fluidity.

<u>An active safety co-pilot when approaching a cross road</u> [4] [5]

In that scenario, our car circulates on a rural road and is going to catch up with a preceeding vehicle and overtake it. The visibilty is not good and there is a crossing 400 meters ahead that we don't not see. Our car is equipped with a radar, a GPS and a digital map, and with a fronthead digital camera. All this devices are connected and managed by our software. The preceeding car is detetected by the radar, the GPS and GIS permit to localise the crossing that the driver don't see. The conjonction of this two events launch a vision watching algorithm which detect the turn signal and the brake lights of the preceeding car while observing the safety distance maintened by the driver.

In case the driver do not respect correct speed and safety distance, an onboard alarm is produced on the dash board. This is what we call intelligent on board signing.

Figure3 On board signing while approaching dangerously a crossing

<u>Approaching an intersection with a stop sign</u> [4] [5]

We circulate on a rural road which intersects on the right, a road whit a stop signal.
Although we have the priority, it seems safe to observe the eventual presence and maneuver of a car at the intersection.

To do that, we only need the localization function (GPS and a digital map with the STOP sign registered) and a digital video camera.
The vision algorithm is guided in its job by the information coming from the localization function since the region of interest in this case is limited to the right part of the image. If the vehicle does not respect the stop sign, an alert is produced on the dash board.

Figure 4: On board surveillance on approaching a dangerous intersection

Temporary speed limits on board announcement

Drivers claim they want to be informed at every moment, at every location about the speed limits. Because respecting speed limits at every moment especially near road workings save lives, French motorways have decided to set up and transmit in real time a data base containing speed limits on their network. The idea of transmitting the speed limit to the driver in order to increase road safety is not new. The originality of our contribution is that the database will not only include permanent speed limits but also temporary limits (weather, road workings…) frequently updated.
Our work is different from a classical navigation system (classically the vehicles carries its own database and, using GPS, finds the relevant information). In the case of non permanent speed limits, a V2I (vehicle to infrastructure) connection has to be set up to upload the database in the region of interest.
One key aspect is that the database will not only include the permanent speed limits but also the temporary ones (due to bad weather, traffic, road workings). This demand leads to two different collecting methods with two levels of difficulty.
The permanent speed limits are already registered by navigation systems companies such as Navteq, Tele Atlas. Most of the motorways companies already collect this information by reading local decrees. The main work is to make the data consistent at a national level.
For temporary speed limits, motorways companies work with software tools to deal with traffic and road workings. The work has consist in adapting these tools to associate with, for instance a road working, a precise location, moment and speed limit and then transmit it to the central telematic server which should be updated every few minutes.
We have used a GPRS connection and protocol to update the speed limits concerning the driver at one time and location.

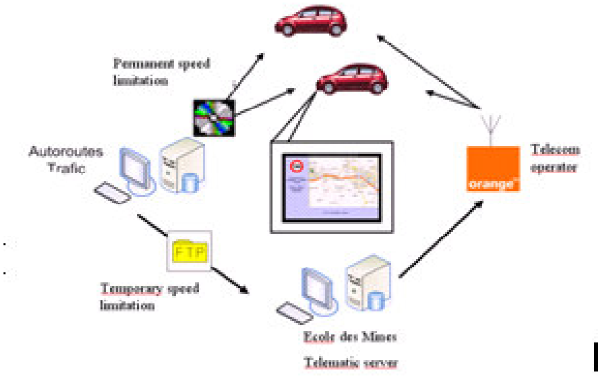

Figure 5: Architecture of Vehicles to Infrastructure communication system

A user friendly interface has been created as a first draft of what this system will look like in future personal cars.

Figure 6: The experimental interface in the C3 vehicle

Thanks to ASFA, a public demonstration has been realised on 12th of June 2006, on ATMB (Mont Blanc High way) near Bonneville in France.

Figure 7: Temporary speed limits alerts on navigation interface

The companies exploiting the French High Ways assisted to the demonstrations were convinced and are now in a dissemination process of this new safety technology.

Real time crash avoidance at cross road using V2V communication [6]

The preceding paragraph illustrated a possible V2I contribution to traffic safety. The time constraints were not too high and were satisfied by a GPRS communication channel. Now we are tackling with an application of vehicle to vehicle communication with time constrains more severe.

Crossroads are very dangerous zones on the roads. Thus occlusion and bad estimation of the position, velocity and even intention of other drivers are the main sources of accidents on intersections. The cooperation thanks to V2V communications could be a source of accurate information for the driver. We have thus to estimate the risk (or the gravity) of a possible collision and to inform the driver to anticipate accidents. The problem is to calculate the instantaneous probability that the vehicles trajectories intersect at an upcoming time regarding the current uncertain vehicles positions. The predicted filtered trajectories must take into account the respective vehicles speeds and accelerations but also the respective positions errors. Because of these errors the intersection of the trajectories take place inside an area of uncertainty which is the intersection of uncertainty ellipses centred at the intersection point (***IP***) of both trajectories geometric curves (Fig.8).

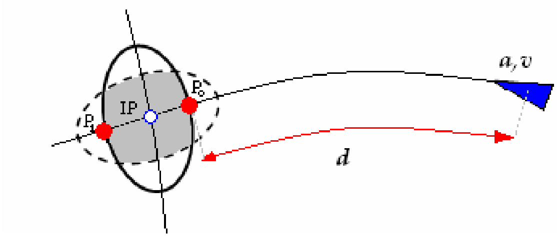

Figure 8: TTI(Time To Intersection) computation using the distance to the uncertainty area (d).

The impact can occur anywhere in this intersection region but the most probable location will be at *IP*. In our experimentation, when two vehicles arriving at a crossroad exchange their positions, speeds, accelerations and errors. The trajectory prediction engine extrapolates the future positions (in the next 10 sec) of our vehicle and for other vehicles arriving at the intersection. We thus can estimate how dangerous the situation is and alert the drivers. The risk is estimated by the time to impact (TTI) and in our case it is the time to reach the uncertain area. We use a prediction system and errors change dynamically and consequently the size and the location of the intersection area. In figure 9 is shown representation of the experimentation area. The car represents our vehicle and the dots represent the positions of the other vehicle as communicated to us.

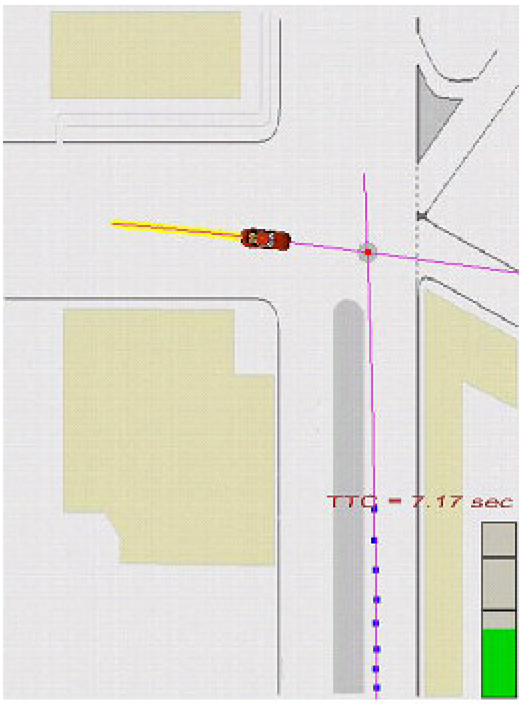

Fig.9: Lara-1 and Lara-2 vehicles approaching a crossroad.

In order to detect if a collision is possible, we compute for each vehicle a couple of TTI values. Each TTI is the time to reach a given point at a distance (d) forward away on the trajectory. (d) is respectively the distance between the vehicle's position on the estimated trajectory and the nearest point P_0 (resp. furthest P_1) belonging to the uncertainty area border of the predicted trajectory for the other vehicle (the uncertainty ellipse is centred at the estimated *IP* as illustrated by Fig. 11).

If (v, a) are respectively speed and acceleration, we can show that:

$$TTI = \left(-v + \sqrt{v^2 + 2ad}\right) / a$$

With: $a \geq -\left(v^2 / 2d\right)$ *if a < 0*

If no correction is made to the current speed of the vehicle then the vehicle would reach the intersection area within a time interval [TTI_{P0}-TTI_{P1}]. Similarly, the other vehicle would reach the same area within a time interval [TTI_{Q0}-TTI_{Q1}]. The collision is possible if both intervals overlap.

This experimentation confirmed that the key elements for this experiment are latency as well as the precision of positioning. The first can be exceeded by the prediction of the position thanks to filtering. The latter influences the ellipses sizes and the IP position. However, unless the PDOP is high, the positioning errors lead in general to a limited error in TTI. Our experiments show that for standard GPS positioning errors of 4 meters and speeds ranging between 50 km/h and 100 km/h, errors in TTI can range between 0.2s and 0.33s. We believe this is fair for our application if data loss or latencies do not become critical.

CONCLUSION

The ITS research domain is very active due to the economical importance of automotive industry. Car manufacturers are generally hostile to driverless idea and totally autonomous vehicles. Although, we can observe a similarity of researches in the field of academic autonomous collaborative robotics with ITS ADAS approaches.

The concepts, the tools are similar. We have tried to understand the past progress to infer the future one. Vehicles will become more and more autonomous and more and more collaborative.

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ACRONYMS

GPRS: General Packet Radio Service

GPS: Global Positioning System

PDOP

RT MAPS: Real Time Multisensor Advanced Prototyping System

TTI: Time To Intersection