In-Vehicle Service Architecture, Advanced Driving Assistance Systems, Location Based Services, Navigation Systems, Inter-Vehicle Communications, Ad hoc Networks, IMM, EKF

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QUADRANT: AN ARCHITECTURE DESIGN FOR INTELLIGENT VEHICLE SERVICES IN ROAD SCENARIOS

Summary. The current growth of different services in our road vehicles has brought the need of organizing their implementation, both from the hardware and the software points of view. The implementation of location based services (LBS), navigation, route guidance or advanced driving assistance systems (ADAS), such as collision avoidance or crash prevention systems, encourages the use of a common flexible architecture in order to supply well-arranged information to the final user. This paper is to present Quadrant, an architecture based on four different levels of abstraction that provides the modularity and flexibility required by a wide set of services, paying special attention to its communication framework.

PAPER TITLE IN POLISH

Streszczenie. No longer then 3 sentences, in Polish, 10 point characters.
(For natives obligatory, for foreigners organizer ensure translation)

INTRODUCTION

The current development of new services and advanced driver assistance systems (ADAS) allows supplying new interesting features in our future vehicles. A few examples of these are:

- Collision avoidance,

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- Detection of unfriendly situations and risky scenes,
- Emergency vehicle management,
- Automation of tasks, such as parking maneuvering and monotonous situations,
- Adaptive cruise control.

To achieve their purposes, new ADASs demand a higher level of performance on the supporting road side equipments (RSE). In a low level of abstraction, applications based on the denominated Location Based Services (LBS), such as fleet management, hazardous good tracking, or automated emergency calls mainly rely on the positioning of the vehicle. The main requirements regarding the navigation system of the vehicle concern continuity of an accurate positioning, fault detection and the provision of an integrity parameter. In more complex ADAS, a decision making process demands a scene interpretation in order to determine the vehicle role in its environment. In this frame, the need of a high level of abstraction of the situation cannot be fulfilled by traditional multi-sensor data fusion filters.

For military purposes, the issue of situation awareness has been pointed by several authors from the point of view of the artificial intelligence [1 – 6]. According to these works, multi-sensor data fusion is divided into four levels of increasing situation complexity. Level one concerns object refinement and is defined as the fusion of data related to detection, tracking, classification and the identification of platforms such as ships and aircraft without consideration to the intent of the platforms [7]. In level two the relations between platforms become important. Level three is about threat refinement and addresses the intent of hostile platforms. Level four addresses process refinement in which a commander tries to predict hostile actions. Some of the concepts presented in these works can be apply to understand the multi-layer fusion complexity in non-military applications.

Several authors have been focusing their efforts in the recognition of vehicle behaviors by using a set of diverse kinematical models. Each model is developed to represent the vehicle behavior in a particular maneuvering state. In [8] a concrete model is selected according to its dynamic state. Most recently, some of these authors in [9] proposed an interactive multi-model (IMM) configuration. In this very interesting paper, different vehicle models and the IMM implementation are proved to evaluate the vehicle behavior in Stop\&Go and lane change situations.

OBJECTIVE AND PAPER STRUCTURE

The aim of this work is a reliable RSE capable to provide service to ADASs in road vehicles at attainable price. This paper presents Quadrant, a complete system architecture based on the separation of four layers according the level of abstract fusion performed, paying special attention to its communication framework. The rest of the paper is organized as follows. Section 2 presents the basis of the proposed architecture. In this Section, a description of the hardware setup and the first layer is given. Following, the communication network proposed to perform the inter-vehicle communication is presented. Finally, the possibilities for the transmitted information analyzed.

THE ARCHITECTURE DEFINITION

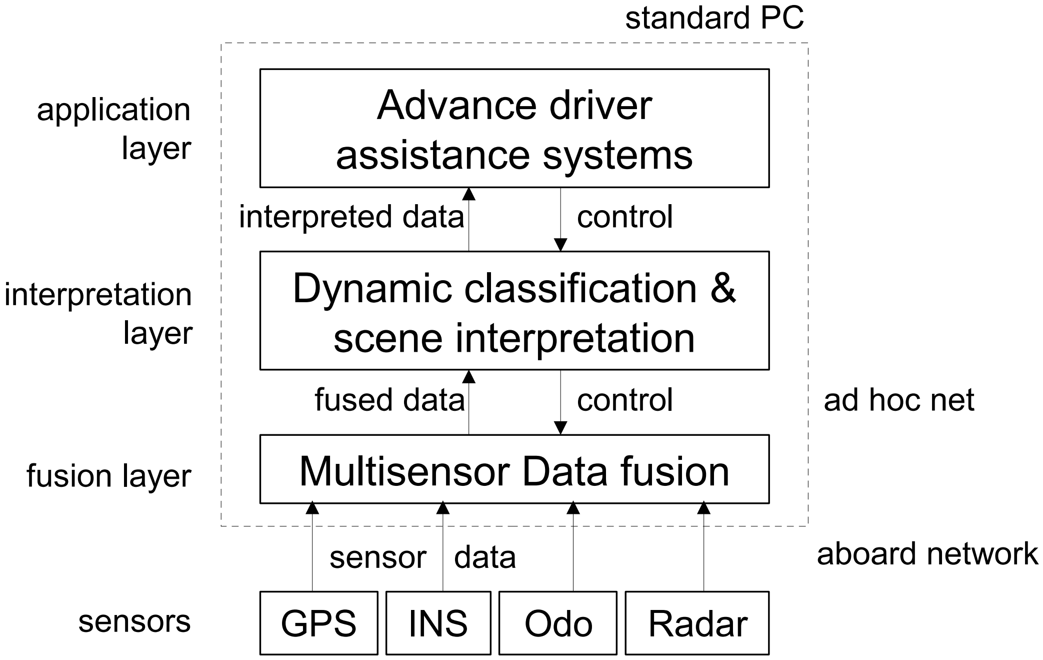

Figure 1. The Quadrant architecture schema.

Fig. 1 shows the proposed multi-layer based schema of the system architecture. On it, the sensor layer is in charge of the measurement collection, sorting and synchronization. The sensor data is sent to its upper layer via the sensor network, consisting of RS-232 serial ports for the INS and the GPS device, and CAN bus for the odometry. The Radar sensor presented in Fig. 1., despite of being considered in the development of the system architecture, is out of the scope of this paper, so no more consideration will be done about it. Secondly, the fusion layer fuses the data coming from the sensors. In Quadrant, this layer is oriented to the interpretation of the vehicle behavior (to be performed in the following phase), and can be described as an IMM-EKF multisensor data fusion filtering algorithm in which the vehicle models represent different maneuvering states of the vehicle, critical to determine the role of the vehicle in a concrete scene. Fused data is supplied to the third layer via ad hoc networks defined in the vehicle environment. Those networks are supported by the WLAN connection availability, thanks to the WIFI PCMCIA card installed in the vehicle computer. The third layer or interpretation layer is in charge of the dynamic classification of the vehicle and the scene interpretation. The use of an IMM method in the previous layer eases the dynamic classification process according to the information collected in the previous phase and considering the probabilities of the vehicle models as calculated in layer 2. Finally, the interpreted data (and any other data coming from previous phases) are used by the ADAS application in order to provide the final service to the user.

In the other sense, the ADAS definition establishes constraints in the lower layers. Clear examples of that are collision avoidance applications and automatic emergency brake, where the success of the system performance depends strongly on the reaction time, and takes into account the velocity of the vehicle involved.

THE HARDWARE SETUP

Fig. 2 presents our test bed vehicle, the SatAnt prototype. The SatAnt vehicle is a standard roadster vehicle, equipped with a complex hardware.

Figure 2. The SatAnt prototype.

The sensor deployment use installed in the test bed vehicle is next:

- GNSS: An EGNOS capable GPS sensor,
- Odometry coming from the ABS encoders,
- INS: A low cost IMU based on MEM (Micro-Electro-Mechanical) technology,
- Radar: a 50 MHz. long range radar with a range capability of 100 m.

The sensor network employs two RS-232 serial ports to connect the INS and GNSS devices to the local PC, and a CAN bus for the odometry captors. The odometry signals reach a custom-made capturing board for transforming the odometers pulse count to velocity data. The three upper layers of the system architecture run over a standard single board computer with a 32bit Pentium processor. The vehicle PC interacts with the user via the HMI (Human Machine Interface) by a custom-made monitor, keyboard and mouse. A BlueTooth wireless link can be used to connect the vehicle PC with mobile devices such as mobile phones, PDAs, PocketPCs, etc. A WLAN connection is available through the PCMCIA slot of the CPU, facilitating the communication with nearby vehicles which share the scene. Finally, a GPRS/UMTS link supplies Internet connection to the system. The GPRS/UMTS link is used for receiving the EGNOS messages via SISNeT (Signal In Space through Internet), and can also be used to communicate the vehicle with remote stations (or other vehicles), for remote location based services. Further details of the WLAN ad hoc communications are given next.

THE COMMUNICATION FRAMEWORK

COMMUNICATION PROTOCOL

Fixed networks are not advisable to make an inter-vehicle communication, because this communication is established and lost very quickly. For this reason ad-hoc WLAN networks will be used. All the vehicles that are circulating will connect to this network to send and to receive traffic data, through a multicast group named *Road information*, with a public and well-known address in advance. In order to decide the multicast protocol to use, several options with very positive characteristics for our type of system have been studied.

1. STANDARD MULTICAST VS. GEOCASTING

The first option to think about is the use of *geocasting*. The geocasting groups are known as the set of all the nodes in a specific geographic area at a particular moment, unlike the conventional protocols which will be formed by the nodes registered in a multicast address. The main communication of the system is the one among vehicles and it increases considerably with the number of vehicles on the road. It is important to determine when the information is going to be transmitted avoiding the overload of the network with unnecessary traffic. A vehicle should analyze just those messages it is interested in, in order that it would just hear from the nearest vehicles and the warnings related to places on its way. The transmitter vehicle can make the decision whether the warning interests the surrounding vehicles or not. This can be done before sending the message, or on the receiver vehicle, after sending it.

Using *geocasting* that decision can be taken a priori, by sending the message to the associated group to the geographic area where the warning or the vehicle that generated the localization message is found. For example, take a warning associated to an specific geographic position; if we are on the motorway, it can be considered that the group of vehicles interested in that alarm will be situated in the same road as well as the same direction as the warning. That is to say, a vehicle is interested in warnings which take place along the way it is going to circulate within a short period of time. In these cases, it would be useful to send the warning by geocasting, and it would also very easily determine the geographic area where the nodes interested in getting the warning message.

However, geocasting doesn’t seem to be the proper protocol due to the drawbacks that arise when the nodes on the network are regarded as vehicles:

- The nodes of the ad-hoc network change very quickly and this causes constant changes in the nodes forming each group.
- The vehicles, which soon will get on the route where the warning is (a bridge, a roundabout) are not considered as being in the geographic area and therefore they wouldn’t get the message.
- In a city, the interested area in a message gets bigger as it reach the streets crossing the route where the warning is, even the entries to the mentioned area through parking spaces.

By using a multicast standard protocol, vehicles would join a multicast group and would get all the messages, without taking into account their interests. Once the message is received, the geographic position it refers to, is also obtained. From that information it is decided whether to ignore it, check it or check it and immediately after transmit it. For this decision to be token, it is calculated the present distance from the vehicle to the warning point, as well as if the vehicle approaches or moves away from this point, and even if it is in the same route, the same direction, and the same lane.

2. STANDARD MULTICAST VS. MULTICAST SPECIFIC FOR AD-HOC NETWORKS

In a Mobile Ad-hoc Network (MANET) is really important to use a specific protocol for this kind of networks, due to the fact that standard protocols are not able to offer a good performance in this type of networks because the structures of distribution used are very weak and their update is too slow to support the frequent changes that happen in MANET's topology [10]. If we consider the vehicles as the unique nodes in the network, we have a pure MANET, so we can use any multicast specific protocol for MANET (hereafter, *multicast*).

3. MULTICAST FOR AD-HOC NETWORKS VS. MMARP

If the connection to linked networks is required, it is necessary a multicast protocol prepared for it, like MMARP. This protocol defined in [11] by Martínez-Ruiz, Gómez-Skarmeta and Martínez-Asensio, is able to offer an efficient routing in MANET and at the same time, and without decreasing its performance, it is able to offer a proper interaction with the wired network and with other standard IP nodes that could use the MANET extension as a network to the wired network.

Regarding the use of the network, multicast does not need maintenance messages of the structure of MANET, hence packets are only sent when there is something to communicate, on the other hand, MMARP requires more traffic for the maintenance of the network. MMARP keeps information about the nodes of the networks, and use it to transmit information from the transmitting node to the group of receiver nodes. Thus when a message is transmitted in the network using MMARP, this message does not flood all the network, only it is transmitted through the nodes on the way to the receiver. For example, to transmit a message that is important to the vehicles behind the transmitting vehicle the MMARP messages are very likely to be transmitted only in the nodes/vehicles that are on the same road, without sending messages to the other side of the road because the messages try to follow the shortest way. The main advantage of multicast is the absence of control messages, so we reduce the risk of overload that these messages can produce. Moreover, the decrease of the traffic enlarges the duration of the batteries and we do not need to have a table with the neighbour vehicles, freeing memory. After studying the advantages of MMARP, it was decided to use it for latter versions of this architecture, where it was integrated with fixed networks, this way a rise of the bandwidth of the network.

In conclusion, the proposed architecture will use in their communications a specific multicast ad-hoc protocol for these networks.

4. SECONDARY COMUNICATIONS GPRS Y BLUETOOTH

In addition to inter-vehicle communication, the system uses other secondary communications. The on board computer of the vehicle has a GPRS/UMTS link, used to receive EGNOS messages via SISNeT (Signal In Space through Internet) and to communicate the vehicle with remote stations. This link allows Location Based Services (LBS) and notifications to the traffic monitoring centre or emergency services.

The vehicles equipped with GPRS are very interesting to expand the architecture of the system. When one of these vehicles detects a potentially dangerous situation, by the GPRS network we have the possibility to communicate it to the competent authorities. For example, if a message notifying a vehicles collision is received, the receiver spreads to the vehicles of its ad-hoc network to avoid a chain collision, and if it has GPRS communication it can notify the emergency services or the traffic authority of it. In other situations, it can be enough to notify the traffic headquarter in order that this one can take some actions such as writing a message "Traffic jam in X" on the information boards of the appropriate roads. A wireless connection Bluetooth is also available. This allows connecting vehicle PC with devices like mobile phones, PDAs, etc.

TRANSMITTED INFORMATION

The architecture transmits two kinds of information: continuous information of the vehicles localization, and isolated information about a possible risk situation. Next, each kind of information will be commented briefly.

1. VEHICLES LOCALIZATION

Each vehicle will send periodically the necessary data so that the rest of the network can locate it. It will send mainly its position, speed and direction, in order that anyone can be aware of the others location at each moment, or estimate its position at the successive moments. This knowledge of the surroundings is essential to be able to react safety in the face of a risk situation.

2. RISK SITUATIONS

When a potential risk situation, or *fact*, is detected by the system a warning message is generated. This one will be sent through the network in order that the rest of the vehicles are aware of the danger and they can react in time. A vehicle that has received a warning can update or complete it, and even forward it with improved information. In some situations, the warning may not be related directly to a danger, but to an uncomfortable situation. This situation can trigger some negligence and a subsequent accident. Traffic jam alarms, road works alarms, etc., are in this group. These messages do not alert other drivers, only inform them. Thus, the drivers can change their route and avoid the problem. Warning messages must contain enough information to locate with exactitude the fact, for that reason it is recommended to include the following data:

- *Warning identifier.* When a message is received, we must know if it is a new message or not. It is very important in order to update a specific fact received previously.
- *Vehicle identifier* which generated the warning.
- *Warning type*, among a range of potentially dangerous facts or situations.
- *Position* in which the fact has been originated.
- *Exact moment* in which the warning was generated.

3. INFORMATION TRANSMISSION

The behavior of the communication system consists of sending, receiving and propagating messages: s*end***,** each node sends messages with its vehicle localization and warning messages of situations detected by the node; *receive***,** each node receives localization and warning messages from others vehicles. If it receives a message generated by itself, the message is ignored; *propagate*, each node propagates warning which it receives. If it can get some more information about the situation the warning refers to, it will extend the information before spreading it. For example, a vehicle receives a warning such as “obstacle on the road” and because of its position it has got some additional information, therefore it spreads “obstacle on the road taking up the central and right lanes”. By doing this, the system adjusts itself to the nature of the ad-hoc networks, in which the messages must jump from node to node in order to cover the whole diameter.

ACKNOWLEDGEMENTS

The authors would like to thank the Spanish Ministerio de Fomento, and ESA-GJU (European Space Agency – Galileo Joint Undertaking) for founding the research activities under the grants FOM/3595/2003 and GIROADS 332599, respectively.

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