MIMICS PROJECT: EVALUATING EGNOS (GNSS-I) FOR SUPPORTING ITS APPLICATIONS

A.F. Gómez Skarmeta, H. Martínez Barberá, M. Zamora Izquierdo, B. Úbeda Miñarro, D. Alonso Cáceres and R. Toledo Moreno

Murcia University, Faculty of Informatics, Campus Espinardo, 30100 Espinardo-Murcia, Spain

E-mail: skarmeta@dif.um.es; humberto@um.es; mzamora@um.es; bubeda@um.es; dalonso@um.es; toledo@um.es.

SUMMARY

This paper will present the results obtained within the evaluation of EGNOS signal in the context of the MIMICS project (Mobile Intelligent Model incorporating Independent Control and Sensorisation) financed by the Spanish Ministerio de Fomento which aims is to provide solutions in the field of intelligent transport systems, more specifically in area of intelligent vehicles. The main aim is to develop a prototype of an intelligent vehicle, where to test the integration of different sensors specially those related to location and awareness.

INTRODUCTION

Future trends in road transport are clear, more electronic intelligence on vehicles, a wider use of cellular wireless broadband communications systems with global coverage, and minimum roadside support. Today, most navigation services in road transport use GNSS navigation sensors, basically GPS based applications are possible making use of improved accuracy and availability in the measurements offered by Satellite Based Augmentation Systems (SBAS) (4). Such systems, joined to 2.5G and future 3G cellular mobile telephony will play a essential role in the next few years until Galileo and the new GPS arrives (1, 2, 6).

The European Commission, through the European Space Agency (ESA), is promoting the Galileo Project. However, the first phase, denominated GNSS-1 or the EGNOS (European Geostationary Navigation Overlay Service) Project, will boost the performance of already existing GPS and GLONASS systems.

The EGNOS System Test Bed (ESTB) is the prototype, broadcasting a Signal in Space (SIS) since February 2000. It is used to support and test the development of the EGNOS system, to demonstrate EGNOS to potential users, to prepare for the introduction of EGNOS, and to test the possibility of expanding this system outside Europe. The ESTB provides users with a GPS-augmentation signal that enables them to calculate their position to an accuracy of a few meters. In EGNOS geostationary satellites in L1 band send signals with the corrections to be made by the receiver. EGNOS is therefore included in the so-called Satellite Based Augmentation System, SBAS (7, 8).

In this paper we present the results of an evaluation of the European EGNOS Test Bed, as part of our researches in autonomous driving, safety management and automatic tolling. The MIMICS (Mobile Intelligent Model incorporating Independent Control and Sensorisation) project financed by the Spanish Ministerio de Fomento, was our starting point (9).

The aim of the MIMICS project is to develop an intelligent platoon of vehicles, where the leading vehicle (which is manned) acts as a guide for the following vehicles (which are unmanned). For practical reasons the real prototype has been limited to only two cars. The operation of the leading car is quite simple: it uses its sensors to send information to the following car. This uses both its sensors and the information received to control the actuators. All the information is shared using wireless links. The forward car is provided with a portable equipment that contains the positioning sensors, a small processing unit and the radio communication link. This portable system can be used in any standard car. The autonomous car is far more complex. First, it has to be automatised to allow a computer to fully control it. Next, it requires enough processing elements and sensors to perform autonomous tasks.

The fully sized COMARTH model S1-50 vehicle (see Fig. 1) modified within MIMICS, included the following electronic equipment:

- GPS receiver with wide area augmentation system (WAAS) and EGNOS compatibility.
- Frontal radar to detect and avoid obstacles.
- Wireless communications unit.
- Intelligent control system to aid driving (3).

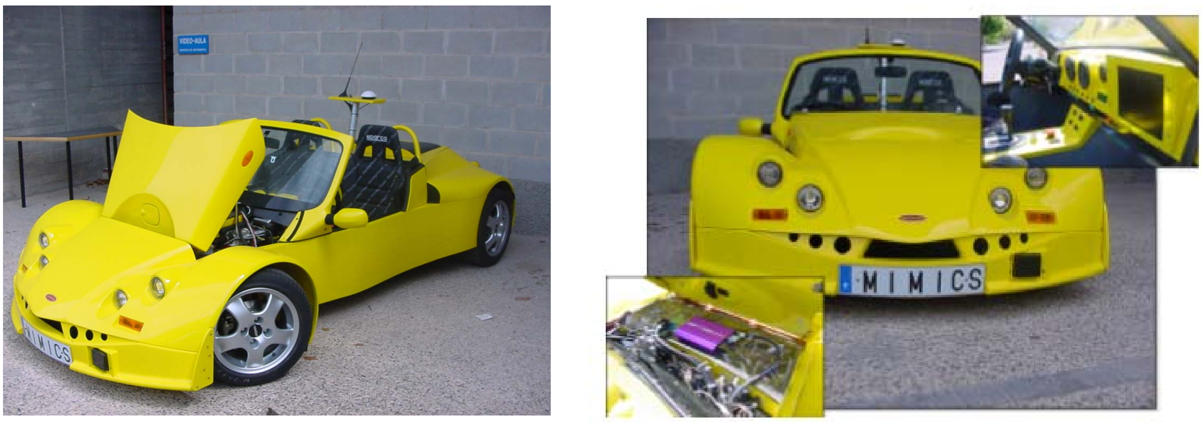

Figure 1. Automated COMARTH S1-50 prototype

This commercial vehicle, with an automatic gear box, was modified in order to be fully automated incorporating the following specially designed systems in a modified version: electrically assisted steering, electronic accelerator and electrical braking. The bodywork and dash were also modified to hold the sensor and monitoring systems, as was the interior so that the actuators and electronics could be accommodated. Other equipment installed were the forward looking millimetric radar, an electronic compass, and an odometer system based on the Automatic Braking System (ABS) sensors. The communication unit is based on the IEEE 802.11b Wireless Local Area Network (WLAN) for short range coverage and the use of a 2.5G Cellular Network (CN) General Packet Radio Service, (GPRS) terminal, for longer ranges. Thus the vehicle transmits control and positioning information to a base station from which it is possible to control the car.

DRIVING SUPPORT SYSTEMS IN MIMICS CAR

The Comarth S1-50 vehicle has a factory-fitted CAN (Control Area Network) for controlling the operating parameters of the engine. The car has no additional electronic exchanges for comfort or passive safety features, which a more luxurious car might enjoy. For this reason we installed our own system of data buses for the additional exchanges and sensors needed. To interconnect the microcontroller-based exchanges we considered integrating the signals in the vehicle's CAN. The main SBC-P111 type CPUs (one board computers) were connected by an *Ethernet* network using a concentrator (*Switch*) for intercommunication.

The CAN and Ethernet networks were connected by a board incorporating a newly developed microcontroller from Dallas Semiconductors, programmable in Java and denominated TINI (*Tiny InterNetwork Interface*). This board can manage different types of buses, such as Ethernet, *CAN*, *I2C*, *Onewire* y *RS-232*, its principal purpose being to serve as translator between different communication inter faces, although it can also carry out small control tasks. In the project we describe here, the principal role of the TINI board is to act as intermediary between the high level control applications and the low level hardware controllers in the car (mainly accelerator, breaks, steering). It therefore acts as translator between the Ethernet interface, which communicates with the machines that execute high level applications and the CAN bus which connects all the microcontrolled exchanges of the vehicle.

The hardware architecture (Fig. 2) has been organised in two layers, in which low level controllers and electronics (typically microcontrollers) communicate trough a CAN bus operating at 500 Kbs, and high level electronics (typically microprocessors) communicate through an ethernet bus operating at 100 Mbs.

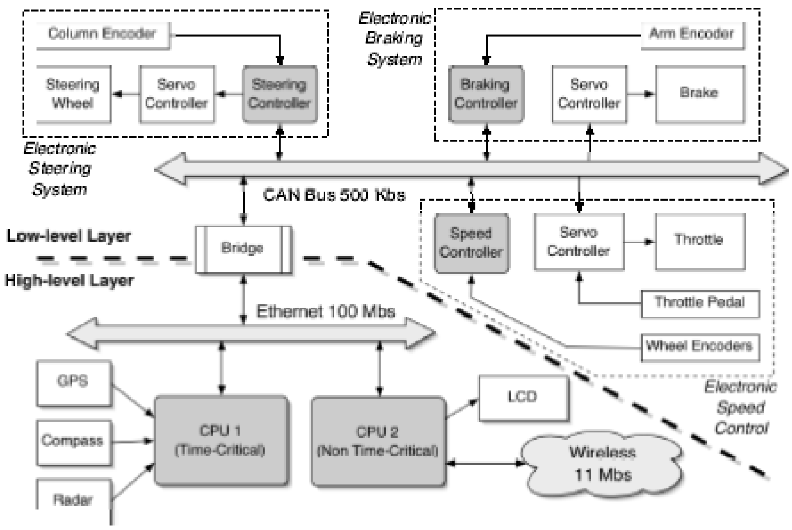

Figure 2. Hardware architecture

The design goals for the hardware architecture were modularity and scalability, in such a way that adding a new module did not interfere with the existing ones. The low level microcontrollers are in charge of close-loop controlling the actuators and sensor data acquisition. The high level microprocessors are in charge of running all the intensive computations software, bridging the two layers, and communicating the vehicle with off-board equipment through wireless links. The following sensor and control modules are found in the car, as can be seen in figure 3:

- Novatel GPS receiver with EGNOS corrector.
- Trimble GPS receiver with RASANT corrector.
- Electronic compass with inclinometer compensation.
- Odometry acquisition module for the four wheels.
- 77GHz radar sensor.
- Steering control module.
- TINI module for Ethernet-CAN interface.
- Principal SBC-P111 control CPU.
- Break control module.
- Accelerator control module.
- Ethernet concentrator module (Switch).
- SBC-P111 CPU console with 12" LCD-TFT.
- Control module for alphanumeric LCD.
- Access point to 802.11 network.

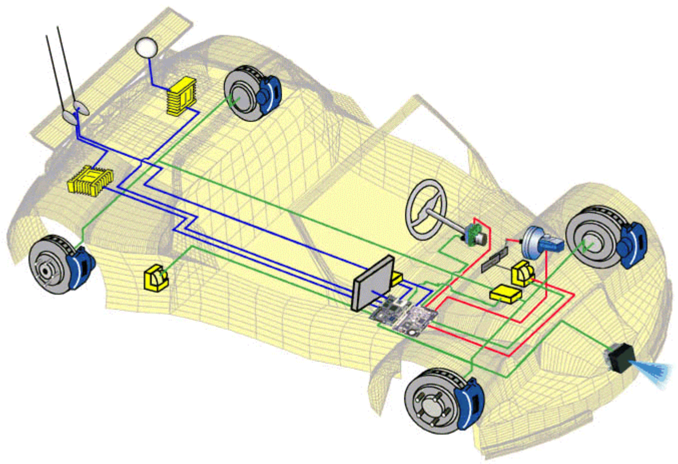

Figure 3. Structure of automated car.

The GPS receivers, electronic compass and radar have an RS-232 series interface and so we opted for direct connection to the SBC-P111 gate. As the radar did not fulfil norm RS-232, an adapter circuit was necessary. The PCs and TINI, as already stated, were connected in ethernet by a concentrator, while all the other modules were interconnected by a CAN network. The following figure (fig. 4) shows an overview of the connections.

Another important element is the IEEE 802.11 network established between the convoy vehicles in order to transmit control and positioning information from the lead car to the following driverless car. In closed circuit tests (University Campus and race tracks) a third node was established as base to receive information from both vehicles and from which it was possible to control the unmanned car.

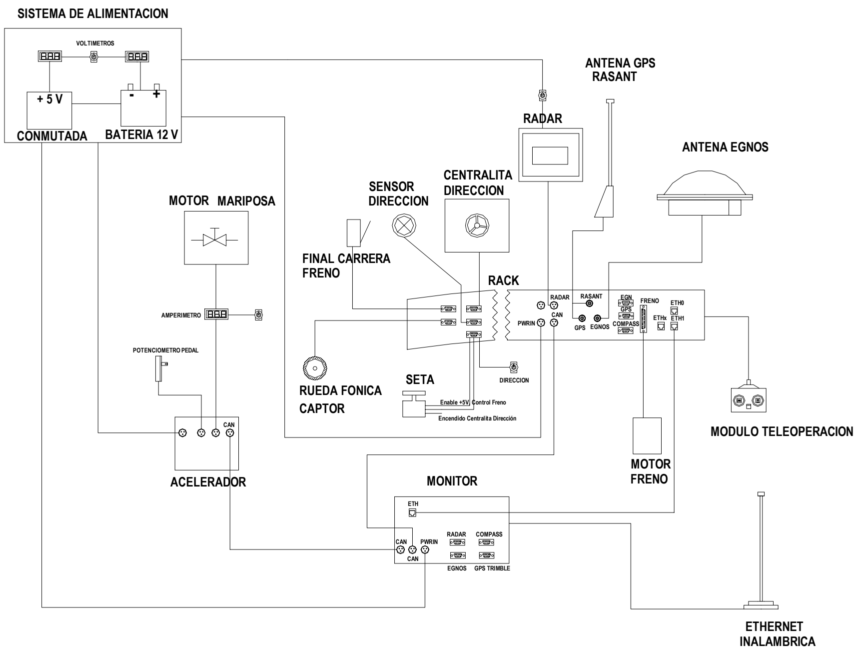

Figure 4. Global Diagram of the Interconnections.

The monitoring and control network was set up in such a way that it can be used both in a local (in the car itself, using screen and keyboard) and remote way from any computer with Ethernet. Such remote control was limited by the maximum reach of the ISM 2.4 GHz band.

Both the interchange of control messages and information on the positioning and state in the Ethernet used UDP connections. Such messages were constructed according to a protocol which took into account the need not to overload the messages and not to slow down the control cycles, but which permitted clear differentiation between the messages sent.

Electronic Speed Control

The electronic speed control system consists on four different elements: the throttle pedal sensor, the servo actuated injector, the servo controller, and the speed controller. The servo controller and the speed controller are connected through the CAN bus. The speed controller is a hierarchical fuzzy controller that uses both the wheel encoders and road steepness information to decide the position of the injection servo in order to maintain a commanded speed. This command is named as *set-speed*. It is important to note that given the available engine power and the light weight of the whole vehicle, the plant presents high non-linearities. In particular, controlling both acceleration and deceleration are important issues. Thus, there are three basic controllers: one for uphill control, one for downhill control and the other for in level control. The selection of the active controller is performed by a high level controller whose input is the pitch/roll data. Depending on the values a combination of the basic controllers is executed. The output of the pitch/roll sensor used is quite noisy and a fuzzy IIR filter is applied to the sensor in order to smooth the signal. The servo controller receives both the throttle pedal sensor signal and the speed controller output and actuates the servo position accordingly. In the case that the throttle is actuated by a human operator, the manual input takes control over in any condition. All the electronics for both the servo control and speed control have been custom designed.

Electronic Braking System

The electronic braking system consists on the pedal actuator, a Maxon motor controller and the braking controller. The pedal actuator is a complex mechanical structure that allows parallel actuation of the pedal for both the human operator and the braking motor. The braking controller is in charge of applying braking patterns by sending signals to the motor controller through the CAN bus. A braking pattern is composed of three parameters: motor pressing time (to control the pressure applied to the brakes), motor standby time (to control how much time the brake is kept pressed), and motor releasing time (to control how fast the brake is released). The braking pattern command is named as *set-brake*. Both the braking controller electronics and the mechanical structure have been custom designed and built.

Electronic Steering System

The electronic steering system consists on a Delphi power steering column and a steering controller. The power steering column is directly attached to the steering controller. It includes a switch to engage or disengage the automatic control. The steering controller is a fuzzy controller that uses the steering column absolute position sensor to maintain a given wheel angle. The steering command is named *set-steer*. The steering controller has been custom designed.

APPLICATION TO NAVIGATION

To know the state of the system at any given moment, we have developed an application, several screens of which are shown in Figure 5 and whose main aim is the remote monitoring of the vehicle. The application permits the operator to know its exact location (GPS/EGNOS and electronic compass), speed, position of obstacles (radar) and the internal state of the devices. The application also incorporates a series of controls for the remote operation of the vehicle.

The window “User Control” shows the car’s direction given by the electronic compass and the speed at which it is moving. The part of the interface which acts on the car is also available. This consists of a slider to turn the steering wheel and another to send values to the accelerator. A set of three sliders determines the behaviour of the brakes, which is sent to the automatic brake controller. Three buttons permit a pre-programmed effect. The controls are easy to use and remote control of the vehicle is straightforward.

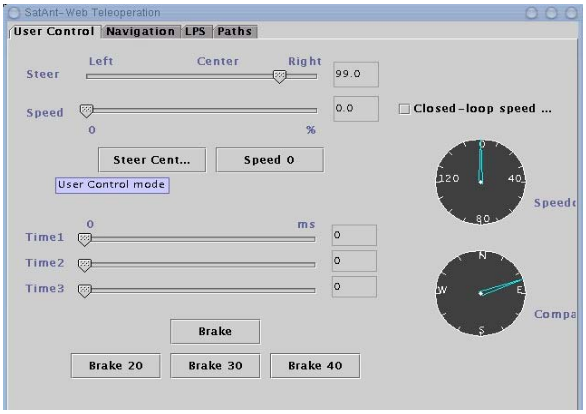

Figure 5. **N**avigation application.

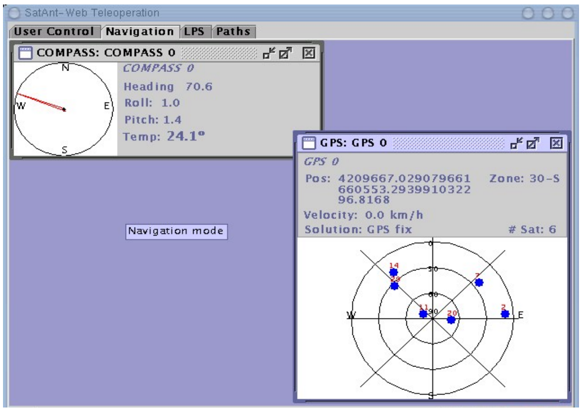

Figure 6. Control application.

The accelerator can be activated by "open loop" or "closed loop" circuit. In the former, an absolute value is sent to the accelerator, whereby the butterfly valve of the engine opens to an extent proportional to the value sent, while in the latter the desired speed is sent to the speed controller, which, in accordance with the values obtained by the sensors, regulates the valve opening to maintain the speed (set point).

To control braking, the behaviours of the automatic brake control is operated. Three bars are included in the application to select the time that the brake control should be in each of its states, along with three buttons with these times preset for given speeds.

The window "navigation" shows the GPS data received by the car and the information from the compass. The compass window provides the heading and other data such as inclination (pitch and roll) and temperature. The GPS window shows the position in UTM coordinates, the speed, solution type and number of satellites being received. These satellites can also be depicted in the lower part of the display according to the elevation and azimuth with respect to the vehicle.

The window "LPS" (*Local Perceptual Space*) shows the data provided by the radar installed in the front of the car. This information gives a picture of the space in front of the car. Lastly, the "Paths" window provides a georeferenced map of the zone through which the vehicle is moving and represents the vehicles in accordance with the data sent by the localisation devices (compass and GPS) of both cars.

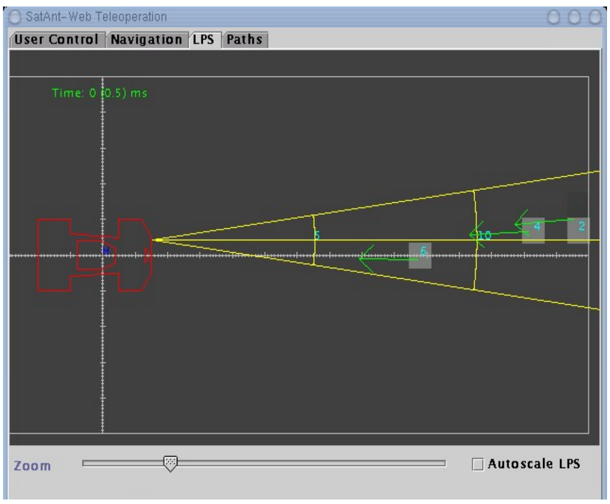

Figure 7. Radar Application.

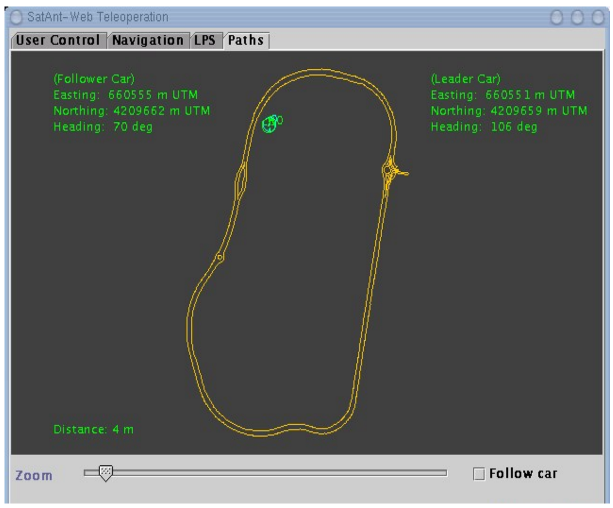

Figure 8. Localisation Application.

The picture shows the cars represented on the map when they were parked outside the Information Technology Department of the University of Murcia. The application also permits zooming to show the position better. The green car in this case is the lead car and the blue car the automated one.

Egnos Evaluation

One of the main interests of this research has been to use a satellite based augmentation system as one of the main onboard sensor for Satellite Positioning System (SPS) and navigation systems in safety driving applications. The objective is to integrate the information of different sensors (GNSS, digital maps, inertial sensors, etc) in order to be able to obtain the position with great accuracy and precision, and in that way to be able to take decision on the driving.

We configured an onboard unit (OBU), with the GPS receiver, an antenna, personal computer and other sensors in the MIMICS vehicle and next we proceeded to circulate with the car through different trajectories in order to acquire some logs around the Espinardo Campus of Murcia University. The objective was to compare the data recorded of the position of the car in relation with a high precision digitalized map of the campus area, and in that way check the precision and accuracy of the navigation using EGNOS.

Fig. 3 shows how the trajectory along the two lanes are recorded. It also shows that the maneuver of a 90º turn to park the car, and another 90º turn after parking have been correctly logged. The dots represent the positioning data and the arrows reflects the direction of the trajectories in each point.

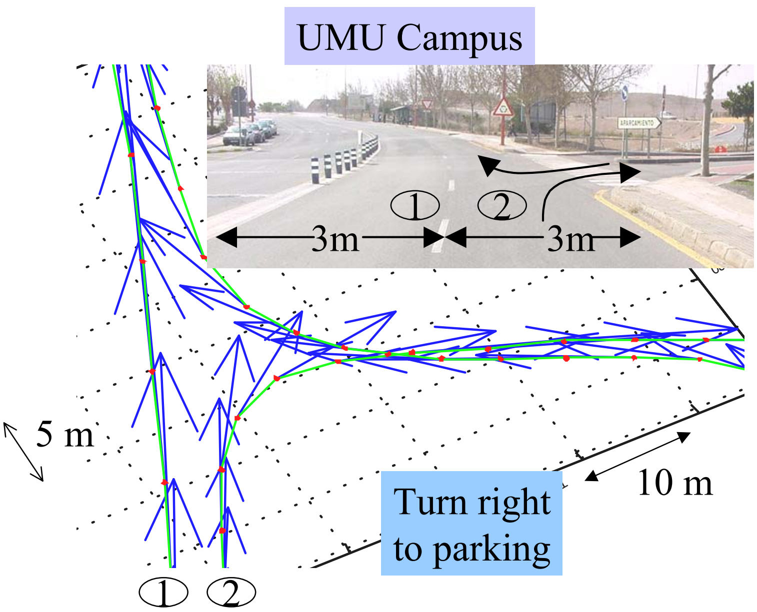

Figure 9. Trajectory recording

The lane width is about 3m, the minimum for a motorway. The data recorded shows the different trajectories of the car by each lane and the operation of parking. In that sense the system may discriminate both trajectories along two lanes, useful for example, in black box data recorder applications after a traffic accident.

CONCLUSIONS

The MIMICS Project, the first step in ITS research in our group, analyses the advantages which new technologies can offer for the future of road transport, both vehicles and the infrastructure itself will make use of the enormous possibilities offered.

The results of the experiments presented in this paper show that the use of the EGNOS signal could be of high value in the management of the vehicle movements and position control. The system is, in general, valid for most ITS applications, for example, automatic driving, trajectory data loggers for vehicle accidents, etc. However, there are many problems still to be solved, i.e. the poor availability of the GPS constellation in urban areas, and how to select the best communications channel to give data corrections to the onboard unit.

SISNeT is a valuable tool for navigation services in urban areas. In applications where a high degree of precision and accuracy in real time is a basic necessity, SISNeT access by GPRS will be an ideal solution.

The MIMICS Project is the first step in ITS research into the advantages which new technologies can offer for the future of road transport, in which both vehicles and infrastructure will make use of the enormous possibilities offered. It should be emphasised that MMICS has focused on the kinematics of two vehicles assisted by satellite navigation systems and radar, and that more research is necessary within the wider framework offered by all concurrent technologies.

Based on an evaluation of the results obtained, our forthcoming objectives will be:

- in the framework of positioning and localisation, to evaluate in a real and varied environment the EGNOS technology and its benefits from different perspectives, including its associated services such as the reception of correction signals by Internet with the corresponding advantage of overcoming problems of cover in urban areas;
- to look at safety by integrating the information received by various sensors through a control architecture that will warn drivers of possible anomalous situations;
- to analyse on board systems by integrating navigation systems, positioning information, access to CAN bus with signals from the systems and with access to different sources of information, both internal and external, which can be presented to the user on screen;
- to access information and different telematic services, by example by connecting the user's PDA equipment to the car's information system, for the exchange of personal information, such as navigation maps or any other interaction between the user and the vehicle.

To achieve these ends fourth generation mobile systems and the corresponding techniques for their use will be necessary. New solutions in the 5 to 18 GHz bandwidth, the management of radio resources in a multi-system environment and new techniques accessing techniques in radio systems will be developed.

ACKNOWLEDGEMENTS

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