IEEE802.11p Field Operational Test implementation and driver assistance services for enhanced driver safety

U. Hernández-Jayo, *Member, IEEE,* N. Sainz, I. Iglesias, M.P. Elejoste, D. Jiménez, I. Zumalde

Abstract— **This paper describes the work-in-progress that Mobility research group of Deusto Institute of Technology has been doing in the area of Intelligent Transport Systems for the last two years. This work is divided in two main areas: one is focused on the development and test of a real VANET network and the aim of the second one is to provide the services that could be provided over this validated VANET network.**

I. Introduction

Great efforts, both in research centers and companies are currently underway to develop and deploy vehicle communications networks. Most of the times, the applications to be deployed over these networks are designed to improve the drivers' safety, traffic management and to inform about events or accidents that may happen on the road [1]. To this end, it is necessary to have a robust and reliable communications network and a set of services aimed at providing information to drivers and to the managers of the roads.

Therefore in this paper we propose a set of simulations based on the NCTUns engine in order to validate a set of proposed scenarios (RSU to OBU and OBU to OBU communications) that we will then test on real Field Operational Test (FOT). These FOTs are designed to compare the results obtained in the simulations with those obtained in the real FOTs and therefore, use the simulator as a tool for subsequent prototypes. Thus, Section II of this paper intends to describe the work we are doing with the NCTUns simulator and the results achieved in this regard with the proposed scenarios. Then, Section III presents the communication modules in which we are currently working to deploy a real VANET communications network, in a near future, at the proposed FOTs.

As we said at the beginning of this section, once communications network are provided, we need to deploy services in order to improve driver safety and to provide data and information about the road drivers and managers. To achieve this, in Section IV we present the work we are currently developing in the field of video processing in real time. This work is based on a set of services designed to report the driver with information collected from the road using a video camera that in future applications could be embedded in a Smartphone. Section V describes the work that we are developing to obtain information from the road using a Wireless Sensors Networks connected to the RSU, so that we can bring this information to the driver (using an On Board Unit) through the VANET communication network previously deployed. Finally we present the conclusions and future work to develop in these areas of this work.

Manuscript received April , 2011. This work was financially supported by Basque Country Government under the Gaitek funding program (IG-2009/0000188).

The authors are with the Mobility Research group at Deusto Institute of Technology, Av. Universidades 24, 48007 Bilbao, Spain (e-mail: unai.hernandez[at]deusto.).

II. FOTs Simulations and Results

Deploying a new service based on a new and not mature technology is necessarily complicated. Even harder when, in order to check its correct behaviour, a large number of interoperating nodes or a well established infrastructure is required.

In many cases it is necessary to base previous research on a simulation of the scenarios before any Field Operational Tests (FOTs) can be done. Anyway, having to choose a simulator for C2X-Communications is not always an easy task. Many of them are very powerful but lack the necessary implementation of the standard so it has to be developed or bought, with the cost or the time attached to such proceedings. Most of the simulators consist of different software modules which are responsible for simulating some specific protocols. Those modules can be bought in some cases but sometimes they simply do not exist and therefore have to be programmed if the simulator is prepared for it.

For that reason and taken as a basis a previous study [2], it was decided to lead a series of simulations on NCTUns 6.0 simulator. This software requires a specific Linux kernel so that it can use the protocol stack of the operating system. This technique makes the simulations more reliable, as the packets being transmitted within the multiple scenarios travel through an authentic protocol stack. Another important aspect of this simulator is that it offers the researcher the possibility to test their software, both networking applications such as protocols, or just desktop applications configured to use the simulator, as it provides a common interface to that purpose [3].

Using this simulator, we have performed different simulations in order to study the IEEE 802.11p communications link in different scenarios, the first one between road side units and on board units, and the second one with two OBUs transmitting data information to each other. These two different scenarios are shown on Fig. 1 and described below.

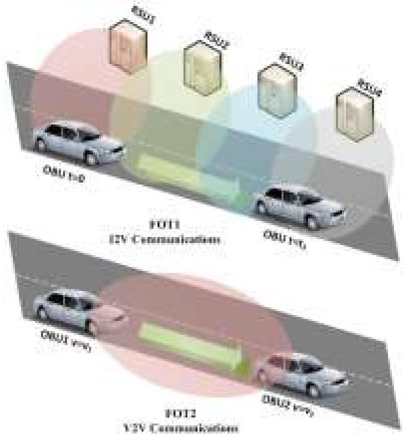

Fig. 1. Proposed FOTs

A. RSU to OBU communications scenario

In this way, we have carried out some simulation tests over the same scenario in which there are four different road side units, with 1km of distance between them, transmitting packets to one vehicle that circulates over their coverage area.

The transmitting power of the RSUs is 21 dBm, and the data rate of each RSU is different; 3, 6, 18 and 27 Mbps. Moreover to check the influence of the vehicle´s speed on this type of communications we have performed four simulations in this scenario, with one vehicle circulating at different speeds; 50, 80, 120 and 180 km/h.

Seeing the results of Fig. 2, we can see clearly the handovers between RSUs over the simulation time, which are represented with the steps on the graphic, corresponding to the variation of throughput obtained in the OBU measurement. There are four different steps, each one from each RSU. First one corresponds to RSU 1 that is transmitting with a rate of 3 Mbps. Second one, with RSU 2 transmitting with 18 Mbps of data rate. RSU 3 transmits with a rate of 27 Mbps and the last one corresponds with RSU 4, transmitting over 6 Mbps.

The obtained results shown in Fig. 2 illustrate the measured throughput on the vehicle when it moves across the entire simulation scenario. Besides, on Table I the values of average throughput measured on the OBUs moving with different speeds are shown.

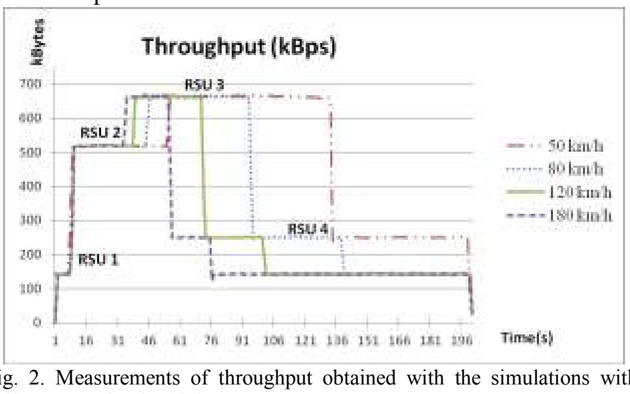

Fig. 2. Measurements of throughput obtained with the simulations with different speeds of vehicles.

TABLE I
THROUGHPUT IN RSU TO OBU COMMUNICATIONS WITH VEHICLES AT DIFFERENT SPEED

	RSU 3 Mbps	RSU 6 Mbps	RSU 18 Mbps	RSU 27 Mbps
OBU 50 km/h	9,01 kBytes/s	47,16 kBytes/s	66,63 kBytes/s	135,85 kBytes/s
OBU 80 km/h	30,75 kBytes/s	33,51 kBytes/s	52,45 kBytes/s	88,68 kBytes/s
OBU 120 km/h	44,19 kBytes/s	24,39 kBytes/s	44,18 kBytes/s	61,15 kBytes/s
OBU 180 km/h	53,27 kBytes/s	18,17 kBytes/s	38,49 kBytes/s	42,47 kBytes/s

Analyzing these results, we can conclude that the variation of the RSU´s transmission rates affects to the throughput of the received data in vehicle. When the RSU transmits with low data rates, the measured throughput on the vehicle is low, meanwhile if the data rates of the road side units increases, the measured throughput is higher.

With the results shown in Table I, we can conclude that the throughput is higher when the vehicle is moving at 50 km/h and decreases as speed increases. We can say that vehicle´s speed affects to the communication throughput, because the system works better when the vehicles move with low speeds in V2I communications. And when the vehicle is moving with low speed, about 50 km/h, the system works better when the RSU transmits with high data rates, about 27 Mbps. Instead, at high speeds, about 180 km/h, the system works better with a RSU transmitting at low data rates, about 3 Mbps. Finally, we can conclude that for moderated speeds (between 80 and 120 km/h) the system works better with a RSU transmitting at 27 Mbps. These conclusions will determine the throughput for safety alerts depending on the speed of the vehicle.

B. OBU to OBU communications scenario

The second scenario created aims to find out the influence of the vehicle´s speed on V2V communications. For that purpose, the scenario analyzes the transmission behavior between two vehicles that are moving with different speeds and transmitting packets between them. One of these vehicles works as a transmitter (always moving at 120 km/h and transmitting with a data rate of 6 Mbps) and the other one is the receiver (in the first test moves at 80km/h and in the second one, its speed is 40 km/h).

The obtained results in this simulation scenario are shown in Table 2 in terms of average throughput. Also, Fig. 3 shows the results of both tests on a graphical mode that compares the throughput along all the simulation time.

Thanks to these results, given a road speed, it will be possible to optimize data transmission and adjust

TABLE II
AVERAGE MEASURED THROUGHPUT ON INTER-VEHICLE COMMUNICATIONS WITH DIFFERENT SPEEDS.

	Receiver 80 km/h	Receiver 40 km/h
Transmitter 120 km/h	63,84 kBytes/s	32,71 kBytes/s

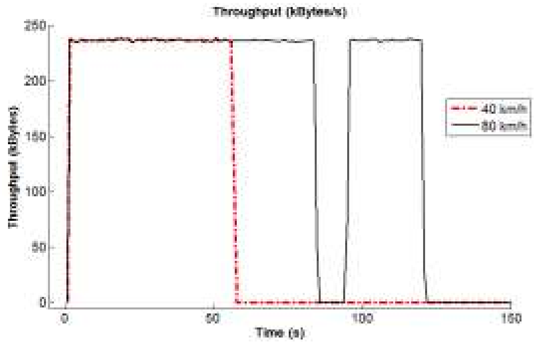

Fig. 3. Comparison of the throughput obtained when the receiver moves at 40 km/h and at 80 km/h

Analyzing Table II and Fig. 2, we can say that when the receiver is moving with high speed, the number of received packets increases. So, we conclude again, that speed on vehicles affects the quality of the transmissions. In this case, we have to pay attention to the fact that the throughput of the vehicle that is moving at 40 km/h is low due to the spent time of this vehicle inside the coverage area of the transmitting node, because it is less than in the case of the vehicle that moves at 80 km/h.

So, we can conclude that, on V2V communications, speed of vehicles that are transmitting data between them is a very important factor. If the difference between both speeds is high, the throughput of the communication will be low, due to the coverage area´s influence of the transmitter node.

III. Developing a Real Scenario over 802.11p

An aspect which has always been of great interest in our laboratory is evaluating the performance of the applications in a close to reality situation. For that purpose, and taking into account that we are focused on Car-to-Car or Car-to-Infrastructure communications our work is centered on operating with two NEC LinkBird MX modules, that are shown at Fig. 4.

Other alternatives were taken into account such as [4]. It proposes a full-stack prototype implementation to data exchange among vehicles based on FPGAs. This was discarded in favor of the commercial solution offered by NEC.

These modules offer a great variety of interfaces for communicating in the 5.9GHz band. A 30MHz band was allocated by the ETSI for Intelligent Transport System to use it in Car-to-Car and Car-to-Infrastructure (C2X) communications centered in the 5.9GHz band [5].

Fig. 4. NEC LinkBird MX

The technology is founded on ad hoc networking, using protocols based on knowing the position of nodes rather than their situation in the topology. The so called "Geocast" routing protocol, assumes that vehicles acquire information about their position (i.e. geodetic coordinates) via GPS or any other positioning systems [5]. Routing becomes a matter of knowing where the target is located, and then forwarding packets so that in each hop, they get closer to their final location. For that purpose each node keeps track of other node's position in a table.

The LinkBird MX modules, with their compact size and communication capabilities offer a great chance to test whether the simulations where correct and to emulate some scenarios in a way that is much more realistic than the one presented on the simulations.

In order to evaluate the performance of these modules in a close real situation, it was decided to regard one of them as being a Road Side Unit (RSU) offering a service such as those referred to as Infotainment, and the other module as being part of the On Board Unit within a car. Starting sufficiently far from the RSU and getting closer, it was possible to determine the association time needed to establish a connection between both modules. As a sub product of these experiments it was also possible to determine antennae coverage, signal level threshold for a communication to be established, achievable throughput between nodes etc.

The original idea of introducing applications in the On Board Unit was recently discarded. Nearly every user will have a Smartphone with the capabilities to run resource-demanding applications such as those needed for the Safety or Infotainment services, which will be developed in the near future. These applications should be able to access the On Board Unit creating a Wireless Personal Area Network (WPAN) such as a Bluetooth based communication, to then access the rest of the network.

Further experiments will focus on the one hand, on the possibility of handing over a dataflow from an IEEE802.11p based network to an IEEE802.11g one. This scenario represents the Infotainment point of view of Car-to-X communications. An example of this kind of communication is proposed by Marica Amadeo et al [6]. On the other hand, other set of experiments are going to be focused on Safety. In this later case, the throughput and handover tend to be less relevant but delays and latency between safety applications becomes critical. Both scenarios require a similar architecture but in order to start with the FOTs a deep analysis of the situation must be performed so as to have at least an idea of what results should offer the implementation in terms of BER vs speed and latency vs speed and throughput vs speed.

Once the results are valid, we will focus on developing services that could benefit from this architecture such as those presented in this paper. As an example we could modify the "Driving Guidance Service" to notify further vehicles, that a lane change is taking place. In case another vehicle is circulating close to the emitter, a warning message could be displayed and have the driver informed about the changing of line of a vehicle close to him.

IV. DRIVING GUIDANCE SERVICE

These driving guidance systems are focused on providing drivers with real-time information related to the car's environment by performing a continuous image process together with other techniques.

The main purpose of the "Driving Guidance Service" (Fig. 5) is to generate relevant information in order to help the users' driving and try to simplify it as much as possible. However, it is important to bear in mind that all these systems should always make driving easier without interfering the users' effort o attention. Thus, even though this service is just a prototype executed on a computer, it is regarded to be displayed through low cost common devices which can be afforded by almost every driver. So as to accomplish this goal, smart phones or video-cameras should be used. The selected device is placed on the car's dashboard and records everything in front of the car.

The system described in this paper could work in the following way:

1) In the first place, the recorded video is divided into frames and each frame is processed individually.
2) Secondly, the frame is processed to adjust the image to some specific characteristics such as weather conditions, frame size...
3) Subsequently, the modified frame is analyzed to recognize and identify several issues involving road lanes detection, traffic lights detection, obstacles detection, traffic signs detection… The cardinal task of the system in question is carried out at this point.
4) Finally, once the previous tasks have been performed, the system makes use of the provided information and gives the user some advice concerning the overtaking conditions, the recommended driving speed, the distance to the front vehicle and so on.

All these services rely on the fact that humans tend to lose their attention while executing the same activity for a long time [7][8][9]. So, according to this, what the users expect to receive are warnings when an unexpected event occurs (e.g. one car stops all of a sudden, the user is changing of lane…).

Fig. 5. Driving Guidance Service Interface

Nevertheless, this is insufficient. Not only the user needs to know that an unforeseen act is taking place, but he/she needs to know if it is possible to perform one action or not (e.g. know the maximum driving speed permitted at a road section, know whether it is possible to overtake or not…). Besides, even though the system processes each frame separately, successive frames are compared and analyzed together in some situations to identify relations concerning an object position or to discard false positives. Hence, the system accuracy is higher and performance increases considerably.

Compiling the total previous characteristics, we decide to take advantage of MATLAB products to develop this service. MATLAB, apart from being one of the best languages of technical computing, fits perfectly the system requirements [13][14] More precisely, all the algorithms utilize the "Image Processing Toolbox" which provides the user with many functions that significantly simplify the image analysis [10][11][12].The core of the application relies on the following feature which can be easily executed in the user interface: Road Lane Detection.

The road lane detection algorithm works with individual static images, so, as it has been said before, the video needs to be separated into several frames. Once this step has been carried out, the colored frame is transformed into a black-and-white frame in order to be able to execute the two main functions of the algorithm:

- Bwboundaries. It seeks both, internal and external region boundaries in a binary image. "Traces the exterior boundaries of objects, as well as boundaries of holes inside these objects." [15]
- Regionprops. It gets the properties of all the regions found at the previous step. "Measures a set of properties for each labeled region in the label matrix."[16].

In spite the fact that 'Regionprops' function combines many properties, just some relevant ones have been selected: Eccentricity, Area, Orientation, Extrema, MinorAxisLength and MajorAxisLength. With all these properties, we develop a filter to eliminate all the unnecessary regions. Each property play an important role described below:

- Eccentricity: exclusively find the straight shapes.
- Area: discard regions with too many pixels or the other way round, discard regions which have not got enough pixels.
- Orientation: get rid of horizontal regions.

MinorAxisLength and MajorAxisLength specify the road lane dimension. The first term refers to the road lane width and the second one to its length.

- MinorAxisLength: discard those regions with a high amount of pixels in that axis.
- MajorAxisLength: discard those regions with a low amount of pixels in that axis.

At this point, very few regions are left but, in order to avoid having false positives, we perform one more algorithm. (To accomplish this process, it is necessary to

Fig. 6. Different driving situations

make use of the 'Extrema' property that provides an 8-by-2 matrix specifying the eight external points in the region.) This algorithm looks for the longest two regions and determines whether these two regions intersect at some point or not. Moreover, if the two regions intersect between them, it guarantees that this intersection is valid by analyzing its position. Not only is the intersection position analyzed, but also the distance between both regions (in the other ending point) to ensure that the two selected regions are not together. In other words, to assure that one of those two regions does not correspond to the median strip or so.

Finally, there are some situations in which none regions are found. Therefore, once two regions are correctly identified, the two regions properties are stored on a variable to be able to recover them in the next frame process and base the algorithm on such properties in case any intersection is identified, so as to keep providing information to the driver.

The main purpose of this service is not just detecting the road lanes, is being able to generate relevant information and messages by means of the whole process. This relevant information involves road lanes change detection (Fig. 6), distance to front vehicles, know if it is possible to overtake or to park…

Apart from the described service, the system performs some more tasks to give additional information to the driver. These services are: Traffic lights detection, traffic signs detection and obstacles detection among others. All these services provide the user with great advantages. Once the algorithms have been carried out satisfactorily, the system processes the information obtained and displays guidelines in that specific situation, recommending the user what it should be done to accomplish the ideal goal.

All these data transmitted need to fit data rate values in order to guarantee a successful transmission. Now we know throughputs at different speeds, it is possible to optimize the information to be transmitted.

V. WSN and VANET Networks

Sensor networks provide a simple effective and inexpensive way to gather critical environment information that may be different as needed. Advances in microelectronics to reduce cost and targeting a minimum consumption and maximum durability of this type of network, offer a wide range of possibilities that Mobility group is exploring with the aim of incorporating them to Intelligent Transport Systems.

The goal is to combine the Wireless Sensor Networks (WSN) with VANETs to provide the driver with relevant information about the area in which he/she enters. The developed system will be aware of the surrounding events in order to encourage the driver as to reduce the actual speed or to alert them of fortuitous risks. Basically, our work focuses on three security applications in completely different environments, although over time our intention is to expand the supply of on-board services.

The first developed demonstrator consists of a pedestrian detection system. The clearest example would be a crosswalk near a school. While in Spain near the schools and childcare centers speed is limited 30Km/h and they must be provided with adequate horizontal and vertical signals, the reality is that knocking downs occur even in areas of good visibility, due to forgetfulness or loss of attention.

What we propose is to deploy a proximity sensor network (a low cost PIR[1] solution [17] would be enough, focused on the crosswalk to detect people) close to pedestrian crossing. At a certain distance in the opposite direction of vehicles, a RSU should determine whether the coming cars may not have time to react and send them via IEEE 802.11p (WAVE), a warning message or recommendation to moderate their speed.

In the future, this same implementation could be applied with minimal changes to rural environments, or poor visibility areas (sharp bends or dips in the roads) in which there is pedestrian crossing, or even to control animal crossing to avoid knocking down in access of hunting areas or nature reserves.

As a second implementation, we are working on using sensors to measure air quality in urban areas [18]. Recent studies by ecological organizations say that 14% of Spanish population breathes polluted air, traffic being a major cause of pollution in metropolitan areas [19]. To improve this situation, we propose the following scenario. If the sensors in a particular area of the town detect levels of CO, NO, SO_2 and CO_2 exceeding the recommended ones, then they will inform the RSU of the event, so it could warn those vehicles approaching that location, informing them that they will contribute to increased pollution if they continue their way and providing parking options to use public transport within the city or even limiting access to the area at certain times of day (outputs of schools) or enabling dynamic speed limits signals.

Finally, the combination of low temperatures, humidity or shadow areas can generate adverse driving conditions, in extreme cases black ice or slippery roads [20]. Deploying sensors networks that measure temperature, light or humidity can help identifying situations of risk and then inform approaching vehicles to drive with the utmost care.

Though the previously discussed scenarios are diverse, the architecture used in all is the same and is explained in the logical-conceptual diagram shown in Fig. 7.

[1] A Passive Infrared sensor (PIR sensor) is an electronic device that measures infrared (IR) light radiating from objects in its field of view. PIR sensors are often used in the construction of PIR-based motion detectors.

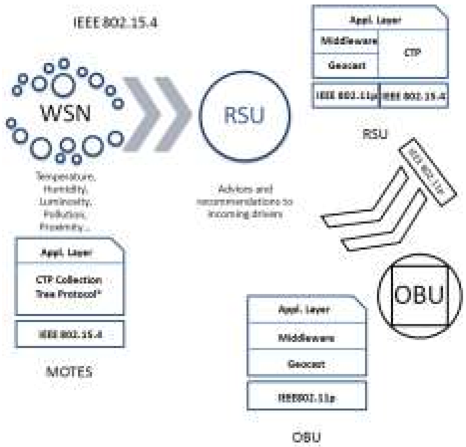

Fig. 7. Common systems architecture

The RSU acts as a gateway between the sensor network and the ad-hoc vehicular network. The WSN nodes will conform the road-side infrastructure, each scenario will implement different measures and data information sources but in all of them the smart element will be the roadside unit, who should determine (based on the received environmental data) if it's a risky situation or not. The Road Side Unit processes all the available information and informs to the On Board unit when necessary.

Both the RSU and OBU nodes are the NEC modules, Linkbird-MX, previously quoted in Section III, whose stack includes the IEEE802.11p latest protocol version, with the NEC proprietary C2X-SDK (release 1.5.1) Geocast routing scheme [21]. They have USB interface that makes possible to connect the WSN master node to the RSU.

The actual work is focused on the development of the RSU application in order to combine both wireless networks and provide intelligence to react according to the collected information. We are making laboratory tests with TelosB motes[2] with the TinyOS official distribution for the WSN and developing the applications for three test cases. Next steps will be to improve the network protocol to another one that minimizes the energy consumption of every mote. The Collision Tree Protocol (CTP) included in the official packages is not aware of that, but in the actual stage is not a critical issue for us. Then, we will be ready to test them in pseudo-real scenarios.

VI. Conclusions and future work

As a conclusion to the presented work-in-progress we can say that there is still much work to be done in the field VANET communications. We must continue to improve the functionality and features of vehicular communications based on IEEE 802.11p, testing it in more real FOTs. Then, once this communication system is stable, we could begin to deploy security services as we have described in this paper, using this network infrastructure. In addition, we are currently testing the ability of smartphones to work as HMI in the vehicle in order to use these gadgets as access points to the on board deployed services and to the information sent by the traffic management units, thorough the RSU arranged to this purpose.

[2] MTM-CMT3000 MSP, IEEE 802.15.4 compliant wireless sensor node based on the original open-source "TelosB" platform design developed and published by the University of California, Berkeley ("UC Berkeley") designed and developed by Advantic Sistemas y Servicios S.L..

References

[1] Car-to-Car Communication Consortium, "C2C-CC Manifesto, Version 1.1," August 2007.

[2] P. Urmeta, "Simulation and Improvement of the Handover process in IEEE 802.11p based VANETs".

[3] S.Y. Wang and C.C. Lin, "NCTUns 5.0: A Network Simulator for IEEE 802.11(p) and 1609 Wireless Vehicular Network Researches," 2nd IEEE International Symposium on Wireless Vehicular Communications, September 21–22, 2008, Calgary, Canada. (demo paper)

[4] D. Carona, et al., "A IEEE802.11p prototype implementation" IEEE Intelligent Vehicles Symposium, University of California, San Diego, CA, USA, 2010.

[5] A. Festag, et al., "Car-2-X Communication for Safety and Infotainment in Europe"

[6] M. Amadeo, et al., "Enhancing IEEE IEEE802.11p/WAVE to provide infotainment applications in VANETs". Ad Hoc Networks. S.1.: Elsevier, 2010

[7] National Institute of Mental Health (NIMH) in the U.S.A., "Attention Deficit Hyperactivity Disorder", March 18, 2011.

[8] National Institute of Neurological Disorders and Stroke in the U.S.A., "Attention Deficit-Hyperactivity Disorder", March 21, 2011.

[9] National Center for Biotechnology Information in the U.S.A., "Adult ADHD", March 21, 2011.

[10] Robert Kastner, Thomas Michalke, Thomas Burbach, Jannik Fritsch, Christian Goerick, "Attention-based traffic sign recognition with an array of weak classifires". 2010 IEEE Intelligent Vehicles Symposium University of California, San Diego, CA, USA, June 21-24, 2010, pp. 333-339.

[11] Robert Kastner, Thomas Michalke, Jannik Fritsch, Christian Goerick, "Towards a task dependant representation generation for scene analysis". 2010 IEEE Intelligent Vehicles Symposium University of California, San Diego, CA, USA, June 21-24, 2010, pp. 731-737.

[12] A. Jazayeri, H. Cai, J. Y. Zheng, M. Tuceryan, "Motion Based Vehicle Identification in Car Video", 2010 IEEE Intelligent Vehicles Symposium University of California, San Diego, CA, USA, June 21-24, 2010, pp 493-499.

[13] MathWorks (Massachusetts, U.S.A.), "Image Processing Toolbox", March 13, 2011.

[14] The University of Western Australia, Peter Kovesi, "Why I use matlab for forensic image processing". March 13, 2011

[15] MathWorks, R2010b Documentation, Image Processing Toolbox, bwboundaries. March 26, 2011.

[16] MathWorks, R2010b Documentation, Image Processing Toolbox, regionprops. March 28, 2011

[17] Pramod, P.J., Srikanth ,S.V. et al. "Intelligent Intrusion Detection System (In2DS) using Wireless Sensor Networks" in proceedings of 2009 IEEE International Conference on Networking, Sensing and Control, VOLS 1 AND 2, Pages: 581-585, Okayama, Japan, Mar 26-29, 2009

[18] Ibarra-Berastegi, G. Saenz, J. et al. "Using neural networks for short-term prediction of air pollution levels" in Proceedings of International Conference on Advances in Computational Tools for Engineering Applications, 2009(ACTEA '09), Page: 498, Zouk Mosbeh, July 15-17 2009

[19] Informe: La calidad del aire en el Estado español durante 2009. Ecologistas en Acción. Oct 2009.

[20] Luchetta, A. Manetti, S. et al. "Forecast: a neural system for diagnosis and control of highway surfaces" in Proceedings of IEEE Intelligent Systems and their Applications, Vol. 13, Issue: 3, pp.20, May/Jun 1998.

[21] Festag, A. Baldessari, R., et al. "CAR-2-X Communication SDK - A Software Toolkit for Rapid Application Development and Experimentations" in Proceedings of IEEE International Conference on Communications Workshops, 2009(ICC Workshops), Dresden, June 14-18, 2009.