SESSION 1A :

TOOLS AND METHODOLOGIES FOR SAFETY AND USABILITY ASSESSMENT

COOPERATIVE INFRASTRUCTURE-BASED INTELLIGENT TRANSPORTATION SYSTEMS FOR IMPROVING SAFETY OF VULNERABLE ROAD USERS

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ABSTRACT:

Innovative advanced systems have been proposed up to date for improving the safety and the efficiency in the mobility of the users of the European transport network. Particularly for road transport, new ITS-based cooperative services for preventing accidents are emerging where users, vehicles and a sensorised integrative infrastructure are the main actors. This paper aims to provide a first set of guidelines for speeding up the convergence process among the different technologies used for multi-heterogeneous sensor data fusion, high level situation understanding and assessment, and for communications, all of them necessary for the development of advanced ITS safety-related services. Analysis will be focused on Vulnerable Road Users (VRUs) and on how this kind of services would contribute to provide them more intelligent and safer urban traffic environments.

1 INTRODUCTION

Innovative advanced systems have been proposed up to date for improving the safety and the efficiency in the mobility of the users of the European transport network. Particularly for road transport, new ITS-based cooperative services for preventing accidents are emerging where users, vehicles and a sensorised integrative infrastructure are the main actors.

The evolution of the technology in the fields of signal processing, high-level behaviour understanding and communications makes possible the development of a set of advanced ITS services. Regarding Vulnerable Road Users (VRUs), safety systems and cooperative services can be deployed in the transport infrastructure, thus contributing to a more intelligent and safer environment.

Focusing the analysis on the behaviours of non-motorised road users (mainly pedestrians, including specific groups such as disabled, elderly and children, and cyclists), this paper aims to provide a first set of guidelines for promoting the advance of technology that will allow in the near future the development of advanced cooperative services for preventing accidents involving VRUs in complex urban traffic environments.

2 RELATED WORK

A lot of efforts are being done at European level for integrating in the same architecture recent advances in sensing, data management and communications technologies, with the common objective of having at the end a framework of reference for the development of new cooperative systems (e.g. projects COMeSAFETY2 [1], DRIVE C2X [2]). In most of them [3-5], safety of road users is addressed by the enhancement of the corresponding on-board subsystems for information gathering and the necessary communications from vehicle to infrastructure (V2I). In addition, only a few of them integrate cooperative systems and VRU [6][7], dealing with the specific requirements that different groups of road users have [8][9].

Therefore, in order to have safer urban traffic environments in the future, the full integration of all road users in cooperative systems is a priority. In addition, new advanced cooperative services for safety need to be designed not only from the perspective of the vehicles but also from the road infrastructure as proposed in [10]. It can be achieved by means of development of efficient communications from the infrastructure to vehicles (I2V) and between infrastructure and the VRU (I2VRU) developing appropriate Human Machine Interfaces (HMI) that may be complementary to other V2X approaches. With this motivation, this paper proposes a framework able to better connect vehicles, infrastructures and urban traffic management centres that aims to serve as reference to deploy ITS services that have a positive impact in terms of safety for the VRU.

3 COOPERATIVE SERVICES DEVELOPMENT FRAMEWORK

By means of the integration of different technological approaches, functionalities offered by the range of ITS oriented architectures existing

nowadays can be extended. From our point of view, any framework for the development of Cooperative Services requires the deployment in the infrastructure of the appropriate technological components [12]: (1) sensors for sensing the environment; (2) powerful machines for processing at different levels of abstraction the information provided by these sensors in order to make appropriate assessment of the

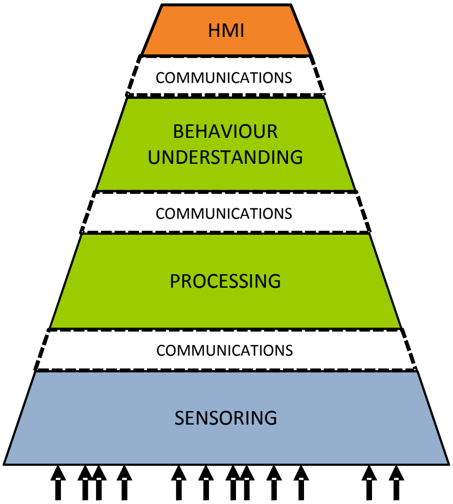

Fig. 1 Proposed framework

situation; (3) communications to guarantee short and medium range link between infrastructure and users; and, finally, (4) personalised HMI, where the proper information of interest for the road user will be provided. These components are further explained below. In addition, a typical scenario involving VRU will be studied in section 4 as a preliminary analysis of the impact these systems have on the safety of a specific group of road users.

3.1 Multi-heterogeneous sensor data fusion

At low level, multi-heterogeneous sensor data fusion has proven its capability to achieve advanced solutions in different fields of research that can be applied in many real traffic monitoring situations [11]. In particular, camera and LIDAR-based technologies have shown remarkable developments over recent years, reaching at the same time cost-effectiveness and reliability. On one hand, cameras provide a lot of visual pre-processed data but are quite sensitive to illumination and weather changes. On the other hand, laser scanners offer robust and accurate distance information even in poor lighting conditions although they do not provide visual information. The integration, fusion and analysis of data coming from multiple sensors allows developing a more accurate and reliable sensing environment.

3.2 High-level situation understanding and assessment

At a higher level of abstraction, the infrastructure gathers and process all the information provided by lower levels. By means of the application of advanced signal processing techniques, exploiting the capabilities that Computer Vision offers, along with recent progresses made in the field of machine learning, we can provide the system with the enough knowledge to perform high level situation understanding and assessment. This high level knowledge covers object detection (pedestrian and vehicles) and event reasoning (E.g. pedestrian crossing the street, cyclists at intersections, etc.) Thus, incidents can be automatically detected as well as other abnormal behaviours that constitute a real risk that may have a negative impact on the safety of road users. With all this information the infrastructure is able to provide intelligent cooperative ITS services.

3.3 Communications

The third basic element of the concept of Cooperative Systems is the communications framework. Communications are involved at every level of the cooperative systems concept, linking different elements of the infrastructure, these with the users, and the users with other users. As it happens with the whole cooperative systems concept, the implementation of advanced communication ideas requires advances at different levels: mobile elements requires the use of specifically mobility oriented radio access technologies such as the IEEE 802.11p microwave-based short range communication link, while the increasing number of communication-aware elements, fixed or mobile and in varied topologies, requires the use of the advanced addressing capabilities of IPv6-based mobile protocols. On the other hand, particular protocols have to be considered at higher level, such as Cooperative Awareness Message (CAM) and Decentralized Environmental Notification Message (DENM) protocols, which specify a set of standard messages between cooperative-aware applications [13].

Particularly, cooperative communication from the infrastructure to the vehicles and the targeted groups of VRU interacting in the urban traffic environment is only possible if the European architecture proposed so far by ETSI TC ITS WG is duly adapted.

3.4 Human Machine Interfaces

The type of information required by each group of road user is completely different, making necessary the adaptation of these systems in order to maximize their safety impact on a broader group of users. It means that information need to be provided through personalised HMI, ensuring safety and privacy in terms of confidentiality, integrity, authentication and authorisation. There exist many possibilities for providing suitable information to the VRU. On one hand, panels and displays can be installed in the infrastructure for non-motorised road users. Data can be also exchanged between the infrastructure and nomadic devices, suitable for their easier life-cycle management and their continued use during the journey. Cooperative applications for safety are expected to be run on different types of adapted nomadic devices which shall actively assist the specific group of VRU while they are interacting with the urban traffic environment.

4 EXPECTED IMPACT ON VULNERABLE ROAD USERS

We have selected for our analysis an urban area with intersection (see figure Fig. 2). On one hand, infrastructure sensors (cameras and LIDAR sensors) acquire data (images and LIDAR points respectively) about the road and traffic environment in order to take at high level appropriate actions, usually of notification to the users involved. Thus, it is possible to detect pedestrian crossing the street in order to warn cyclists and other vehicles moving around about this situation. I2V/I2VRU communications allow the proposed cooperative system to secure a proper connectivity from the urban traffic control centre with the different road users, making it possible the delivery of fast and personalized information to both the different groups of VRU and the surrounding vehicles. Finally, the targeted groups of VRU (in this case, pedestrian and cyclists) are informed by means of adapted interfaces, through PDAs or by the setting of appropriate warning devices and VMS displays in the specific context. In all the cases, the HMI elements should follow a design criteria established by a set of requirements studied beforend.

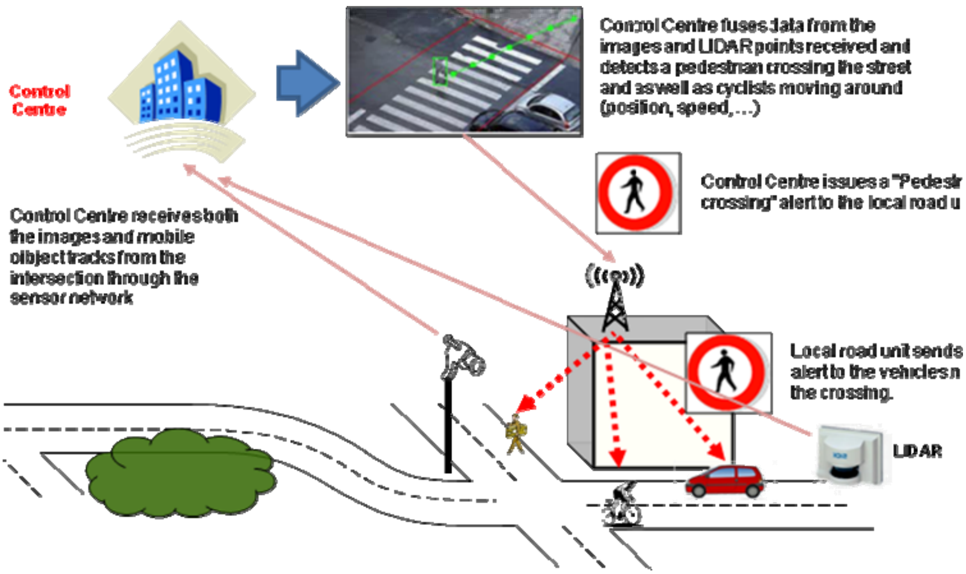

Fig. 2 Automatic detection of pedestrians and other VRUs on the road

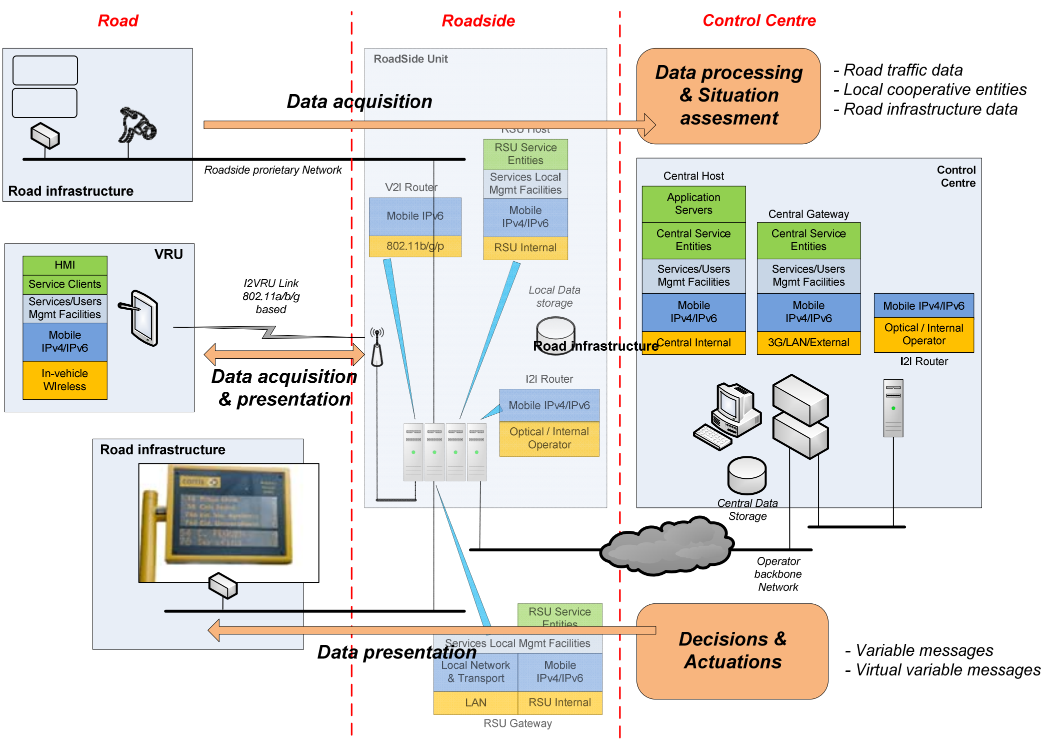

Fig. 3 Architecture for the cooperative service of example following the recommendations from the proposed framework

In order to let this kind of cooperative service have a positive impact on VRU is necessary that Community standards applied to the ITS equipment are used from design, as well as the attention is enhanced in critical situations so that the service allows the road user to make decisions easily. Following recommendations in the proposed framework, the architecture shown in Fig. 3 represents a major step forward to better connect vehicles, infrastructures and urban traffic management centres.

5 CONCLUSIONS AND FUTURE WORK

There are several reasons to act on road deaths: nearly 1.3 million people are killed on the world's roads each year (90% of casualties occur in developing countries), while up to 50 million people are injured, and many remain disabled for life. According to WHO reports, the most vulnerable users—pedestrians, cyclists and motorcyclists—account for 46% of global road traffic deaths.

Innovative advanced ITS systems have been proposed at international level for improving the safety of VRU, as well as the efficiency in their mobility. In this paper, it has been shown how cooperative environments, where road users, vehicles and a sensorised integrative road infrastructure are the main actors, are an indispensable solution for the prevention of accidents with VRU in the field of Intelligent Transportation Systems.

As a result, in this paper a first set of guidelines for speeding up the convergence process among the different technologies used for multi-heterogeneous sensor data fusion, high level situation understanding and assessment and communication purposes are specified when deploying ITS services that have a positive impact in terms of safety for the VRU.

However, impact measures that can be mapped on the existing ITS oriented architectures need to be further studied in order to guide, after their evaluation, new developments, or to improve the existing ones. The creation of new services that enhance users' safety, independence and active living is possible, only if the convergence of behavioural studies and the technological ones is ensured.

6 REFERENCES

[1] COMeSAFETY2 project, Communications for eSafety2: http://www.comesafety.org/

[2] DRIVE C2X project, DRIVing implementation and Evaluation of C2X communication technology in Europe: http://www.drive-c2x.eu/project

[3] INTERSAFE2 project, Cooperative Intersection Safety: http://www.intersafe-2.eu/public/

[4] CVIS project, *Co-operative vehicle-infrastructure* systems: http://www.cvisproject.org/

[5] SAFESPOT project, *Cooperative systems for road safety Smart Vehicles on Smart Roads:* http://www.safespot-eu.org/

[6] WATCH-OVER project, *Vehicle-to-Vulnerable roAd user cooperaTive*

communication and sensing teCHnologies to imprOVE transpoRt safety.

[7] SAVE-U project, *Sensors and system Architecture for VulnerablE road Users protection*: http://www.save-u.org/

[8] PROMISING project, *Promotion of measures for Vulnerable Road Users.*

[9] ACCESS2ALL project, *Mobility Schemes Ensuring Accessibility of Public Transport for All Users:* http://www.access-to-all.eu/

[10] FOTsis project, *European Field Operational Test on Safe, Intelligent and Sustainable Road Operation:* http://www.fotsis.com/

[11] N. Sánchez, A. Cuerdo, D. Sastre, J. Alfonso, J.M. Menéndez, "*Multisensor Data Fusion for Accurate Modelling of Mobile Objects".* Information Systems Technology Panel Symposium on Emerged / Emerging "Disruptive" Technologies (NATO RTO IST-099 /RSY-024), Madrid, 2011.

[12] Alfonso, J., Torres, J. and Menéndez, J.M., ITS-EMEA-0181-2011. "Towards a user goals-based multilayered ITS Architecture". 8th ITS European Congress, Lyon, 8 June 2011.

[13] Menéndez, J.M and Alfonso, J., "Cooperative Systems" Workshop on Resilience engineering to support safe mobility in road transport. Humanist VCE, International invited lectures, Paris, 9 November 2010.

SOFTWARE PROCESSING AND CLASSIFYING OF VEHICLES WITH LASER INTELLIGENT SENSOR (LMS-221)

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ABSTRACT:

Growth in the size of cities and the number of vehicles on them has increased needs for mobility matters. Among negative effects of an excess of circulation we can find the contamination (produced by vehicles) and a reduction of health of drivers related with stress if they do not arrive to their destiny. In order to minimize negative impact of circulation, it is necessary that traffic control systems themselves can change their behaviour to modify traffic status. The Intelligent Traffic Sensors (ITS) can accomplish this task; inside this group, we can find the laser sensor LMS-221. It is possible detect and classify vehicles in real time with designed software and give reliable information for traffic control centre (TCC).

1. INTRODUCTION

According with study realized by UNFPA [1], “In 2008, the world reaches an invisible but momentous milestone: For the first time in history, more than half its human population, 3.3 billion people, will be living in urban areas. By 2030, this is expected to swell to almost 5 billion”. This radical rise of population that lives on cities, will force to optimize elements, which intervene on their trips. Routes of cities can support a peak flow of vehicles by design. If the number of vehicles exceeds the maximum value, the circulation will be slower. The city has many sensors installed on their roads, which give information related with traffic circulation for TCC. This information includes vehicle presence or queues on the road among other things. TCC’s computers process this information and update the status of traffic signals in order to optimize circulation. If vehicle flow raise as time goes by it is a need a better knowledge of vehicle characteristics, it is class and drivers behaviour. An additional effect of increase in the vehicles in the city is pollution. On an article published on DGT magazine [2] “16000 people dies prematurely on Spain by traffic pollution”, deaths related with traffic accident on 2008 were 3100.

In order to reduce negative circulation effects we can use a new generation of intelligent sensors called ITS. Traditional sensors can communicated in one direction with the TCC and they give a measure parameter, such as number of vehicles or images of camcorders. Data processing is a separate element of sensor. ITS sensor can join both stages (measure and process) and give qualified information for TCC. In addition, this sensor class can interact with other sensors located on the road or on vehicles. For example, we have a traditional inductive loop; this sensor can give us vehicle count. An ITS equivalent can give us vehicle class or direction of traffic. This improvement can be accomplished joining sensor and processing system that optimize sensor information.

2. INTRUSIVE SENSORS AND NON-INTRUSIVE SENSORS

They are two classes of sensors [2]: intrusive and non-intrusive. The cut of the road is required for installation and maintenance on intrusive sensors. We can find inductive loops (fig. 1) and piezoelectric sensors on this class. Their advantages are hardness and protection versus environment conditions. On the other hand, non-intrusive sensors have not previous problems. Non-intrusive sensors can work on several roads simultaneously. Camcorders and laser sensors (fig. 2) are on this category. Both sensors can use high structures for their installation (as they need direct view of the road). Their "problem" is the high CPU cost for images processing and the effect of environment condition over the measure process. Laser sensor must be installed perpendicular to the road in traffic light support. Computational cost is lower than camcorders and its less affect by environment condition

Table 1: Traditional sensors

Fig.1. Inductive loop

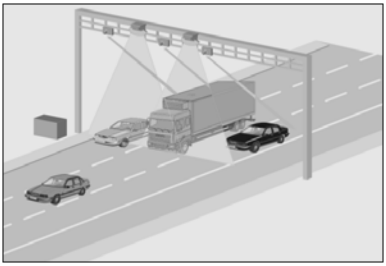


Fig.2. Laser sensor

3. LASER SENSOR

Laser sensor [3, 4, and 5] has three modules: an infrared sensor, a mirror joined with a motor and a control unit. Infrared module work with the principle of "time of flight", i.e., it measures time difference between on emission and reception of laser beam. With the help of the mirror, laser beam can be deflecting along the road. We will call "sweep" a measure over the working range. Control unit, which configure sensor and calculate measures is the last module. Data transmitted to "real world" are coded in frames, formed by several control codes and a vector of heights. Frame structure is as follow:

- STX (1 Byte): Start of Frame.
- Address (1 Byte): contains the address of the laser sensor.
- Length (1 Byte): frame dimension without headers and CRC code
- Command / Response (1 Byte): depends on the mode of the sensor.
- Data (variable): if the sensor is measuring the height, contains the vector of heights.
- Status (1 Byte): contains information of environmental conditions.
- CRC (2 Bytes): code to detect errors in data transmission

We can configure several parameters of laser sensor: baud rate, angular range, angular resolution, and unit of measure (cm/mm). Angular range is the working angle of the motor (0...100º, 0...180º) and angular resolution is the increment of angle of the motor (0.25º, 0.5º, 1º). If we use lower values of angular resolution, it will take more time do sweeps, but we will have more information about vehicle and vice versa. For live world, we will use a balance between quality and time of sweep.

4. CONTROL AND COMMUNICATION CARD

The configuration and processing of data from laser sensor use a PCB developed on SCT group [6]. This board (fig. 3) contains a control unit (dsPic30F4011), two communication modules for RS422 / RS232 and auxiliary circuits for testing and programming. Firmware developed can read data from sensor process it and send it to the computer.

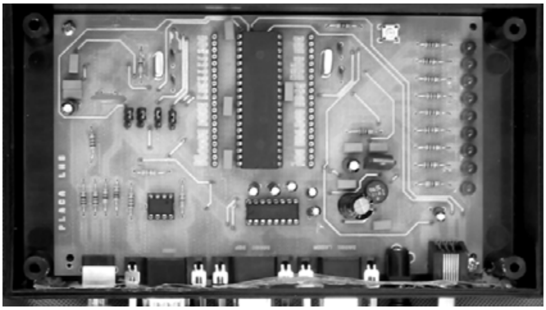


Fig.3. Control and communications card

Firmware has several tasks:

- Calibration of sensor: we store the vector of heights, called offset, with no vehicle under the sensor (fig. 4). Vector of heights does not start at road level; their start is on the laser sensor.
- Conversion from polar coordinates to Cartesian coordinates (fig. 5)
- Heights higher than a threshold will be sent to the PC (fig. 6)
    - For all the vehicles on the sweep:
        - Start of data: 0xFF 0xFF
        - Index of data: 1 Byte
        - Heights: several Bytes.
    - End of sweep: 0xFF 0xEF
- Joining several consecutive sweeps, we obtain a 3D representation of the vehicle (fig. 7).

Table 2: Process phases

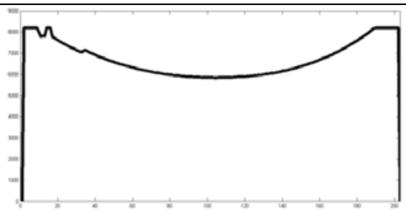


Fig.4. Sweep in the absence of vehicles

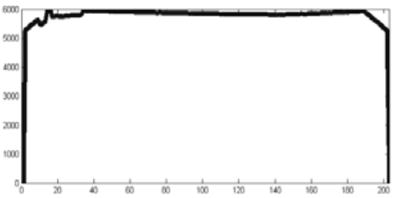


Fig.5. Sweep in Cartesian coordinates

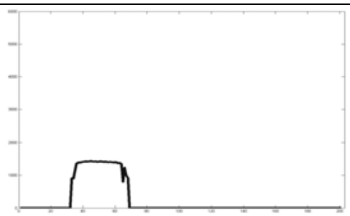


Fig.6. Sweep vehicle processing

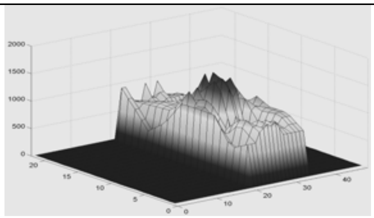


Fig.7. 3D vehicle

5. PROCESSING SOFTWARE AND CLASSIFICATION

Information transmitted by PCB continuous its processing on PC. Process on PC includes several stages: frame reception, data classification into vehicles, close of vehicles, and normalization of vehicle data and classification. We use TLS standard for vehicle classification (5+1 class) [7]

5.1. Reception of the frames

The data link between PCB and PC is asynchronous. Synchronization is done by searching start (0xFF 0xFF) and end codes (0xFF 0xEF). After sync, index and vector of heights are stored on an auxiliary variable for the next phases of processing.

5.2. Classification of vehicles and closing frames

We must define several concepts before we can explain classification algorithm. “Open vehicle”: this vehicle had new data on current sweep. “Closed vehicle”: it is a vehicle had not new data on current and previous sweep. “Candidate to close vehicle”: it is an intermediate state between previous statuses, there is not data on current sweep (fig. 8).

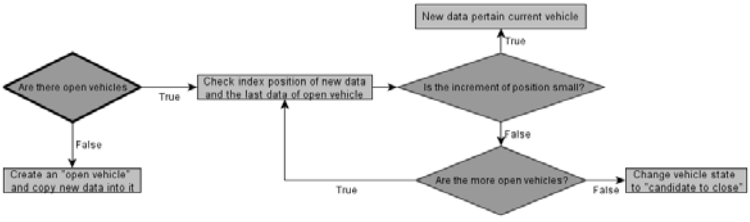


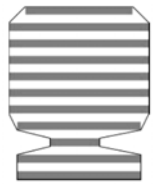
Fig.8. Process classification

If one vehicle has not new data on a second sweep, then change its state from “candidate to close vehicle” to “close vehicle”. Then, classification process can follow.

5.3. Vehicle Normalization

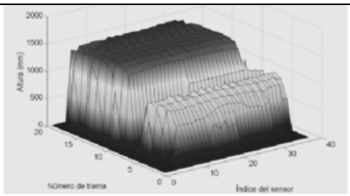
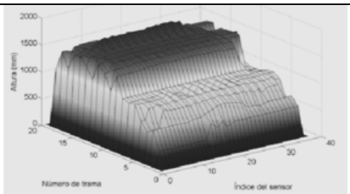
On this stage of the process, we have all the vector of heights related with current vehicle in one matrix. There are three algorithms to apply: fix of start position for all the rows of vehicle, fix of missing reflections and minimize velocity effect over vehicle data. Matrix of vehicle contains several vector of heights aligned into left (fig. 9). We search the minimum index of all the rows of the matrix and we move data to their real position (fig.10)

Table 3: Vehicle normalization

 **Fig.9. Original data**	 **Fig.10. Real data**

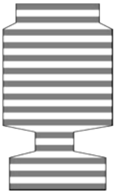
Presence of crystal of the vehicle can affect the measure process. In crystal position, the laser beam will not return to laser sensor. Then we will have a wrong data value on that position (fig. 11). We can reconstruct original data with the information that surrounds the wrong data (fig. 12).

Table 4: Missing reflections

 **Fig.11. Vehicle lost reflections**	 **Fig.12. Vehicle fixed**

Vehicle velocity can affect the measure process. The same vehicle will have different matrixes of heights at 100 Km/h (fig. 13) or 50 Km/. Use of an algorithm of interpolation and decimation can minimize effect of velocity (fig. 14).

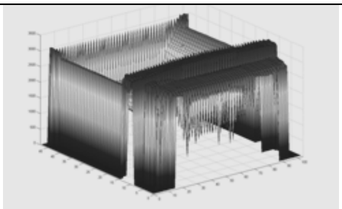
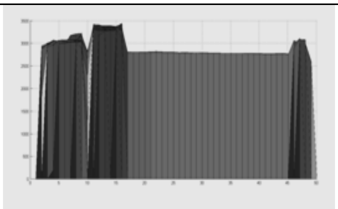
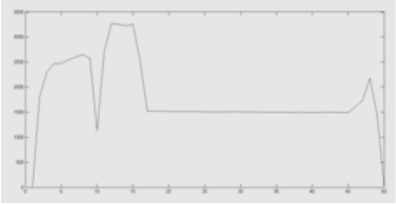
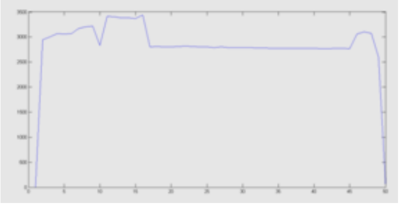
Table 5: Velocity normalization

 **Fig.13. Original vehicle**	 **Fig.14. Normalization of speed**

5.4. Classification of vehicles

Classification algorithm developed on [7] uses a vector, which contains the profile of the vehicle. There are two methods for convert from matrix representation (fig. 15) to profile representation (fig.16): calculating the average of every row (fig. 17) or using the maximum value of every row (fig. 18). The first method works ok with close vehicles (passenger car, van, etc) but it does not work with open vehicles such as truck with trailers.

Table 6: Vehicle profile

 **Fig.15. Original vehicle**	 **Fig.16. Vehicle profile**
 **Fig.17. 1º method of conversion**	 **Fig.18. 2nd method of conversion**

There are (5+1) categories according to German standard TLS. Equations use a set of parameters, which take into consideration the vehicle's width and height in specific points in the profile. There are several checks

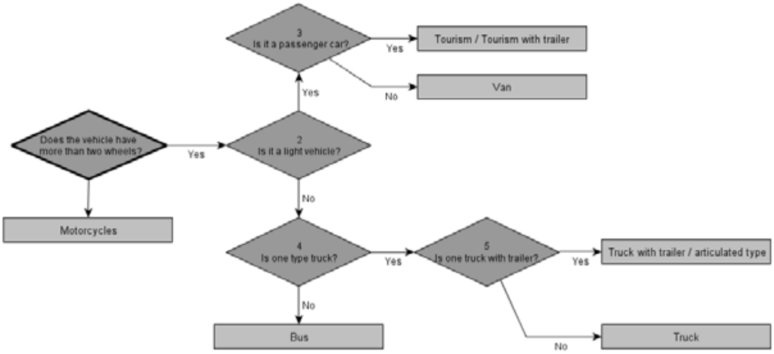


Fig.19. Algorithm of classification

6. ACKNOWLEDGMENTS

I want thank the group “Traffic Control Systems” and Drs Antonio Mocholí Salcedo and Nieves Gallego Ripoll the opportunity to work on this project.

7. CONCLUSIONS

All the measures used over the various stages were real data taken in live in urban environments. Laboratory tests helped on debug of initial firmware, later, streets of Valencia were an important resource on the firmware improves. System detects wrong behaviour of drivers and minimizes effect upon the process of measurement and classification of vehicles. Additionally, we have created a database with all information received in the process, which includes arrays of vehicles, photograph and more.

8. REFERENCES

[1] UNFPA, State of world population 2007. Unleashing the potential of urban growth, United Nations Population Fund, 2007

[2] Martin, P. T., Feng, Y., and Wang, X., Detector technology evaluation, Technical report, Department of Civil and Environmental Engineering University of Utah Traffic Lab, 2003

[3] SICK AG · Auto Ident, Quick Manual for LMS communication setup, v.1.1, 2002

[4] García, L. A., Diseño e implementación de una arquitectura multiagente para la ayuda a la toma de decisiones en un sistema de control de tráfico urbano, PhD thesis, Departamento de Informática. Universidad Jaime I, Castellón de la Plana. España, 2000.

[5] Gallego. N., Requisitos técnicos para la aplicación de sensores de tecnología láser en Sistemas inteligentes de transporte (ITS), PhD thesis. Departamento de Ingeniería eléctrica. Universidad Politécnica de Valencia, Valencia. España, 2010

[6] Menéndez. M., Plataforma para clasificación de vehículos en tiempo real

mediante un sensor laser. Aplicación para el laser Sick LMS-221.

[7] Für Straßenwesen, B., Technical delivery terms for route stations, TLS, Bundesanstalt für Straßenwesen, 2008.