Experimental Evaluation of Perception and Actuation Architectures for the Articulated Vehicle Automatic Control

M. Armada**, Héctor Montes*, Carlota Salinas**, Javier Sarria**
*Universidad Tecnológica de Panamá
**Industrial Automation Institute – CSIC
Crta. Campo Real Km 0.2, La Poveda
28500 Arganda del Rey, Madrid, Spain
armada@iai.csic.es

Summary

Bus Rapid Transit systems as well as Intelligent Transport Systems are being subject of research since many years. Nowadays with highly developed instrumentation, sensing and actuation technologies it is possible to foresee an important advance in the field of autonomous and or semi-autonomous transportation systems. Among the most promising transport infrastructures the articulated bus is an interesting, low cost and friendly option. In this paper an experimental platform for research on automatic control of articulated bus is presented. Platform consists in a mobile platform (the bus) fully instrumented and in a ground test area composed of asphalt roads inside CSIC premises. Paper presents also the development of a HMI to ease progress in control system evaluation.

Keywords: Intelligent Transport Systems, Bus Rapid Transit, autonomous transport systems, vehicle control, human machine interface.

1 Introduction

The development of automated vehicles has been the subject of important research activities, where control systems play a very relevant role [1]. By other side, the interest of new, safer, more reliable, mass transportation systems is of growing interest, leading to Intelligent Transport Systems (ITS) [2-3]. Control of vehicle dynamics has been increasingly investigated over the last 15-20 years [4-8].

Bus Rapid Transit systems are a promising transportation system that is becoming very popular and their automation is of major relevance [2].

In this paper an experimental platform for research on automatic control of articulated bus is presented. The aim of the platform is to allow full experimentation in real conditions for testing technology developments and control algorithms. Platform consists in a mobile platform (the bus, a Volvo BM10) fully instrumented and in a ground test area composed of asphalt roads inside CSIC premises [9].

In addition, some experimental results guide rail detection using a laser sensor (SICK) are presented. Likewise, this paper focuses in the development of the HMI to ease progress in control system evaluation.

2 Description of the system

The experimental platform purpose is to provide a reliable starting point to carry out research on automatic control of articulated buses. Figure 1 shows the main elements of the overall architecture of the experimental platform set-up using a Volvo B10M articulated bus. This experimental platform is used on a private inner road facility located at IAI-CSIC premises in Arganda del Rey (Madrid). There are a number of applied research projects involving several Spanish industrial companies engaged in transport issues that are being realized in co-operation with the IAI-CSIC.

In particular, the participation of the Department of Automatic Control is headed to undertake feasibility studies on automatic control of vehicles of large dimensions. Proper research on automatic bus control requires deploying multiple sensors and actuators so that they will be used for both monitoring and control. Furthermore, a control system of this kind involves a lot of variables to analyze and to monitor during the testing period of the system and also during the various stages of implementation and demonstration. Therefore, it is of considerable importance to organize a robust observation and acquisition information architecture to gather the sensor signals that are set in the system.

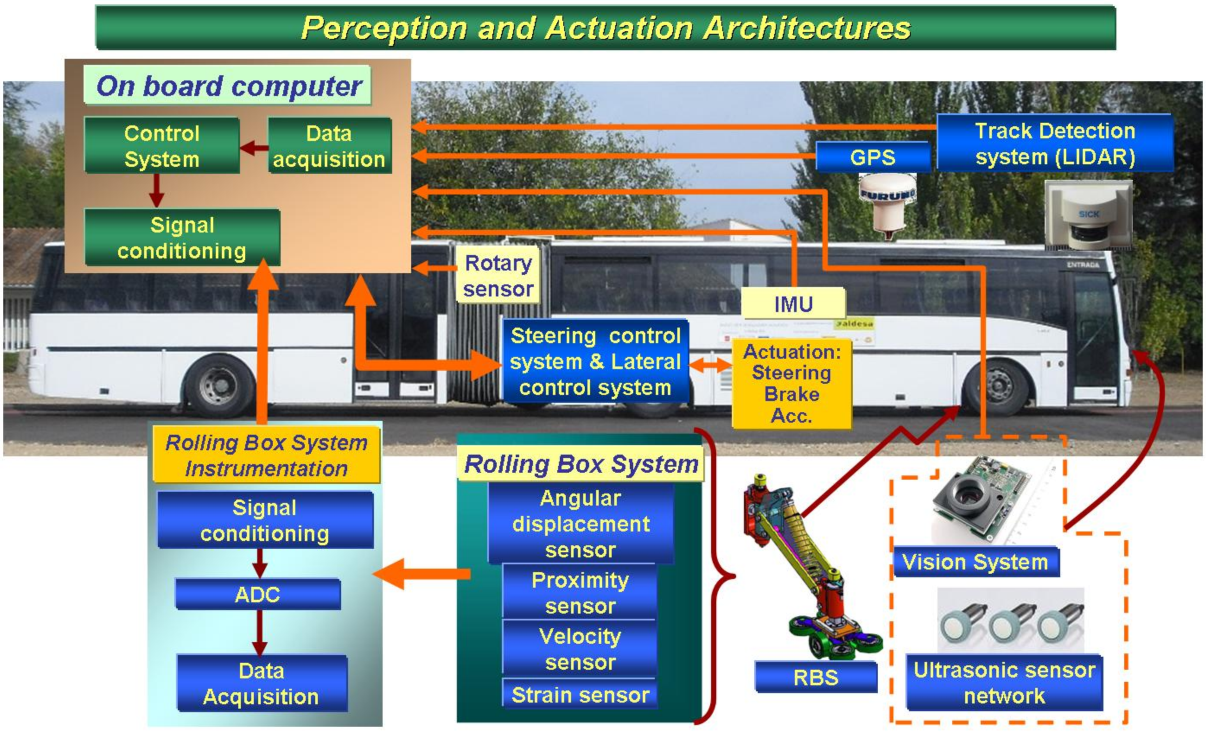


Figure 1. Architecture of the systems of perception and actuation for automation of articulated bus.

The analysis and interpretation of these variables will benefit the design and the comparison of the different control strategies to be implemented for the automation of articulated bus.

Additionally, experimentation with transport systems of large dimensions requires special care for safety, and this requires knowing the state of the vehicle at all times. This information must be known to both the people who go on board the vehicle, and to those working at different points of the test facilities.

3 Human Machine Interface

The Human Machine Interface (HMI) development usually is not a priority issue; moreover, intelligent systems are completely designed when the researchers approach the HMI dilemma. However, several works illustrate the importance of the simultaneous development of the robotic system and the HMI that comprise the users' needs and requirements, considerations that we applied in this work.

In order to obtain efficient, effective and usable HMIs, Raskin [13] quotes: "a goal for HMI developers should be the creation of human machine interfaces that are humane", the designers need "an understanding of the relevant information on how both humans and machines operate". The User Centered Design (UCD) is the term for the incorporation of the users into the process design [12]; its main purpose is to understand the user as well as the tasks and goals that must be achieved by the intelligent system [10].

In this section the main characteristics of a Human Machine Interface developed to operate during the research on automatic control of articulated bus will be described. At this moment the important consideration for HMI design can be gathered as the targeted user group, in this case comprised by the researchers involved in the study of this project. The environmental constraints are considered a key point for designing this HMI. First, the mobile system is a long vehicle, with multiple variables, working in tough conditions under real time operation system. Because it must cover large displacements, the operator's safety (and confort whenever possible) is a high priority. The HMI must display comprehensible information and significant information, and the real-time requirements must be satisfied.

The main purpose of the HMI is to establish friendly, remote and intuitive communications between the vehicle and the people who operates it, and it also includes an adaptable and open configuration. Thus, the HMI contains the following properties:

- Multiple sensors and variables can be visualized; two and tree dimensions are considered for some sensors.
- Real-time visualization of the information.
- Multiple and simultaneous clients connexion can be accepted.
- Adaptable according to the requirements/ configuration of every client.
- Data storage for every testing session.
- Old session can be visualized – offline mode.
- TCP/IP communication protocol has been used to communicate the vehicle and the users (researchers).

The HRI client - server architecture is based on a server running onboard the vehicle, operated on the RTOS named QNX® [14] and the client can run in any PC with OS Windows Xp or Vista, it has been developed over Matlab [15]. A simultaneous connexion of several clients, from i=1…n, is possible, where each client is denoted as i-client. Figure 2a shows the general diagram of the remote system communication between the server and the n-clients.

The server consist of a Clients Manager, its purpose is to create and to control the communications channels with every connected *i*-client. It also has to handle the clients' requests considering the clients' initial configuration. In order to communicate the server and the main controller, an interface has been created called *data_devices Manager*, which is charge of acquiring the information of the active devices and variables of the system.

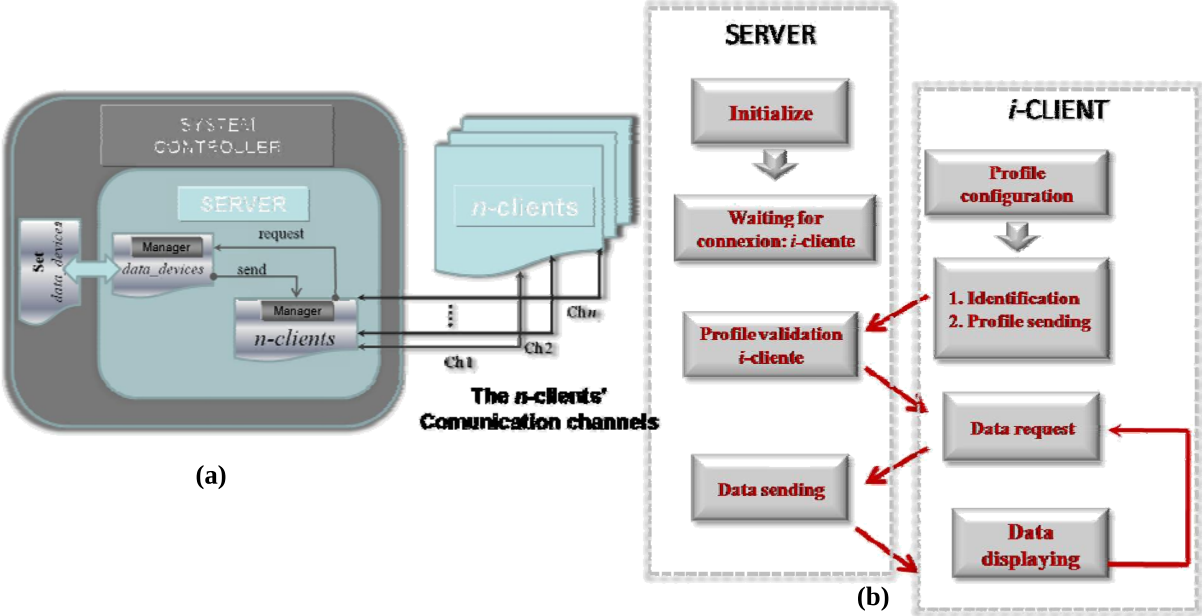


Figure 2. (a) General diagram of the remote system communication; (b) Block diagram of communication sequence between server & *i*-client.

The *i*-client consists of a graphical interface and a *Configuration_Profile Manager*. The graphical environment is intended to display the multiple variables of the vehicle; the variables are classified and positioned in four groups or modules (See Figure 3). The module #1 displays the variables strongly associated to the steering control: the steering wheel position (angle), the deviation angle detected by the range sensor and the position sensors (encoders) of the articulation of the RBS. The variables related to vehicle movement as the velocity and the interpretation of the brake and accelerator pedals are displayed in the module #2. The depiction of the information acquired by the range sensor, whether it is displaying the data in 2D or 3D is presented in the module #3. Finally, the module #4 display the trajectory plane if the test lane. In addition, the module #4 shows a cursor indicating the position of the articulated bus, in real time, during the execution of a task.

The *Configuration_Profile Manager* is in charge to supervise execution of the *i*-client, according to its user's requirements. The operation mode whether it be online or offline and the correct displaying and storage of the chosen devices, this initial configuration is performed through a configuration window (See Figure 3).

The remote communication begins by means of any *i*-client. The first action is the *i*-client identification, then it sends its initial configuration profile, previously established where the user chooses the variables of the system that the user wants to monitor, such as: power steering, laser angular position and data, angular position of the RBS, bus velocity, accelerator driver, brake driver, GPS, IMU. Once the configuration has been confirmed, the server starts the data sending procedure. The process while be performed until one of the linked part breaks the connexion, the connexion sequence is shown in Figure 2b.

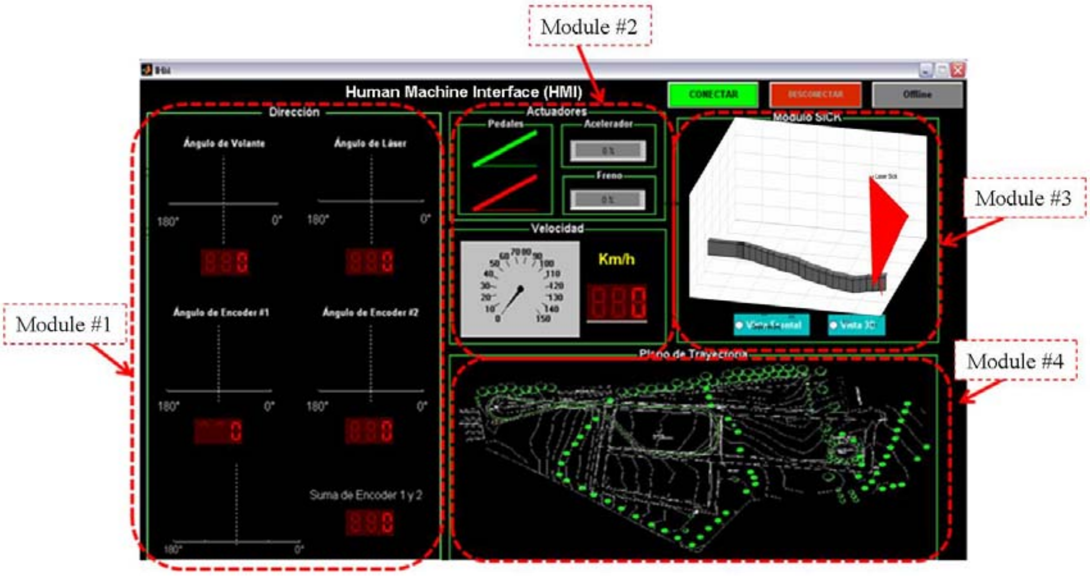


Figure 3. HRI graphical environment with range sensor 3D visualization (module #3).

Due to the communication system is designed to operate with multiple and simultaneous clients/users, the server performance is not affected when an already *i*-client is disconnected or a new *i*-client is connected. The *Clients Manager* creates independent channel for every *i*-client and when the server is disconnect it sends a shutting down signal to all connected clients.

4 Experimental results

To evaluate both different sensing, communication and actuation systems for automatic control of articulated bus, the mobile platform is complemented with a ground facility where infrastructure modifications can be made to investigate new transport systems (See Figure 4).

Figure 4. Partial and panoramic views of the new monorail test lane of 385 m long.

Many experiments have been performed within this experimental test area. Figure 5 illustrates automatic control of the articulated bus following a required trajectory. Steering wheel angular rotation experimental data is shown in correlation with real trajectory. In this way, many lateral control algorithms were compared using this experimental platform, where clear and reliable external references and instrumentation have demonstrated to be very useful.

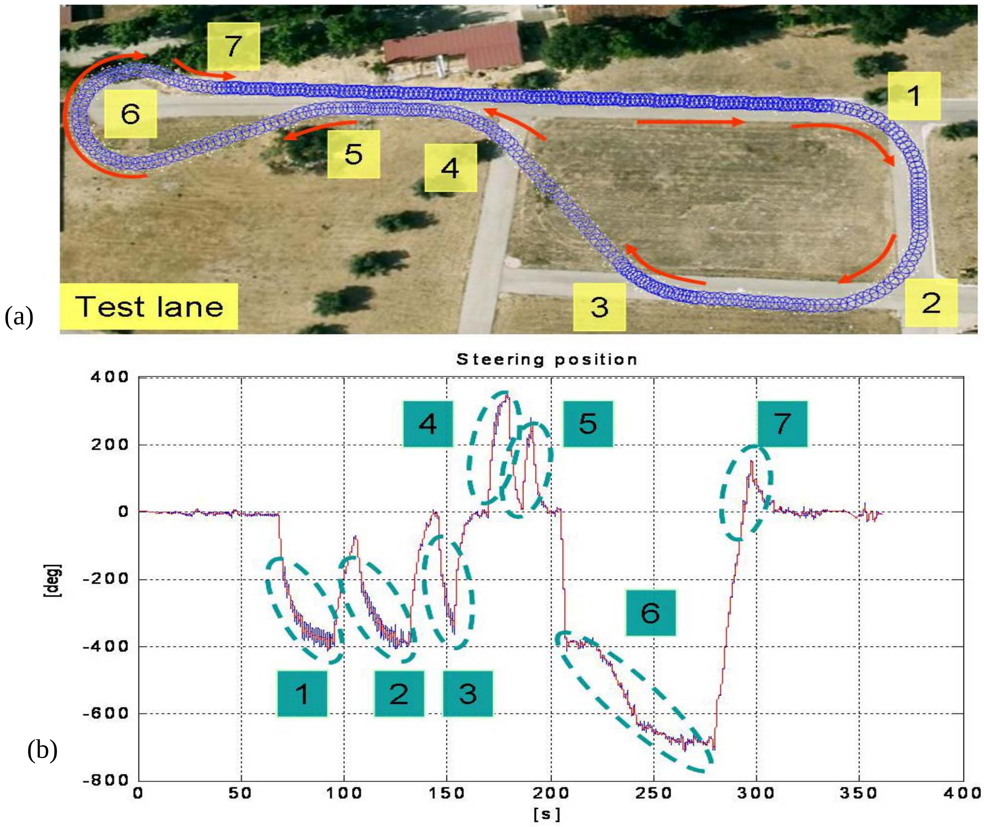


Figure 5. (a) New test lane over the old road at the IAI-CSIC; (b) Steering wheel position during a experiment conducted on the new test lane.

In the results presented in Figure 5b, it is possible to see the functionality of the automatic control to follow the test lane. During follow-up of curves, the control strategy makes the central axis of the bus conforms to the curvature of the trajectory. This strategy includes a Kalman filter in order to get a better result. For the reason that the radii of curvature of the test lane are very small, the experiments have been performed at low speed. However, it is evident that with higher radii of curvature, the bus speed will increase significantly in the experimental tests.

The laser sensor is used to anticipate the position of the test lane during a trajectory. Depending on the speed of the bus and the resolution of the laser sensor, sets its angular position for it can get measurements within a specific range. Figure 6 shows the rail detection from the point of view of the laser sensor. In this figure the rail trajectory represent the 40% of the test lane. The laser sensor detects the depth of the rail in the entire test lane, which is 170 mm. In addition, the laser sensor detects the driftage of the test lane and the inclination of the surface, providing adequate information to the control system. In the experimental results shown in Figure 6, the laser sensor anticipates three meters ahead of the front of the bus, and it besides can detect angular deviations of the rail and its inclination. On the other hand, it can be detected, very easily, obstacles located in front of the bus within the range of the laser sensor.

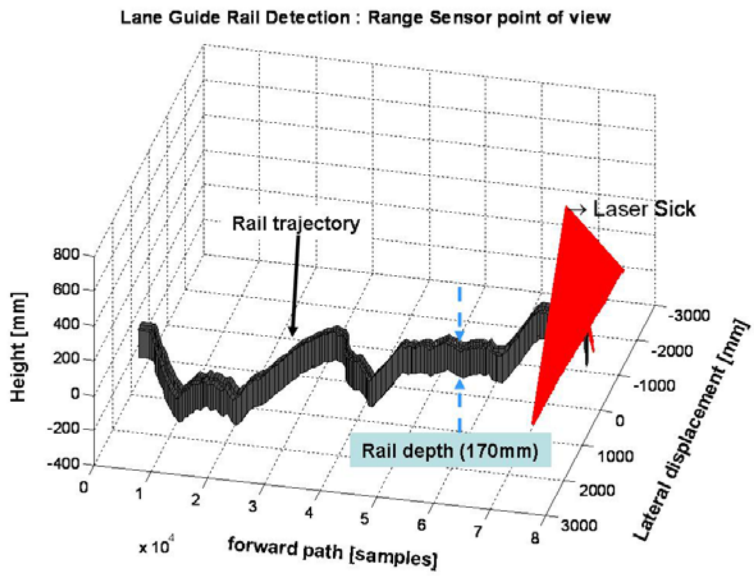


Figure 6. Test lane detection using laser sensor (SICK).

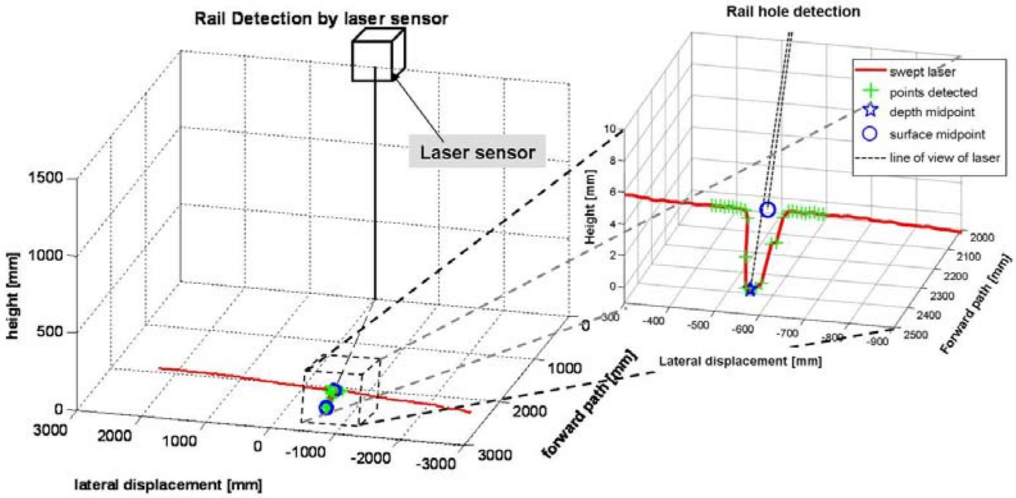
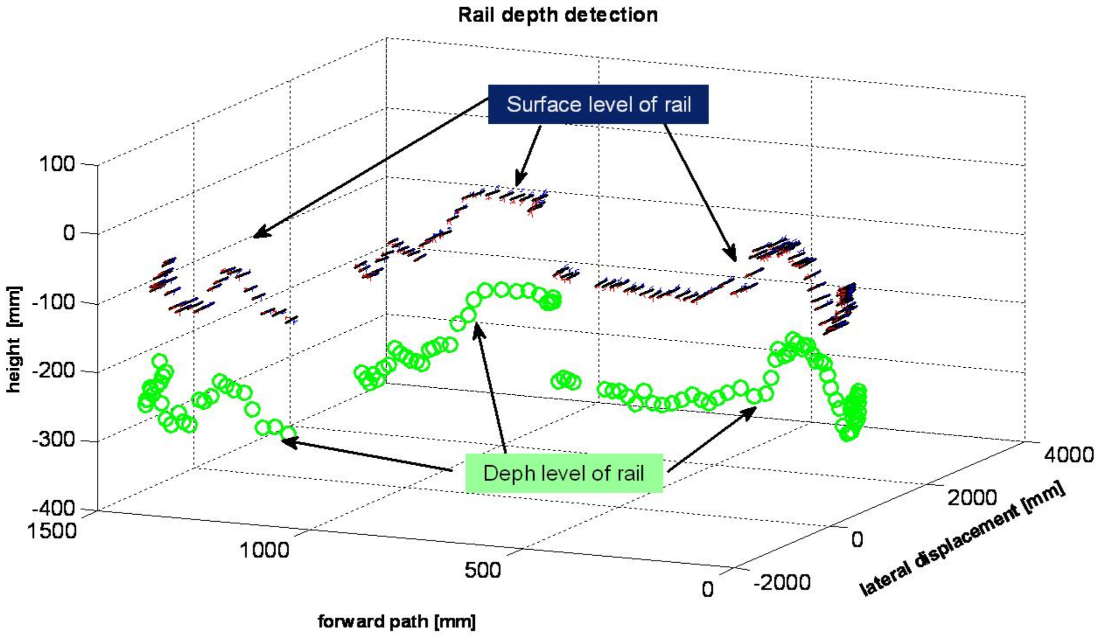


Figure 7. Detection of rail depth by means of laser sensor.

The opening of the rail at the surface is 60 mm and its depth is 170mm. The laser sensor can detect the opening and the depth of the guide rail. The algorithm designed to process signals from the laser sensor is able to get the shape of the cutting plane of the rail from the point of view of the laser sensor. Figure 7 shows a laser beam on a portion of the test lane that it detects the location of the midpoint of the hole on the surface and the midpoint of the depth of the rail. The crosses drawn on Figure 7 show the laser beams incident on the rail. With these points, the algorithm reconstructs the shape of the lane, taking into consideration the shape and slope of the depth of the rail, which is related to the curvature of the test lane.



5 Conclusions

In this paper an experimental platform for research on automatic control of articulated bus has been presented. Apart from the mobile system (a Volvo B10M) fully instrumented, a ground infrastructure was also introduced. To help and ease development, a HMI was realised, to monitor all the variables of interest. Experimental results regarding lateral control of articulated bus were also offered.

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