The VisLab Intercontinental Autonomous Challenge: 13,000 km, 3 months,… no driver

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ABSTRACT

This document presents a new exciting effort in the intelligent vehicles arena which is going to set a new milestone in the history of vehicular robotics. Autonomous vehicles have been demonstrated able to reach the end of a 220 miles off-road trail (in the DARPA Grand Challenge), to negotiate traffic and obey traffic rules (in the DARPA Urban Challenge), but no one ever tested their capabilities on a long, intercontinental trip and stressed these systems for 3 months in a row.

This paper presents the VisLab Intercontinental Autonomous Challenge that VisLab organized in 2010, during which 4 autonomous vehicles are driving from Italy to China with no human intervention.

The challenge is taking place from July 26, 2010 to Oct 28, 2010, therefore being currently under execution, this paper can only describe the preparation and the technical details of the vehicles and the main challenges.

INTRODUCTION

The 2010 World Expo is being held in Shanghai, China, May 1-Oct 31, 2010. It is the third most relevant worldwide event after the FIFA World Cup and the Olympic Games. 70 millions visitors from all over the world are visiting the Expo. The 2010 Expo theme is *'better cities, better life';* therefore issues related to sustainable mobility are indeed central to the Expo, which is a huge display of new ideas developed worldwide in this field.

The Expo will constitute a great opportunity to showcase new and innovative technologies in the field of intelligent mobility, especially urban mobility.

VisLab has been working for more than 15 years in the field of intelligent vehicles and participated in many worldwide events, like the DARPA Challenges. Many of VisLab's results are considered as worldwide milestones in the field of vehicular robotics, like the ARGO project (a passenger car that in 1998 drove for 2000+ km on Italian highways in automatic mode; 94% of the event was performed without human intervention), or the TerraMax vehicle. TerraMax is an Oshkosh MTVR truck that VisLab equipped with sensing systems (primarily artificial vision) and that was able to reach the end of the DARPA Grand Challenge in 2005 (220 miles of off-road driving with no human intervention) and was qualified for the DARPA Urban Challenge in 2007 (100 miles of urban driving).

VisLab wants to set a new milestone in the domain of intelligent vehicles with a new initiative, completely conceived and sustained by VisLab: the idea is to demonstrate, through an extensive and impressive test, that the current technology is mature enough for the deployment of non-polluting and no-oil based autonomous vehicles in real conditions. The municipalities of a number of cities are currently exploring the possibility of using these electric and autonomous vehicles downtown to deliver goods to shops, collect trash, and sustain mobility in the last mile.

THE CHALLENGE

The challenge, named '*VisLab Intercontinental Autonomous Challenge' - VIAC*, has a unique final goal: to design vehicles able to drive autonomously along a 13,000 km trip, with no human intervention.

Figure 1: The launch of the VisLab Intercontinental Autonomous Challenge in Milan, Italy

Although this goal is definitely very complex, VisLab approached this exciting endeavor by adding additional innovative ideas. The vehicles are electric and power is delivered to the autonomous pilot by solar panels. These additional requirements, if the challenge will be won, will help demonstrate that it is possible –although in a prototype version– to move goods between two continents with non-polluting vehicles powered by green energy and with virtually no human intervention. Some goods were packed in Parma before the start of the adventure and taken to Shanghai with virtually no impact on world's pollution. Figure 1 shows the official presentation and launch of the challenge in Milan, Italy, on July 20, 2010.

THE VISLAB RESEARCH GROUP

The VisLab Intercontinental Autonomous Challenge is organized by VisLab, which is a laboratory of the Engineering Faculty of the University of Parma who recently launched a spinoff company, named VisLab srl.
VisLab is mainly involved in research and development of intelligent systems for the automotive field and is composed of 20+ engineers. Figure 2 shows the research group and the vehicles used for the cross-Asia autonomous trip.

Figure 2: The VisLab research group and the 4 autonomous vehicles developed for VIAC

THE ROUTE

The route will pass through different countries both in Europe and in Asia as depicted in figure 3; roads will not always be paved and particular challenges are expected in eastern Russia and western China. The route is part of the ancient Silk Road and the trip is scheduled to pass in very crowded and very lonely areas and during different weather conditions like hot areas in Russia and cold parts in China.

Figure 3: The VisLab Intercontinental Autonomous Challenge route and the VIAC logo.

SCIENTIFIC OUTCOME

The VisLab Intercontinental Autonomous Challenge will be the first demonstration of autonomous driving using electric vehicles whose driver is powered by solar energy, on a route that is:

- **Long**: more than 13,000 km. This extensive test will allow a thorough test of the developed technology
- **Extreme**: different environments will be crossed to validate the system in several different conditions

All data will be logged for a subsequent analysis in laboratory at the end of the trip.

THE VEHICLES

The expedition is composed of 4 autonomous vehicles (2 vehicles traveling, plus 2 vehicles as backups) plus support vehicles (4 RVs, 2 trucks to carry tools and a small mechanical shop, and a truck able to carry two autonomous vehicles).

Figure 4: The VisLab autonomous vehicles: outside and internal view

Thanks to the cooperation with Piaggio, the vehicles selected for VIAC are Piaggio Porter Electric Power. VisLab equipped them with additional devices such as sensors, processing systems, and actuators to make them perceive the environment and drive autonomously. One of the vehicles is shown in figure 4. Figure 5 shows the different look of the VIAC vehicles and BRAiVE, another prototype of autonomous vehicle recently developed by VisLab. Sensors on the VIAC vehicles are not as integrated as on BRAiVE since they have to be easily reachable during the test for additional calibrations and checks should they become necessary.

Figure 5: Different integration levels on two prototypes of autonomous vehicles developed by VisLab: BRAiVE and the vehicles used for VIAC

AUTONOMOUS DRIVING

During the challenge two autonomous vehicles are driving. Although the two vehicles are exactly identical (same sensor suite and identical control system) they have different goals.

THE FIRST VEHICLE

The first vehicle conducts experimental tests on sensing, decision, and control subsystems, and collects data throughout the whole trip. Human interventions are needed to define the route and intervene in critical situations.

THE SECOND VEHICLE

The second vehicle automatically follows the route defined by the preceding vehicle, requiring no human intervention. It will be regarded as a readily exploitable vehicle, able to move on loosely predefined routes. At the end of the trip, its technology will be ready to be transferred to sets of vehicles to move in the inner part of cities in the close future.

LEADER-FOLLOWER APPROACH

The vehicles follow a leader-follower approach: when the leader is visible, then the follower follows exactly its trajectory; local sensing is used to refine its position on the road (see figure 6.left). When the leader is hidden or is too distant to be seen by the follower, GPS information are used to define the route, while local sensing is again used to refine its position on the road. Indeed, when the leader is not visible and local sensing cannot deliver robust information (missing lane markings, no berms or ditches along the road, no vehicle to follow) then autonomous driving has to be stopped.

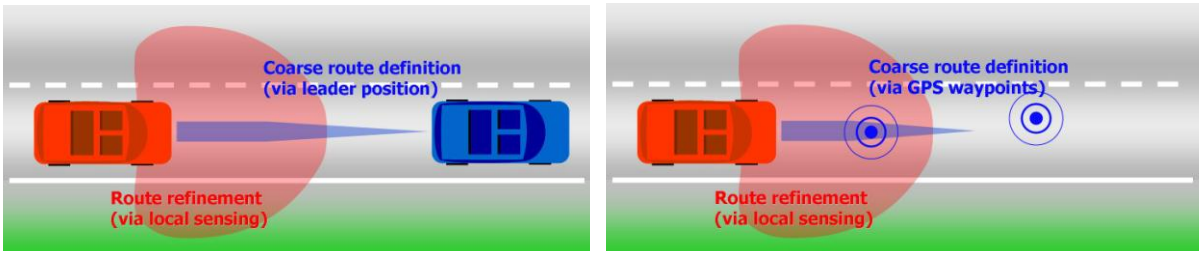

Figure 6: Left: leader follower approach when the leader is in line of sight; Right: leader follower approach when the leader is not visible by the follower

VEHICLE SETUP

The 4 electric vehicles are all equipped with the very same sensing and actuation technologies to optimize development time and help in case of failures.

THE SENSING SYSTEM

The vehicle sensing system is based on cameras and laserscanners. 7 cameras are installed on the vehicle (5 forward and 2 backward looking), while 4 laserscanners with different characteristics are placed around the vehicle. Figure 7 shows the frontal vision systems, figure 8 shows the frontal laserscanners placement, while figure 9 shows additional sensing systems to allow the vehicle to move off-road and backward.

The forward and backward vision systems locate obstacles and lane markings, while the 3-camera frontal system stitches the 3 images together to form a single panoramic view of 180 degrees in front of the vehicle in order to locate the leader vehicle. The laserscanners are used to locate obstacles, the vehicle in front, and other road participants.

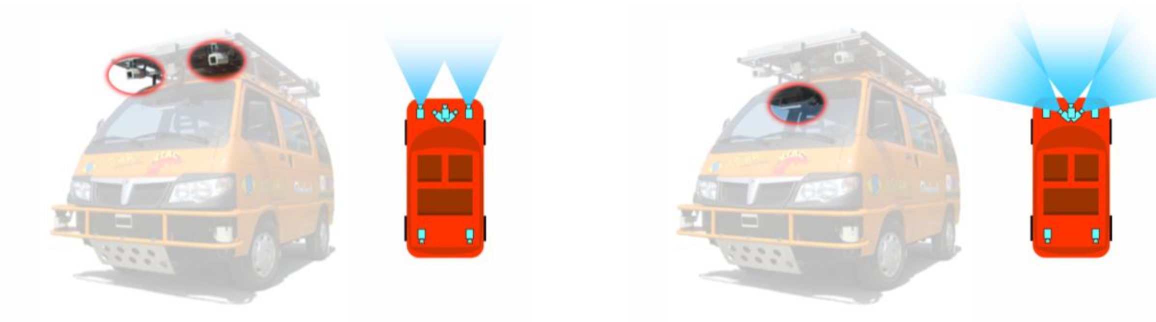

Figure 7: The vehicle's front vision sensing. Left: frontal stereo vision systems able to detect lane markings and obstacles; right: frontal panoramic vision system, used to locate the leader vehicle

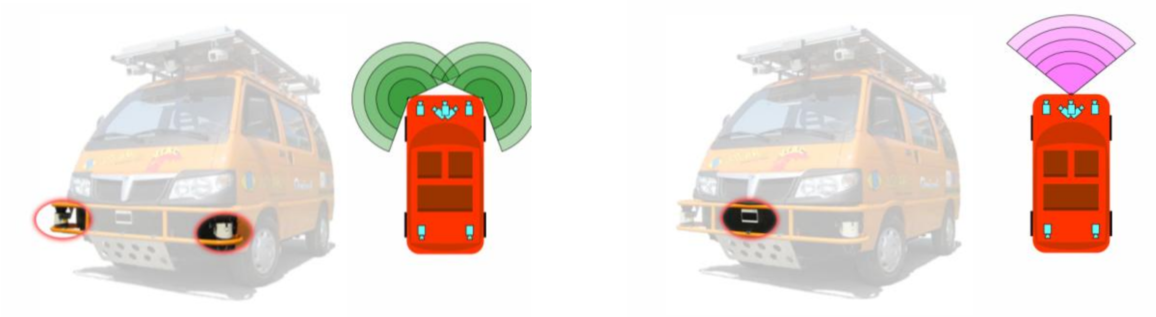

Figure 8: the laserscanner systems. Left: monobeam laserscanners covering the front and the sides of the vehicle; right: multibeam frontal laserscanner

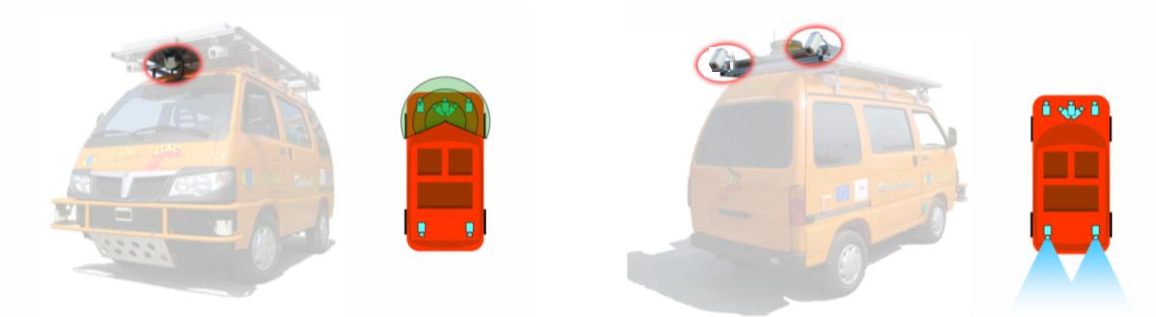

Figure 9: additional sensing. Left: laserscanner to detect berms and ditches during off-road driving; Right: back stereo system used to detect upcoming traffic and obstacles during backup maneuvers.

Two technologies (vision and laser) are used together and their data fused in order to achieve a more robust detection in all scenarios like mountain, urban, off-road, and in all weather situations like dust, heavy rain, frontal sunshine.

The vehicle also features GPS, IMU, and a radio for intervehicle communication. Plus, the vehicle is equipped with a solar panel which is able to provide sufficient power to run all the sensors, the processing systems, the actuators, and the communication systems (including a satellite device used to stream video data live during the whole trip). Figure 10 shows the position of the GPS/IMU/Radio device and the solar panel.

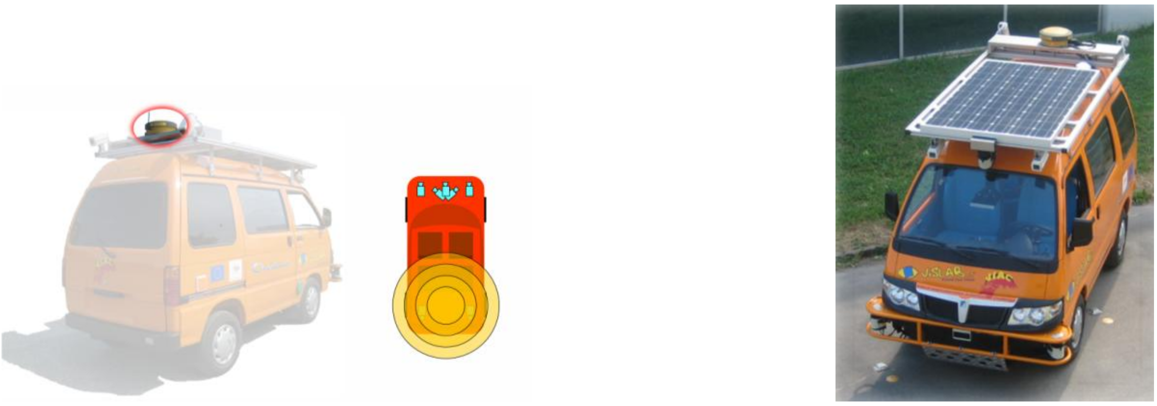

Figure 10: left: the GPS, IMU, and Radio device; right: the vehicle showing the solar panel on the roof

THE PROCESSING SYSTEM

The vehicles are equipped with 3 PCs each: two PCs are used to process data coming from the sensors, while one PC holds a world model which is constantly updated by messages sent by the two other PCs. This synthetic model is then processed to select the best maneuver, then therefore the best trajectory that accomplishes the selected task. Figure 11 shows an internal view of the booth where the 3 PCs are visible.

Figure 11: internal view of the booth and the 3 PCs

THE X-BY-WIRE SYSTEM

Each vehicle is equipped with x-by-wire, allowing the full control of speed and steering via CAN messages. Specific control mechanisms have been designed and realized to control the steering wheel, the brake pedal, and the gas pedal. Figure 12 shows the TopCon steering, which is configured to capture commands from a CAN bus and control the steering; the same figure also shows the VisLab board to interface the CAN bus with the gas control.

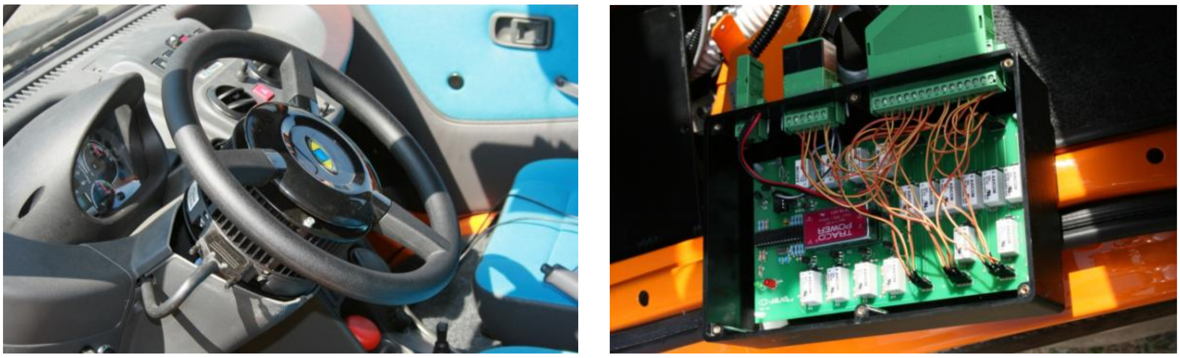

Figure 12: left: the TopCon steering system and the board to control gas

To control brakes, a simple mechanical solution was adopted: a cable that when pulled, presses the brake pedal, as shown in figure 13.

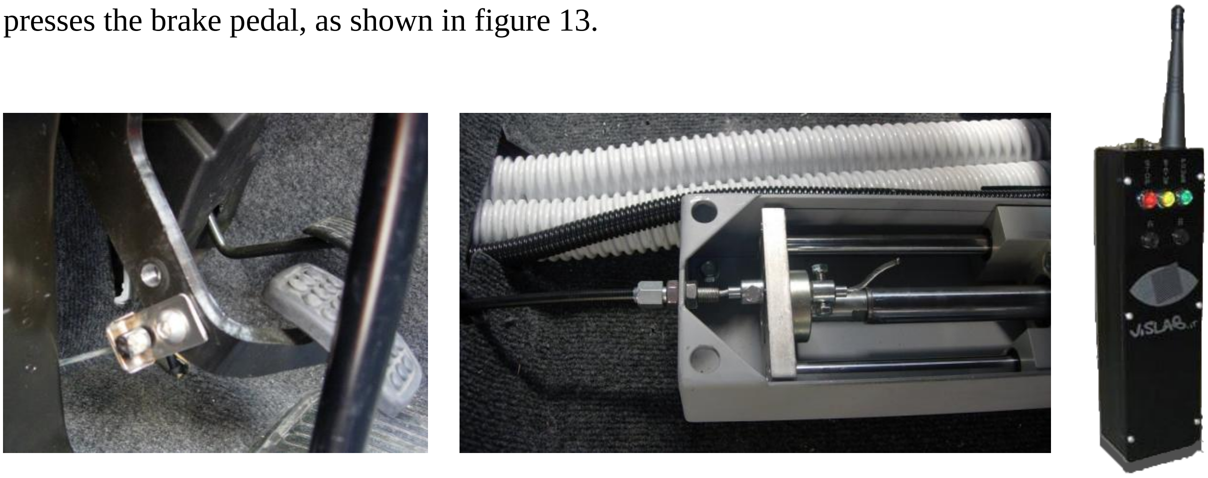

Figure 13: the mechanical braking system and the VisLab e-stop control

To ensure safety when driving autonomously, each vehicle can be stopped thanks to a remote called e-stop. This device is shown in figure 13 as well.

THE GRAPHICAL USER INTERFACE

The vehicles have two different GUIs depending on the tasks which is required: in case of autonomous driving, the GUI shows the current world representation stored in the World

Perception Server (the 3rd PC), together with other debugging information to help eventual passengers to monitor the vehicle behavior. Plus the same interface, shown in figure 14, gives the possibility to turn on and off the various perception, actuation, and decision subsystems.

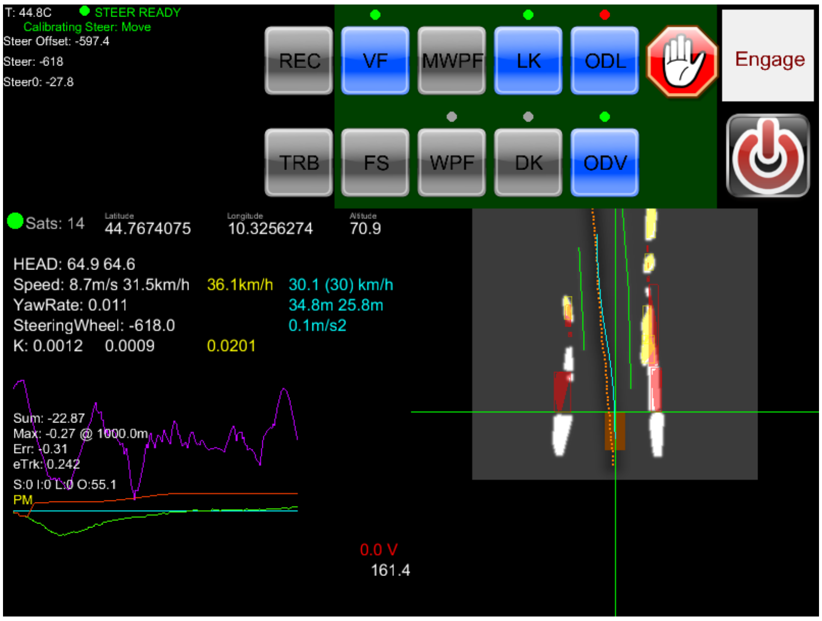

Figure 14: the GUI running on the autonomous vehicle

The second GUI is used when the vehicle is acquiring data. At the end of the trip, it has been estimated that 100 terabytes will be acquired. This huge amount of data will be available for processing in laboratory, virtually running again the very same route multiple times. The raw data would be difficult to classify, therefore during acquisition the second GUI, shown in figure 15, allows to input short messages into the data stream in order to annotate the data sequence.

Figure 15: the GUI for manual annotation of the data stream

CONCLUSION

The 4 electric vehicles left Italy on July 26, 2010, and are scheduled to reach Shanghai on October 28, 2010, after more than 13,000 autonomous km. At the moment of writing this paper the vehicles are in Moscow, Russia. A part from small issues related to the vehicles' batteries and the satellite system, no special problem has to be reported so far.
Figure 16 shows the vehicles running autonomously in different environments.

Figure 16: the vehicles running autonomously in different environments such as urban or rural

Being this a unique experiment, never tried in history, as soon as the experiment will be concluded VisLab will analyze the data and the statistics about the trip and will prepare detailed reports, which will be posted on the official website at: www.viac.vislab.it