A trip from Italy to China using autonomous vehicles: behavior and testing

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Abstract: This paper describes behavior and testing of the vehicles set up by VisLab to cover, in autonomous mode, a long 13.000 km trip from Italy to China, passing through Moscow. The paper, begins with a short description of the hardware and focuses on the vehicle behavior, what kind of situations is able to negotiate and how they are managed. A description of how the system has been tested and how it performs on a test track concludes the paper. The journey started on July 20 from Milan. At the time of writing, the first 10 days of result are positive. A live video demonstration will be shown at the conference talk.

Keywords: Autonomous Vehicles, Vision, Sensing Testing

1. Introduction

VisLab, in partnership with Overland World Truck Expedition project, is going to set up a new milestone in the history of intelligent vehicles for the 2010 Shanghai Expo. The aim is to demonstrate, through an extensive and impressive test, that current technology is mature enough for the deployment of non-polluting and no-oil based autonomous vehicles in real conditions. Shortly after the trip this technology, readily exploitable on vehicles, will be transferred to a set of urban vehicles driving in Rome city center.

Two electric vehicles, like the one depicted in Figure 1, will perform a 13,000 km trip controlled by VisLab's solar powered autonomous driving systems. Two vehicles as backups, four Overland trucks as mechanical assistance, storage, and accommodation providers and two trucks for media coverage and live satellite broadcasting complete the convoy.

The autonomous vehicles are ruled by a leader-follower approach. Leader defines the route: if follower sees the leader, it visual servoing is exploited, if not, GPS waypoints are followed.

The leader vehicle drives autonomously in some trip selected sections and conduct experimental tests on sensing, decision, and control subsystems, collecting data nonstop. Although limited, human interventions help to define the route and manage critical situations. The leader always broadcasts its received GPS position to the follower.

Figure 1. One of the four autonomous vehicles prepared for the challenge.

The follower automatically follows the leader defined route, requiring no human intervention (100% autonomous).

Although both vehicles are identical in terms of sensor suite and control, they have different goals: the leader's being to face completely unknown environments employing all available sensors onboard (including expensive ones); the follower's to demonstrate its 100% autonomy using just a subset of sensors (low cost ones).

In highway-like environments, overtaking vehicles together with obstacles on the road will be detected while performing vehicle following. In urban environments, opposite traffic, generic obstacles and vulnerable road users detection will be activated. The vehicle will also be able to detect oncoming traffic at crossroads.

In off-road environments, berms, ditch and obstacle detection will be performed. Smooth areas detection will provide information on drivable free space.

At the time of writing the journey, started the 20th of July reached Hungary, and the first week of results and statistics collected is positive. The system is running fine and the covered road per day is more than the expected.

Testing phase has been completed completed and new data recordings are available for development and evaluation. A thorough description of these achievements as well vehicles behavior changes introduced during the testing phase will also be provided in the presentation.

In October, while VISION 2010 conference will be held in Versailles, the complete convoy will be approaching the journey's final destination: Shanghai city. Autonomous driving sessions might be shown live during the conference via a live network connection with the convoy.

3. Vehicle setup

Four electric vehicles have been equipped with the very same sensing and actuation technologies to optimize development time and help in case of failures. 7 cameras are installed on the vehicle (5 looking forward and 2 backward), while 4 laserscanners with different characteristics are placed around the vehicle. GPS, IMU, and intervehicle communication systems complete the sensing suite.

Each vehicle is equipped also with full x-by-wire, allowing to control speed and steering. Specific control mechanisms have been designed and realized to control the steering wheel, the brake pedal, and the gas pedal.

All the autonomous driving system is powered by a solar panel placed on the roof of the vehicle.

3. Behavior

Two autonomous vehicles will be driving during the challenge. A leader-follower approach is used to manage the whole trip: due to the lack of digital maps, the first vehicle defines the route and the second follows.

The two vehicles have the same sensor suite and identical control system but they will have different goals:

- the first one will use the whole sensor suite (including expensive sensors) and will face a completely unknown environment
- the second one will use a subset of sensors (only cheap ones) and will demonstrate 100% autonomy when coarse route information will be provided by the first vehicle

3.1 Leader Vehicle

For most of the trip the first vehicle drives autonomously; it will run experimental tests on sensing, decision, and control subsystems, and will collect data throughout the whole trip. Although limited, human interventions will be needed to define the route and intervene in critical situations.

3.2 Follower Vehicle

The second vehicle will automatically follow the route defined by the preceding vehicle, requiring no human intervention (100% autonomous). 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 transferred to a set of vehicles to move in the inner part of Rome.

Two main situations are possible, according to the visibility of the leader. If the leader is in line of sight and the follower can see its shape, then the follower will use its position to determine its trajectory; local sensing is used to refine its position on the road. Figure 2 shows this situation.

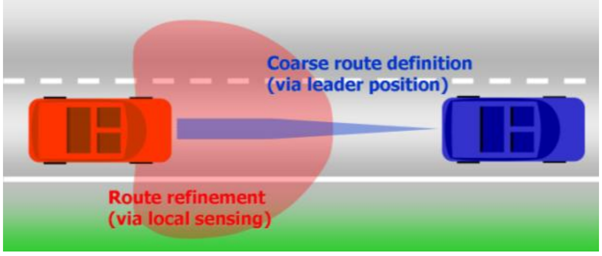

Figure 2. The driving pattern when the leader is in line of sight: the second vehicle follows the route described by the first vehicle and uses local sensing to refine its position on the road.

On the other hand, when the leader is not visible by the follower (for example it is behind a curve or a third vehicle is in-between), the second vehicle follows the coarse GPS waypoints broadcasted via radio connection by the first vehicle, and –again- local sensing is used to refine the vehicle's position on the road. Figure 3 sketches this behavior.

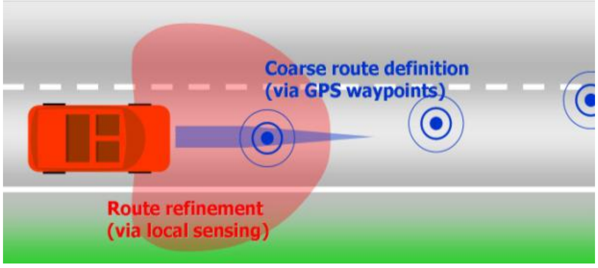

Figure 3. The driving pattern when the leader is not visible by the follower: the second vehicle follows the route described by GPS waypoints; local sensing refines its position on the road.

4. Controller design and testing

The control system is capable of perceiving and describing the environment using different inputs, such as GPS waypoints, roadways borders and lines, leader vehicles, and obstacles to be avoided.

To fulfill this mission a general-purpose real-time motion planning system has been designed, implemented. The pathplanner is based on the estimation of feasible trajectories on a cost map.

In order to evaluate vehicle following performance the controller has been validated experimentally on the vehicles taking part in the VIAC experiment.

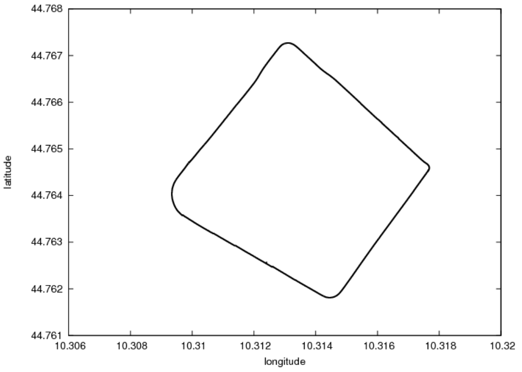

Figure 4. The test-bed in the University of Parma campus area.

Tests on the vehicles has been performed:

- inside the Parma University Campus track depicted in Figure 4, a 2 km long loop repeated several times in autonomous driving mode
- in the surroundings of Parma either in urban and extraurban environments.

The result of 22 minutes autonomous test (6 laps performed inside the campus) are presented in Figures 5 and 6: the mean error between tracks is 13 cm, with a standard deviation of 15 cm.

The average speed on this test was 26 km/h (maximum 46 km/h).

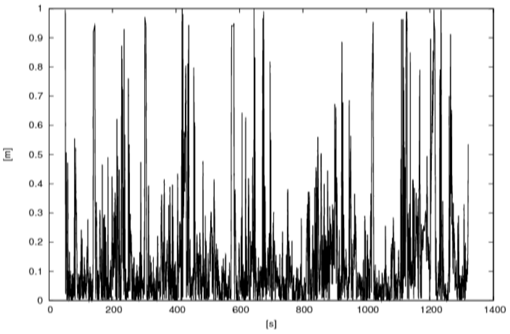

Figure 5. Cross-track error for 22 minutes of autonomous operations.

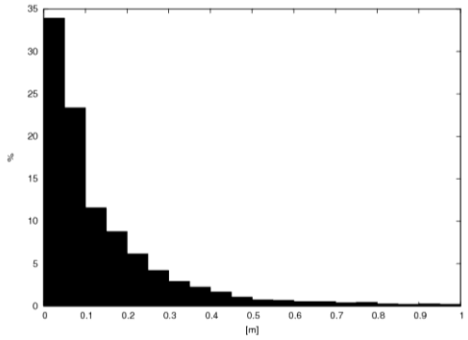

Figure 6. Histogram of lateral cross-track error for the experiment.

4. Conclusion

This paper briefly describe the behavior and testing methodology employed in the VisLab Intercontinental Autonomous Challenge: the first demonstration of autonomous driving using electric vehicles 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

This is the scientific outcome related to the challenge, which opens the way to a number of real applications in automotive, industrial and agricultural environments.

5. Acknowledgement

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7. References

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8. Glossary

VIAC: VisLab Intercontinental Autonomous Challenge

OFAV: Open intelligent systems for Future Autonomous Vehicles

GPS: Global Positioning System

IMU: Inertial Measurement Unit