Cristina Olaverri, Editor

Intelligent Vehicles at the Mobile Robotics Laboratory, University of Sao Paolo, Brazil

History

The University of Sao Paulo (USP) is the largest Brazilian public university and the country's most prestigious educational institution. It was founded in 1934 and currently has approximately 95.000 students. Besides the main campus in the city of Sao Paulo, USP also has campi in 6 other cities. The Mobile Robotics Laboratory (LRM) is affiliated to the Institute of Mathematics and Computer Sciences (ICMC), in the city of Sao Carlos, 235 km from the main campus. LRM was established in 2008 and since then it is directed by Prof. Denis F. Wolf.

Similarly to many other Robotics groups, the research at LRM started with small mobile platforms, investigating problems like mapping, localization and autonomous navigation. The group soon became interested in developing software methods and techniques to perform in outdoors, which are usually more challenging for robot operation. In 2010 the lab acquired a Golf cart that brought new challenges for the group. Simple reactive navigation algorithms were not enough anymore to navigate in dynamic environments at higher speeds. The technical and scientific challenges of vehicle navigation associated with the opportunity to reduce the number of road accidents and improve urban mobility were strong motivations to contribute to the ITS community. Since then, a large proportion of the LRM research effort has been dedicated to the development of perception, control and decision making techniques for intelligent vehicles. Not only with passenger cars in urban spaces but also heavy vehicles in unstructured environments.

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Intelligent Vehicles

CaRINA 2 (Intelligent Robotic Car for Autonomous Navigation) is our main research platform. It consists of a Fiat Palio Adventure modified for computational control of steering, throttle, and brake. It is also fully instrumented with cameras, 3D LIDAR, radars and high precision GPS. All mechanical and electrical modifications have been made while maintaining the original aesthetics of the vehicle (Figure 1).

In April 2012 the first computational control (drive by wire) tests with Carina 2 were performed. In September of the same year, the vehicle was tested in USP/SC campus with fully autonomous control. In October 2013, Carina 2 performed a public demonstration of

QUICK FACTS

Mobile Robotics Laboratory
Affiliation: University of Sao Paulo

Website: http://www.lrm.icmc.usp.br

Established: 2008

Research Focus: Intelligent Robots and Vehicles

Email: denis@icmc.usp.br

Director: Denis Fernando Wolf is an Associate Professor in the University of Sao Paulo. He obtained his PhD degree in Computer Science from the University of Southern California in 2006. His main research interest is the development of robotic systems for field operation and intelligent transportation systems. Most of his current work focus on computer vision, sensor fusion and machine learning applied to terrestrial and aerial autonomous robots and vehicles. He served as Program Chair of the International Conference on Intelligent Transportation Systems (IEEE ITSC) in 2016.

(a) (b)

FIG 1 CaRINA 2 experimental platform equipped with 3D LIDAR, radars, stereo camera and high precision GPS. In October 2013, it was tested in the streets of Sao Carlos with no human intervention.

autonomous navigation in the streets of Sao Carlos. During the demonstration, the vehicle was able to detect obstacles such as people and other cars and _kept a safe distance from them. To the best of our knowledge, this is the first autonomous driving experiment in public streets ever performed in Latin America.

In 2015, LRM presented the first autonomous Truck developed in Brazil in cooperation with Scania Latin America. The experimental platform used in the tests is a G360 (9 ton) equipped with stereo camera, radar and high precision GPS. A public demonstration with participation of university and industry associates was covered by national media. Besides fully autonomous operation, the truck also features an image/sound-based interface with passengers to allow assisted driving (Figure 2).

FIG 2 Autonomous truck developed in cooperation with Scania Latin America.

Software Architecture

The software architecture used in both LRM experimental vehicles is based on the following modules: map server, localization, perception, control, diagnostic and low level actuation. The communication among the processes is based on ROS (Robotic Operating System), leading to a modular software structure. Given the complex logistics and inherent risks of performing experimental tests, simulation is a fundamental tool to develop the software components. One of the group's more important development tool over the last years is a simulation framework fully compatible to the real vehicles software architecture. The same code can run on both transparently. Our simulation framework is based on MORSE for sensor modeling and Blender for physical simulation. It also allows tests with multiple vehicles and real time external control, used for research in both intelligent vehicle cooperation and assisted driving respectively.

Perception

Perception is certainly a fundamental capability of intelligent vehicles. We have been working on a number of perception approaches using a variety of sensors over the years. Our study of machine learning-based

FIG 3 Road detection using convolutional neural networks.

techniques started in 2009 with a committee of multi-layer perceptrons for vision-based road detection. Nowadays we are still investigating this problem using more modern approaches such as convolution neural networks (CNN). Although it is a well known problem, it still poses interesting challenges in non-structured environments and unfavorable illumination scenes. Our more recent approaches using CNN consist of both proposing new network architectures and adding custom semi-global layers to existent network models, improving their classification results (Figure 3). Machine learning-based approaches usually require large data sets with representative examples of the domain which we are working on. Unfortunately, such data is not always available for complex environments. Since 2011 we have been working on perception (obstacle and road detection) techniques that do not rely on previous information about the environments. Later we were able to benefit from both vision and distance information on a sensor fusion approach. Our method takes advantages of screen coordinates (u,v) with 3D information (x,y,z) from a range sensor to detect obstacles. This approach has been successfully tested with both stereo cameras and LIDARs with a minimum change of few parameters. A 3D point cloud is input to our obstacle-cost-function that compares each point with its neighborhood. Applying a threshold, we discard points on the ground to cluster the remaining points in several sets. Notice that besides uses of color as features, our fusion of LIDAR with cameras also allows us to use high accurate readings even when it has only small and sparse amount of points in long range. Real-time navigation in dynamic urban scenarios is certainly not a trivial task, and detecting obstacles is usually not enough to guarantee safety. Recently we have been working on tracking obstacles to predict and avoid collision. Our tracking system uses a Kalman filter to estimate the orientation and velocity of obstacles. Based on that information we are able to estimate our vehicle's safe velocity to minimize the chances of collision (Figure 4).

Mapping

In urban environments, most of the vehicles motion is based on traffic lanes. This is fundamental information

FIG 4 Real time obstacle tracking.

FIG 5 LRM team.

for intelligent vehicles to do path planning and control. As accurate lane information is not always available, a mapping approach was developed based on GPS data collected during regular human driving. Roundabouts and intersections are automatically detected and connected to the traffic lanes. An ongoing work on this topic is the capability of automatic mapping, including semantic information such as the presence of traffic lights, bumps and cross walks.

Control

The generated maps, together with localization information and the perception of static and dynamic obstacles, are used to enable the autonomous control of the vehicle. The group has designed novel controllers for low-speed scenarios using the kinematic vehicle model, which are suitable for most in-campus vehicle tests, and has since focused on the development of robust controllers for high-speed and limits of handling maneuvers, to ensure passenger and vehicle safety in emergency scenarios.

Future Directions

As mentioned before, a considerable research effort has been dedicated to the perception in urban environments in the last decades. However, most techniques developed for well paved roads and structured traffic lanes may not be appropriated for unpaved, non structured or poorly maintained roads. Frequent transition between different types of pavement, absence of painted lane marks and frequent occurrence of depressions and slopes are real challenges to road detection and navigation algorithms. Since Brazil has roads from well paved type until rough conditions in dirt road, we are trying to create public data sets that explore and encourage other research groups develop algorithms and solutions in these challenges.

ITS

PRESIDENT'S MESSAGE *(continued from page 3)*

initiatives and we wo-uld love to have more of our members to engage in these initiatives actively. Also, if you are passionate about any topics that could become candidates for future "Future Direction Initiatives," you are welcome to email me as well. Keep in mind that such topics need to have broader appeals than usual ITS topics such that at least a couple of other IEEE societies or councils could be collaborating with us. Let's get involved in IEEE Future Direction Initiatives!

Sincerely,
Daniel Zeng
President, IEEE ITS Society

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