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The VISTA Project and Its Applications

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This interesting installment presents the current projects and research activities under investigation at the University of Arizona and at the Chinese Academy of Science's Intelligent Control and Systems Engineering Center. The authors describe the VISTA Project and its main achievements so far and discuss the most important objectives that will be reached in 2005, at this initiative's end.

If you have any comment on this department, feel free to contact me. I also seek contributions on the current status of ITS projects worldwide as well as ideas on and trends in future transportation systems. Contact me at broggi@ce.unipr.it; www.ce.unipr.it/broggi.

—Alberto Broggi

In Arizona, a window of opportunity exists for using planned infrastructure expenditures to construct "intelligent lanes" on Interstate Highway 10 between Phoenix and Tucson for deploying intelligent vehicles (IVs). The Arizona Department of Transportation (ADOT) has identified the need for a third lane on I-10 in each direction between the two cities by 2005 and a fourth lane by 2020. Research shows that deploying IVs is feasible and beneficial if the communication and electronics infrastructure can be incorporated with minimal additional cost into the construction of additional lanes.[1] In fact, a study by BRW has proposed a six-phase, three-track approach that addresses both the need to increase the Phoenix–Tucson corridor's capacity and the deployment of IVs if necessary.[2]

Although BRW discussed options for IV technologies for the Phoenix–Tucson corridor, it did not recommend any specific technology. The choice of technology involves these issues:

- The vehicle's "intelligence" must be affordable by a large segment of the population.
- Initially, conventional vehicles should be able to use the infrastructure.
- The additional agency cost for equipping the infrastructure must not be so high that it offsets the IV's benefits.

In 1998, the University of Arizona formed the Vehicles with Intelligent Systems for Transport Automation research team, which the ADOT charged with the mission of investigating new and existing technologies and concepts that address those issues. The Arizona state legislature and ADOT funded the VISTA Project initially. The VISTA team consisted of 16 faculty members, research associates, and assistants from the University of Arizona and Arizona State University.[3] Since 2000, the VISTA project has been continuing as a joint project with the Chinese Academy of Science's Intelligent Control and Systems Engineering Center (ICSEC), sponsored partly by the University of Arizona's ATLAS (Advanced Traffic and Logistics Algorithms and Systems) Center, China's National Natural Science Foundation, the Triangle Group, and the CASIC Corporation.

The vehicle and control system

To demonstrate the deployability of VISTA's IV and automated-highway-system concepts, the team built VISTA Vehicle I, a demonstration vehicle based on the PATH (Partners for Advanced Transit and Highways) Vehicle.[4] Figure 1 shows VISTA Vehicle I and its hardware. VISTA Vehicle II, built at ICSEC, is equipped with an additional Differential Global Positioning System, an inertial measurement unit, and a laser reader that determines the vehicle's position and velocity by reading a special bar code on the ground for calibration.

Based on the behavior-programming approach for robotic vehicles,[5] the VISTA vehicles' control system comprises a set of hierarchically organized agent programs. These agents perform such functions as long-range path plan-

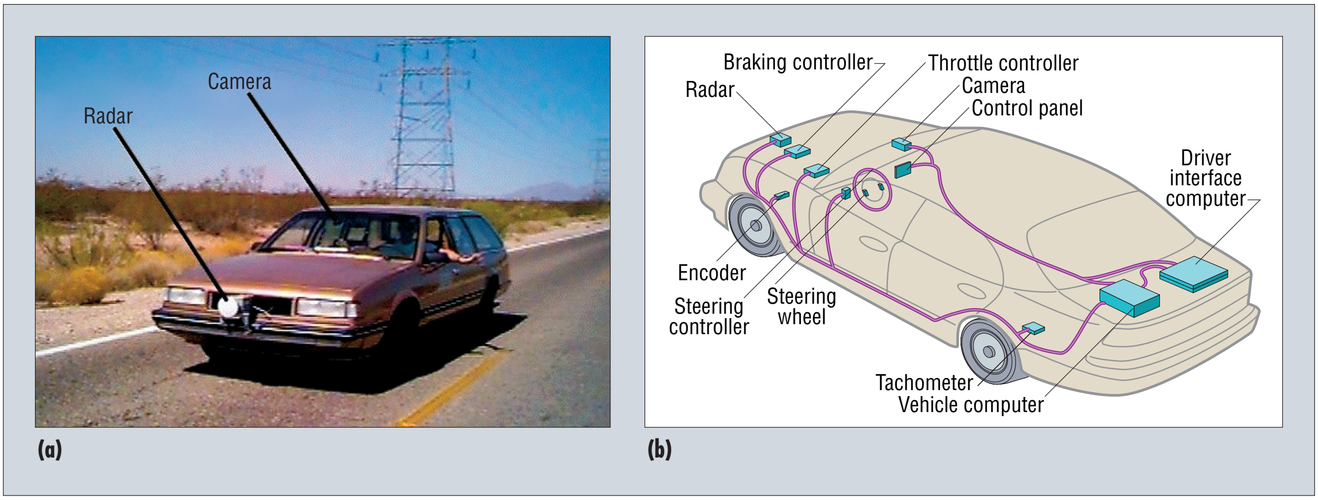

Figure 1. (a) VISTA Vehicle I and its (b) hardware (based on the PATH vehicle[4]).

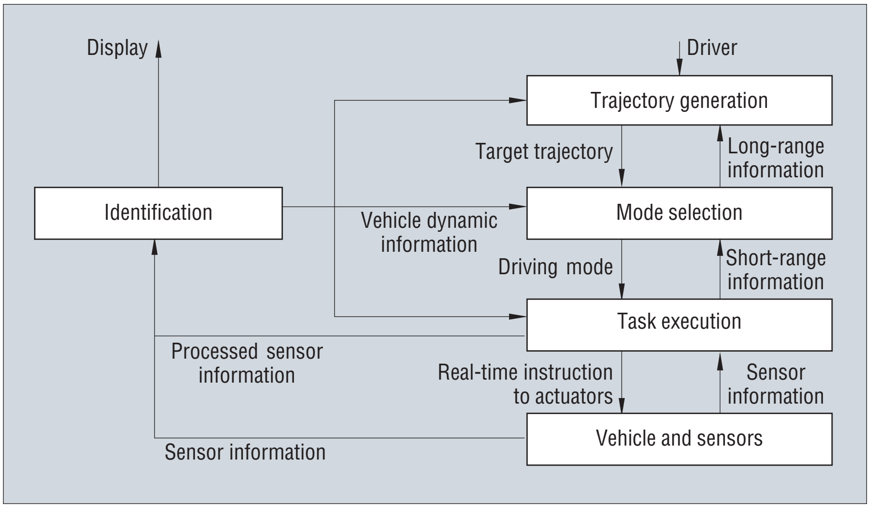

Figure 2. The VISTA control system's hierarchical structure.

ning, radar-based headway maintenance, radar-based road following, and close vehicle following. One agent classifies the driving conditions into different modes and then activates the agent corresponding to the current mode to control the vehicle. Figure 2 presents the VISTA control system's hierarchical control structure.

Each agent consists of a set of fuzzy rules that organize basic control commands. The system obtains many of the fuzzy rules directly by mimicking human driving behaviors. Because fuzzy control rules use linguistic terms such as "if the distance between the two vehicles is a little large, then increase the speed a little bit," the team can easily convert human driving skills and experiences into agents. At first, the system used a nonadaptive fuzzy technology. Later, the team implemented the neurofuzzy method[3] to add learning capability to the agents to improve driving performance.

Methods

To achieve the specified objectives, the team has developed and tested three methods.

The first is *calibration-based vehicle control* instead of guidance-based vehicle control. The team uses bar code-based *calibration stations* to determine the vehicle's position with high accuracy. These stations also offer a parameterized curve representing the center line of a lane to be followed for a long distance ahead. The distance between two stations is relatively large (about one mile in the test); between them, the vehicle uses only the in-vehicle sensory information for driving. The control system recalibrates the in-vehicle sensors when the vehicle passes a station. This method reduces the cost of constructing and maintaining road-site sensors and provides vehicles with long-range road information.

The second method is *trajectory planning and optimization* based on the long-range road information. This can help reduce energy consumption and air pollution while increasing traffic throughput for vehicles and traffic control.

The third is *distributed hierarchical agent-based control* instead of traditional functional decomposition into sensing, planning, and acting. As we mentioned before, the vehicle control system is decomposed into hierarchically organized special-purpose task-achieving modules—that is, agent programs.

On 21 March 1999, the VISTA team successfully demonstrated autonomous control of VISTA Vehicle I to its Technical Advisory Committee at an Arizona State University field test (see Figure 3a). On 27 and 28 April 1999, the VISTA team successfully demonstrated VISTA Vehicle I's longitudinal and lateral controls to the public and ADOT on Highway 51 in Phoenix (see Figure 3b).

Applications

The three methods have applications in many fields; here are three examples.

Automated vehicle proving grounds. Deployment of calibration-based vehicle control (or any automated driving techniques, for that matter) for automated driving on highways will take a long time. However, this method is practical, economical, and reliable for constructing automated vehicle-proving

(a) (b)

Figure 3. (a) Field test and (b) demonstration of autonomous control of VISTA Vehicle I on Highway 51 in Phoenix, Arizona. (In both pictures, the front car is a human-driven test vehicle and the car behind is VISTA Vehicle I.)

grounds to test mass-produced cars. Because proving grounds are controlled, known environments, barcode-based calibration stations can provide accurate information on vehicle position and velocity. They can also greatly simplify the computational and communications requirements for automated driving on vehicle test tracks.[6] China's National High-Technology Research and Development Program (also called the 863 Program) is using calibration-based vehicle control to construct a prototype of an automated vehicle- and tire-proving ground.

Recommending vehicle speeds and steering angles. Current technologies such as Global Positioning System, Global Information System, Global System for Mobile Communication, and digital maps support long-range road information. Because the VISTA approach exploits such information, vehicle trajectory planning and optimization become practical and useful. The current GPS-based vehicle navigation systems give drivers only the direction and distance. With optimal-trajectory planning, a vehicle navigation system can calculate online or offline the desired vehicle speed and steering wheel angle, at any time and point, for driving to a destination on a specified path. The system can also take into account optimality criteria such as minimum energy consumption, minimum time, and minimum jerk (the rate of change in acceleration). So, instead of just suggesting direction and distance, the system might also recommend the appropriate speeds (for example, telling the driver to speed up or slow down a little bit) and steering angles (for example, telling the driver to turn the steering wheel left or right a little bit). Initial results for this application appear elsewhere.[7]

Individualized automatic vehicle control. Because human driving skills and experiences are easily converted into agents, VISTA's control system can train an autonomous IV to acquire a human driver's behavior using a neurofuzzy network. The basic idea is to install an initial automated control system using a fuzzy-logic agent and then modify its control rules to fit an individual driver's behavior.

To achieve this, the system records driving actions and the corresponding vehicle motions during the learning phase. Through the neurofuzzy network implementation of the initial control system, the system plays back the recorded information offline as the training data to refine the membership functions for linguistic-input signal patterns, output control actions, and conjunction operators in the fuzzy reasoning. After extensive training, automated driving adapts to the driver's behavior.

This method provides an effective mechanism to construct driving control systems with personality for IVs. Initial results for learning longitudinal driving behaviors appear elsewhere.[8]

The US Federal Highway Administration, ADOT, and CASIC are sponsoring the Arizona Digital Highway Project through the ATLAS Center. This project uses VISTA's methods to develop and test digital vehicle and highway technologies to enhance driving safety. The project's basic technical concept is that if, through state-of-the-art sensor and geolocation technology, a vehicle knows within centimeters where it is and knows to a similar precision where the roadway is, many highway accidents can be prevented by warning drivers of possible hazardous situations. Furthermore, if, through vehicle-to-vehicle communication, the vehicle knows where all other vehicles in its vicinity are, most highway fatalities can be eliminated. The project will be completed in 2005.

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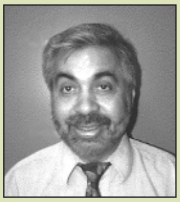

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