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An introduction to Demo 2000: The cooperative driving scenario

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Cooperation and coordination of activities and actions among independent agents moving in unknown or partially known environments are the key to success in accomplishing a complex common goal.

During the last few years, researchers have started several projects on this topic in different areas. Some of these projects include the European Handshaking Project, where road vehicles exchange information to better organize traffic flow; the Japanese rescue project for intervention of autonomous robots during catastrophic events; and the international RoboCup initiative, where a team of autonomous indoor robots have to coordinate their actions to implement a common strategy to play soccer against another team.

Although these applications are different in nature, they share the same underlying concept of coordination. In this installment of the ITS department, Sadayuki Tsugawa presents some important considerations for coordination through intervehicle communication, describes the history of different projects in this area, and tells about an upcoming demonstration of this technology.

For further information and for suggestions on this department, please contact me at broggi@ce.unipr.it, www.ce.unipr.it/broggi.

—Alberto Broggi

A formation of migrating geese is aerodynamically efficient. Dolphins swim without collision while communicating with each other. Like the movement of wild geese or dolphins, *cooperative driving* is the flexible platooning of automated vehicles across several lanes, involving lane changing,

smooth merging, and passing. The Super Smart Vehicle System studies, conducted from 1990 to 1992 by the Japanese Ministry of International Trade and Industry, proposed cooperative driving using *intervehicle communication* to make traffic safe and efficient. Studies of intervehicle communication had already started in the early '80s at JSK (the Association of Electronic Technology for Automobile Traffic and Driving), a MITI foundation, and researchers had conducted experiments on Advanced Traffic Management Systems (ATMS) and Advanced Traveler Information Systems (ATIS) applications in the mid '80s. The SSVS studies emphasized intervehicle communications as an essential technology for Advanced Vehicle Control and Safety Systems (AVCSS).

Following up on the SSVS

Based on the SSVS studies, JSK started Phase 1 of a cooperative driving project in 1993. The intervehicle communication system employed infrared transceivers,

using triangulation to measure the intervehicle distance. In March 1997, JSK demonstrated a cooperative driving system with four nonautomated or longitudinally automated vehicles on MITI's Mechanical Engineering Laboratory (MEL) test track in Tsukuba, Japan, to show the advantages of intervehicle communication during merging and emergency braking. A driver who wanted to merge would look at a display on the side mirror, which showed the right time to merge. An onboard computer calculated this timing using the locations and speeds of neighboring vehicles in the main lane, which were obtained through intervehicle communication. The communication period was 20 ms, so each vehicle could have real-time data on the neighboring vehicles. In a platoon, the transmission of emergency braking by the lead vehicle to the following vehicles through intervehicle communication could safely stop all the vehicles, because no braking delay would occur.

Phase 2 started in 1997. This phase in-

volves cooperative driving with intervehicle communication and automated vehicles. JSK is handling the communication; the MEL is handling the automated vehicles and the cooperative driving with the communication and the automated driving. The intervehicle communication protocol, which employs 5.8-GHz dedicated short-range communications, is called Dolphin (*Dedicated Omnipurpose Interverhicle Communication Linkage Protocol for Highway Automation*).

Demo 2000

To show the feasibility of these technologies, the MEL and JSK will sponsor Demo 2000, a cooperative-driving demonstration, from 22 to 27 November 2000. An MEL-JSK team will operate a platoon of five autonomous vehicles, equipped with an intervehicle communication unit and with DGPS (a differential global positioning system), machine vision, and laser radar or millimeter wave radar. The vehicles require no infrastructure intelligence. The cooperative-driving scenario will consist of

- the platoon starting and stopping,
- platooning,
- splitting into two platoons,
- merging into one platoon,
- passing by the last vehicle,
- detecting obstacles and avoiding them by changing lanes, and
- driving a winding course under platooning.

The scenario will cover three circuits of the MEL's 3.2-km oval test track.

People have become less skeptical that *automated highway systems* will be needed for future road transportation, because they see that AHS not only can solve current traffic problems but also can provide a new transportation means for an aging society. Toward that end, as part of Demo 2000, a University of Tokyo team will demonstrate an automated vehicle for the disabled. This vehicle uses robotic manipulators to load and unload a disabled person in a wheelchair. Their research is not included in the cooperative driving research, but they wanted to demonstrate with us.

Future directions

Demo 2000 will verify the importance

of intervehicle communication to AHS. The deployment of intervehicle communication, however, is quite another story. Now I examine the deployment of AHS and the intervehicle communication involved in AHS.

AHS should materialize through cooperation between vehicle intelligence and infrastructure intelligence, with optimal trade-off between them. However, solving the chicken-egg problem in AHS—if there is no infrastructure intelligence, there will be no vehicle intelligence, and vice versa—is still difficult. This problem emerged in the Comprehensive Automobile Traffic Control System in the '70s, which was the first dynamic route-guid-

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ance system. The Vehicle Information and Communication System (www.its.go.jp/ITS/index.html) has solved this problem, with the help of the widespread penetration of car navigation systems in the '90s. An AHS on a dedicated lane under protected conditions will materialize in the near future, but an AHS for regular road transportation will take somewhat longer.

The difficulty in deploying intervehicle communication is that, unlike road-vehicle communication, it depends on only the vehicles. Also, the services that intervehicle communications will provide are not yet clear, and all the technologies have not been developed. It will be some time until a platoon drives using intervehicle communication. However, some candidates for initial deployment exist. One is a system proposed by Opel, BMW, and Bosch.¹ It uses a car phone antenna to transmit an emergency to vehicles approaching in the same lane. This information will prevent multiple accidents in that lane.

Other candidates are Toyota's Intelligent Multimode Transit System and Honda's Intelligent Community Vehicle System. In

Toyota's system, vehicles (in this case, transit buses) drive automatically on a dedicated lane but are driven by a driver on a public roadway. The vehicles have an intervehicle communication system for automated driving; this function can also be used on a public roadway. Honda's system works similarly.

Adaptive cruise control can probably provide a basis for both AHS and intervehicle communication. ACC can work as a stand-alone system or can be extended to a driver aid system under stop-and-go conditions. The laser radar in ACC can be a communication medium if the vehicle ahead has an optical receiver at the laser beam reflectors.

The introduction of autonomous vehicle intelligence successfully solved the chicken-egg problem in road-vehicle communication. The deployment of intervehicle communication will be different from that. It will involve finding a way to solve traffic problems caused by accidents and congestion. For AVCSS applications, the equipment's reliability is crucial.

For more information on Demo 2000, access www.demo2000.gr.jp/index_e.htm or contact me at tsugawa@mel.go.jp. ■

Reference

1. C. Passmann, C. Brenzel, and R. Meschenmoser, *Wireless Vehicle to Vehicle Warning System*, SAE paper 2000-01-1307, Soc. Automotive Engineers Int'l, Warrendale, Pa., 2000.

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