The Exploratory Advanced Research Program Fact Sheet

Lane-Level Vehicle Positioning

Integrating Diverse Systems for Precision and Reliability

Exploratory Advanced Research . . . Next Generation Transportation Solutions

Fusion of data from several sources could deliver the highly accurate, real-time positioning information that new driver assistance applications require. Investigating that promise is the task of an Exploratory Advanced Research (EAR) Program project, "Innovative Approaches for Next Generation Vehicle Positioning," at the University of California at Riverside, funded by the Federal Highway Administration (FHWA) in 2009.

The Vehicle Positioning Challenge

Integrated global positioning system/inertial navigation system (GPS/INS) technology, the backbone of vehicle positioning systems, cannot provide the precision and reliability needed for vehicle-based, lane-level positioning in all driving environments at all times—INS or encoder based navigation systems tend to accrue error unless corrected and GPS signals are blocked by obstacles. Feature-based technologies—camera, LIDAR, and RADAR, often used to augment GPS/INS, succeed only where detectable structural features are found. To access critical positioning data in any location, at any time, regardless of weather and visibility, the next generation of vehicle positioning systems will need to integrate data from satellites, terrestrial radio signals, and feature-based sensors.

"Manufacturer and university research groups are pursuing data fusing solutions independently," says Jim Arnold of FHWA, "but a low-cost, public-sector solution could advance the availability of a robust lane-positioning architecture nationwide. This 3-year EAR Program study is investigating widely available technologies to augment an integrated navigation system."

Exploring Viable Approaches

In phase I, now completed, the project's task was to compare the capabilities—accuracy, reliability, availability, continuity—and deployment costs of candidate approaches, addressing these questions:

- Which aiding sensors are feasible for automotive applications, now and in the future? What advancements are required to alter this assessment?
- Which combinations of feasible sensors can achieve the lane-level positional accuracy, availability, and continuity specifications?
- How do the successful sensor combinations compare from the cost perspectives of roadway infrastructure and vehicle-based equipment?

Candidate approaches considered in terms of their accuracy, vehicle cost, roadway cost, and advances they may require included the following technologies:

- Global Positioning System: GPS, differential GPS, carrier phase differential (CPD) GPS.
- Terrestrial radio: Pseudolites (local, ground-based transceivers that can substitute for GPS), cell phones (time of arrival, time distance of arrival), digital TV, radio (AM analog, FM analog, digital), packet radio.
- Feature-based technology: Vision, RADAR, LIDAR.

Based on their evaluation, the investigators selected (1) FM and digital TV radio navigation methods and (2) vision, LIDAR, and RADAR for further exploration and testing in phase II of the study. These approaches will serve as integrated adjuncts to the primary, dual system: inertial navigation aided by CPDGPS. CPDGPS provides the centimeter-level precision necessary for automated highway systems by referencing the high-frequency carrier signal to provide position

U.S. Department of Transportation
Federal Highway Administration

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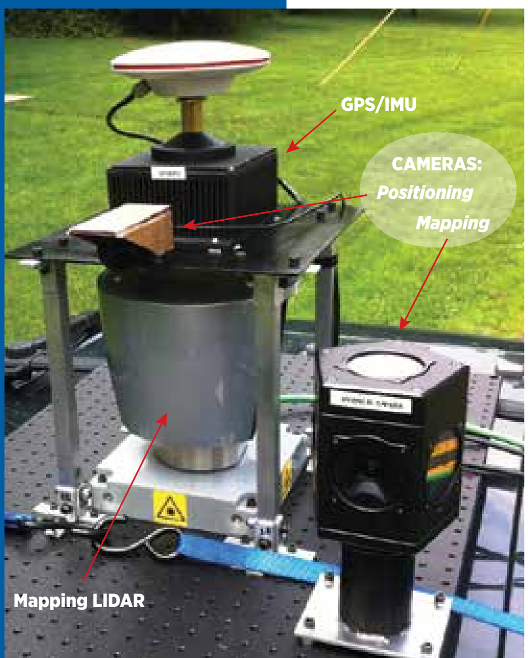

Feature-based mapping and positioning sensor suite showing a GPS/IMU (inertial measurement unit) box and a forward-looking camera for positioning, and a 360-degree camera and Velodyne® LIDAR for mapping.

corrections in real time. The phase II work is following a three-step approach:

- Integrated (or aided) navigation system fuses asynchronous, possibly latent, data from a diversity of sensors to reliably estimate vehicle state.
- High-rate sensor readings are integrated through a model of a moving vehicle to produce a continuously available vehicle state estimate.
- Integrated errors from high-rate sensors are corrected from a diversity of aiding sensors.

The researchers plan to develop and evaluate prototype integrated positioning systems. For sufficiently advanced systems, they will conduct field tests and propose a full-scale deployment plan.

Moving Forward

The experience and products obtained through the successful completion of this project will speed the development of vehicle positioning systems and further the maturity of the Connected Vehicle Program, in which FHWA participates. Many driver-assistance applications targeting roadway safety and mobility (with reduced energy use and emissions) will benefit, and much will be learned about the strengths and limitations of sensors, components, algorithms, and strategies.

Cross-cutting in nature, the project's findings will be of interest to other Federal agencies and to automotive manufacturers. "If successful, this project could provide a major step forward in realizing the safety and mobility benefits of intelligent transportation systems," says Arnold.

EXPLORATORY ADVANCED **RESEARCH**

What Is the Exploratory Advanced Research Program?

FHWA's Exploratory Advanced Research (EAR) Program focuses on long-term, high-risk research with a high payoff potential. The program addresses underlying gaps faced by applied highway research programs, anticipates emerging issues with national implications, and reflects broad transportation industry goals and objectives.

To learn more about the EAR Program, visit the Exploratory Advanced Research Web site at www.fhwa.dot.gov/advancedresearch. The site features information on research solicitations, updates on ongoing research, links to published materials, summaries of past EAR Program events, and details on upcoming events. For additional information, contact David Kuehn at FHWA, 202-493-3414 (email: david.kuehn@dot.gov), or Terry Halkyard at FHWA, 202-493-3467 (email: terry.halkyard@dot.gov).

Learn More

For more information on this project, contact Jim Arnold, FHWA Office of Operations Research and Development, at 202-366-8422 (email: james.a.arnold@dot.gov).

Publication No.
FHWA-HRT-13-059
HRTM-30/04-13(1M)E