New Bus Rapid Transit service will put ITS technologies in the spotlight

A team of engineers and researchers from the ITS Institute’s Intelligent Vehicles Laboratory and HumanFIRST Program is getting ready to put a new spin on public transportation in the Twin Cities. By early 2010, a fleet of ten buses equipped with advanced driver assistive technologies is scheduled to begin offering bus rapid transit (BRT) service on one of the area’s most important commuter routes, the I-35W/Cedar Avenue corridor linking downtown Minneapolis to the southern suburbs.

The project is part of Minnesota’s efforts to improve the performance of its transportation system under the U.S. Department of Transportation’s Urban Partnership Agreement (UPA) program. In June, 2008, the federal agency selected Minnesota to receive $133.5 million under the U.S. Department of Transportation’s Urban Partnership Agreement (UPA) program.

ITS meets BRT

Bus rapid transit uses transit buses to provide the kind of fast commuter service usually associated with light-rail transit systems. Because it does not require the construction of rail lines or other specialized facilities, BRT is highly cost effective and relatively easy to implement, making it a good option for rapidly improving commuter transit service, says ITS Institute director Max Donath.

One of the advantages of the new UPA funding is that it enables the IV Lab to leverage previous BRT-related collaboration with the Minnesota Valley Transit Authority (MVTA), which has operated transit service along the corridor for several years, says IV Lab director Craig Shankwitz, who is also the lead researcher on the project. The Minnesota Department of Transportation and local transit agencies have worked together to provide service on shoulder lanes for several years. Bus drivers on designated highway routes are allowed to operate their vehicles in shoulder lanes at their discretion to avoid traffic congestion on the main roadway.

The bus-only shoulder program has proven extremely popular with transit riders—in fact, transit officials report that riders call in to complain if their drivers are not taking advantage of an open shoulder. However, operating a nine-foot-wide bus in a ten-foot shoulder lane can be challenging for even experienced drivers. To ensure safety, the decision to use a shoulder lane is always left to the operator’s discretion, and they may decide to stay in the main roadway if visibility of the shoulder lane is low.

In 2002, Donath and IV Lab director Craig Shankwitz saw an opportunity to use the ITS Institute’s expertise in driver-assistive systems to improve transit service on bus-only shoulders. The lab had already been working on a suite of driver-assistive systems for special-purpose vehicles such as snowplows, including lane guidance based on high-accuracy Global Positioning System data, digital mapping, obstacle detection, and head-up display technologies. In a series of research projects, IV Lab engineers began to adapt these technologies for the unique needs of transit vehicle operations, and they were tested in collaboration with Metro Transit, the largest transit operator in the Twin Cities.

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IEEE honor for Autoscope

Professor Panos Michalopoulos received the 2007 IEEE Outstanding Intelligent Transportation Systems (ITS) Application Award for his development of Autoscope™, a video detection sensor. He was presented the award at the 2008 IEEE ITS Conference held in Beijing, China, in October 2008.

Michalopoulos has been a professor of traffic and transportation engineering at the University of Minnesota since 1977. He played a pivotal role in founding the Center for Transportation Studies, and is a CTS Research Scholar.

Research by Michalopoulos led to the development of Autoscope, the first and most widely used machine-vision-based vehicle detection and surveillance system, with more than 20,000 installations worldwide since 1993. To commercialize the technology, Michalopoulos founded Image Sensing Systems, Inc., for which he served as chairman, chief scientific advisor, and board member. The video imaging system is patented by the University of Minnesota and generates significant royalties. IEEE, formerly the Institute for Electrical and Electronic Engineers, is a nonprofit organization, is a leading professional association for the advancement of technology.
Pre-college outreach builds ITS awareness

Students at Patrick Henry High School in Minneapolis got an extra lesson in the science of traffic management when ITS Institute program coordinator Shawn Haag visited the school to teach a curriculum unit on traffic engineering.

Approximately 25 students from the eleventh and twelfth grades worked through a curriculum unit developed by the ITS Institute as part of its outreach efforts to high school students. The unit has also been used in a summer day camp program sponsored by the University of Minnesota's Institute of Technology.

The curriculum unit is designed to teach high-school students about fundamental traffic management issues with an Intelligent Transportation Systems perspective. It incorporates an interactive traffic simulation developed by Minnesota Traffic Observatory educational systems manager Chen-Pui Liao that puts the students in charge of traffic signal timing in a simulated urban area. Students can change parameters and see how their strategies affect traffic flow.

"It was a very diverse group of students, and they all really dove into the curriculum," said Haag, who coordinates outreach efforts to pre-college students, including school visits and student tours of transportation research facilities on the University of Minnesota campus.

Many new college students entering engineering or technology-related programs are unaware of the wide variety of academic options related to transportation, and the different transportation-related careers that are open to qualified college graduates.

Based on the interest generated by Haag's visit, instructors at Patrick Henry High School are now interested in bringing a group of students to the University for a tour of the Institute's research facilities.

The Institute is involved in a variety of other outreach efforts targeting pre-college students.

The Institute has brought several groups to the University to learn about careers in transportation and see demos of current research technologies, including approximately 75 high school students enrolled in a summer transportation camp through the Fond du Lac Tribal and Community College; students and teachers from the Blaine High School Center for Engineering, Math, and Science; and students in the St. Cloud Summer Transportation Academy.

For the second year, the ITS Institute will be an exhibitor at TechFest, a day of special interactive exhibits held at The Works Technology Discovery Center. This year's theme is aerospace engineering, and CTS Scholar Demoz Gebre-Egziabher will be on hand to show young people his unmanned aerial vehicle research prototypes.

Haag says the Institute is also excited about participation in the American Indian Science and Engineering Expo this year. The Institute will be among the exhibitors at St. Paul RiverCentre March 26–28. The event is part of the 21st Annual National American Indian Science & Engineering Fair, and will feature a wide variety of hands-on demonstrations and informal educational opportunities for middle school and high school students.

Arpin named 2008 Student of the Year

Mr. Eddie Arpin, a recent graduate from the University of Minnesota with a M.S. in Mechanical Engineering, was honored as the University of Minnesota’s University Transportation Center Student of the Year at the Transportation Research Board annual meeting in January.

Arpin started his graduate studies at the University of Minnesota in January of 2006, and emphasized in robotics, controls, and automation. He began working for the University of Minnesota's Intelligent Vehicles (IV) Laboratory in September of 2006. At the IV Lab, he was part of a three man team that competed in the Intelligent Ground Vehicle Competition, taking second place in the Autonomous Vehicle Challenge. At the same time, he began his thesis research on developing a vehicle positioning system to work in urban environments.

ITS Institute director Max Donath says Arpin was selected as Student of the Year for many reasons: he graduated with a 3.83 GPA in his graduate studies, recently finished his thesis, “A High Accuracy Vehicle Positioning and Guidance System Fusing RFID and LIDAR” in September of 2008, and is currently employed as a Research Fellow at the Intelligent Vehicles Laboratory working on the driver assistance system for transit bus drivers featured in this issue of the Sensor. Arpin’s advisor notes that “It is truly remarkable what Eddie has been able to accomplish these past two years since he started working in his thesis research.”

Each year, the U.S. Department of Transportation (USDOT) honors an outstanding student from each UTC at a special ceremony held during the TRB Annual Meeting. Each student receives $1,000 and the cost of attendance at TRB from his/her Center, plus a certificate from USDOT.

Faculty, students, and researchers from the University of Minnesota presented current and recently completed ITS-related research at the Transportation Research Board 88th annual meeting January 11–15.

Each year, the Institute awards travel grants to graduate and undergraduate students. Students must be nominated by a faculty member based on criteria including transportation-related coursework, research, or presentations. Students selected for a travel award receive up to $1000 based on travel expenses.

Faculty and researchers presenting ITS-related research this year represented a range of academic departments including mechanical and civil engineering, the Humphrey Institute of Public Affairs, the HumanFIRST Program, the Intelligent Vehicles Laboratory, the Minnesota Traffic Observatory, and the Center for Human Factors Systems Research and Design.

ITS researchers, students attend TRB annual meeting
Those efforts led to a successful multi-year collaboration with the MVTA in which driver assistive technologies developed by the ITS Institute were tested and deployed on an MVTA bus. The feedback from experienced bus drivers using the equipment under real-world conditions has been instrumental in refining the driver assistive systems for the specific needs of BRT operations.

The long and winding road
To guide a nine-foot-wide bus along a ten-foot-wide shoulder lane, the IV Lab’s vehicle guidance system needs both a detailed map of the route and a continuously updated set of highly accurate vehicle position measurements. The route map takes the form of a digital geospatial database, carried in the system’s onboard computer, containing precise measurements of every twist and turn of the roads and shoulders on which the busses travel as well as data on signs and other obstructions near the roadway. In previous research projects, the IV Lab researchers developed data gathering techniques that support the rapid construction of geospatial databases for vehicle guidance systems, enabling them to create digital route maps much more quickly and cost-effectively than is typically done.

Keeping track of the bus’s position to within a few centimeters over the entire route is one of the most significant technical challenges of the project, says IV Lab researcher Pi-Ming Cheng. In addition to requiring extremely high accuracy—far beyond the capabilities of the satellite navigation units in new cars—the system must avoid losing track of its position even when the signals from GPS satellites are temporarily interrupted by bridges, buildings, and other obstacles along the route.

The guidance system achieves centimeter-level accuracy by using differentially corrected GPS, which augments the signals from orbiting GPS satellites with a correction signal derived from base stations on the ground. A network of six virtual reference stations around the BRT service area provides high-accuracy position data to a central server, which in turn transmits a customized correction signal to each bus via a cellular data modem.

An additional benefit of receiving the GPS correction signal is that the cellular modem’s extra bandwidth can be used to deliver high-speed Internet service to passengers. Although Cheng says the engineers have been careful to give priority to the navigation system, riders will still be able to surf the Web en route, or even get some extra work done.

IV Lab engineers have devoted considerable effort to improving the robustness of GPS-based vehicle positioning systems over the past several years. After early experiments with inertial measurement systems that measure acceleration in two dimensions to determine movement proved unsatisfactory, the researchers settled on a new approach that combines laser range sensors (lidar) mounted on the vehicle with radio-frequency identification (RFID) tags embedded in the road surface. A lidar sensor monitors the vehicle’s lateral position relative to a curb or barrier, while RFID is used to track longitudinal position along the route.

Under the UPA program, this system will be deployed in urban areas where buildings and overpasses interfere with GPS signals, and near bus stations to help guide the vehicle into position for loading and unloading. The RFID technology used in this system are similar to the anti-theft tags attached to many consumer goods to discourage shoplifting. In both cases, the passive circuitry of the tag is activated by a low-powered radio beam, causing it to transmit a coded signal that is then picked up by a receiver. In the BRT system, the RFID tags simply transmit their exact locations to the vehicle’s navigation system.

Meanwhile, lidar scanners on the sides of the bus measure the distance to the edge of the bus lane with an infrared laser beam. An onboard computer combines the data from the RFID and lidar sensors and updates its internal estimate of the vehicle’s position whenever it determines that the position provided by the GPS system is not up-to-date.

The human in the center
In keeping with the ITS Institute’s “human-centered technology” approach, the driver assistive system of the new BRT vehicles surrounds bus operators with a suite of tools designed to make their jobs easier and safer. The driver interface, the product of collaboration between IV Lab engineers and human factors researchers from the HumanFIRST Program, employs both visual and haptic (touch-based) modes to allow the driver to understand safety-critical information quickly and intuitively.

Early work by human factors researchers in the HumanFIRST Program showed that using narrow bus-only shoulders placed greater cognitive demands on drivers than operating in regular lanes, increasing the risk of stress and distraction. The overall design goal of the driver-assistive system is to help drivers manage the cognitive demands of BRT operation, reducing their cognitive load and improving their performance.

Information from the route-guidance system and the vehicle-detection system is integrated and displayed to the driver using a head-up display (HUD) unit mounted between the driver and the windshield. A projector behind the driver’s head projects lane boundaries and graphical icons of vehicles within the forward field of view onto the HUD screen, through which the driver can also see their normal view of the road. Even if the driver’s normal view were obscured by blowing snow or fog, they would still be able to see land boundaries clearly and judge the distances to surrounding vehicles.

A compact flat-panel display mounted to the driver’s left serves as a virtual rear-view mirror, showing graphical representations of vehicles in the blind zone to the bus’s left as they are detected by a lidar unit mounted low on the bus’s left side.
The steering wheel is equipped with a computer-controlled servomotor that provides haptic feedback in the form of steering resistance whenever the guidance system determines that the bus has begun to deviate from its lane. In fact, the guidance system is capable of steering the bus entirely on its own—though Shankwitz emphasizes that it is intended only to assist a human operator. The driver retains steering control at all times, and can override the steering servo simply by turning the wheel to avoid an obstacle or maneuver out of the shoulder lane.

In addition to the steering servo, a second haptic interface lets bus operators literally drive by the seat of their pants. A pair of haptic actuators—essentially computer-controlled vibrators—mounted beneath the driver’s seat can be activated by the guidance system when the bus deviates to the right or left, creating a pair of “virtual rumble strips” that the driver can feel without taking their eyes off the road.

**Behind the yellow line**

For the commuters who rely on BRT service to get them to and from work every day, the biggest benefits of the new technologies will be improved schedule adherence and a better overall riding experience, says IV Lab researcher Pi-Ming Cheng.

Research has shown that transit riders rate consistent travel times as an extremely important factor in the quality of transit service. For commuters who need to be at work on time in the morning and at home in time to meet their kids, a transit service that deviates from its schedule is not a viable travel option.

By making it possible for bus operators to use shoulder lanes under a wider range of conditions, buses equipped with the ITS Institute’s driver assistive technologies will be able to avoid delays associated with traffic congestion and provide a service with many of the scheduling advantages of light rail transit systems.

Of course, the onboard high-speed wireless Internet service, a byproduct of the system’s high-accuracy GPS technology, is sure to appeal to multi-tasking executives—or those who just need a few extra minutes to update their blogs, says Cheng.