SMART-Signal targets improved arterial intersection performance

One of the primary obstacles to improving the performance of signalized arterials has been the difficulty of gathering accurate and reliable data to assess arterial traffic conditions. The need to manually collect the data and then calculate performance metrics for individual intersections or arterials has made performance assessment a time-consuming and expensive process for transportation agencies.

Researchers at the University of Minnesota's Department of Civil Engineering and Minnesota Traffic Observatory (MTO) developed a new system that automates data collection and performance assessment in real time. Because it can also refine the traffic signal parameters intelligently using archived data, the system has been dubbed “SMART-Signal,” the acronym for Systematic Monitoring of Arterial Road Traffic Signals. The effort was funded by the ITS Institute, Minnesota Local Road Research Board, and Minnesota Department of Transportation, with significant in-kind support from Hennepin County.

Principal investigator Henry Liu’s research is focused on traffic control and operations, network modeling, and simulation of transportation systems. Since joining the University of Minnesota faculty in 2005, Liu has led a series of research projects focusing on various components of the SMART-Signal system. Chen-Fu Liao, a senior systems engineer at the MTO, has also participated in the projects.

The SMART-Signal system is intended to be installed at a series of intersections along an arterial road. A dedicated microprocessor module is installed in the signal control cabinet at each intersection, interfacing directly with the cabinet without interfering with signal operations. SMART-Signal collects two types of event data: signal-phase change events and vehicle-detector actuation events. Event data are then packaged and transmitted in real time to the server located at the MTO.

Shockwave dynamics and queue length

Queue length is invariably the most important performance measure at a signalized intersection. A major shortcoming of traditional input-output models used to estimate queue length has been their inability to determine queue length under saturated conditions—i.e., when the queue of cars waiting to pass through an intersection extends beyond the upstream vehicle detector. Under saturated conditions, data on incoming traffic flow are no longer available and the input side of the input-output model breaks down.

The SMART-Signal developers overcame this limitation by developing a new algorithmic approach to queue length estimation based on the mathematical properties of shockwaves. A shockwave forms whenever the density of vehicles in a traffic flow changes, such as when traffic is forced to stop at an intersection. This queuing shockwave will continue to propagate upstream as more and more vehicles arrive at the end of the queue. When the signal phase changes to green, however, vehicles will begin to depart from the head of the queue, forming a discharging shockwave; because this wave propagates more quickly than the first, under most traffic conditions, it will eventually meet the front of the first shockwave. At that point, the queue disappears, as all vehicles are again moving forward. If all the vehicles from the queue are not able to pass through the intersection before the start of the next red phase, a residual queue forms and begins to propagate upstream, starting the cycle again.

SMART-Signal uses data from the upstream vehicle detector to identify three critical points in the shockwave propagation: when the queuing shockwave reaches the upstream detector; when the discharging shockwave passes the detector; and, most important, when the rear of the queue of stopped vehicles passes the detector. Before the rear of the queue reaches the detector, vehicles are generally moving under saturated traffic conditions, so they are closely spaced and there is little variance in the size of inter-vehicle gaps. But as the queue dissipates, vehicle spacing increases and the size of inter-vehicle gaps becomes more variable. These characteristic changes make it possible for SMART-Signal to identify the moment when the shockwave corresponding to the rear of the vehicle queue passes the upstream detector.

Using these three critical points, SMART-Signal’s estimation algorithms can estimate traffic states upstream from the intersection and determine the maximum length of the vehicle queue, an important performance metric for arterial intersections. Extensions to the traffic

MTO research explores options for Denali National Park

Since 2005, the Minnesota Traffic Observatory (MTO) has worked with the National Park Service to understand the effects of park traffic on the animal inhabitants and on the experience of park visitors in Denali National Park. To preserve the park’s unspoiled beauty, visitor traffic is limited to special tour buses. However, with high public demand for access to the natural beauty of Denali, park officials have sought new ways to ensure that as many visitors as possible are able to experience the natural wonders of the remote park without driving away wildlife or reducing the quality of visitors’ experiences.

Working with the University of Vermont Park Studies Laboratory, MTO researchers developed a specialized model of traffic and wildlife sightings in the park. The model incorporates data on wildlife sightings collected by bus operators using a GPS-based data-gathering system developed specifically for the project. The model has allowed park managers to better understand the capacity limits of the current transportation system as well as the impacts of traffic on critical animal crossings and migration routes.

Now the MTO team is extending its research by creating tools that will allow Denali officials to evaluate alternative traffic scenarios in terms of their impacts on the park and on the quality of visitors’ experiences (indicated by the level of crowding). A range of alternative traffic management scenarios has been proposed, involving different route destinations, designated scenic rest stops, and the number of buses on the route. These scenarios must be evaluated to ensure that the park’s unique beauty and integrity are maintained.

INSIDE

International visitors ......................... 2
State Fair exhibit ............................. 2
Technology camps .......................... 3
Tech Plan report, roundtable .......... 4
Recently published research .......... 4

INSIDE

International visitors ......................... 2
State Fair exhibit ............................. 2
Technology camps .......................... 3
Tech Plan report, roundtable .......... 4
Recently published research .......... 4

Denali continued on page 2

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Henry Liu

— www.its.umn.edu —
examined as part of the environmental impact statement (EIS) process required for transportation projects that affect natural areas. Simulating the impacts of each proposed scenario will help park managers more fully understand the relative advantages and disadvantages of transportation policy decisions before they are implemented in the real world. Once a new transportation system is actually deployed, park managers will be required to continually monitor the quality of visitor experience and wildlife impact indicators to ensure that set standards of these indicators are not violated; should that happen, park managers must intervene to mitigate violations.

Because it is impractical to continually monitor the complete roadway by human observation over the course of the tourist season (the road is more than 90 miles long, with several scenic rest stops, campgrounds, and sensitive wildlife areas), the MTO will be developing new database and data collection tools that will help park managers with the monitoring process. Virtual sensors along the simulated route will measure a variety of traffic variables that relate to indicator measures, such as traffic counts, rest stop monitors, vehicle bunching frequency, and other relevant factors. Park managers will then be able to “deploy” these virtual sensors wherever they want to know more about traffic conditions within the park. Data on animal movements may also be incorporated into the scenario evaluation process.

The ITS Institute team plans to continue working with the National Park Service and Denali National Park through 2013, gathering data and providing updated performance metrics and reports as well as developing new tools and helping park managers evaluate their transportation needs.

Editor’s note: This research was the cover story in the Fall 2010 issue of Park Science Journal, available online at www.nature.nps.gov/parksceindex.cfm?IssueID=24.

International visitors tour U of M research labs

The ITS Institute was among several University of Minnesota research laboratories that hosted tours from European transportation organizations in recent months.

On September 22, members of FEHRL–ECTRI visited campus as part of a scan tour of U.S. transportation research facilities. FEHRL, the Forum of European National Highway Research Laboratories (www.fehrl.org), provides a coordinated structure for the interests of more than 30 national research and technical centers from Europe, together with associated institutes from around the world.

ECTRI, the European Conference of Transport Research Institutes (www.ecri.org), is an international nonprofit organization whose members are 27 major transport research institutes or universities from 20 European countries. Together, they account for more than 3,800 European scientific and research staff in the field of transport.

Steve Phillips, FEHRL secretary-general, presented the objectives of the tour—the group’s first to the United States—and introduced FEHRL–ECTRI scan team members from France, Great Britain, Spain, Germany, Hungary, Poland, South Africa, and Sweden.

Phillips said the aim of the scan was twofold: to identify what’s missing in existing U.S. and European research facilities to meet current and emerging needs, and to recommend opportunities to use existing facilities and collaborate to develop new ones. Minnesota was selected for a site visit because of its research facilities and its extensive experience with international cooperation, he said.

Michael Manser, director of the HumanFIRST Program, gave an overview of the program’s simulation equipment and John Houdos, Minnesota Traffic Observatory (MTO) director, demonstrated the MTO’s technologies. On September 23, a similar tour was given to representatives from the Swedish Transport Administration. Alec Gorjestani and Justin Graving, research fellows in the Department of Mechanical Engineering (ME), gave a demonstration of a Teen Driver Support System under development in the Intelligent Vehicles Lab, another facility of the ITS Institute. ME professor Rajesh Rajamani gave a lunch presentation about his research. The group also toured the MTO and HumanFIRST labs and attended an ITS Institute Advanced Transportation Technologies Seminar.

On August 26, a delegation from Russian transportation organizations visited campus for an information exchange and tours focusing on safety innovations. The group heard overviews of various CTS programs and also toured the HumanFIRST lab and the MTO.

Institute at the 2010 Minnesota State Fair

The ITS Institute and CTS showcased a variety of transportation-related attractions at the 2010 Great Minnesota Get-Together. Visitors to the University of Minnesota building on August 27 and September 3 chatted with CTS and Institute staff and checked out the latest transportation innovations.

Fairgoers of all ages played Gridlock Buster, an interactive traffic-control game designed by the ITS Institute and Web Courseworks. The game incorporates tools and ideas used by traffic engineers every day to give players a taste of what it’s like to manage traffic flow. Since its original online posting, the game has been played 1.9 million times (see www.its.umn.edu/GridlockBuster).

Adult visitors viewed SafeRoadMaps, a powerful and visually innovative crash-mapping tool that maps every roadway fatality in the nation, down to the local level.

During the past summer, the ITS Institute participated in a variety of educational camps focused on introducing science and technology to more than 200 elementary through high school-aged students. Institute staff and graduate students gave tours of University of Minnesota labs and presented transportation-related demonstrations to participating campers.

On July 14, approximately 25 students from the Leech Lake Indian Reservation Transportation Camp visited the University of Minnesota. This program, in its second year, receives funding from the Federal Highway Administration’s National Summer Transportation Institute Program and is designed to encourage students ages 10 to 15 to explore careers in transportation-related fields. As part of the visit, students toured the Institute’s Minnesota Traffic Observatory (MTO) and the Robotics Lab. ITS staff also taught visitors to play Gridlock Buster, the Institute’s traffic-control game.

Students attending the College of Science and Engineering’s Exploring Careers in Engineering and Physical Sciences Summer Camp also visited the University in July. This camp, offered in five sessions, provided hands-on instruction in engineering, science, and math to 55 students entering grades 10 through 12. ITS program coordinator Shawn Haag gave a traffic engineering demonstration during the July 12 and July 20 sessions. Students in the program also worked with University faculty, toured labs, and attended panel discussions during their time on campus.

The Institute also assisted the Center for Distributed Robotics and the Digital Technology Center with their Technology Day Camps. This program, organized by Center for Distributed Robotics director Nikolaos Papanikolopoulos and his graduate students, brought 125 students to campus during four separate two-and-a-half-day camps August 16–27. Attendees included primarily underprivileged students ranging in age from 12 to 18. The Institute gave students virtual-reality demos in the MTO and taught students Gridlock Buster. A demo with Associate Professor Demoz Gebre-Egziabher of an uninhabited aerial vehicle and experiments with robot building were among the other camp highlights.

On July 26 and August 23, the ITS Institute traveled off campus to a summer camp program at The Works museum in Edina, Minn. Two civil engineering graduate students, Michael Collins and Nicholas Ollrich, demonstrated Gridlock Buster to kids in fourth through seventh grade.
The impact of ITS technology on driver privacy, how school choice affects the environment, and how the Internet influences shopping travel are several topics explored in a recently released report by the Humphrey Institute of Public Affairs’s TechPlan Program.

TechPlan: Planning and Policy for Intelligent Transportation Systems discusses work to date on projects that have the potential to address long-term issues in transportation policy, says Frank Douma, TechPlan principal investigator and associate director of the Humphrey Institute’s State and Local Policy Program (SLPP).

“If you want to improve technology nationally, you need to consider the level of privacy protections,” Douma writes in the report. “There is a complicated legal landscape to navigate for ITS developers and planners.”

TechPlan is a program housed within the SLPP and funded by SAFETEA-LU through the ITS Institute. The report can be downloaded at www.its.umn.edu/Publications/ResearchReports/pdfdownload.pl?id=1422.

In related news, transportation experts, scholars, and industry professionals from Minnesota and across the country gathered in July in Minneapolis for roundtable discussions of several TechPlan projects. In the annual forum, “TechPlan: New Frontiers in Transportation Policy, Technology, and Planning,” researchers received feedback from forum participants about their current research findings. The presenters and their projects were:

- Jason Cao, Humphrey Institute, “Benefit-Cost Analysis of Value Pricing: Case Study for MnPASS”
- Lee Munnich, Humphrey Institute, “Implementing Distance-Based User Fees as a Replacement for the Fuel Tax”
- Melissa Stone and Barbara Crosby, Humphrey Institute, “From Start to Finish: Cross-Sector Collaboration and the Urban Partnership Agreement”
- Tom Horan, Humphrey Institute, and Benjamin Schooley, Claremont Graduate School, “ITS and Transportation Safety: EMS System Data Integration to Improve Traffic Crash Emergency Response and Treatment—Phase II”
- Greg Lindsey, Humphrey Institute, “Understanding Use of Nonmotorized Transportation Facilities”
- Frank Douma, Humphrey Institute, “ITS and Locational Privacy: Suggestions for Peaceful Coexistence”
- Max Donath, director of the ITS Institute, gave closing remarks.

For more information about the TechPlan Program, see www.its.umn.edu/ProgramsLabs/PolicyPlanning/index.html.

Recently Published Research

Available at www.its.umn.edu/publications/researchreports/

TechPlan: Planning and Policy for Intelligent Transportation Systems September 2010

The Interactions Between E-Shopping and Store Shopping: A Case Study of the Twin Cities August 2010, Report no. CTS 10-12


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