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ITS INSTITUTE SENSOR
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Ensuring the integrity of critical ITS data

The ability to gather and analyze data is what makes intelligent transportation systems "intelligent"—none of the modeling, forecasting, and advanced traffic management functions that characterize ITS implementations could take place without a constant flow of high-quality data on traffic patterns and road conditions. As the implementation of ITS systems increases, the flow of data becomes a raging torrent.


Dr. Taek Kwon

In his laboratory on the University of Minnesota's Duluth campus, Dr. Taek Kwon is focused on taming the river of sensor data. Kwon has spent several years developing new tools and techniques for automating the collection and archiving of data from Mn/DOT's sensor network. Through his work in data storage, Kwon has also led efforts to make this information accessible to researchers at universities, traffic analysts at state transportation departments, and other research organizations.

A comprehensive set of data from a large metropolitan area like the Twin Cities represents a goldmine for researchers in diverse fields. But while the potential benefits of Kwon's work are large, the technical obstacles include accounting for missing or corrupt data from bad detectors, and integrating the output of different kinds of sensors into a single common format from which they can be readily retrieved.

Cleaning dirty data

In 2001, Kwon's Transportation Data Research Lab (TDRL) began a collaborative project with Mn/DOT's Office of Transportation Data Analysis (TDA) and Regional Traffic Management Center (RTMC) to automate the collection and archiving of traffic data from the Twin Cities area.

A key component of this project was the development of techniques to deal with missing or inaccurate data. With several thousand individual loop detectors deployed across the metropolitan area and subject to power failures, construction damage, and other hazards of real-world environments, it is inevitable that some detectors will return inaccurate vehicle counts, or no data at all. Unless these errors are identified and corrected, the final data set will show a distorted picture of traffic patterns.

Kwon developed two methods for imputing missing or incorrect data, based on spatial and temporal patterns inherent in detector data sets. The spatial technique pre-defines multiple sets of detectors for a given sensing location, relying on the fact that spatially similar recording points will produce similar data. The detector sets for each location are prioritized based on the spatial relations with the original location. Beginning with the primary detector set, an acceptance test is carried out on the data derived from each detector set for a given location; if the recorded data fail the acceptance test, the algorithm evaluates the next set in the chain until an acceptable body of data is found.

The second, temporal approach to data imputation is based on the fact that traffic patterns tend to repeat from day to day—Thursday's traffic pattern will tend to be similar from week to week, except in the case of a holiday or special event. Within each 24-hour period, furthermore, repeating patterns such as rush hours provide additional temporal structure. Kwon used these temporal trends to construct a probability model capable of simulating candidate values of missing data through multiple Bayesian selections; missing data are replaced by a statistical average of simulated candidates.

Incorporating both the temporal and spatial approaches into a data-processing algorithm has improved the availability of data for estimating average daily traffic volumes, according to Mark Flinner of Mn/DOT's Office of Traffic Data Analysis. "It's been a great improvement," Flinner says; "instead of using 48-hour samples to generate average traffic counts, we can work with more than 300 days worth of data from many stations—it's almost like having continuous data."

Taming the data torrent

Traffic sensors are increasingly common and relatively inexpensive, but the cost and technical challenges of archiving sensor data has discouraged many agencies from preserving it. Recognizing the potential value of this data for planning and system analysis, the USDOT created the Archived Data User Service (ADUS) Program to encourage the development of new techniques for preserving data.

With procedures in place to improve the quality of traffic sensor data, Kwon and the TDRL team turned to the problem of storing large volumes of information in a form that researchers and engineers could easily use and access. Much of the previous work in this area had focused on the use of relational databases, and this was where the TDRL directed its initial efforts. However, the complexity of the system and the computing resources required made this approach inconvenient for Mn/DOT engineers, and the TDRL team subsequently developed an entirely new system based on packaging daily data sets in a uniform format and distributing them through a public file server.

The Unified Transportation Sensor Data Format (USTDF), which is the basis for the TDRL's current data archiving system, was designed from the ground up to accommodate any type of fixed-rate transportation sensor data in a single, easy to manage format usable by any computer operating system, and capable of handling both numeric and non-numeric data, including data from pavement-embedded vehicle detectors and road/weather information sensors, in an efficient compressed form.

Using a single data format for both vehicle-detector data and road/weather information will make it easier to integrate these two important sources of information and analyze relationships between driving conditions and traffic patterns in specific locations. "We all know bad weather and road conditions reduce the traffic capacity," Kwon said, "but we don't know how much it is reduced. With integrated data, we should be able to answer this type of question."

Mn/DOT Traffic Research Director Eil Kwon says the new USTDF system saves the staff of the RTMC considerable time and effort. "The main value of the system from the Traffic Management Center's perspective is that researchers don't have to come to the TMC staff for assistance—they can just directly download what they need," he says.

Portable data collection

Another major TDRL project is extending the collection of traffic data to unpaved roads, which make up a large part of the rural transportation network. Data collection on these roads is often carried out using portable pneumatic-tube vehicle detectors, which are prone to puncture failure and poor sensitivity when used on loose gravel. Also, tube detectors have a large error in vehicle counting when trucks are mixed in the traffic, because the detectors can only count the number of axles passing over them, and the vehicle count is obtained by dividing the number axles by two. After reviewing several sensing technologies, Taek Kwon successfully developed a new vehicle sensing technology based on a fluxgate sensor that detects changes in the earth's local magnetic field density caused by passing vehicles.

Using knowledge gained during the development of the portable vehicle counter, Kwon and his research team are currently developing a portable weigh-in-motion (WIM) system to record vehicle weights in the field. Vehicle weight data are used by transportation agencies to set standards for road construction and maintenance, and by researchers and the freight industry to gauge the movement of goods on the road system. Kwon hopes to complete work on a fully portable system within three years.

As researchers continue to develop more complex ITS applications for traffic management and analysis, the importance of accurate, large-scale data sets will inevitably increase. The work of Taek Kwon and the Transportation Data Research Lab will no doubt play a central role in efforts by the ITS Institute and the Minnesota Department of Transportation to improve the quality of the transportation system.

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Researcher spotlight: Rajesh Rajamani


Rajesh Rajamani

From technology-enhanced snowplows to narrow commuter vehicles, Rajesh Rajamani's work has been a key component of many ITS Institute research projects. Rajamani, who joined the Mechanical Engineering faculty in 1998, is currently an associate professor and the director of the Advanced Controls and Microsensors Laboratory, where he has advised numerous graduate students. In addition to his transportation related research, Rajamani is actively involved in the development of MEMS (micro-electro-mechanical systems) sensors for a variety of applications including biomedical devices and acoustic control.

Rajamani's expertise in vehicle control and fault detection systems found its way into the pioneering SAFETRUCK, a commercial tractor-trailer truck modified to serve as a testbed for intelligent vehicles technologies. Rajamani led the team that designed an intelligent cruise control system which adjusted the vehicle's speed based on the speeds of other vehicles, and could automatically compensate for vehicles cutting into the truck's lane. He also worked on the complex problem of detecting faults in the vehicle's sensor systems, which include GPS, lateral dynamic sensors, and forward-looking radar. Monitoring the health of the radar system proved particularly challenging, due to the fact that the radar measured distances to independent vehicles on the highway. Many of the techniques Rajamani developed for the SAFETRUCK were later applied to the SAFEPLOW, a snowplow designed to operate in extreme low-visibility conditions.

Adaptive cruise control (ACC) systems, which change a vehicle's speed in response to the proximity of other vehicles, have been a continuing part of Rajamani's research. In theory, highway capacities could be increased if a large percentage of vehicles used such systems, because ACC-equipped vehicles could maintain closer vehicle spacing while avoiding unstable traffic flow that leads to congestion. In 2000, Rajamani set out to examine the stability of traffic flow under various ACC vehicle-spacing policies, including the well-known constant-time-gap policy; his research determined that constant-time-gap spacing can become unstable under certain conditions, and indicated possible alternative spacing algorithms for better performance.

In addition to his work on the SAFETRUCK and SAFEPLOW, Rajamani has also lent his expertise to the development of a very different kind of vehicle: a narrow commuter vehicle designed to operate in less space than conventional automobiles, effectively increasing highway capacities. A central problem for a narrow and relatively tall enclosed vehicle is the need for the vehicle to maintain stability in turns by tilting using a computerized tilt-control system. Working in collaboration with fellow mechanical engineering faculty members Lee Alexander and Patrick Starr, Rajamani has led the development of a tilt-control system in the Advanced Controls and Microsensors Lab; the system has been tested in a reduced-scale model and will be used in a full-scale prototype currently under construction.

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2005 Advanced Trasnportation Technologies Seminars

The Advanced Transportation Technologies Seminar Series kicked off the 2005 season on September 13 with an update on ITS projects in Mn/DOT's Guidestar program, presented by Assistant State Traffic Engineer Ray Starr. Since 2001, the series has showcased the work of University of Minnesota faculty and distinguished visiting researchers. Each seminar qualifies for one Professional Development Hour (PDH).

Seminars are held on alternating Tuesdays, from 4:00–5:00 PM, in Room 102 of the Mechanical Engineering Building on the Minneapolis campus. A video link to the Duluth campus is available in 713 Kirby Plaza. Dates for this year's series are: September 13 & 27; October 11 & 25; November 8 & 22; December 6. Topics and presenters are posted on the Seminar Series page.

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