ITS INSTITUTE LABORATORIES AND FACILITIES

ITS Laboratory
The Intelligent Transportation Systems Laboratory is a dedicated facility supporting ITS research and education. The lab’s mission is to develop and provide state-of-the-art resources for researchers, students, and collaborators pursuing research in ITS.

Focused on supporting research in surveillance, monitoring, and management of traffic systems, the ITS Laboratory works in partnership with other University of Minnesota research facilities including the HumanFIRST Program and the Intelligent Vehicles Laboratory to enable a full spectrum of ITS research.

The lab’s facilities are used by faculty and students in civil, mechanical, and electrical engineering, computer science, and affiliated disciplines. The lab’s data-gathering capabilities and modeling expertise serve as the foundation for the development of interactive laboratory modules to support ITS-related courses at the University. The lab also hosts training and outreach events.

The ITS Laboratory has developed several generations of data-acquisition systems to meet the needs of researchers working on freeway traffic-flow issues. The most recent of these is the Beholder system, a fully independent network of video detectors providing space- and time-continuous coverage of the I-35W/I-94 commons freeway area in Minneapolis.

Beholder expands on the pioneering Autoscope system, originally developed at the University of Minnesota and now in commercial use. Beholder’s portable monitoring stations are currently deployed on the roofs of several high-rise buildings overlooking the freeway, and transmit data back to the lab via a high-speed IEEE 802.16 wireless network.

Besides the data provided by the Beholder system, the lab is supplied with eight switchable compressed/streamed Internet video feeds by the Minnesota Department of Transportation (Mn/DOT). Researchers have the ability to switch between any of the approximately 300 Mn/DOT cameras monitoring the metropolitan freeway network.
Several traffic simulation packages are used in the ITS Laboratory, chiefly AIMSUN2 for microscopic flow simulation based on individual vehicles, and the KRONOS 9 package—developed at the ITS Institute—for macroscopic or platoon-based simulations. Other packages such as VisSim are used as needed.

Recent simulation and modeling projects at the ITS Laboratory have focused on improving the efficiency of metered access to urban freeway networks and on developing a dynamic, centrally regulated traffic signal preemption system for emergency vehicles.

Putting the researcher inside the simulation is the goal of the ITS Laboratory’s Digital Immersive Environment, or DEN. Three large rear-projection screens surround the user; behind the scenes, a bank of six computers controls a visual environment developed using Open Scene Graph (OSG) and driven by data from an AIMSUN2 traffic simulator.

Each screen displays both left- and right-eye projections simultaneously, and polarized eyeglasses fuse the image channels to create a three-dimensional virtual world where the corners of the DEN melt away. Users can navigate and interact with the simulated world using a handheld wand; a high-accuracy tracking system constantly adjusts the perspective of the projected scene according to the position and orientation of the user’s head.

The DEN can help investigators understand traffic flow within the context of urban design constraints, pedestrian uses, and other factors that have been impossible to visualize using conventional display technologies. It also complements the vehicle simulation capabilities of the HumanFIRST Program, including the ability to use the same virtual worlds in both environments.

**Human Factors Interdisciplinary Research in Simulation and Transportation**

The Human Factors Interdisciplinary Research in Simulation and Transportation (HumanFIRST) Program’s mission is to apply human factors research in order to understand driver behavior and support the design and evaluation of usable intelligent transportation systems. As implied by its name, the program’s research strategy is based on a finding solutions for limited bandwidth

The ITS Laboratory, with dedicated computer facilities and access to a wide range of traffic data feeds, offered professor Vladimir Cherkassky and graduate student Harry Rostovtsev an ideal research environment for their work on traffic video data transmission. The two researchers from the Department of Electrical Engineering and Computer Science received funding from Mn/DOT to implement a Quality of Service (QoS) system for limited-bandwidth IP networks carrying multiple video streams plus other low-priority data.

Video cameras to monitor traffic conditions are an increasingly important tool for metropolitan traffic managers. Often, multiple cameras are connected to a wireless IP network. As the number of cameras (and other data sources) grows, so do the demands placed on the network; network congestion leads to packet loss and poor performance.

Cherkassky and Rostovtsev constructed a dedicated IP network within the ITS Laboratory, including a mechanism that allowed them to constrict the network’s bandwidth to simulate variable real-world conditions. The design of this network was determined after evaluation of Mn/DOT traffic data networks revealed that bottlenecks typically occur at wireless links to remote sites with multiple cameras and at junctions between networks of different types.

Using the open source ALTQ software package as a base, the researchers implemented a system of class-based traffic prioritization and bandwidth allocation—giving data streams different levels of network access and a portion of total network capacity. As data packets enter the network, they are first marked or “colored” to indicate what class they belong to; the packets then pass through a software filter that gives them access to the network according to their class.

Unlike many other QoS systems, this implementation allows dynamic reallocation of network capacity; for example, in the case of a crash, users can give higher priority and more bandwidth to cameras at the crash scene—even if this means “borrowing” bandwidth from other data streams.
driver-centered approach, considering the “human first” within the transportation system.

The HumanFIRST Program has a core staff of transportation research specialists made up of psychologists and engineers who provide a consistently available base of expertise. This core group is linked to a broad interdisciplinary network of experts in basic and applied sciences throughout the University to provide a flexible and comprehensive research capacity. This network is supported by affiliations with additional University research units, which allows the program to create responsive interdisciplinary teams to investigate a range of complex human factors research issues in transportation safety. The program also has close relationships with the Minnesota Department of Transportation and the Department of Public Safety, as well as with traffic engineering consultants. These connections provide support for implementing research that will influence transportation policy in response to real-world problems both regionally and nationally. In addition, to ensure that research takes into account developments on the world stage, the program’s work is supported by international collaborations with experts in relevant disciplines.

Research in the HumanFIRST Program seeks to propose, design, and evaluate innovative methods to improve transportation safety based on a scientific understanding of driver performance and the psychological processes associated with traffic crashes. This research considers how a driver will accept and use a proposed system, while also considering the possibility of its producing undesirable driver responses and adaptation (e.g., distraction, complacency, fatigue, risk taking) that could undermine the system goal of improved safety.

Recent research topics include driver distraction from in-vehicle tasks and cell phones; rural and urban driver attitudes and crash risk; interventions for crash reduction at rural intersections; bus rapid transit using dedicated narrow shoulders; driver fatigue and methods for its detection; intelligent driver-support systems such as vision-enhancement, collision-avoidance, hazard-awareness, and lane-keeping systems for passenger and specialty-purpose vehicles; learned and inherited factors related to unsafe driving; alcohol impairment; attention-deficit/hyperactivity disorder and novice drivers; and in-vehicle use of Advanced Traveler Information Systems (ATIS).

The facility includes equipment for basic research on driver psychological functioning including a vision tester, DOT-certified alcohol Breathalyzer, mobile psychophysiology recording system, mobile eye-tracking system, video editing and behavior analysis suite, and a comprehensive psychometric test battery validated for traffic psychology.
Much of the research of the HumanFIRST Program uses a state-of-the-art driving simulator (supplied by AutoSIM and OKTAL) engineered specifically for human factors research in surface transportation. This Virtual Environment for Surface Transportation Research (VESTR) is a versatile and realistic simulation environment linked to a full-cab SC2 vehicle donated by Saturn using software that can create virtual environments that precisely reproduce any geospecific location. This visual environment is generated with high-resolution images (2.5 arcmin per pixel) over a wide field of view (210-degree forward, 50-degree rear, 2 x 20-degree side mirror images). This immersive driving experience is enhanced by realistic motion generated by a three-axis motion base and both high- and low-frequency vibration units, including a surround-sound system. With multiple sound systems, configurable touch panel displays (including head-up displays), and haptic feedback through the seat and accelerator pedal, this simulator supports the investigation of a wide range of interface options for ITS development, design, and assessment. These features make VESTR one of the premier driving simulators in North America and Europe.

To support the validity of HumanFIRST research, the program has access to a variety of closed test tracks and road network field sites for on-road studies with instrumented vehicles.

Gaining insight into driver distraction

Cell phones. Navigation systems. Hot coffee. Drivers face numerous, potentially hazardous distractions. Researchers with the Institute’s HumanFIRST Program believe that tracking a driver’s gaze will tell them more about how distraction might affect driving performance. However, since monitoring and quantifying everything a driver might look at is difficult, they’re relying on help from two sophisticated eye-tracking systems.

The first, a video-based faceLAB system, has been used over the last year in the program’s immersive driving simulator. From two cameras mounted on the dashboard, the system generates a digital map of a driver’s face by looking for areas of high contrast. The system notes head position and movement to locate the eyes and can estimate the direction of a driver’s gaze from his or her pupil orientation.

“On a superficial level, the eye tracker gives us the XY coordinates of the eyes—that’s what it does in its most basic form,” explains Michael Manser, a research associate with the HumanFIRST Program. But more important, he says, it can give researchers an indication of how vision and behavior are linked, and how a distraction can change cognitive processing stages.

The researchers have integrated the simulator and the eye tracker so that the simulator can react in real time to what a driver does or where he or she looks. For example, if a driver’s attention is diverted from the road, the simulator can trigger an event requiring more attentive driving.

Some of the ways the researchers have been distracting test subjects is by having them operate the CD player and temperature controls, answer questions, repeat words, and complete tasks on an LCD panel using a touchpad.

The HumanFIRST Program also recently acquired a head-mounted eye-tracking system by ISCAN that consists of a camera mounted on a visor worn by a test subject. Because the camera is located closer to a subject’s eyes, the accuracy is much greater than with the dashboard-mounted system. Another advantage is that it’s portable; the driver wears the camera, and the base computer can be placed in the back seat. HumanFIRST researchers have just begun using the new system in a test vehicle on a closed-road network.

Ultimately, Manser says, researchers want to learn from the eye trackers more about how drivers process information. This knowledge could then be used to teach drivers how to better respond to various driving situations and possibly avoid a crash.

Down the road, the eye trackers will be put to use in HumanFIRST research on driver fatigue, impairment, mental workload, and other information-processing issues. In addition, researchers are planning to integrate the eye trackers with their digital databases to allow them to examine the design of road infrastructure (e.g., signs, traffic signals) by observing the effectiveness of visual sampling.
Making rural intersections safer
Intersection decision support (IDS) represents an innovative new approach to preventing crashes at rural through-stop intersections, where secondary roads intersect high-speed rural expressways. Instead of regulatory signals, which disrupt mainline traffic flow and may lead to higher rear-end collision rates, IDS uses technologies developed in the Institute’s intelligent vehicles research to give stopped drivers better information about vehicles approaching the intersection at high speed.

In the prototype system currently under development, a network of radar and lidar detectors deployed along a rural expressway tracks vehicles approaching a specific intersection. These speed and position data are communicated to a roadside central processing unit via a dedicated wireless network; the central unit computes the vehicles’ trajectories and determines when gaps between approaching vehicles are too small to allow safe crossing by a driver waiting on the secondary road.

Human factors research to develop an optimal infrastructure-based driver interface is a crucial component of this project. By using a wrap-around driving simulator, researchers can test multiple interface configurations in a safe yet realistic environment, under a wide range of virtual traffic and weather conditions.

The research team, led by Institute director Max Donath and IV Laboratory director Craig Shankwitz, hopes to develop a reliable, cost-effective system that can be widely deployed in rural areas. The ITS Institute has formed a partnership with state transportation agencies in eight states; participating agencies are sharing rural crash data for analysis and will have the opportunity to install a prototype system in their states to gather data and evaluate the technology under local conditions.

Data-gathering components of the IDS system have been installed at a rural test intersection, which was selected based on an analysis of crash information from around the state. Knowledge gained in this phase about traffic characteristics and driver behavior will be used to refine the system prior to testing the driver interface.

Intelligent Vehicles Laboratory
The Institute’s Intelligent Vehicles Laboratory focuses on developing and testing innovative, human-centered technologies that improve the operational safety, mobility, and productivity of vehicles. These human-centered technologies integrate sensors, actuators, computer processors, and custom human interfaces to provide drivers with needed information under difficult driving conditions, including low visibility, severe weather, and narrow and congested roadways. Initially, these driver-assistive systems have been tested on specialty vehicles, including snowplows, patrol cars, ambulances, heavy vehicles, and transit vehicles. Ultimately, these systems will also be able to warn drivers and assist them with collision-avoidance and lane-keeping tasks on passenger vehicles.

The University of Minnesota is recognized as a leader in developing and testing driver-assistive systems and is one of a small number of universities nationwide conducting this work. The IV Laboratory’s core staff is made up of engineering and computer science professionals who work closely with an interdisciplinary team of specialists, including cognitive psychologists specializing in human factors from the ITS Institute’s HumanFIRST Program. The IV Laboratory staff has developed expertise in wireless communications, embedded computing, visibility measurement and quantification, geospatial databases, virtual environments, image processing, driver-assistive technologies, control systems, and sensors.

IV Laboratory research seeks to increase driver safety in difficult driving conditions through the use of vehicle-guidance and collision-avoidance technologies. Several vehicles serve as experimental testbeds, including...
the SAFETRUCK (an International 9400 tractor-trailer), the SAFEPLow (an International 2540 crew-cab snowplow), a state highway patrol car, and the TechnoBus (a Metro Transit bus). Using these vehicles, IV Laboratory researchers are developing, testing, and integrating advanced technologies including centimeter-level differential global positioning systems (DGPS); high-accuracy digital-mapping systems; range sensors, including radar and laser-based sensors; a windshield head-up display (HUD), a virtual mirror, and other graphical displays; haptic and tactile feedback; and intersection decision support systems to assist drivers at rural intersections.

The IV Laboratory’s lane-assist technology is unique in that it uses DGPS and does not require hardware in the roadway surface. The technology is transferable between various transportation modes and works in all low-visibility situations, including snow, fog, smoke, heavy rain, and darkness. In addition, these systems use human-centered technologies to enhance driving ability and reduce driver error due to distractions, fatigue, and other factors related to difficult driving situations.

Other current research topics include the design and testing of custom human interfaces, collision-avoidance sensors and algorithms, intersection-surveillance sensors, and wireless communication among vehicles and with the infrastructure.

The IV Laboratory’s partnership with the Minnesota Department of Transportation provides access to roads and other infrastructure, including the Minnesota Road Research Project (Mn/ROAD) test track, which consists of a freeway and a low-volume road pavement test track with 40 different road material test sections, 4,500 electronic sensors, a weigh-in-motion scale, a weather station, and DGPS correction signals. The IV Laboratory also has relationships with a number of other organizations and government agencies, including the U.S. Department of Transportation’s Research and Special Programs Administration, Federal Highway Administration, and Federal Transit Administration; Twin Cities’
Metro Transit; Minnesota’s Local Road Research Board; and various counties. These partnerships provide additional support for implementing research that will influence transportation safety in the United States and around the world.

**Northland Advanced Transportation Systems Research Laboratories**

The mission of the Northland Advanced Transportation Systems Research Laboratories (NATSRL), located at the University of Minnesota Duluth, is to study comprehensive winter transportation systems and the transportation needs of cities in small urban areas. Research covers a wide range of topics, including optical and electronic traffic and road sensors, transportation data management, and the benchmarking of transportation infrastructure management practices. NATSRL is collaborating with the Minnesota Department of Transportation, city and county engineers, and other agencies to address transportation-related needs, especially those specific to northern areas and climates.

NATSRL’s current laboratories are the Advanced Sensor Research Laboratory, the Transportation Data Research Laboratory, and the Transportation Engineering Research Laboratory. The Advanced Sensor Research Laboratory goals include development and testing of advanced sensing technologies for pavement and road conditions (speed, weather impact, and traffic density); development of new techniques to detect incidents and abnormal traffic conditions; and real-world analysis and real-time measurements of road, weather, and traffic information. The Transportation Data Research Laboratory has developed a statewide traffic data archival and analysis system that is used by Mn/DOT for long-range planning and development of strategic traffic management plans, and continues research in the improvement of data integrity retrieved from the road sensors. The Transportation Engineering Research Laboratory is developing, in conjunction with Mn/DOT, an automated inventory management system for transportation infrastructure, as well as designing efficient management practices by benchmarking state DOT procedures, with a specific project in snowplow fleet management.

Other NATSRL research includes projects on developing and incorporating non-intrusive vibration testing techniques for inspecting timber, steel, and concrete bridges, and the student development of software tools to manage large volumes of transportation-related data.

In addition, NATSRL joins with Mn/DOT District 1 each year to hold a formal presentation of ongoing research efforts [see related article in the Technology Transfer section of this report].
Getting more mileage from inductive loop detectors
Inductive loop detectors (ILDs) embedded in pavements are commonly used to measure traffic flow by registering each time a vehicle passes over them. But Professor Stan Burns of the Northland Advanced Transportation Systems Research Laboratories thinks that we could get much more information from the existing ILD network.

A typical ILD consists of a solenoid loop of wire buried about two inches below the surface of the pavement. When a vehicle passes through the detector’s magnetic field, the vehicle’s metal structure causes a disturbance in the electrical inductance of the loop. A sensor attached to the loop registers an event each time the inductance change exceeds a threshold value.

An automobile’s complicated arrangement of metal parts, however, produces a correspondingly complicated set of inductance changes as it passes over the detector, and the traditional method of recording only the threshold value discards potentially valuable information. Another side effect of the threshold-value system is that large vehicles—particularly commercial trucks—may be recorded as two separate vehicles rather than one large one.

An ILD system capable of capturing the “inductance signature” of different types of vehicles would reduce counting errors due to inaccurate readings of large vehicles and could also enable traffic managers to calculate more accurate point-to-point travel times by tracking individual vehicles.

An experimental system developed by the NATSRL research team consists of three interdependent software modules: the Sampler module, which gathers data by controlling the sensing instruments and saves the inductance profiles for identification; the Viewer, which allows users to view one or more inductance profiles on a graph after user-selected signal processing algorithms have been applied; and the Identifier module, which classifies vehicles by comparing inductance curve data from the Sampler with inductance profiles stored in a database.

Burns and the NATSRL researchers have installed the experimental system at a Mn/DOT test station on Interstate 35 south of Duluth. At this stage, the system is able to distinguish between different vehicle types, although it still has trouble discriminating between cars with similar inductance signatures.

The test results illustrate the complicated nature of inductance-signature analysis. In addition to vehicles with similar construction, a detector system based on inductance curves must also contend with numerous environmental factors that affect each loop’s three-dimensional magnetic field.

Work on ILDs is continuing at NATSRL, including three-dimensional modeling of the loop’s magnetic field, exploration of “cross-talk” interference from adjacent loop detectors’ fields, improved system accuracy, experimental verification, and the possibility of measuring vehicle speed using a single ILD.