University of Minnesota Duluth
Swenson College of Science and Engineering

2009 Research Workshop on Intelligent Transportation Systems

10:30 - 4:30 p.m., March 12
Conference Room, District 1, Mn/DOT

Co-sponsored by
District 1, Minnesota Department of Transportation
NATSRL, University of Minnesota Duluth

Northland Advanced Transportation Systems Research Laboratory (NATSRL), University of Minnesota Duluth

Mission

The NATSRL was established in 2000 as the advanced research program at UMD for developing the Intelligent Transportation Systems technologies that can make the transportation systems in northern areas safe, efficient and sustainable. Current research focus areas of NATSRL include:

- Advanced sensing technologies for detecting and measuring traffic/driver/pedestrian/pavement conditions,
- Vehicle and Driver safety technologies,
- Winter road snow/ice management decision support strategies,
- Advanced traffic safety, operations and management strategies under various conditions.

The major funding for NATSRL comes from the U.S. Department of Transportation (through the CTS/ITS Institute, UMTC), while the matching funds are provided by various local agencies including UMD, UMTC, Mn/DOT and St. Louis County.

NATSRL Partnership

NATSRL has formed a strong partnership with its key stakeholders, whose staff actively participate in the NATSRL activities as the members of the Advisory Board and the Research Advisory Panel. The strategic directions and yearly program activities of NATSRL are discussed and finalized at the annual Advisory Board meeting. Further, the Research Advisory Panel, which meets every quarter, plays the major role in guiding the NATSRL research/outreach program as the ongoing communication channel between NATSRL faculty and local transportation practitioners.

Advisory Board Members:

Bernie Arseneau, Mn/DOT Division Director
Michael Robinson, District Engineer, District 1, Mn/DOT
James Foldersi, County Engineer, St. Louis County
Marthand Nookala, Associate Administrator, Hennepin County
Cindy Voigt, City Engineer, City of Duluth
James Riehl, Dean, SCSE, UMD
Max Donath, Director, ITS Institute, UMTC

Research Advisory Panel Members:

Cory Johnson, Research Engineer, Mn/DOT
Robert Ege, Traffic Engineer, District 1, Mn/DOT
Linda Taylor, Maintenance Research Engineer, Mn/DOT
Cari Pederson, Chief Transportation Engineer, City of Duluth
Peter Eakman, Design Engineer, St. Louis County
Victor Lund, Traffic Engineer, St. Louis County

NATSRL Director:

Eil Kwon, Professor, Civil Engineering (eilkwon@d.umn.edu)

2009 Northland Transportation Research Workshop Program

10:30 Reception/Poster Session

10:45 Welcome and NATSRL Overview
Mike Robinson, District Engineer, District 1, Mn/DOT
Eil Kwon, NATSRL Director, UMD

11:00 Portable Cellular Wireless Mesh Sensor Network for Vehicle Tracking in an Intersection
: Ryan Weidemann and Taek Kwon, Electrical and Computer Eng.

11:30 Real-Time Non-intrusive Detection of Driver Drowsiness – Phase II
: Shan Hu, Ye Gu, and Xun Yu, Mechanical and Industrial Eng.

12:00 Intelligent Pavement Sensor for Traffic Detection
: Baoguo Han and Xun Yu, Mechanical and Industrial Eng.

12:30 Development of Novel Hydrogen Storage Materials for Road Traffic Related Applications
: Venkatram R. Mereddy, Chemistry and Biochemistry

1:00 Development of a Low-Cost Interface between Cell Phones and DSRC-based Vehicle Unit for Efficient Use of VII Infrastructure
: M. Imran Hayee, Electrical and Computer Eng.

1:30 Snow Rendering for Interactive Snowplow Simulation: Supporting Safety in Snowplow Design
: Pete Willemsen, Computer Science

2:00 Improve Safety and Efficiency of Roadway Maintenance Using Robotics – Feasibility Study
: Ryan G. Rosandich, Mechanical and Industrial Eng.

2:30 Detection of Water and Ice on Bridge Structures by Time Domain Reflectometry/Dielectric Relaxation Spectroscopy
: John F. Evans, Brian Finstrom and Lucas Busta
Chemistry and Biochemistry

3:00 Development of a New Tracking System based on CMOS Vision Processor Hardware
: Hua Tang, Electrical and Computer Eng.

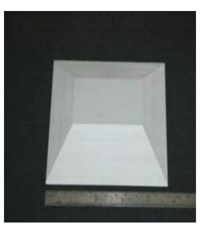
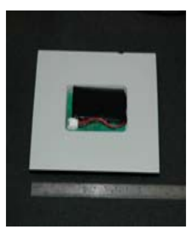
3:30 Identifying Methods and Metrics for Evaluating Interagency Coordination in Traffic Incident Management
: Robert Feyen, Mechanical and Industrial Eng.

4:00 Exploring Effective Methods to Evaluate and Optimize the Systematic Implementation of Proactive ITS Safety Strategies
: Hongyi Chen, Mechanical and Industrial Eng.

Portable Cellular Wireless Mesh Sensor Network for Vehicle Tracking in an Intersection

Ryan Weidemann and Taek Kwon
Electrical and Computer Engineering

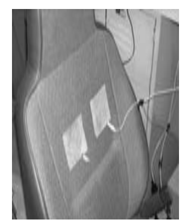
Automatic vehicle tracking has been one of the challenges in traffic detection technologies. Video cameras and radars had only limited success in part due to the problems with occlusion, land object noises, weather, and high computational and physical costs. This thesis presents the development of a more reliable and robust approach based on a cellular wireless mesh sensor network (WMSN). Utilizing recent advances in ZigBee technology, the WMSN is self-constructing, self-healing, and can support a large number of nodes. Each node of the WMSN has a minimum footprint that consists of a microcontroller with a radio frequency transceiver, an anisotropic magnetoresistance sensor for detecting vehicles, and a lithium-ion rechargeable battery. A node is placed in each lane of the intersection to form a WMSN. A separate node is responsible for collecting and logging the data from each node in the network. From this logged data, a vehicle tracking algorithm analyzes the logged intersection data and tracks the trajectories of the vehicles through the intersection. In order to obtain simulated data and to develop the vehicle tracking algorithm, an intersection simulator was created. This simulator allowed vehicle movements to be simulated and helped to determine the minimum number and position of nodes needed to successfully track vehicles. Actual intersection data was collected and tracked using the vehicle tracking algorithm.

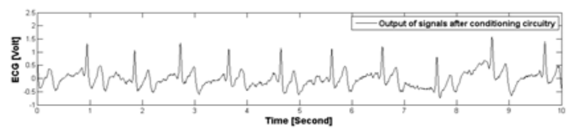




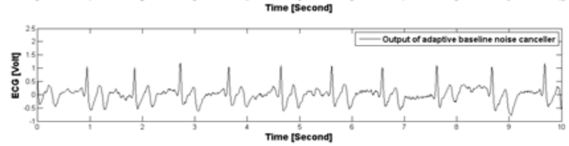
Real-Time Non-intrusive Detection of Driver Drowsiness Phase II

Shan Hu, Ye Gu, and Xun Yu
Mechanical and Industrial Engineering

Driver drowsiness is one of the major causes of serious traffic accidents. According to the National Highway Traffic Safety Administration (NHTSA), there are about 56,000 crashes caused by drowsy drivers every year in US, which results in about 1,550 fatalities and 40,000 nonfatal injuries annually. Continuous monitoring of drivers' drowsiness thus is great importance to reduce drowsiness-caused accidents. The aim of this research is to develop a real-time, non-intrusive driver drowsiness detection system. Biosensor will be built on the automobile steering wheel and driver seat to measure driver's heart beat signals. Heart rate variability (HRV), a physiological signal that has established links to waking/sleepiness stages, thus can be analyzed from the heat beat pulse signals for the detection of driver drowsiness. The design of measuring heat beat signal from biosensors on the steering wheel and driver seat makes this drowsiness detection system has almost no annoyance to the drivers, and the use of physiological signal can ensure the drowsiness detection accuracy.

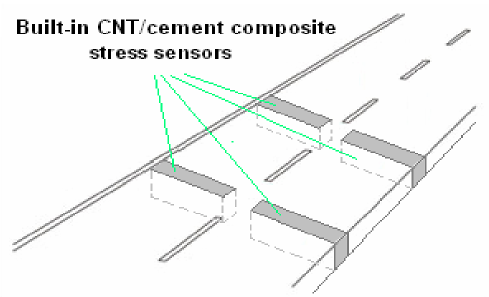


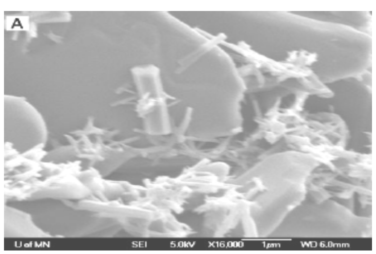


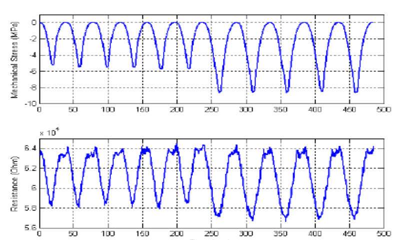
Intelligent Pavement Sensor for Traffic Detection

Baoguo Han and Xun Yu
Mechanical and Industrial Engineering

This project aims to explore a new approach in detecting vehicles on a roadway by making a roadway section itself as a traffic flow detector. Sections of a given roadway are paved with carbon-nanotube (CNT)/cement composites; the piezoresitive property of carbon nanotubes enables the composite to detect the traffic flow. Meanwhile, CNTs can also work as the reinforcement elements to improve the strength and toughness of the concrete pavement. In contrast to current traffic flow detection technologies that require separate devices to be installed either in the pavement or over the road, the proposed sensing approach enables the pavement itself to detect traffic flow parameters. Therefore, the proposed sensor is expected to have a long service life with little maintenance, and wide-area detection capability.





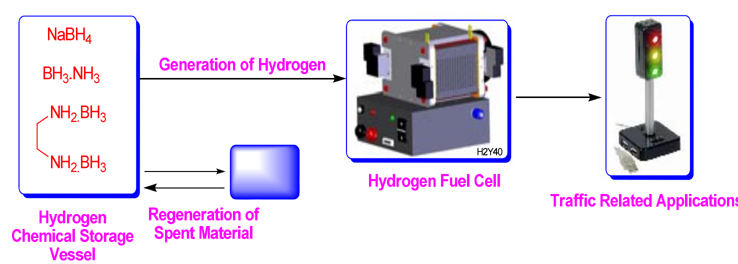


Development of Novel Hydrogen Storage Materials for Road Traffic Related Applications

Venkatram R. Mereddy
Chemistry and Biochemistry

There are many remote traffic signals on the road that don't have access to a regular power supply, so they use batteries that need to be changed quite often. A hydrogen fuel cell is an electrochemical device that combines hydrogen and oxygen to produce electricity. It offers clean, and high efficiency energy source to circumvent the problems associated with the conventional batteries. However, one major drawback that limits their utility is the use of compressed metal cylinders as a source of hydrogen. Metal hydride-based chemicals can provide a very compact and low-pressure storage option for the controlled release of hydrogen gas in large amounts. The hydrogen based fuel cells can also be used as backup power source at critical traffic signals to prevent accidents during power outages. The other possible applications include alternating-traffic signs, directional signals, speed-limit signs, blinkers in series, and warning blinkers etc.

The proposed project (Phase I) deals with the development of novel boron based hydrogen storage materials, efficient generation of hydrogen and recycling of spent materials. Our preliminary results on the preparation, hydrogen generation, studies towards the regeneration of amine-boranes and future plans on this project will be presented. The completion of the project would lead to future Phase II studies towards the construction of fuel cells utilizing these hydrogen storage materials for transportation and other energy related applications.



Development of a Low-Cost Interface between Cell Phones and DSRC-based Vehicle Unit for Efficient Use of VII Infrastructure

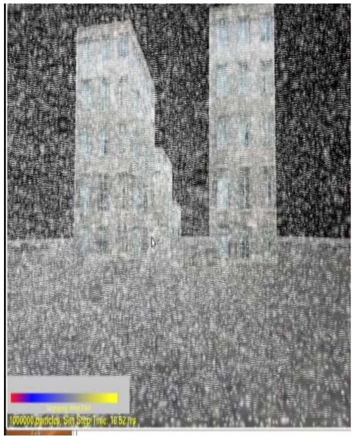
M. Imran Hayee
Electrical and Computer Engineering

To save lives and prevent injuries on roadways, inter-vehicle communication as well as communication between vehicles and roadside is required. Intelligent Transportation system (ITS) is a mission of the US department of transportation which focuses on intelligent vehicles, intelligent infrastructure and the creation of an intelligent transportation system through integration with and between these two components. Dedicated Short Range Communications (DSRC) is a tool approved for licensing by the FCC in 2003 which promises to partially fulfill this mission. DSRC is the approach which most US and European departments of transportation are adopting for traffic safety data transportation from the roadside to central station. This presentation will talk about a research project of how to take advantage of the DSRC infrastructure to communicate the traffic safety information available at DSRC to a cell phone in the vehicle. The specific objective of this research project is to design, build and demonstrate a wireless communication interface device which can act as a traffic-safety-information transportation agent between the DSRC vehicle radio unit and a cell phone (or a navigation system) inside a vehicle. By having this interface device along with the DSRC radio unit in a vehicle, any driver will be able to receive the valuable traffic safety messages on his cell phone (or in vehicle navigation unit).

Snow Rendering for Interactive Snowplow Simulation :Supporting Safety in Snowplow Design

Pete Willemsen
Computer Science

In snowing conditions, following a snowplow or any vehicle creates an extremely dangerous situation. The danger comes from the human visual system's inability to accurately perceive speed and the motion of the lead vehicle, increasing the potential for a rear-end collisions. The overall goal of this project is to use our understanding of how the human visual system processes optical motion, under the conditions created by blowing snow, to create a simulation framework that can be used to test emergency lighting configurations aiming to reduce rear-end collisions with snowplows and other vehicles. Reaction times for detecting motion of the snowplow will be measured empirically for a variety of lighting configurations on a simulated 3D snowplow that varies its speed while driving on a virtual, curving hilly roadway. This driving simulator environment will serve as the basis for testing the effects of lighting alternatives on snowplows. The talk will focus on the recent blowing snow model as well as our ongoing experiments examining reaction times for detecting the approach of a snowplow in low luminance contrast conditions.



Improve Safety and Efficiency of Roadway Maintenance using Robotics – Feasibility Study

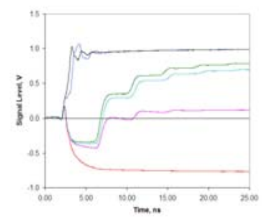
Ryan G. Rosandich
Mechanical and Industrial Engineering

A study was completed in June 2008 in order to demonstrate the feasibility of using a robotic actuator to paint roadway markings. This study was funded as a NATSRL seed grant project. The system used an existing robot arm, which was equipped with a standard pavement striping paint sprayer for the duration of the study. This combination was capable of painting symbols, letters, and numbers up to a maximum size of approximately 3 ft. x 3 ft. Software was developed for the system that enabled it to paint a variety of characters and symbols on a simulated roadway. The system was successfully demonstrated in actual painting operations by painting on heavy textured paper to simulate painting on pavement.

Detection of Water and Ice on Bridge Structures by Time Domain Reflectometry/Dielectric Relaxation Spectroscopy

John F. Evans, Brian Finstrom and Lucas Busta
Chemistry and Biochemistry

We have developed low cost sensing systems for deployment on bridge deck, and other critical locations which are able of detecting frozen and liquid precipitation road surface conditions on bridge deck and related surfaces. The technique is an adaptation of time domain reflectometry (TDR) which has long been used by the soil science community to monitor moisture and salt content in agricultural and related contexts. More recently, the technique has been evaluated for use in similar applications in civil engineering to evaluate road bed and foundation moisture content. Our approach to road safety applications involves the use of commercially available TDR hardware to capture transient responses from passive sensors which terminate transmission lines. Such a device in prototype form is shown below left, which is constructed of aluminum and silicone rubber, and can be readily modified for deployment on concrete bridge deck surfaces.



The transient responses from pulse reflections, as shown above right, form the basis for decision making with regard to the surface condition of the bridge deck with regard to the presence of water/liquid or ice which might compromise traction. This presentation will summarize our recent success in developing hardware and software which can provide automated responses as to these conditions. The decision states output by the software may then ultimately be used to activate warning signage or inform maintenance personnel as to surface conditions which require their attention. These results define the design criteria to be used in the optimization of both the sensor hardware and software system components, which will be addressed prior to field deployment of a system for real world testing next winter.

Development of a New Tracking System based on CMOS Vision Processor Hardware

Hua Tang
Electrical and Computer Engineering

Vehicle tracking has been an important area of intelligent transportation systems (ITS), which can be used to monitor vehicle operations and collect traffic data. To improve accuracy and real-time operation of vehicle tracking is the main goal of the proposed project. To achieve this goal, we propose to construct a new tracking system based on a new tracking algorithm and a new way of implementation. The first novelty, the new tracking algorithm, is to incorporate motion estimation techniques in vehicle tracking. The second novelty, a hardware implementation of the tracking algorithm, is to implement the overall tracking system in customized hardware platform as much as possible, which could improve real-time operation of vehicle tracking. In Phase I of the project, we proposed the tracking algorithm and validated it using realistic traffic images through extensive simulation. Also, we had come up with the method for hardware implementation of the tracking algorithm, which was also verified through simulation. Continuing from Phase I, in Phase II our main target is to first physically build the hardware prototype circuit for the tracking system and then to test it in the field. The system prototype is planned to be constructed in the Xilinx Spartan-3A FPGA development board. Filed test of the tracking system will mainly focus on intersections, ramps to highways and roundabouts, where data collection is in great need.

Identifying Methods and Metrics for Evaluating Interagency Coordination in Traffic Incident Management

Robert Feyen
Mechanical and Industrial Engineering

One role of any state's Department of Transportation is managing adverse incidents that impact traffic flow within the interstate highway system under their purview. In most urban locations, management is accomplished through different agencies (e.g., police, fire, maintenance and traffic operations), each with a stake in the overall traffic incident management (TIM) system. Originally intended to identify best practices in evaluating performance assessment, this project found that certain basic performance measures such as response and incident clearance times are collected by almost all agencies – but many agencies do not record additional measures, consistently monitor or review the collected incident response data or analyze this data further unless needed to answer a single, specific question. This may explain why numerous TIM systems in the U.S. report performance evaluation of interagency TIM activities as one area of activity in which little success has been attained (FHWA, 2003).

Notably, though, incident response can be viewed as a process: a network of events that occur, typically in some sequence, to accomplish a goal. For example, once a disabled car blocking traffic is reported, appropriate resources (e.g., state police, tow truck) must be dispatched to the scene and the car safely removed from the road in order to accomplish the goal of restoring traffic flow to normal. Each of these events requires specific steps to be completed and each step may take longer or shorter, depending on various factors that can influence completion time. Utilizing process improvement methods from the field of production and operations management, overall incident response performance can be improved by collecting and analyzing the available timing data to identify areas with long and highly variable times and implementing interventions to reduce the variability. To illustrate this, a process model of interagency incident responses is presented for one basic class of incidents and a preliminary approach utilizing process improvement methods is illustrated. Based on this, recommendations are made with respect to collection and analysis of traffic incident response measures.

Exploring Effective Methods to Evaluate and Optimize Systematic Implementation of Proactive ITS Safety Strategies

Hongyi Chen
Mechanical and Industrial Engineering

As part of the initiative to continuously improve traffic safety, researchers and engineers in the field have been dedicated to the development of Intelligent Transportation Systems (ITS) safety technologies and strategies. Decreases in accident rate have been seen over the recent decades as a result of such initiative. However, the growing number of ITS technologies and strategies also calls for an integrated approach to optimize state-wide or even country-wide resource allocation, and proactively improve the traffic network safety. A starting point is to analyze the interrelationships between the ITS strategies and accident factors, and to understand the impact and dependences of safety improvement in one corridor on the other associated corridors. In this presentation, research methods that effectively quantify the interrelationships and dependences, among infrastructure-based ITS safety strategies will be introduced. An algorithm that systematically evaluates and optimizes the ITS safety strategy implementations and database and software tool design is proposed.

Contact for NATSRL

Dr. Eil Kwon
Director, NATSRL
Professor, Department of Civil Engineering
University of Minnesota Duluth
209 Engineering Building
1303 Ordean Ct.
Duluth, MN 55812
Office: 218-726-8325
Email: natrsl@d.umn.edu
Web: www.d.umn.edu/natsrl