University Transportation Research Center - Region 2

Final Report

Computational Modeling of Driver Speed Control with its Applications in Developing Intelligent Transportation Systems to Prevent Speeding-Related Accidents

Performing Organization: University at Buffalo/SUNY

August 2013

Sponsor:
Research and Innovative Technology Administration (USDOT/RITA)

University Transportation Research Center - Region 2

The Region 2 University Transportation Research Center (UTRC) is one of ten original University Transportation Centers established in 1987 by the U.S. Congress. These Centers were established with the recognition that transportation plays a key role in the nation's economy and the quality of life of its citizens. University faculty members provide a critical link in resolving our national and regional transportation problems while training the professionals who address our transportation systems and their customers on a daily basis.

The UTRC was established in order to support research, education and the transfer of technology in the field of transportation. The theme of the Center is "Planning and Managing Regional Transportation Systems in a Changing World." Presently, under the direction of Dr. Camille Kamga, the UTRC represents USDOT Region II, including New York, New Jersey, Puerto Rico and the U.S. Virgin Islands. Functioning as a consortium of twelve major Universities throughout the region, UTRC is located at the CUNY Institute for Transportation Systems at The City College of New York, the lead institution of the consortium. The Center, through its consortium, an Agency-Industry Council and its Director and Staff, supports research, education, and technology transfer under its theme. UTRC's three main goals are:

Research

The research program objectives are (1) to develop a theme based transportation research program that is responsive to the needs of regional transportation organizations and stakeholders, and (2) to conduct that program in cooperation with the partners. The program includes both studies that are identified with research partners of projects targeted to the theme, and targeted, short-term projects. The program develops competitive proposals, which are evaluated to insure the mostresponsive UTRC team conducts the work. The research program is responsive to the UTRC theme: "Planning and Managing Regional Transportation Systems in a Changing World." The complex transportation system of transit and infrastructure, and the rapidly changing environment impacts the nation's largest city and metropolitan area. The New York/New Jersey Metropolitan has over 19 million people, 600,000 businesses and 9 million workers. The Region's intermodal and multimodal systems must serve all customers and stakeholders within the region and globally.Under the current grant, the new research projects and the ongoing research projects concentrate the program efforts on the categories of Transportation Systems Performance and Information Infrastructure to provide needed services to the New Jersey Department of Transportation, New York City Department of Transportation, New York Metropolitan Transportation Council , New York State Department of Transportation, and the New York State Energy and Research Development Authorityand others, all while enhancing the center's theme.

Education and Workforce Development

The modern professional must combine the technical skills of engineering and planning with knowledge of economics, environmental science, management, finance, and law as well as negotiation skills, psychology and sociology. And, she/he must be computer literate, wired to the web, and knowledgeable about advances in information technology. UTRC's education and training efforts provide a multidisciplinary program of course work and experiential learning to train students and provide advanced training or retraining of practitioners to plan and manage regional transportation systems. UTRC must meet the need to educate the undergraduate and graduate student with a foundation of transportation fundamentals that allows for solving complex problems in a world much more dynamic than even a decade ago. Simultaneously, the demand for continuing education is growing – either because of professional license requirements or because the workplace demands it – and provides the opportunity to combine State of Practice education with tailored ways of delivering content.

Technology Transfer

UTRC's Technology Transfer Program goes beyond what might be considered "traditional" technology transfer activities. Its main objectives are (1) to increase the awareness and level of information concerning transportation issues facing Region 2; (2) to improve the knowledge base and approach to problem solving of the region's transportation workforce, from those operating the systems to those at the most senior level of managing the system; and by doing so, to improve the overall professional capability of the transportation workforce; (3) to stimulate discussion and debate concerning the integration of new technologies into our culture, our work and our transportation systems; (4) to provide the more traditional but extremely important job of disseminating research and project reports, studies, analysis and use of tools to the education, research and practicing community both nationally and internationally; and (5) to provide unbiased information and testimony to decision-makers concerning regional transportation issues consistent with the UTRC theme.

Project No: 49111-18-23

Project Date: August 2013

Project Title: Computational Modeling of Driver Speed Control with its Applications in Developing Intelligent Transportation Systems to Prevent Speeding-Related Accidents

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16. Abstract

Speeding is the leading contributing factor in fatal accidents in NY state, according to NY State Department of Motor Vehicle Accidents Statistical Summary (2009). Understanding and modeling speeding and speed control is one of major challenges in human performance modeling which involves: a) the modeling of several aspects of human cognitive system: perception, decision making and motor control as well as their interaction with the vehicle model; b) individual differences in speed control and prediction of speeding in real time. However, few of existing computational models is able to cover all of these important aspects together. To address this problem, the main objective of this project is to build a new mathematical driver speed control model and apply it to develop an intelligent speeding control system. Multi-disciplinary approaches are used to build the mathematical model of driver speed control, integrating methods in operations research (Queuing Network-Model Human Processor, QN-MHP) and theories in psychology (Rule-Based Decision Field Theory, RDFT) to predict driving speed, pedal angle, acceleration, the time when drivers exceed the speed limit, and the magnitude of speeding. The model not only quantifies an average driver's speed control behavior, but also models individual drivers' decision making references and impulsiveness. A human driver experimental study has been conducted to validate the prediction of the model.

The model is implemented in a real-time intelligent speeding control system, which provides warnings to drivers to prevent speeding proactively. The intelligent system online monitors the pedal behavior of a driver, calculate the probability of speeding for that driver in the next few seconds, and proactively provide necessary warnings to that driver to prevent his or her speeding behavior in real-time.

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UNIVERSITY TRANSPORTATION RESEARCH CENTER

RESEARCH BRIEF

PROJECT TITLE: COMPUTATIONAL MODELING OF DRIVER SPEED CONTROL WITH ITS APPLICATIONS IN DEVELOPING INTELLIGENT TRANSPORTATION SYSTEMS TO PREVENT SPEEDING-RELATED ACCIDENTS

PRINCIPAL INVESTIGATOR: DR. CHANGXU (SEAN) WU

INSTITUTION: UNIVERSITY AT BUFFALO/SUNY

COMPLETION DATE: AUGUST 2013

SPONSOR: RESEARCH AND INNOVATIVE TECHNOLOGY ADMINISTRATION / USDOT (RITA)

Speeding is commonly recognized as exceeding the posted speed limits or driving too fast for conditions. National Center for Statistics and Analysis (NCSA) reported that speeding is a contributing factor in about one-third of all fatal traffic crashes in the United States and costs society an estimated $40 billion annually in 2004. In the U.S. DOT's Region II, speeding is the leading contributing factor in fatal motor vehicle accidents in NY State and more than 34 percent of all fatal accidents were due to unsafe speed in 2009 (Summary of Motor Vehicle Accidents, NY State Department of Motor Vehicles, 2009).

In theory, speed control is a complex behavior of longitudinal vehicle control consisting of speed perception, decision making, motor control, vehicle dynamics modeling, and individual driver differences. However, there are few existing models that can integrate all of these aspects, in a cohesive manner. To address this problem, this work introduces a mathematical model for a driver's speed control with analytical solutions based on a rigorous understanding of the human cognitive mechanisms involved in driving (See Figure 1).

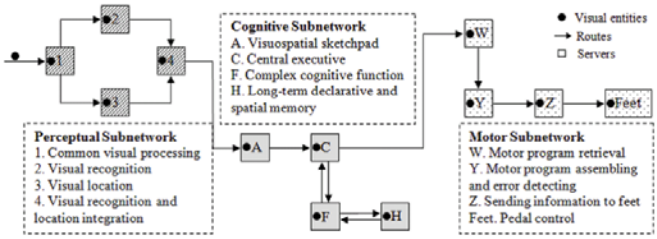


Figure 1. The new speed control model

This model includes an integrated queuing network-model human processor structure, and the rule-based decision field theory. This new model consequently provides new predictions with regards to several components involved in driving: driving speed, throttle/brake pedal angle, acceleration, and the frequency of speedometer inspection.

A laboratory session involving a driving simulator was conducted to validate the current model. The model accounted for over 99% of the experimental speed of the average driver, and over 95% of the experimental speed for the majority of individual drivers (See Figure 2).

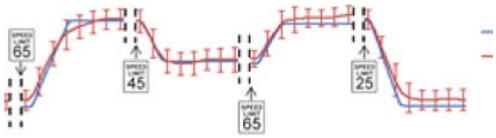


Figure 2. The predicted speed by the model (blue line) and the measured speed in the experiment (red line)

Based on the model, we designed an intelligent speeding prediction system (ISPS) to prevent the occurrence of speeding in advance before it occurs (See Figure 3).

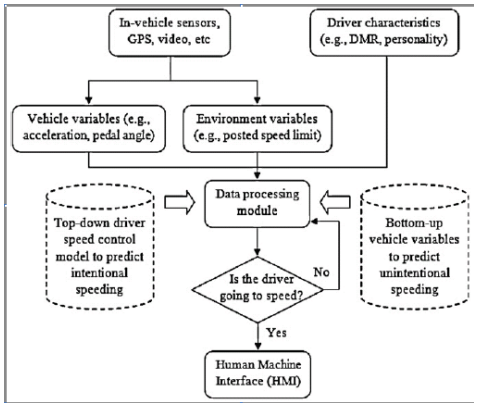


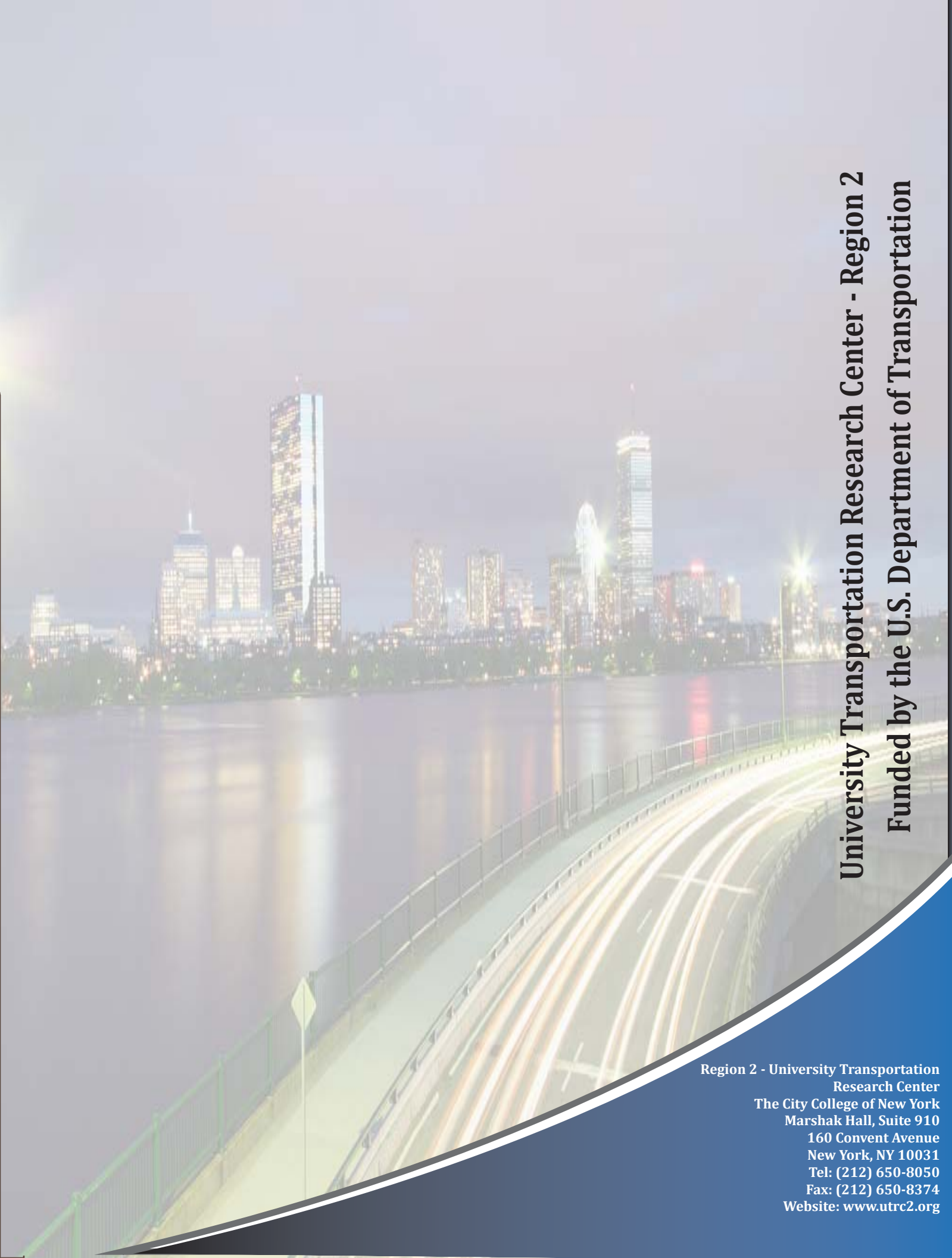
Figure 3. The intelligent speeding prediction system

An experimental study is conducted to compare no speed assistance system, pre-warning system developed based on the ISPS, post-warning system ISA, and combined pre-warning and ISPS system. Both pre-warning and combined systems led to greater minimum time-to-collision. The combined system resulted in slower driving speed, fewer speeding exceedances, shorter speeding duration, and smaller speeding magnitude.

"A Mathematical Model for the Prediction of Speeding with its Validation," IEEE Transactions on Intelligent Transportation Systems
http://dx.doi.org/10.1109/TITS.2013.2257757

"Effectiveness and acceptance of the intelligent speeding prediction system (ISPS)," Accident Analysis and Prevention
http://www.acsu.buffalo.edu/~seanwu/IEEE_SMCA_Speed%20control_final2.pdf

"Mathematical Modeling of Driver Speed Controlwith Individual Differences," IEEE Transactions on Systems, Man, and Cybernetics (Part A)
http://www.acsu.buffalo.edu/~seanwu/IEEE_SMCA_Speed%20control_final2.pdf



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