Addressing Design and Human Factors Challenges in Cyber-Transportation Systems with an Integrated Traffic-Driving-Networking Simulator

Position Paper Submitted to:
Developing Dependable and Secure Automotive Cyber-Physical Systems from Components Workshop, October 28-29, 2010

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Given the critical importance of due consideration of human factors in the design of new applications of Cyber-Transportation Systems (CTS), this position paper argues for the need for developing integrated human-in-the-loop Research, Development, Testing and Evaluation (RDT&E) facility. The paper then presents a proposed Integrated Traffic-Driving-Networking simulator which the authors are beginning to develop. This is followed by a brief description of a longer-term vision for an integrated testing facility for CTS under extreme events.

Motivation

No study of CTS is complete without a full consideration of the human driver and his/her behavior. Due to the complexity of the environment, detection accuracy and legal constraints, it is unlikely that cyber technologies would completely replace human drivers, especially in the near-term. As a result, research into CTS requires an investigation into the multiple interactions (and influences) among the cyber system, transportation system and the human element, as shown in Fig. 1. To the best of our knowledge, a few existing works have studied how a CTS affects drivers and traffic, but research issues related to how to take HF into consideration when designing CTS applications and communications protocols have not been adequately addressed. In this project, we will study how to optimize designs of CTS applications by explicitly taking drivers' behaviors and response into account.

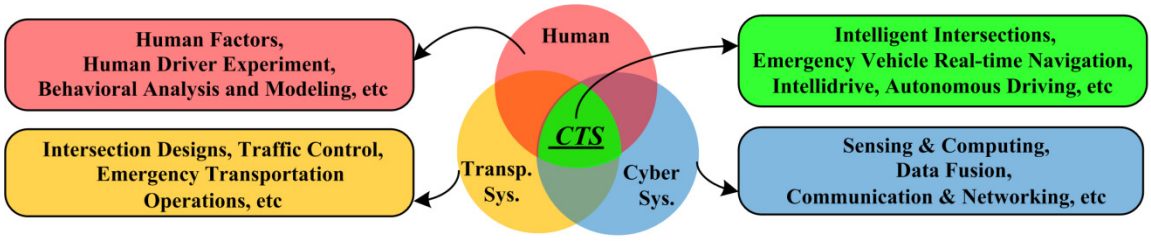

Figure 1. The interactions among the cyber system, transportation system and human element

To achieve this, an effective RDT&E platform which links the human, transportation and cyber elements is required. Existing stand-alone traffic simulators (TS), driving simulators (DS) or networking simulators (NS) fail to satisfy the needs for the design and evaluation of CTS. For example, background traffic in a majority of existing DS tends to be pre-programmed, and hence cannot respond to real-time actions of a human driver. This significantly limits the ability to simulate a realistic driving environment. *Even though* the driver models used in TS can be used to produce realistic *background traffic pattern,* they do not respond to traffic warning and

advisory messages that would be communicated in CTS. Moreover, these models are too "idealistic" in that they do not account for human response time and errors, a key factor in traffic safety evaluation.

Proposed Integrated Traffic-Driving-Networking Simulator

We propose to design and develop an Integrated Traffic-Driving-Networking Simulator (ITDNS), which will consist of a network simulator (e.g., NS-2), a microscopic traffic simulator (e.g., PARAMICS) and a driving simulator (e.g., our surround-screen, 6 D.O.F. motion simulator). We plan to use the "Federated Mode', where the different components will be integrated via inter-communication processes, for integrating the as shown in Figure 2 to promote an open environment where other researchers can build on our work in the future by contributing their own driver models, CTS applications and VANET protocols etc.

One major component to be designed and developed is the "Intermediary Simulation Middleware" (ISM). The "Human Driver" module will relay real-time human input from the HID (e.g., steering wheels and pedals) from DS to TS to control the subject vehicle (SV) in TS. Offline driver modeling will be utilized to produce human-like "Driver Models", which will then constitute another major component of the ITDNS. These driver models will control all other vehicles in the vicinity of SV.

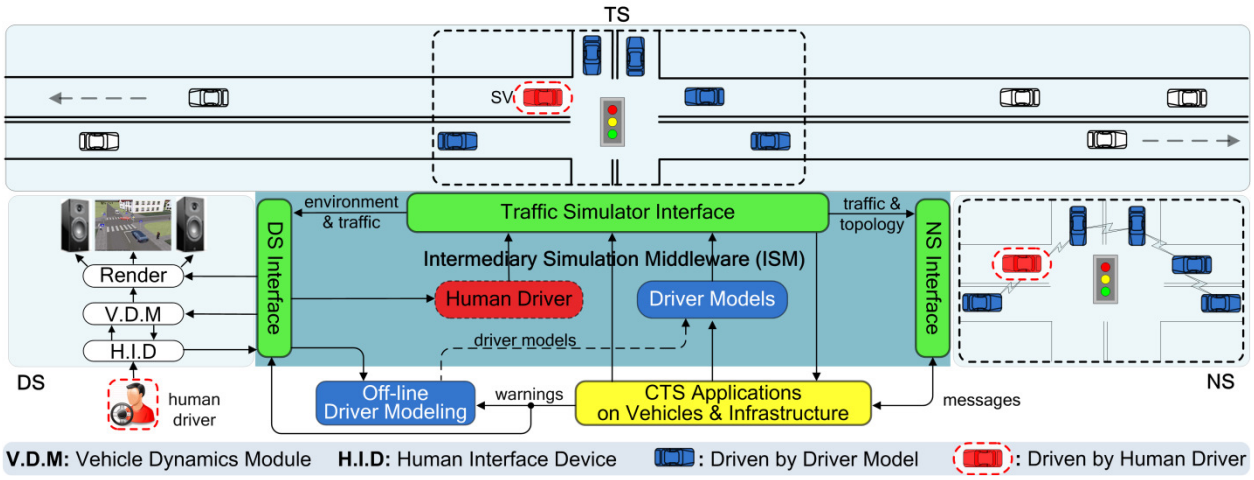

Figure 2. Framework of Integrated Simulator for Cyber-Transportation System

With the ITDNS, the DS can attain necessary environment and traffic information from the TS to reproduce real-time ambient traffic in the vicinity of SV. In addition, the NS can attain real-time traffic and topology information to build a realistic simulation scenario. Furthermore, CTS applications can be "run" on the SV and other vehicles in the vicinity, as well as on the infrastructure. These applications will send/receive messages based on relevant environment and traffic information from the TS. Message exchange among the vehicles using V2V and V2I communications will be simulated in the NS.

Major research issues include: 1) how to adapt the field-of-view traffic data output by the TS, which uses a low update-frequency, for use by the DS. The latter uses a high update-frequency to provide smooth driver perception of the field-of-view traffic environment; 2) how to extend the design to link multiple, possibly distributed, driving simulators so as to allow multiple SVs controlled by multiple human drivers to be simulated simultaneously.

Long-Term Vision for an Integrated Extreme Transportation Event RDT&E Facility
Another area that seems to be somewhat lacking in terms of CTS research is research at the integration of CPS and Extreme Events. We use the term "extreme events" to refer to events such as: (1) inclement weather (e.g. snow storms, high wind, reduced visibility, flooding, and dense fog); (2) major accidents, structural failures or highway construction; and (3) natural or man-made disasters such as earthquakes, hurricanes, and/or terrorist attacks. A RDT&E facility is therefore needed to: (1) study the performance of automotive CPS during extreme events; and (2) develop technologies, systems, and strategies to improve the resiliency, safety, efficiency, adaptability and sustainability of Cyber Transportation Systems under such conditions.

At the University at Buffalo, we have started planning phases for the development of such a facility which we envision would build upon our ITDNS by addition the capability to do some field testing under a controlled environment, as well as by collecting real-world driving and transportation system performance data.

Bios

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