Combining Virtual Reality and Machine Learning for Enhancing the Resiliency of Transportation Infrastructure in Extreme Events

Developing a novel context-aware framework that combines virtual reality with machine learning to improve understanding driver's decision-making

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Traffic management models that include routing choice form the basis of traffic management systems. High fidelity models that are based on rapidly evolving contextual conditions can have a significant impact on smart and energy efficient transportation. Currently, existing traffic/route choice models are generic and are calibrated on static contextual conditions. These models do not consider dynamic contextual conditions such as the location, failure of certain portions of the road network, the social network structure of population inhabiting the region (socio-cultural and economic background), route choices made by other drivers, events, extreme conditions, etc. As a result, the model's predictions are made at an aggregate level and for a fixed set of contextual factors. There is a clear need to develop traffic models that take into account local contexts and are closer to ground reality to provide government agencies with the ability to make well-informed model-based decisions and policies.

Background

In the event of a flooding or a storm (an extreme event) it is often the case that it results in failure of certain links of a road network. This puts regular drivers of the area in a new route choice decision-making context when traveling between any given origin and destination. For example, many dynamic and emergent contextual conditions such as remaining time for travel, familiarity with the area, personality traits (risk taking or risk averse), and the proximity to nearest alternative routes, gas stations with gasoline stocks, constitute a decision-making environment that is different from when the driver starts the trip. A better understanding of factors influencing the driver's decision on spot and messages delivered to drivers for optimizing road network conditions is critical to managing traffic streams.

Routine route choice models that capture decision making rules of day-to-day commute do not reflect decision making that might occur in extreme events. Contextual factors and their impact on driver decision-making can be difficult to understand due to lack of data. Thus, it becomes imperative to use a virtual reality environment to portray alternative scenarios by varying critical contextual factors and capture decision making rules that might occur in a new decision making context. Using Virtual Reality (VR) one can create possible decision making contexts that might arise in extreme scenario. The data on contextual factors collected from VR experiments can be used to train machine learning engines to improve the predictive power of existing models for traffic routing and resource allocation and deployment of resources.

Project Summary

Context-aware data-driven route choice models can enable efficient routing of traffic as well as strategic deployment of resources (personnel, materials, sensors, and actuators). It is important to understand how the use of such resources will affect driver's route selection decision, and support context-aware and driver-centered interactions to help drivers make proper decisions. Existing techniques for allocating and deploying resources (sensors, personnel, materials, etc.) are either based on econometric and game-theoretic approaches or are based on predictive models based on historical data. These models do not capture the contextual factors influencing driving behavior/decision-making in a given situation. In many cases, such approaches and models suffer from performance gaps: there is a significant gap between their predictions and the ground realities that is human-centered. Existing predictive models do not take into account the contextual aspects in which drivers make decisions and thus influence the use and state of traffic infrastructures. As interactions between humans and traffic infrastructures are context driven, the lack of inclusion of specific contexts is a major source of performance gaps.

The overarching goal of this project is to develop a powerful computation and analytic framework that integrates machine learning-based models with immersive virtual environment to improve the predictive power of existing models for traffic routing and resource allocation and deployment of resources (sensors, personnel, etc.) by taking into account contextual factors affecting human interaction with highway infrastructure. To achieve the goal, the project team will:

- Identify contextual factors that affect drivers' decisions;
- Experiment the effectiveness of modeling such contextual factors in IVE; and
- Test the integration of machine learning with results from IVEs to improve predictions.

Status Update

While most of the conventional route choice models use aggregated data, this study provides the opportunity to incorporate any desired contextual factor in the experiment, and investigate human-related factors influencing one's route choice. The major contextual factors experimented in this study were traffic condition, journey type, and social impact. With that, 10 experimental scenarios were created and tested in a VR platform. Furthermore, participants' demographic information (i.e. age, gender, race, education, employment status), familiarity with the area, top concern while stuck in traffic and their financial concerns were gathered. Results of the data analysis showed that "traffic condition," "age," and "race" were statistically significant in this study.

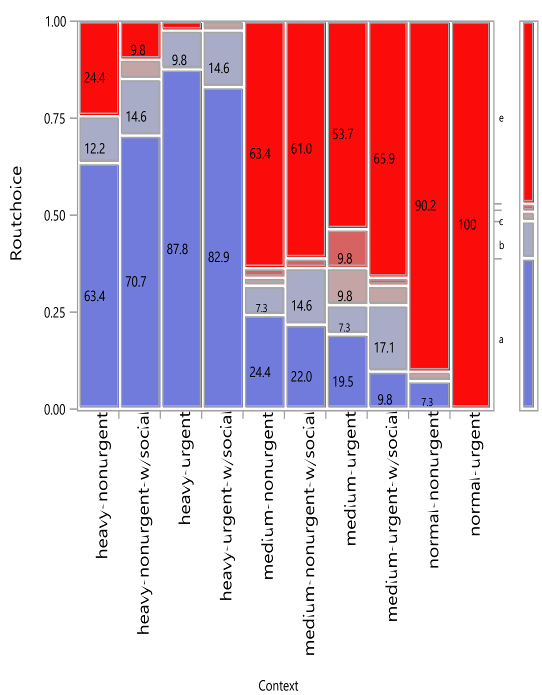

Figure 1. Mosaic plot for contingency table.

Based on the findings of this study: (1) participants (drivers) tend to stay longer in I-10 if the traffic condition is normal or even medium, (2) older people tend to drive longer distances before exiting I-10, and (3) a driver with Middle Eastern background tend to exit I-10 more frequently rather than drivers with Asians background. However, since the sample of this study may not be fully representative, the results of the study would not have strong external validity. Therefore, the main contribution of this study will be introducing a method to provide initial inputs for calibrating statistical models to predict driver's decision-making with respect to the route selection. The method will considerably advance a more customizable research tool for more extensive evaluations and predictions of roadway congestion in different events.

Impacts

Results of this project will allow researchers in the future to further develop a novel context-aware framework that combines virtual reality with machine learning to predict:

- "Optimal" routing of traffic under both normal and abnormal conditions (hurricanes, disasters, football games, etc.) minimizing the average driving time; and
- Appropriate strategic allocation and placement of resources (scheduling traffic light, deploying personnel, sensors, sign boards, actuators, and materials).

The parameterized models developed in this project will take into account the ground reality while predicting, apart from updating itself automatically in a rapidly evolving situation; the fine-grained predictions can be the basis of well-informed policy formulations by the government agencies as well as allowing them to deal with unprecedented and dynamically changing situations.

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

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