Proof of Concept: Examining Characteristics of Roadway Infrastructure in Various 3D Visualization Modes

Final Report
February 2015

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16. Abstract

Utilizing enhanced visualization in transportation planning and design gained popularity in the last decade. This work aimed at demonstrating the concept of utilizing a highly immersive, virtual reality simulation engine for creating dynamic, interactive, full-scale, three-dimensional (3D) models of highway infrastructure.

For this project, the highway infrastructure element chosen was a two-way, stop-controlled intersection (TWSCI).

VirtuTrace, a virtual reality simulation engine developed by the principal investigator, was used to construct the dynamic 3D model of the TWSCI. The model was implemented in C6, which is Iowa State University's Cave Automatic Virtual Environment (CAVE).

Representatives from the Institute of Transportation at Iowa State University, as well as representatives from the Iowa Department of Transportation, experienced the simulated TWSCI. The two teams identified verbally the significant potential that the approach introduces for the application of next-generation simulated environments to road design and safety evaluation.

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PROOF OF CONCEPT: EXAMINING CHARACTERISTICS OF ROADWAY INFRASTRUCTURE IN VARIOUS 3D VISUALIZATION MODES

Final Report
February 2015

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EXECUTIVE SUMMARY

Utilizing enhanced visualization in transportation planning and design gained popularity in the last decade (e.g., TRB 2007 - ABJ95 committee on Visualization in Transportation and TRB 2011 - AFH30 committee on Emerging Technology for Design and Construction).

This work aimed at demonstrating the concept of utilizing a highly immersive, virtual reality simulation engine for creating dynamic, interactive, full-scale, three-dimensional (3D) models of highway infrastructure. For this project, the highway infrastructure element chosen was a two-way, stop-controlled intersection (TWSCI).

VirtuTrace, a virtual reality simulation engine developed by the principal investigator, was used to construct the dynamic 3D model of the TWSCI. The model was implemented in the C6, which is Iowa State University's CAVE Automated Virtual Environment.

Representatives from the Institute of Transportation at Iowa State University, as well as representatives from the Iowa Department of Transportation, experienced the simulated TWSCI. The two teams identified verbally the significant potential that the approach introduces for the application of next-generation simulated environments to road design and safety evaluation.

LITERATURE REVIEW

High traffic volume in towns is a major concern from various perspectives. Significant resources have been invested to increase transportation system efficiency by diverting traffic to bypasses.

Cena et al. (2011) note that the construction of bypasses resulted in a significant decrease in crash rates. The newly constructed bypasses usually result in an increase in traffic volume. The construction of rural expressways most often requires the construction of two-way, stop-controlled (TWSC) intersections, where a two-lane roadway crosses a four-lane expressway. Maze et al. (2004) reported that TWSC intersections are particularly problematic where the traffic volume on the main line is moderate and there is high traffic volume on the minor road.

Thus, the accelerating growth of highway transportation increases the complexity of designing safe infrastructure. One significant factor in the design of highways, for example, is geometry that is consistent with driver expectations. Inconsistent geometry may lead to violations of driver expectations and reduce safety.

This factor becomes even more significant when vehicles are close to each other (Maze et al. 2004, Wooldridge et al. 2003). Another characteristic of intersections that affect traffic safety is lighting (e.g., Isebrands et al. 2004). Other factors such as the way roadway and intersection characteristics are communicated to drivers may have major impacts on traffic safety.

Researchers have utilized sophisticated methods to analyze traffic safety of intersections and the impact of intersection characteristics on traffic safety. These efforts resulted in models and guidelines that serve the highway administration well. However, the research and development efforts above are primarily based on crash data. Furthermore, when attempting to examine the combined effects of more than one or two intersection characteristics, the statistical procedures become much more complicated, data availability becomes limited, and, consequently, the effect size (measure of the strength of the relationship between the variables) becomes a challenge.

Utilizing enhanced visualization techniques in the design of traffic infrastructure is becoming more prevalent (e.g., Taylor and Moler 2010). Bailey and colleagues (2001) examined the effects of three visualization modes—two-dimensional (2D), three-dimensional (3D), and virtual reality (VR)—on public preferences pertaining to highway design. The result indicated that 3D was the preferred mode of visualization. However, the study did not address the impact of the visualization mode on understanding the shortcomings and advantages of design characteristics.

Furthermore, the study did not utilize a full-scale model, where the virtual intersection is the size of a real intersection. Bailey et al. (2001) also indicated that "further development of the VR package would allow the landscape to be populated with moving objects, such as cars, trucks, and people. The trajectories of these objects and their interactions can be governed by rules that simulate realistic motions." This statement epitomizes the limited computational and visualization power available in the very early 2000s.

PROJECT SUMMARY

This report summarizes a proof-of-concept project that demonstrates the feasibility of using a fully immersive, full-scale, 3D, interactive simulation engine for evaluation of safety transportation infrastructures.

The development efforts for this proof of concept resulted in 3D models for TWSC intersections that utilized an advanced interactive virtual reality (VR) simulator called VirtuTrace. VirtuTrace can present the intersections on a computer monitor and on full-scale models in the C6 (a 10 foot by 10 foot by 10 foot room), which is Iowa State University's Cave Automatic Virtual Environment (CAVE). Figure 1 provides an example from a proof-of-concept effort.

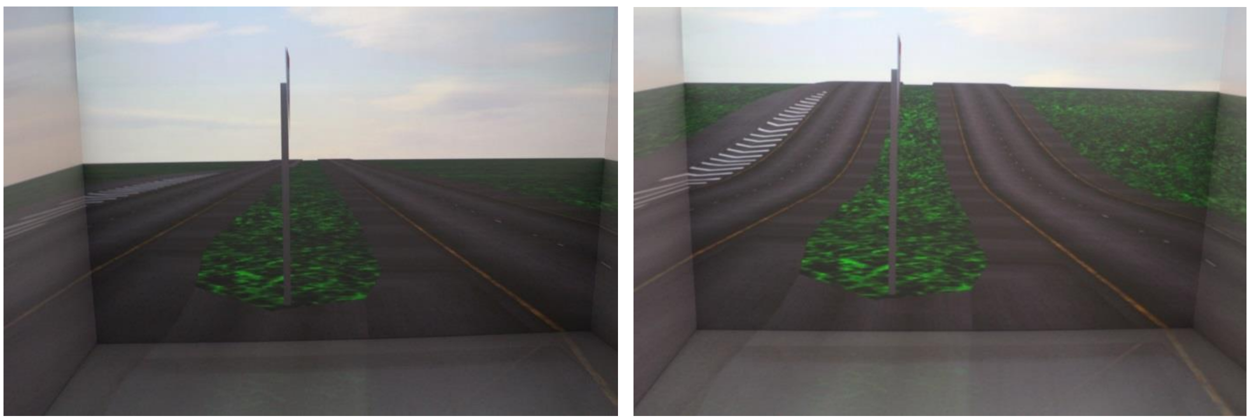

Figure 1. Two-way, stop-controlled intersection on a flat terrain (left) and on a hilly terrain (right)

The image on the left presents one side of a road around a TWSC intersection on a flat terrain, while the image on the right presents the same road, but on a hilly terrain. Similarly, Figure 2 shows a bird's eye view of an intersection with a narrow and a wide merging lane.

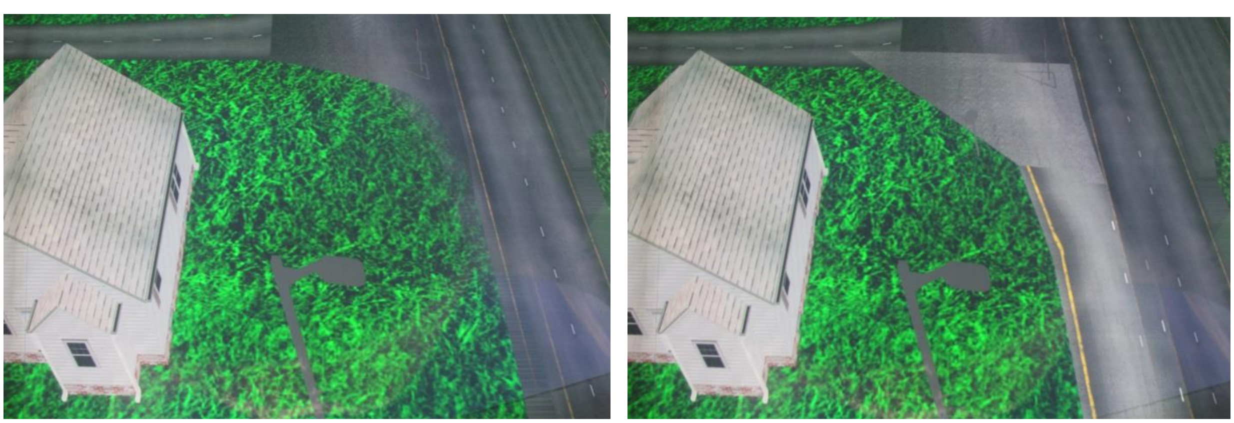

Figure 2. Simulator view of intersection with narrow merging lane (left) and a wide merging lane (right)

These and other terrain features can be modified real-time, in situ, through an arm-mounted wireless keyboard (see Figure 3).

Figure 3. Arm-mounted wireless mini keyboard for dynamic simulation control

Simulation Features

The following is a list of features that have been established in this proof of concept project:

- The simulator allows for moving in the virtual intersection by stepping in the desired direction in the C6. The farther the user is from the center of the C6, the faster the motion in the environments is.
- The simulator allows for viewing and exploring the scene from a bird's eye view with complete control of the bird's-eye view height.
- Changing terrain elevation (Figure 1) is controlled real-time through the mini keyboard.
- Changing acceleration lane (Figure 2) is controlled real-time through the mini keyboard.
- The world around the intersection can be changed in real time by the push of a button on the keyboard. Figure 4 demonstrates two examples.
- The presence of structures upstream or downstream from the intersection is controlled in real time through the mini keyboard.
- The angle of intersecting roads can be controlled in real time.

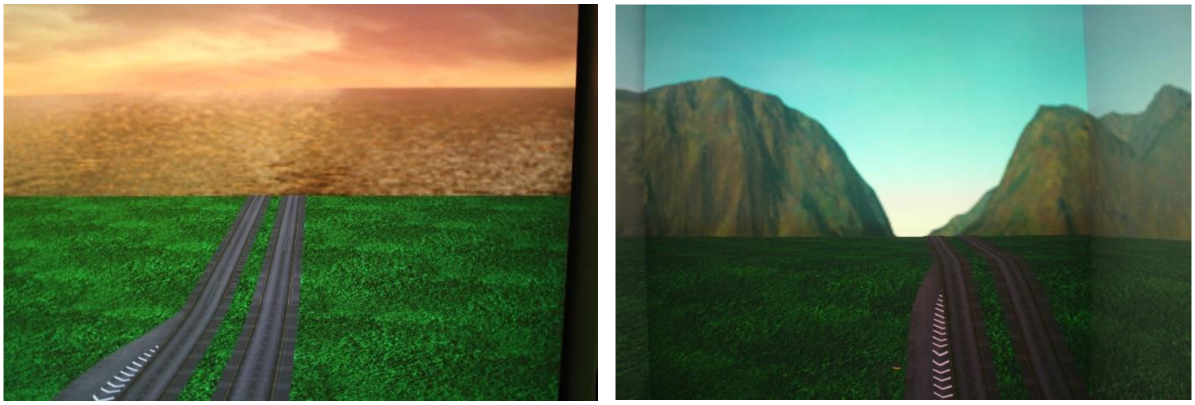

Figure 4. Ocean environment (left) and mountain environment (right)

IMPRESSIONS

The teams from Iowa State University's Institute for Transportation and the Iowa Department of Transportation experienced a demo of the simulation in full scale in the C6 as well as on a television (TV) monitor. Both teams expressed great appreciation for the simulators and the discussion continued as to the significant potential the simulator brings beyond the scope of this project.

NEXT STEPS

The next-phase proposal was submitted to the Midwest Transportation Center team. The proposal suggests the following:

- Extend the features of the simulator
- Develop modules for intersections with safety concerns and evaluate them with the simulator
- Establish focus groups for assessing the utility of the simulator for detecting safety deficiencies, comparing between full-scale and monitor-scale implementation of the simulator
- Work with instructors of highway design to integrate the simulator into their courses

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