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Proposed Watertown Plank Road Interchange Evaluation Using a Full Scale Driving Simulator

Kelvin R. Santiago-Chaparro, Dan Reichl, Andrea R. Bill, and David A. Noyce

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Project Summary

A full-scale driving simulator was used to evaluate a proposed interchange design (Watertown Plank Road and USH 45) in Milwaukee, Wisconsin.

Research team provided the project design team with a unique visualization platform to identify desired/required changes to the design.

Human performance was added to the evaluation; something not possible using traditional design practices.

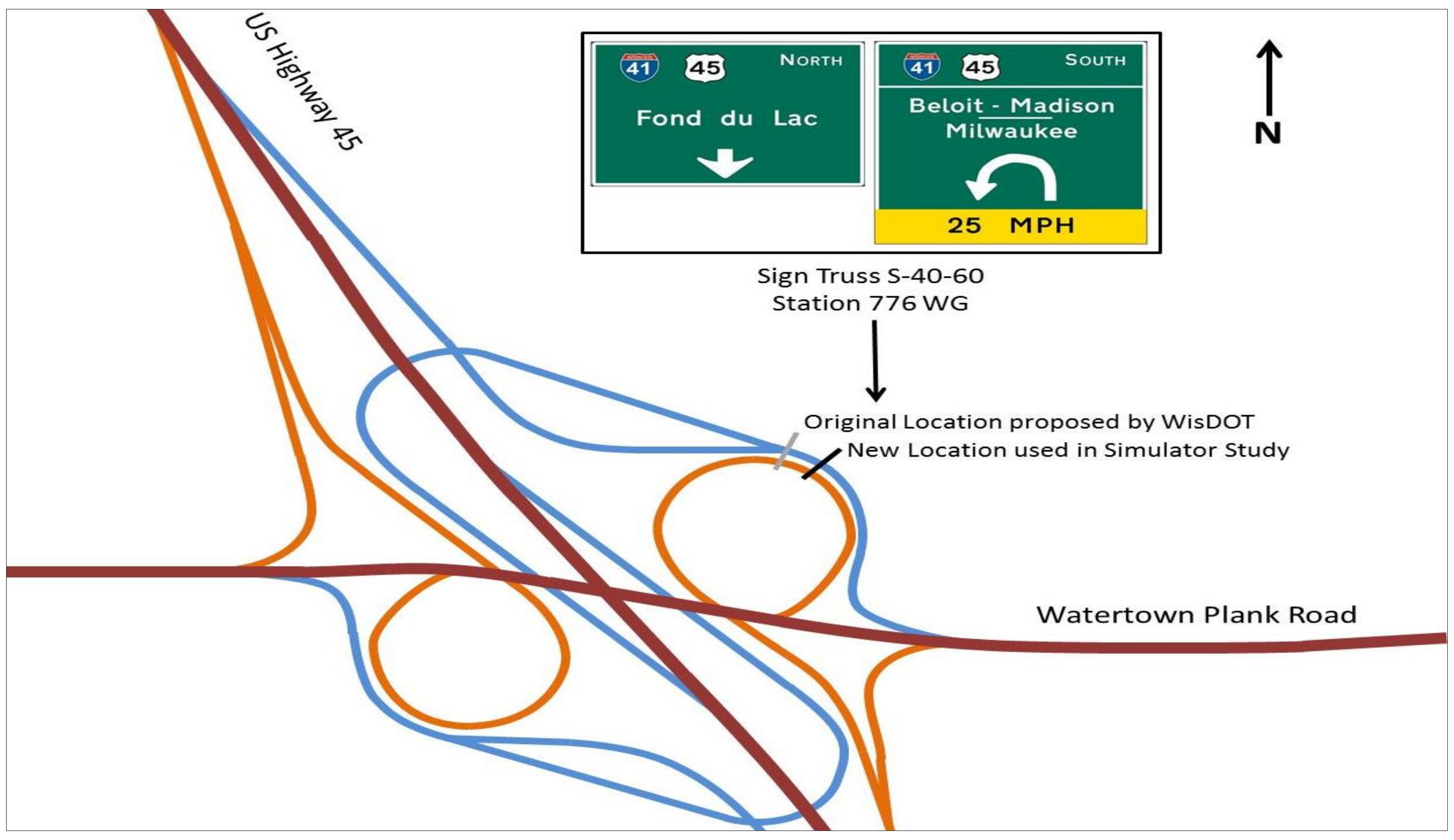


Fig 1. Changes made to design prior to experiments as a result of the rapid visualization process.

Scenario Visualization and Design Changes

The research team utilized a custom workflow to bring CAD drawings from the proposed highway design into a full scale driving simulator.

Custom workflow involves the creation of a 3D model based on triangular surfaces, texturing of the model, and definitions of roadway metadata.

The project design team worked in conjunction with the research team to iterate changes in their design before subject testing.

By allowing the design team to "drive" their project, design components could be discovered and altered.

Among items discovered by the design team during early visualizations was a missing sign bridge and a sign bridge requiring relocation because the view of the signs was obstructed by the A pillar of the vehicle.

Experimental Procedure for Subjects

24 subjects (13 male, 11 female) were recruited to participate in the research. Average driving experience of the subjects was 15 years.

Subjects were asked to "drive" a scenario that containing a model of the proposed Watertown Plank interchange.

Eye tracking equipment was used to monitor visual search patterns as they navigated through the interchange.

Subjects were asked to conduct tasks that involved locating an exit to the hospital and navigating an exit ramp with a pedestrian crossing.

An exit interview was conducted for each subject to receive feedback about the experience of each subject with the proposed design.

Driving Simulator

The full-scale Ford Fusion vehicle operates like an on-street vehicle, with the visual world observed through a 240 degree screen frontward projection and rear projection in both the side a rear-view mirrors. The vehicle is mounted on a 1-degree of freedom platform.

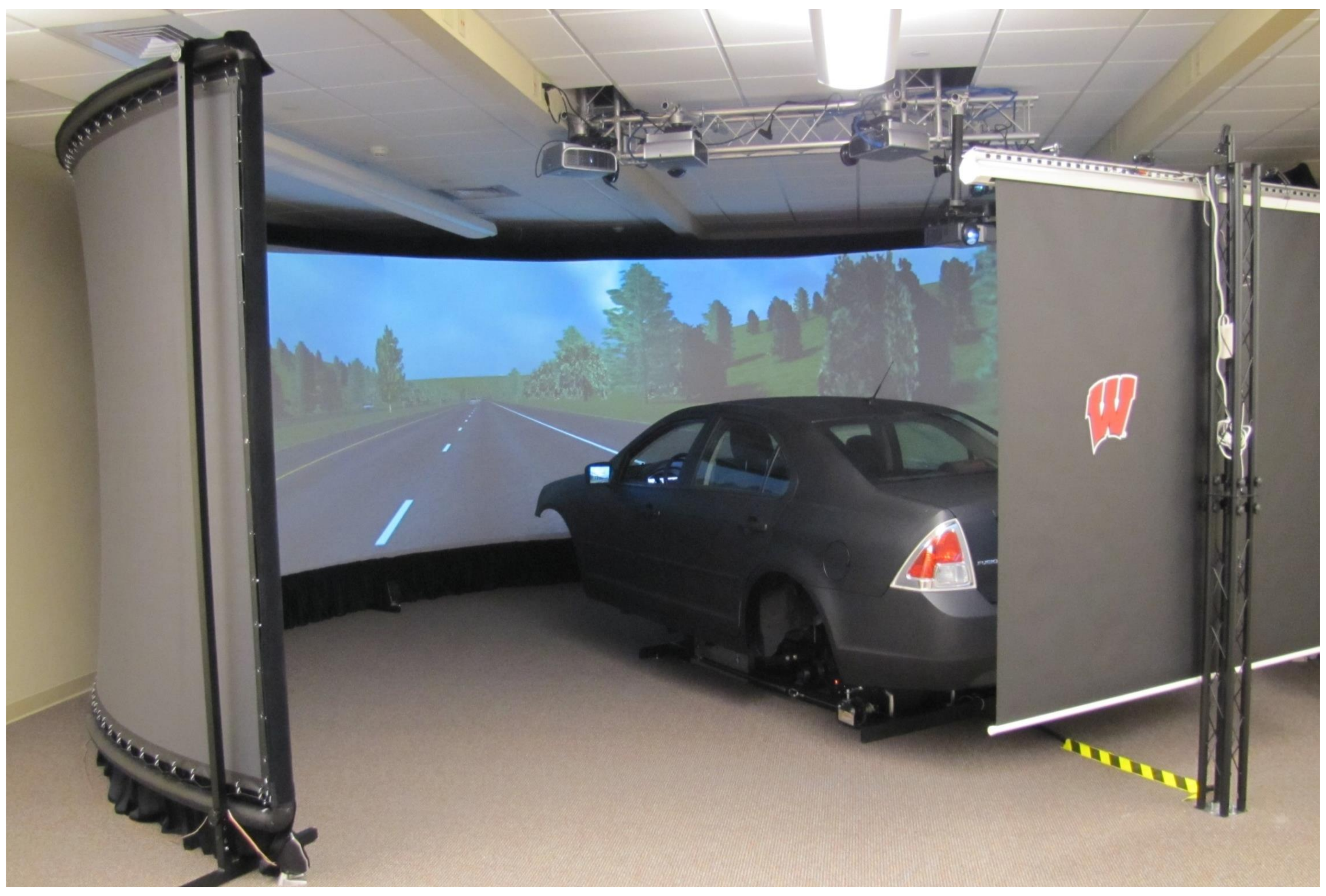


Fig 2. Photo of full scale driving simulator.

Selected Design Changes

Data were analyzed to better understand behavior and visual search patterns of drivers. Design changes were proposed to the project team before design process completion.

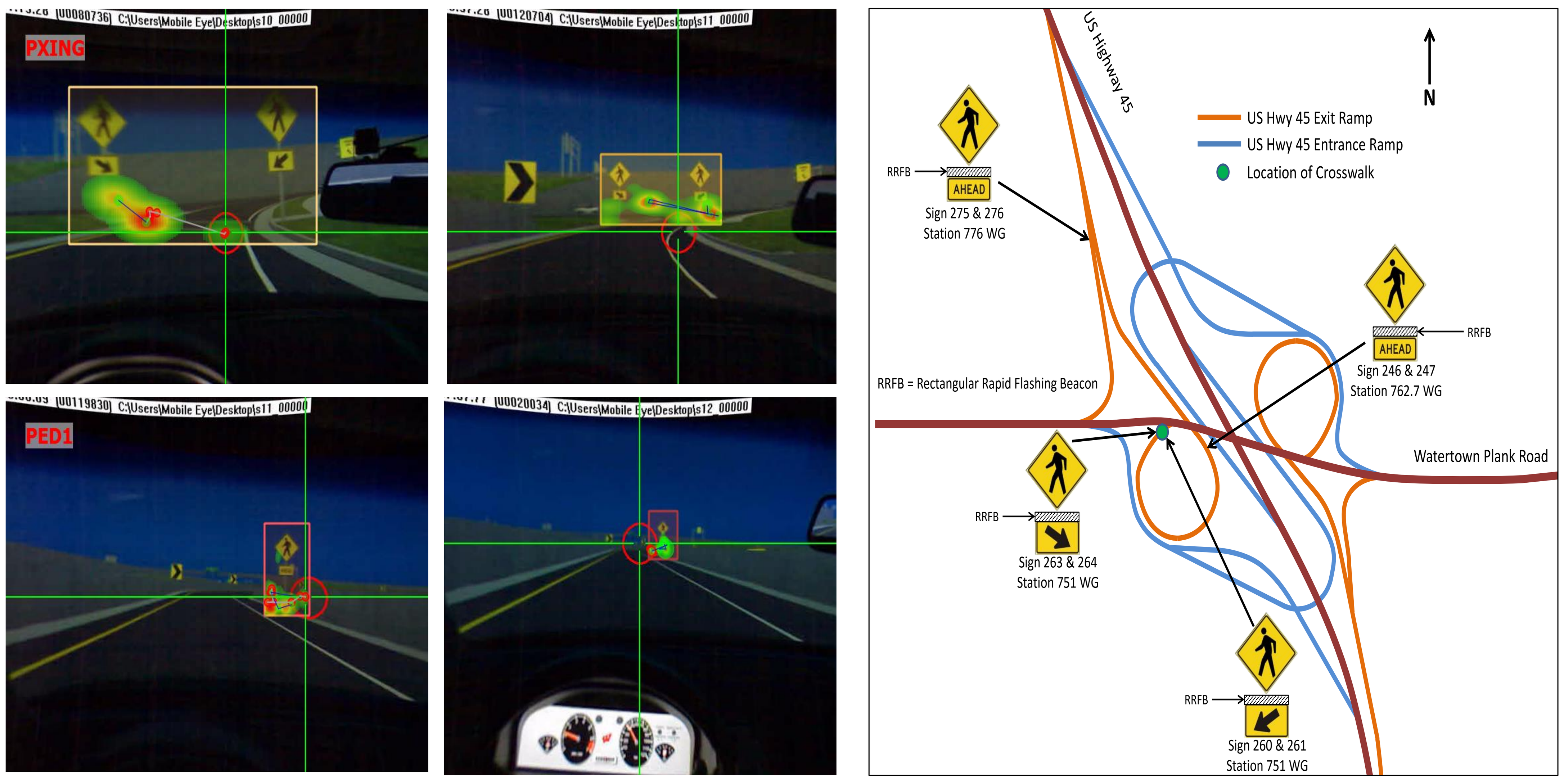


Fig 3. Eye tracking data for subject navigating exit ramp while approaching pedestrian crossing.

Pedestrian Signage

Eye tracking data shows a small time difference between fixation on the pedestrian crossing and arrival to crossing (3 to 4 seconds).

Recommendation: Additional awareness about pedestrian presence needed. Initial design provides advanced notice but focus on the presence of pedestrians is lost due to the complexity of the curve.

Hospital Sign Placement

Exit interviews revealed confusion about hospital sign and location of the hospital.

Recommendation by research team: Add supplemental signs further upstream to help with lane selection.

Guidance Signs

Subjects mentioned that placement of signs indicating appropriate lane for exiting were confusing.

Recommendation by research team: Place sign next to the right lane while pointing to the correct lane to exit.

Intersection Evaluation Using Virtual Road Safety Audit Process

Lingiao Qin, Kelvin R. Santiago-Chaparro, Andrea R. Bill, and David A. Noyce

Project Summary

A Virtual Road Safety Audit (VRSA) of a signalized intersection in Madison, WI will be conducted in a full scale driving simulator and the findings compared with results from a traditional road safety audit.

Custom scenario creation workflows will be used to create a simulator scenario that present users with the same challenges faced on the intersection used for the VRSA.

Challenges

The complexity of the procedures used for bringing proposed/existing road designs into a driving simulator, a crucial aspect of conducting a VRSA, will likely introduce challenges such as:

Time required to create driving simulator scenarios after a working version of the design plans (or as-builts) is available for project.

Compatibility of roadway design software and the scenario creation tools used for driving simulators.

- Availability of design data, aerial photographs, and sources such as LiDAR surveys can be used for 3D scenario creation introduces the need for custom workflows.

Signal phasing at the site evaluated might not be available as a standard option in existing driving simulator scenario creation tools.

- Custom logic and software modules will be required to replicate existing signal conditions.

Experimental Procedures

Subjects will be asked to "drive" a scenario in the driving simulator that is built to reflect similar conditions to those that exist at the test site.

Eye tracking data, along with data produced by the driving simulator, will be used to gain an insight into the performance of drivers when navigating through the site selected for evaluation.

Findings from the simulator evaluation will be compared with the findings of a field road safety audit.

Motivation

Conducting Virtual Road Safety Audits (VRSA) will allow researchers to introduce a behavioral component in the safety evaluation process of proposed/existing roadways.

In a controlled laboratory environment safety characteristics will be evaluated at levels of detail not possible using the traditional road safety audit process.

Driving Simulator

The full-scale Ford Fusion vehicle operates like an on-street vehicle, with the visual world observed through a 240 degree screen frontward projection and rear projection in both the side a rear-view mirrors. The vehicle is mounted on a 1-degree of freedom platform.

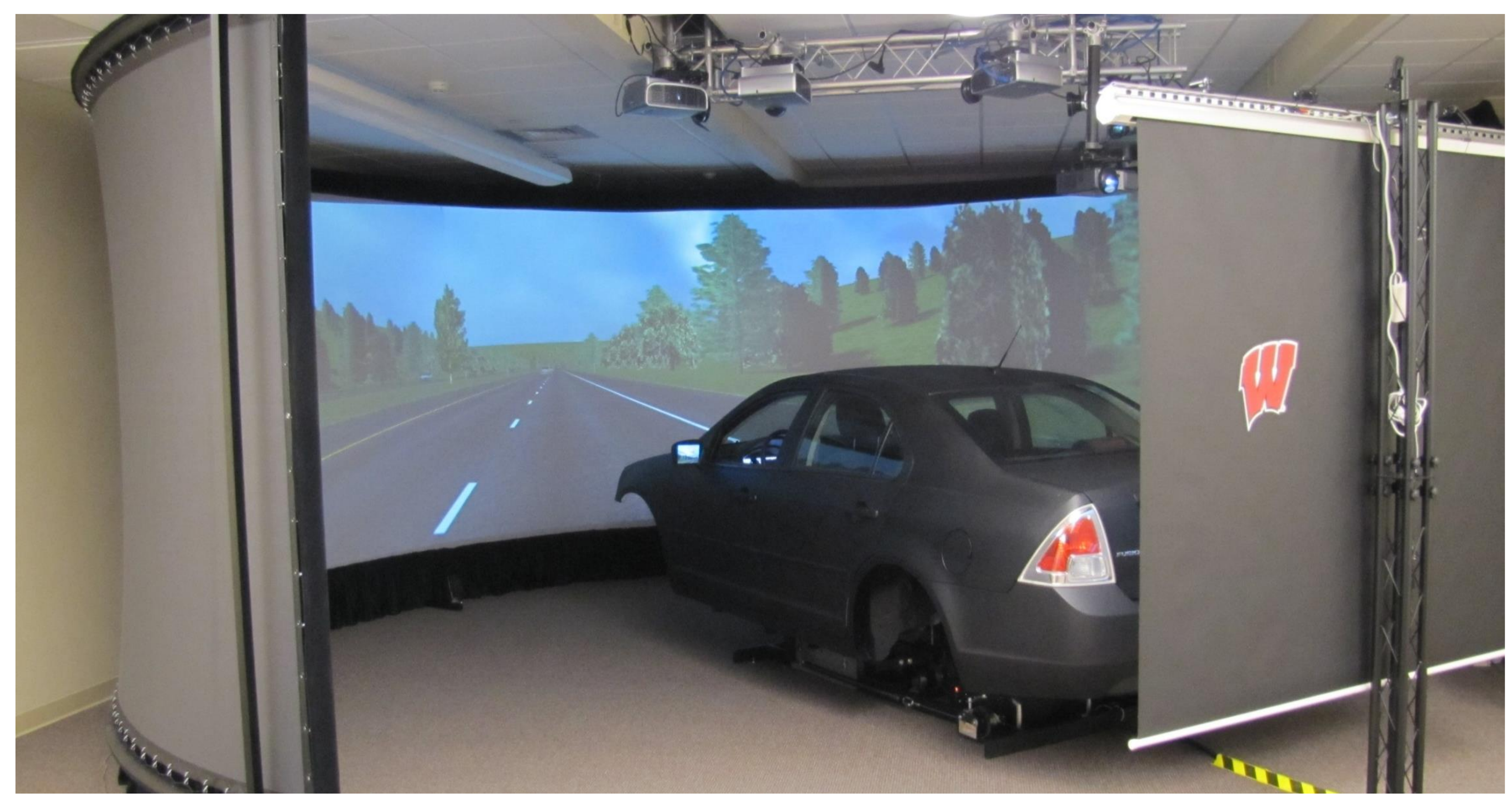


Fig 1. Photo of Full Scale Driving Simulator

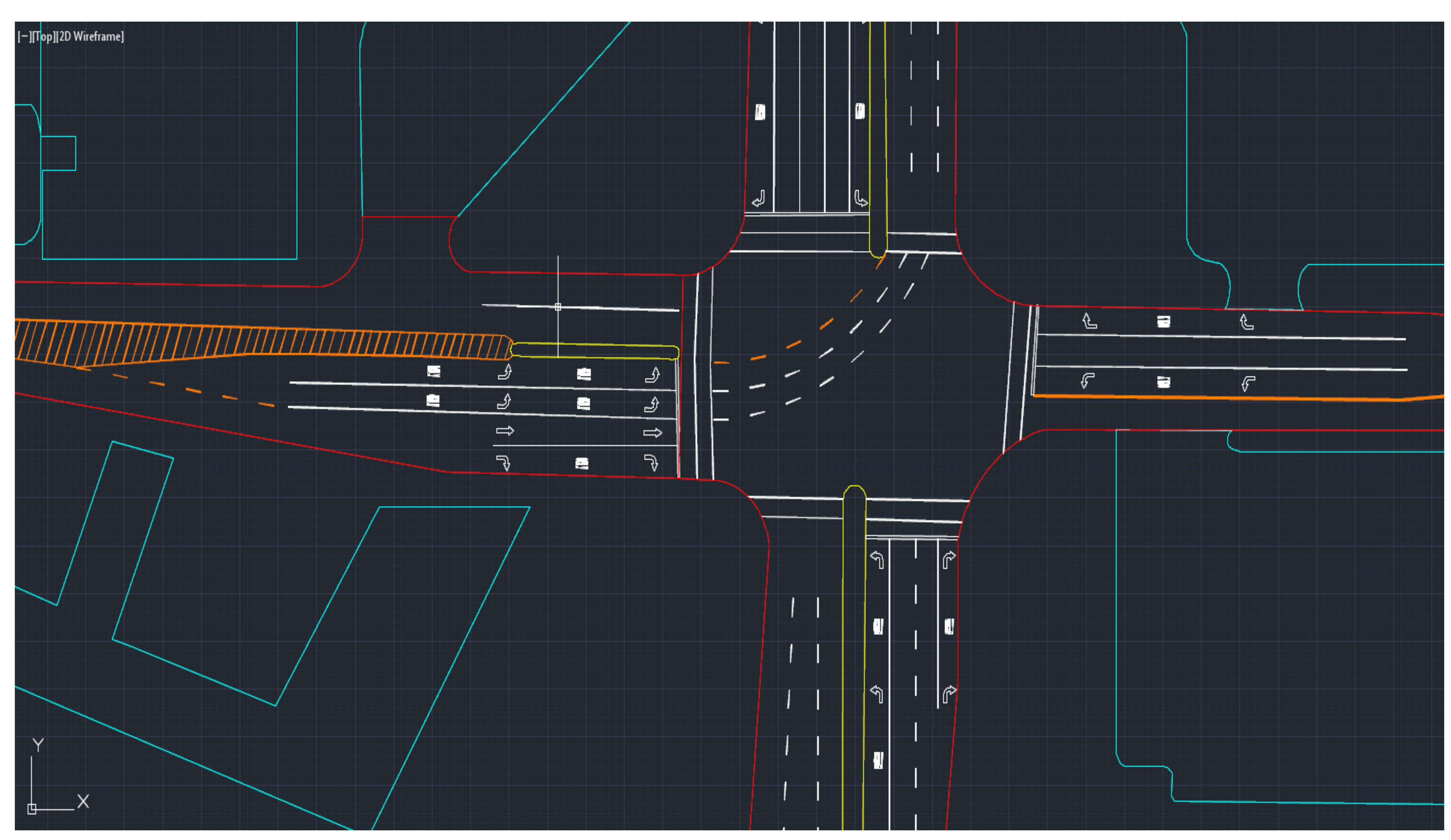


Fig 2. CAD Model Created for Driving Scenario

Site Selected for Evaluation

University Avenue & West Badger Road. Madison, WI

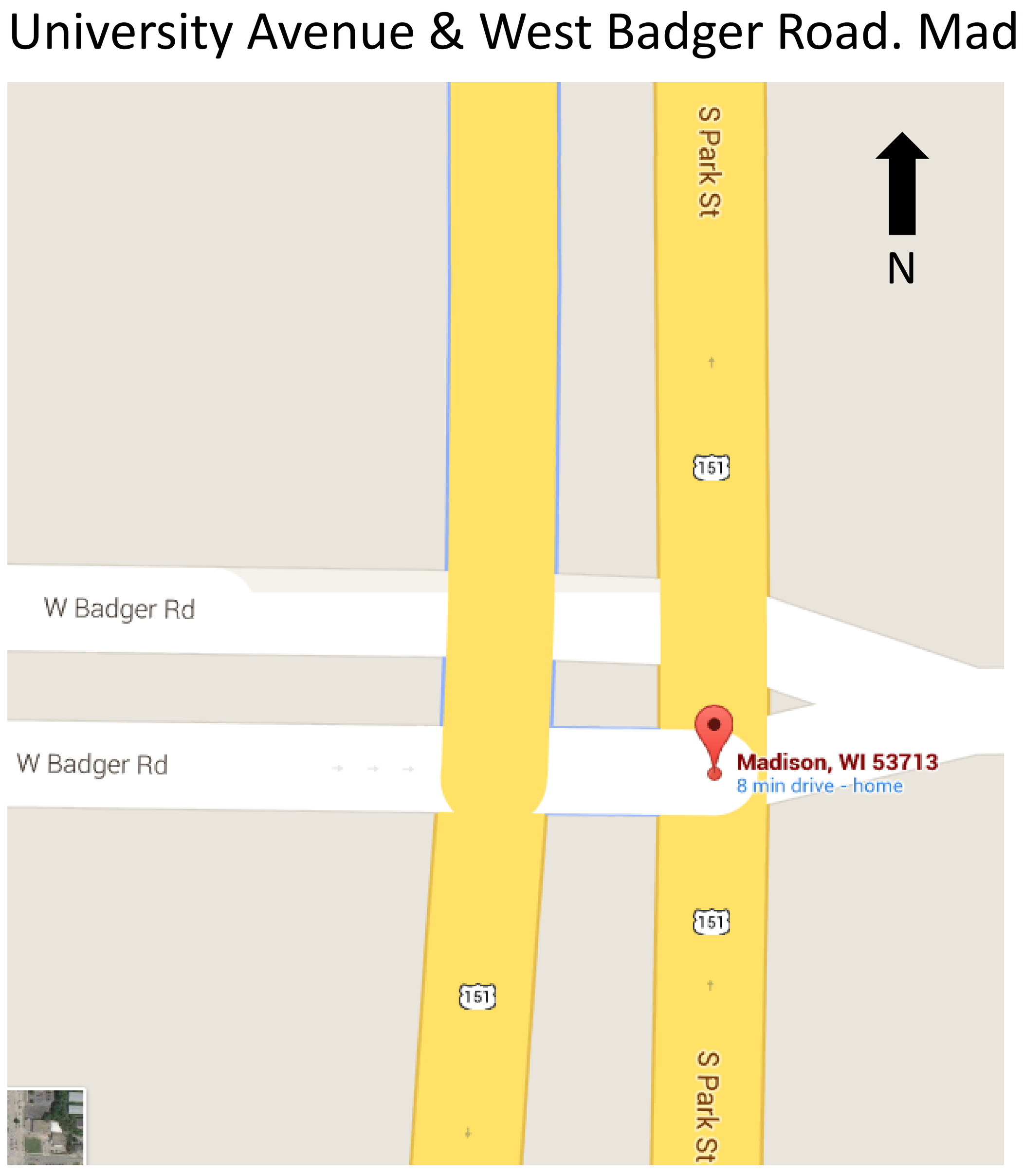


Fig 3. Map View of Intersection

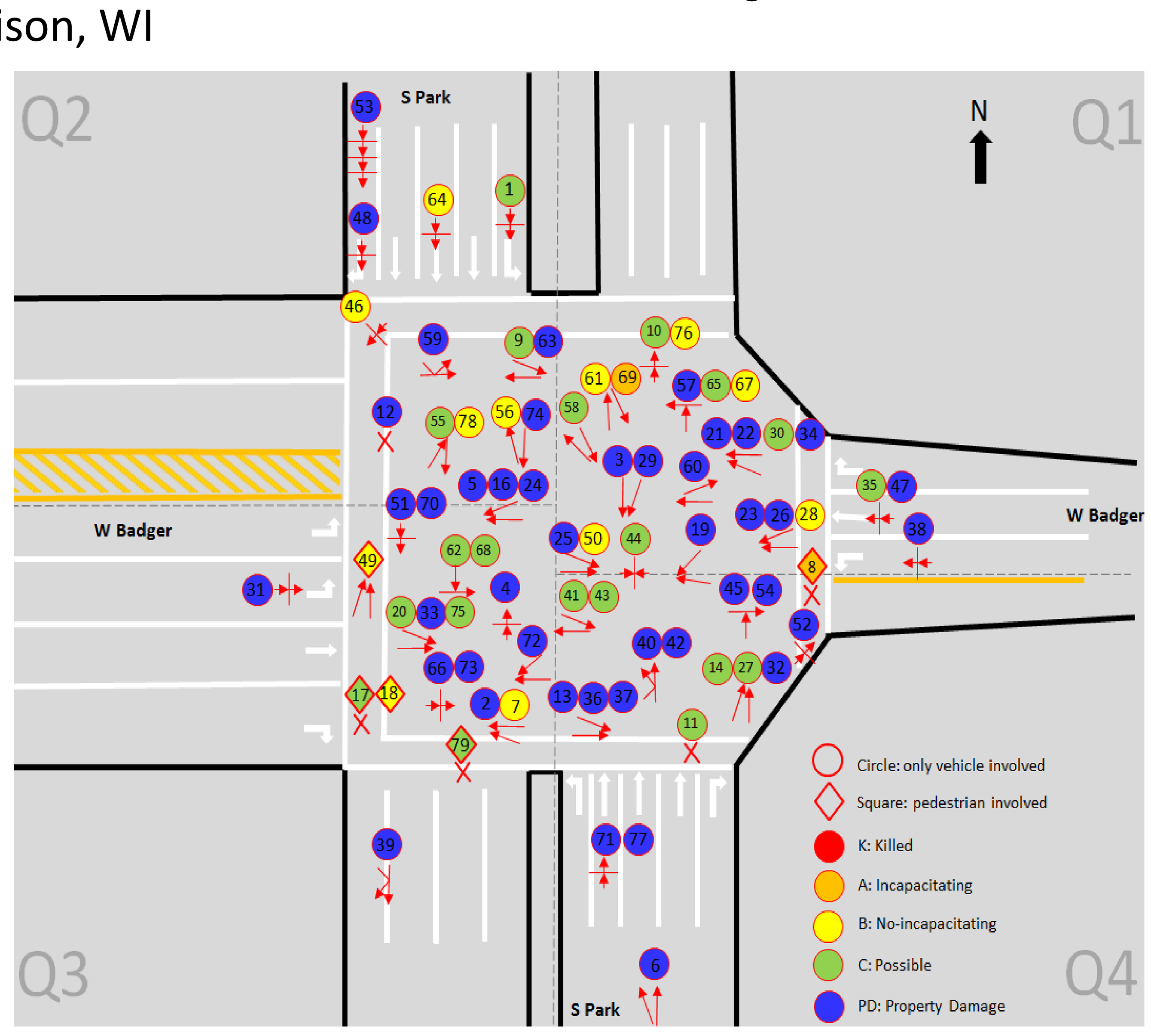


Fig 4. Crash Diagram (Past 3 Years)

Fig 5. Google Streetview Screenshot of Intersection

Geometric Compatibility of Driving Simulators: *Towards a Unified Scenario Creation Process*

Kelvin R. Santiago-Chaparro, Shawn Allen, and David A. Noyce

Project Summary

A set of Python scripts were created to automated the process of created 3d models that can be imported into different driving simulator platforms such as RTI and MiniSim.

The scripts create a 3d model in OBJ format, generate the correct UV map, and produce correlated roadway data. Textures used are part of a database created by the end user.

Input Requirements

A CSV file defining the characteristics of the model in terms of texture and part of the texture used on each face loop of the 3d model.

The coordinates that define the edge lines of the model in a CSV. Coordinates can be obtained from different sources such as:

- Civil 3d corridor model
- Traditional CAD models
- GIS shapefiles

Implementation

Input files obtained from a 3d CAD model that contain superelevation information and vertical profile information.

Python scripts used to process input files and generate a 3d model of the road in OBJ format, the corresponding MTL files, and correlated roadway data.

The UV maps for the OBJ model are also automatically generated by the scripts thus producing a smooth transition between the edges of the model.

Python code relies on existing libraries to perform mathematical operations required to obtain roadway normal if required by the simulator platform.

Potential Applications

Roadway surfaces from real design can be converted into 3d models without the need to learn complex 3d modeling software.

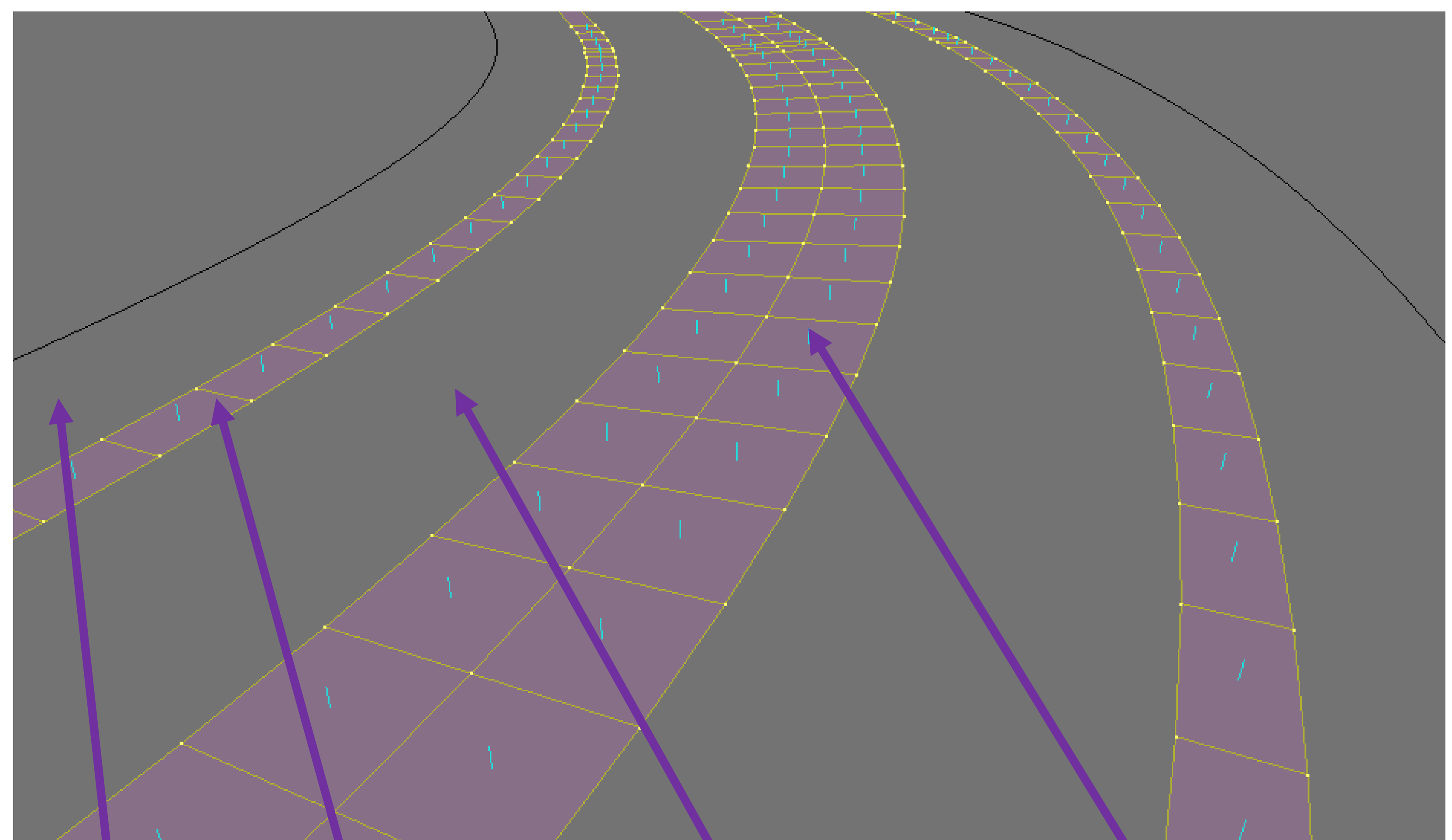
The process of generating roadway surfaces from GPS data collected using a smartphone can be streamlined since GPS traces can be converted into X,Y coordinates along the road with the corresponding offsets.

Motivation

Sharing scenarios across multiple simulator platforms is a difficult process from the creation scenario perspective and acts as a barrier to collaborative research.

Part of the challenge is the need for using scenario creation software with a steep learning curve, especially for researches without formal 3d modeling training.

Name of texture in library that should be applied to the 3d model



Shoulder1	BikePath	Shoulder2	Shoulder2	Roadway
0.25	0	0	0.75	0
1	1	0.75	1	0.5
40	40	40	40	40

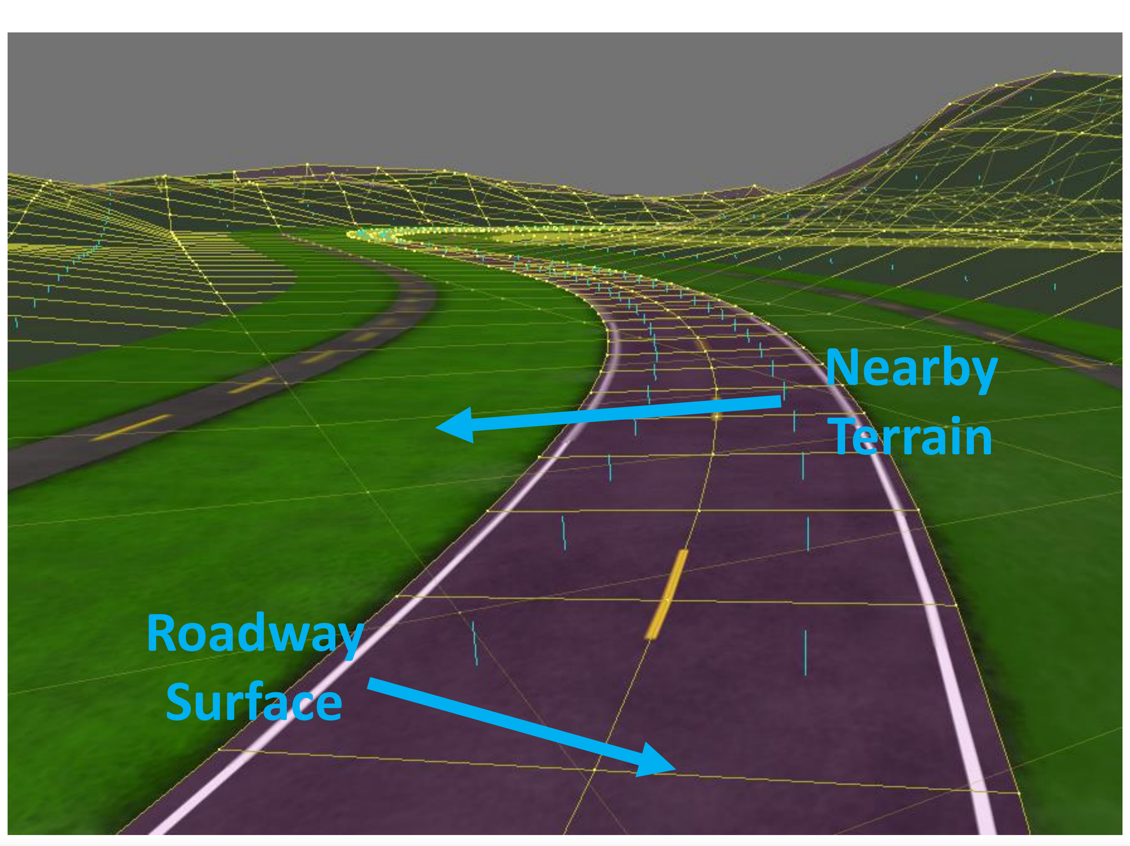
Start width of UV Map

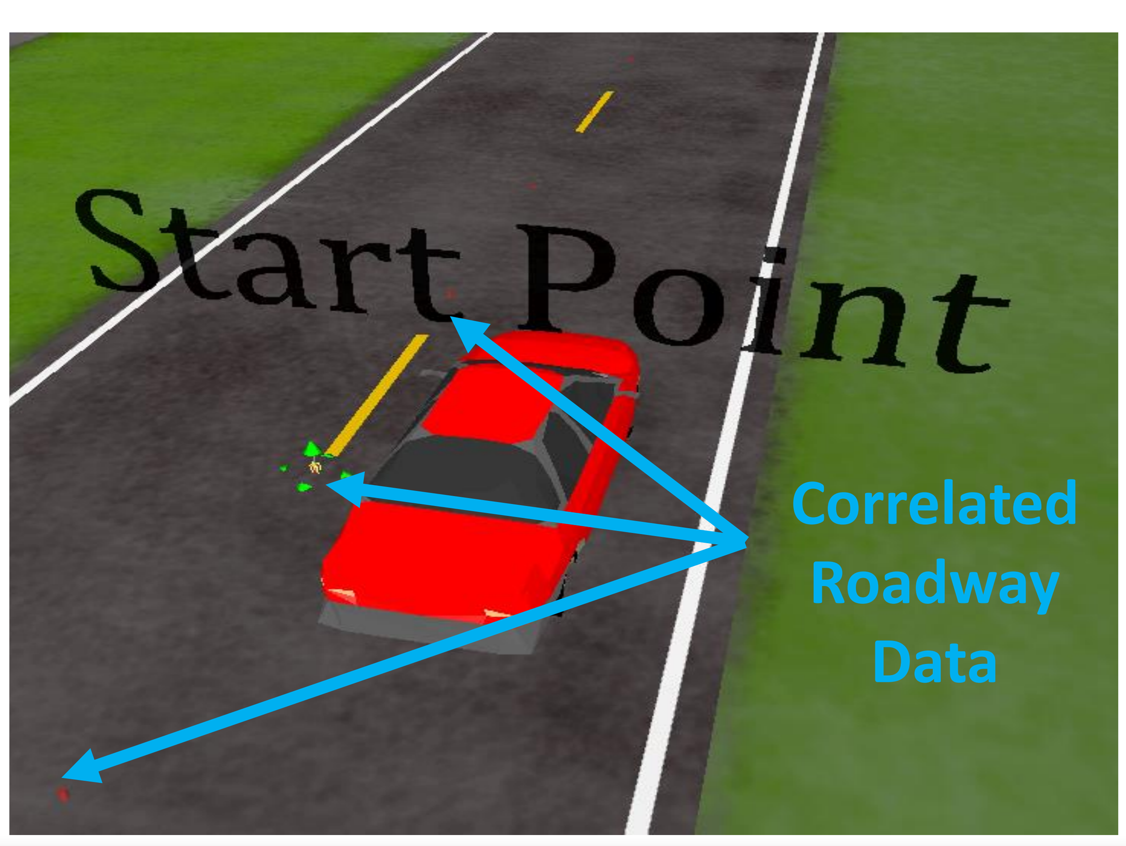
End width of UV Map

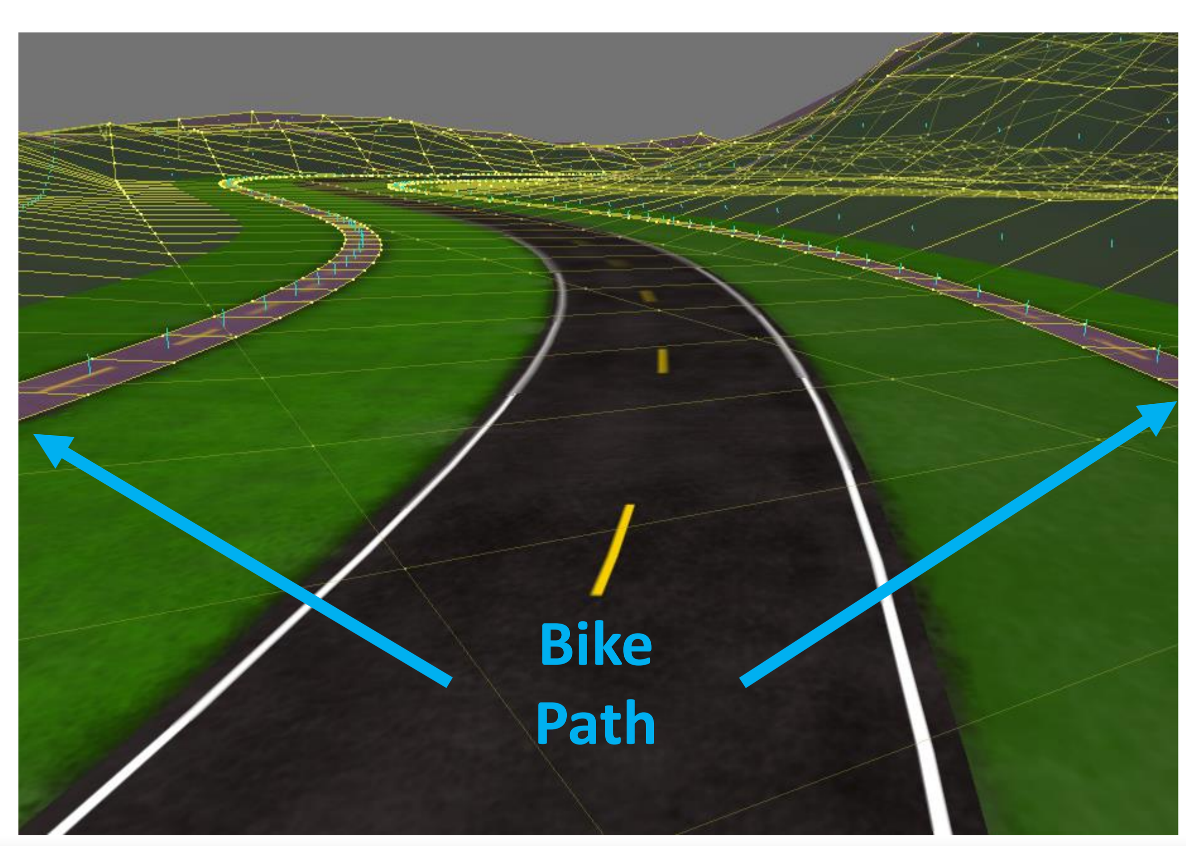
Length presented by texture

Sample Results

Model shown bellows was created by the Python scripts. Textures used were part of an existing library used by the research team. The model is shown using Blender and Internet Scene Assembler.







Neural Correlated of Older Driver Performance

Madhav Chitturi, Veena Nair, Vivek Prabhakaran, Dorothy Farrar-Edwards, and David Noyce

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Project Summary

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The scripts create a 3d model in OBJ format, generate the correct UV map, and produce correlated roadway data. Textures used are part of a database created by the end user.

Motivation

Older drivers crash rate second only to adolescents.

By the year 2020 estimates are that 40% of fatal crashes are expected to involve older drivers.

There is no consensus on a set of tests to reliably and accurately identify unsafe older drivers.

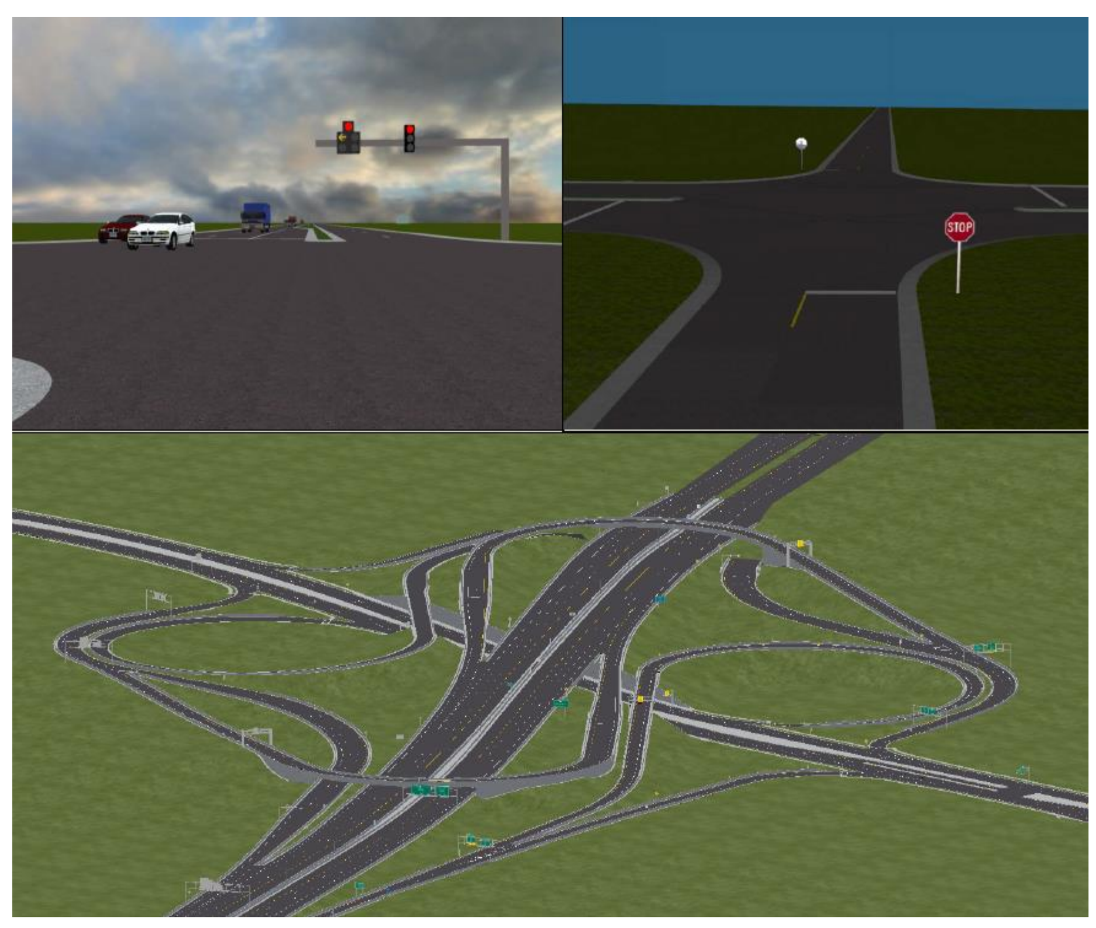
Aims of Upcoming Project

Investigate age-related differences in the brain networks engaged during simulated driving tasks as well as high level processing tasks of executive function and attention/inhibition and low-level processing tasks of visual perception and processing speed in the scanner.

Investigate whether fMRI measures can accurately predict unsafe driving behavior and how such brain-based measures compare with conventional neuropsychological measures.

Driving Simulator

Driving Scenarios



Driving Task in MRI Scanner

Flow of Proposed Methodology

Brain Imaging

- Driving task in scanner
- N-back task in scanner
- Stroop, DSST, Visuospatial Perception

Neuropsych+ Physical Assessment

- Stroop
- Trail making
- Span measures
- UFOV
- Neck rotation and others

Driving Simulation Performance

- Roundabouts
- Intersections
- Freeway weaving
- Busy urban areas

ICA networks → Group difference → Neural correlates

Aim I

SVM classifier → Predictive accuracy

SVM classifier → Predictive accuracy

Unsafe older driver — Safe older driver

Aim II

College of Engineering
UNIVERSITY OF WISCONSIN–MADISON

Road Safety and Simulation 2015

Holographic Traffic Controls Evaluation Using a Full Scale Driving Simulator

James Markosian, Kelvin R. Santiago-Chaparro, Madhav Chitturi, and David A. Noyce

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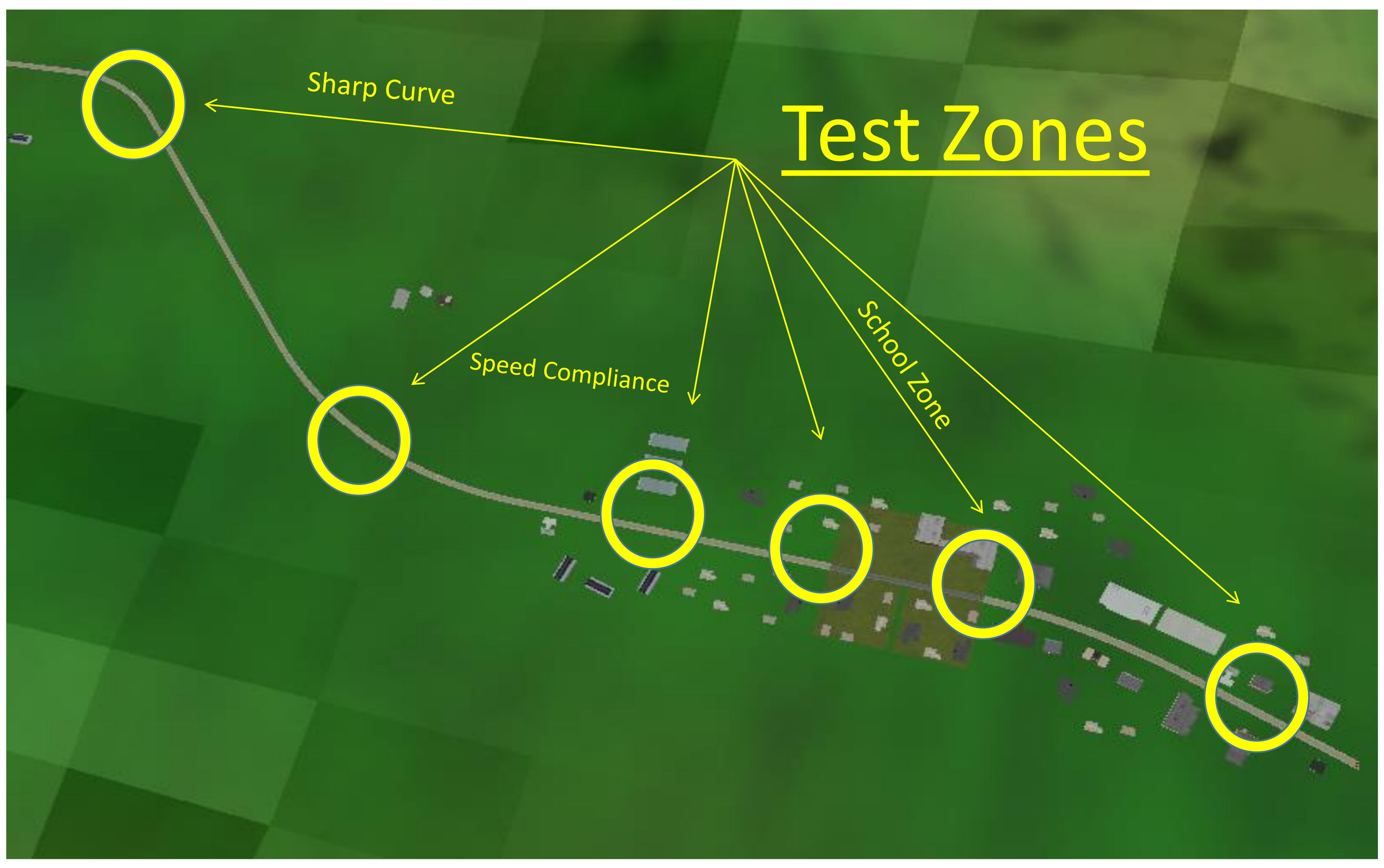
Project Summary

A driving simulator experiment will be used to test how drivers operate on a sign-less roadway that simulates an environment in which holographic displays in the vehicle provide a perfect overlay of virtual traffic control devices.

The scenario will include speed compliance zones, school zones, and sharp curve navigation that include virtual versions of existing traffic control devices as well as alternate traffic control devices.

Scenario Overview



Experimental and Analysis Methodology

Subjects will be asked to drive on a scenario as they normally do on the road until instructed to stop by a roadway block.

During the simulation subjects will navigate through different "test zones" that include speed compliance zones, school zones, and sharp curves requiring speed changes.

The test environment will include rural and sub-urban driving environments using a continuous two-lane roadway that includes intersections.

Data Analysis

Eye tracking equipment in addition to the simulator data collection tools will be used as analysis data sources.

A comparison will be made between how drivers perform in situations containing holographic traffic control and traditional traffic controls.

Performance measures used for comparison will include steering behavior, speed compliance (breaking and acceleration), and eye movement patterns.

Preliminary Findings

Previous research has shown that holographic displays can be simulated using traditional scenario creation practices.

Using "tweaked" scenario components holographic-style overlays that go beyond traditional static signs can be created such as dynamic and flashing components that alert or inform drivers about conditions.

Pavement overlays have shown the most promise in preliminary scenario testing to support the driving task in a sign-less environment.

Motivation

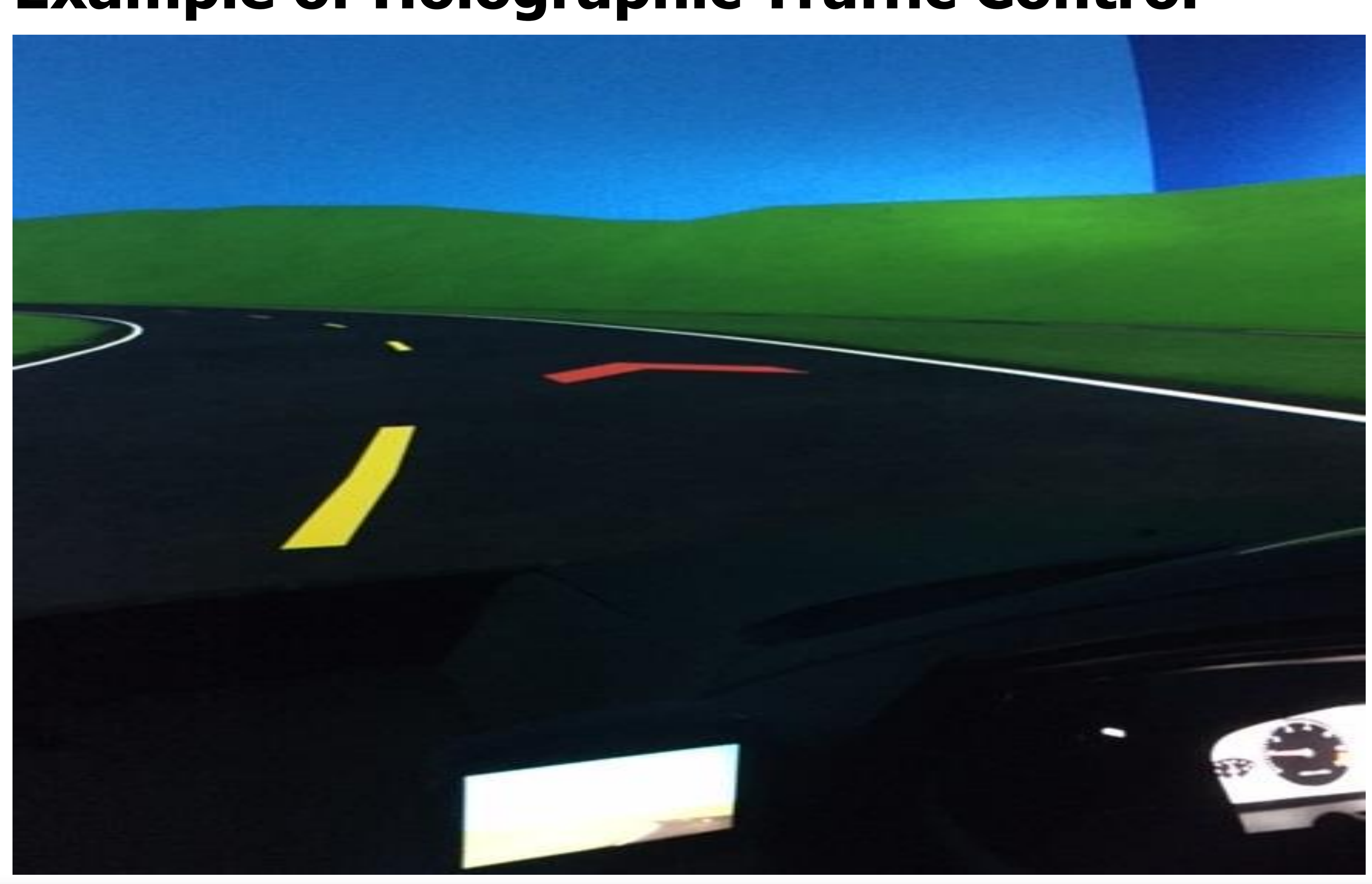
Visual clutter and over-signed roadways are common in the United States. This leads to millions of dollars and the potential for crashes and traffic violations.

The goal will be to examine and understand how a driver would behave if they were presented with a sign-less roadway, using holographic projections of various control and warning signage.

Simulator and Eye Tracking Equipment

Examples of a Baseline Scenario

Example of Holographic Traffic Control



Field and Simulation Evaluation of Elongated Pavement Marking Signs

Madhav V. Chitturi, Ibrahim alsghan, David A. Noyce

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Project Summary

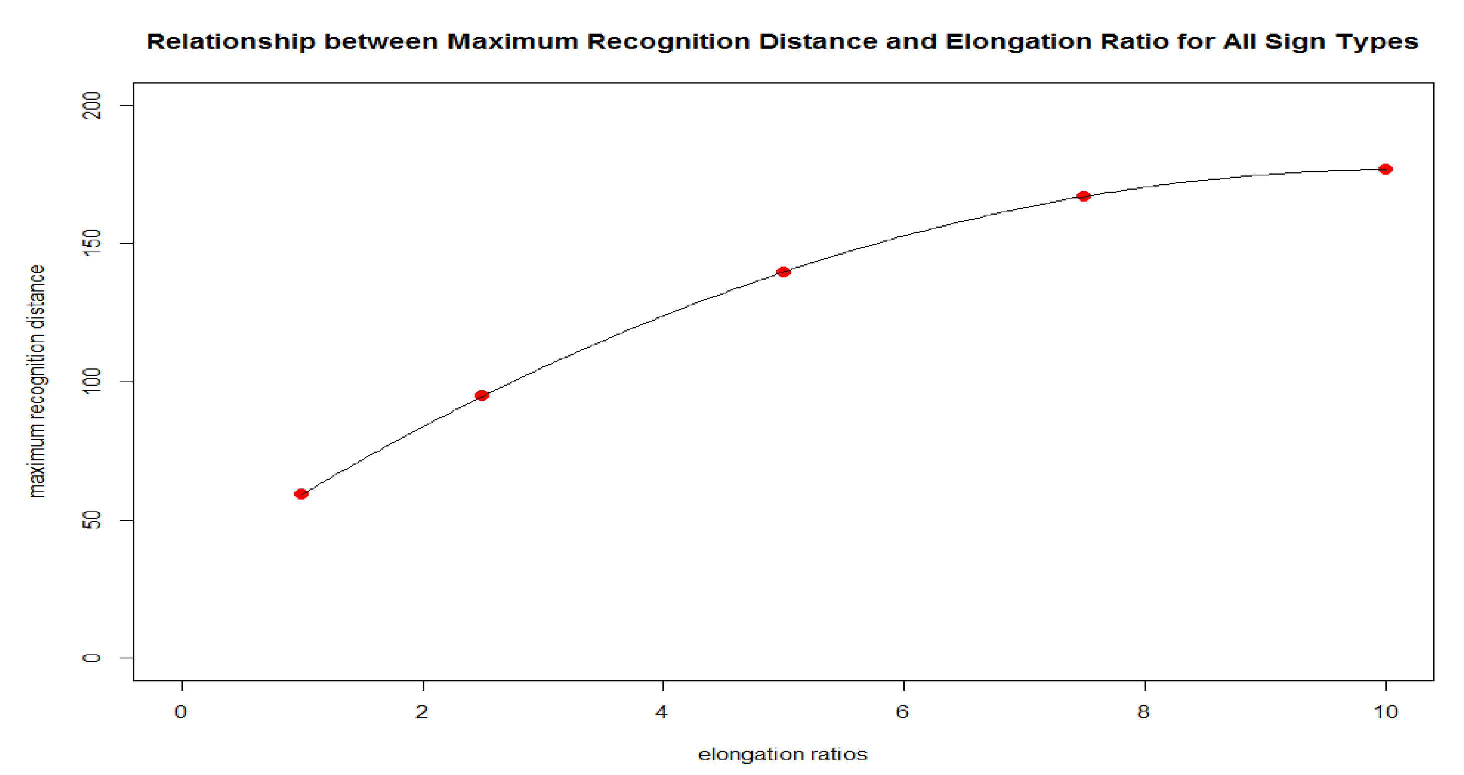
Evaluate the effectiveness of EPMS that are elongated (horizontal) versions of the post-mounted signs they complement. The research has been done in two phases

Phase 1

By using driving simulation, the main object of this phase is to evaluate five elongation ratios: 1:1, 2.5:1, 5:1, 7.5:1 and 10:1 and three signs which are speed limit regulatory (R2-1), curve warning (W1-2) and pedestrian crossing warning (W11-2) sign resulting in 15 sign type and elongation ratios combinations.

Phase 1 Findings

- Maximum recognition distance was calculated for each sign type and elongation ratio at 35 and 55 mph.
- Elongation ratio and sign type were found to be statistically significant.
- The general model is quadratic.
- *Resulting model is:*
  Recognition Distance (feet) = $-1.41 \cdot \text{Ratio}^2 + 28.553 \cdot \text{Ratio} + 32.14$



Phase 2

A field evaluation to measure the effectiveness of EPMS within an actual driving environment and was carried out at 7 locations across KS, MO and WI. Two sign were tested that are speed limit regulatory (in 4 sites) and curve warning (in 3 sites).

Kansas and Wisconsin Speed Sign Sites

Site	Location	Mean speed (mph)				Standard deviation (mph)		Median speed (mph)		85th percentile speed (mph)	
		Before	After	Change	p-value	Before	After	Before	After	Before	After
Andale, KS	Upstream	53.7	52.1	-1.7	<0.0001	6.2	5.7	54	52	60	58
	At	38.7	36.8	-1.9	<0.0001	6.5	5.8	38	36	45	43
	Downstream	35.4	32.8	-2.5	<0.0001	6.6	5.1	36	33	42	37
Bentley, KS	Upstream	52.4	56.4	4.1	<0.0001	5.6	5.8	53	57	58	62
	At	33.8	35.9	2.1	<0.0001	5.1	6.1	34	35	39	42
	Downstream	33.3	33.1	-0.2	0.0364	4.5	4.2	33	33	37	37
Brooklyn, WI	Upstream	46.6	48.9	2.2	<0.0001	7.4	8	47	50	54	56
	At	36.2	31.5	-4.7	<0.0001	6.5	5.7	36	31	43	38
	Downstream	26.1	27.6	1.5	<0.0001	3.6	3.7	26	27	30	31

Kansas and Wisconsin Curve Sign Sites

Site	Location	Mean speed (mph)				Standard deviation (mph)		Median speed (mph)		85th percentile speed (mph)	
		Before	After	Change	p-value	Before	After	Before	After	Before	After
Lecompton-1, KS	Upstream	57	55.3	-1.7	<0.0001	6	5.9	57	56	63	61
	At	62.2	58	-4.1	<0.0001	6	5	62	58	68	63
	Downstream	60.2	57.2	-2.9	<0.0001	7.9	7.2	61	58	66	62
Lecompton-2, KS	Upstream	50.3	51.6	1.3	<0.0001	8.6	8.6	52	53	57	59
	At	57	55	-2	<0.0001	6.3	6	57	55	63	60
	Downstream	51.4	51.1	-0.3	0.0302	5.5	5.7	51	51	57	57
Jefferson, WI	Upstream	56.2	48.5	-7.7	<0.0001	7	5.3	56	49	63	54
	At	54.6	55.2	0.7	1	5.8	6.5	55	56	60	62
	Downstream	48.2	48.7	0.4	1	5.3	5.5	48	49	53	54

Phase 2

Field evaluations show that the evaluated regulatory and warning EPMS reduced speeds of vehicles, demonstrating that they can be effective in reinforcing a warning or a regulatory message to drivers.