ZouSim Transportation Simulators: Virtual Testing of Designs & Construction

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Carlos Sun, Henry Brown, Praveen Edara

Zhu Qing, Sandy Zhang, Michael Schoelz, Jacob Kaltenbronn, Joe Reneker

University of Missouri

Outline

- Introduction
- ZouSim Multimodal Simulators
- Examples of Multimodal Simulator Applications
- Networking Simulators via Federation
- Conclusion
- Collaboration & Service

Introduction

Who needs a simulator?

If cars need a simulator, why not people?

Why Use Simulators

- Minimal risk compared to field testing in live traffic
- Cost-efficient - build in the virtual world vs. paving or pouring concrete
- Flexible – everything is adjustable, e.g., geometric design, traffic, signal timing, weather, lighting
- Controllable, repeatable – each human subject experiences identical conditions
- Use post-simulator surveys to obtain additional feedback
- Investigate future technologies, e.g. autonomous vehicles

Science Behind Simulator Validity

- When similar patterns of behavior are observed
  - in both a simulator and in the field
  - and with similar differences among individuals
  - (Underwood et al. 2011)

Human Subject Studies

- Institutional Review Board (IRB) (21 CFR §56)
- Review of research protocol
- Assessment of risks to subjects
- Mitigation of risks
- Informed consent
- Protection of privacy of subjects
- Data management/protection plan

ZouSim Multi-Modal Simulators

Trucking, Driving, Walking, Wheeling, Bicycling

Multimodal Simulator Development

Trucking Simulator

- Based on Volvo semi-tractor cab
- Force feedback driving wheel
- Engine vibration generator
- Up to 6 104” screens for 360 degrees coverage
- Calibrated by CDL- licensed trucker

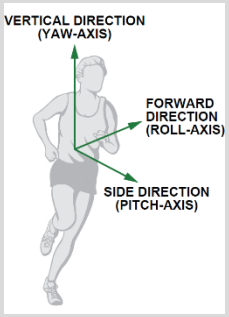
Multimodal Simulator Development

Driving Simulator

- Based on Toyota Corolla sedan body
- Automatic transmission
- Force feedback driving wheel
- Turn signals
- Engine vibration generator
- Up to 6 104” screens for 360 degrees coverage

Multimodal Simulator Development

Walking Simulator



- Based on curved manual treadmill
- MPU-9250 motion tracking microcontroller
- 3-axis gyroscope, accelerometer, and magnetometer
- Step tracking algorithm using gradient detection
- I2C and serial communications

Multimodal Simulator Development

Wheeling Simulator

- Functional Jazzy Pride wheelchair
- Motion control via typical wheelchair controller
- Calibrated by wheelchair user

Multimodal Simulator Development

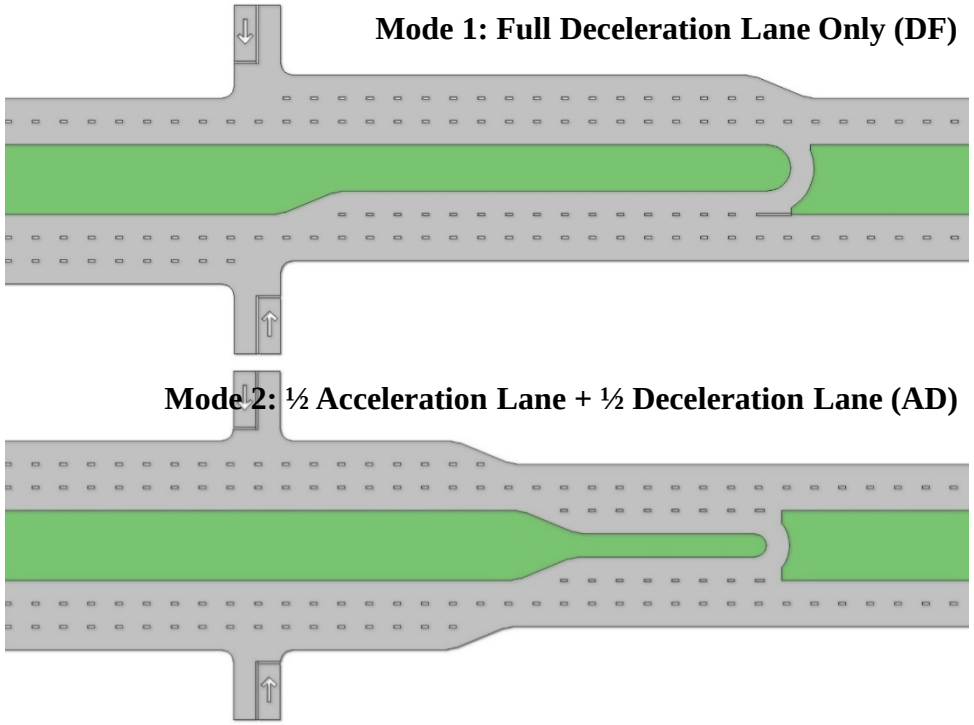
Bicycling Simulator

- Based on TREK 800 bicycle, 7 gears
- Custom speed measurement circuit using dynamo + analog-to-digital converter
- Laser steering tracking
- Brake measurement using analog-to-digital converter

Multimodal Simulator Application

Driving Simulator – J-Turn Design Factors

- Geometric design



- Mode:
  Full Deceleration Lane Only (DF)
  or
  ½ Acceleration Lane + ½ Deceleration Lane (AD)
- U-turn Spacing:
  1000 ft. or 2000 ft.
- Traffic Volume

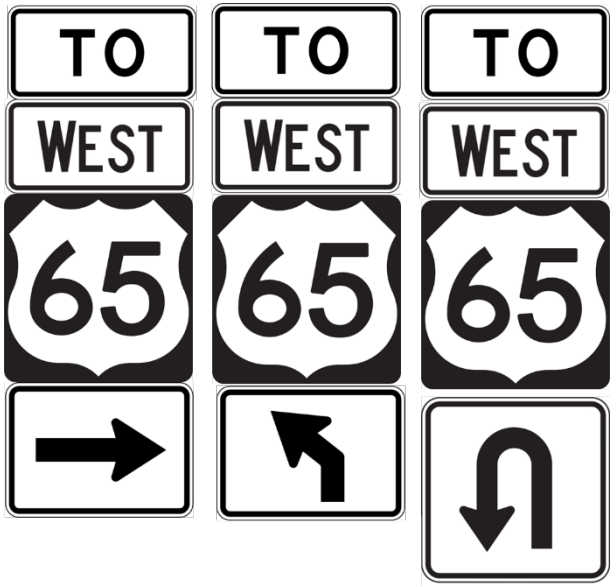
Multimodal Simulator Application

Driving Simulator – J-Turn Design Factors

- J-turn Signs

Diagram Signs (DA)

Directional Signs (DR)



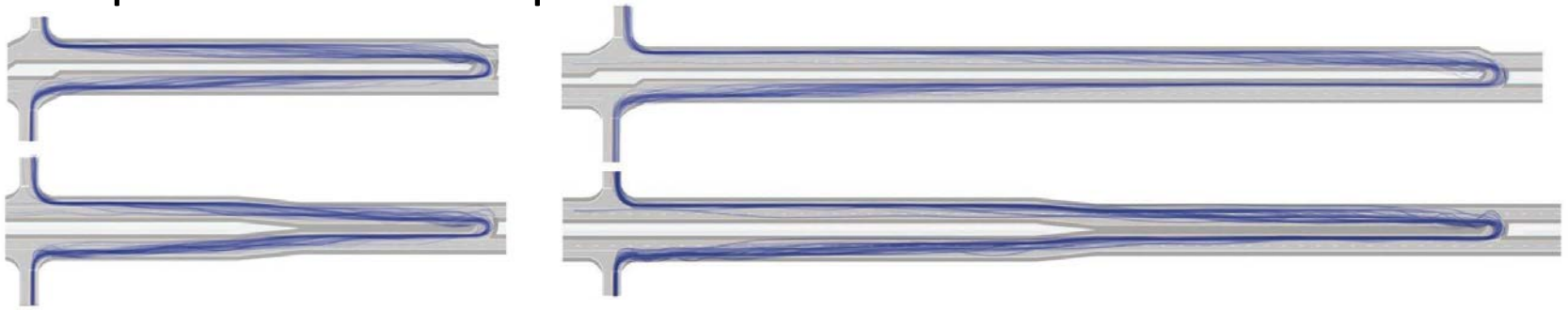
Multimodal Simulator Application

Driving Simulator – J-Turn Design Factors

Multimodal Simulator Application

Driving Simulator – J-Turn Design Factors

Examples of simulator performance measures



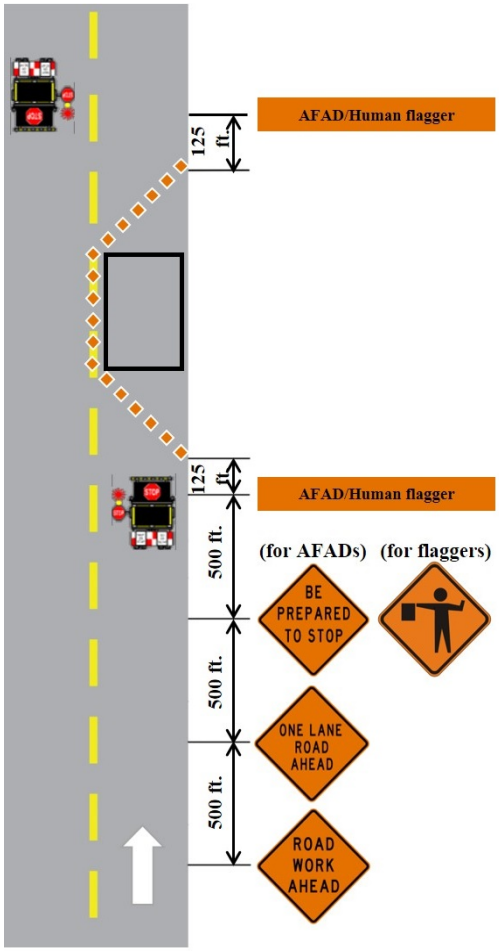
- Time-to-Collision (TTC): “no acceleration lane” had 66.3% more safety-critical TTC values as compared to the acceleration/deceleration configuration (p = 0.02)
- U-turn spacing: 1000 ft length had 31.9% more safety-critical TTC events than 2000 ft length

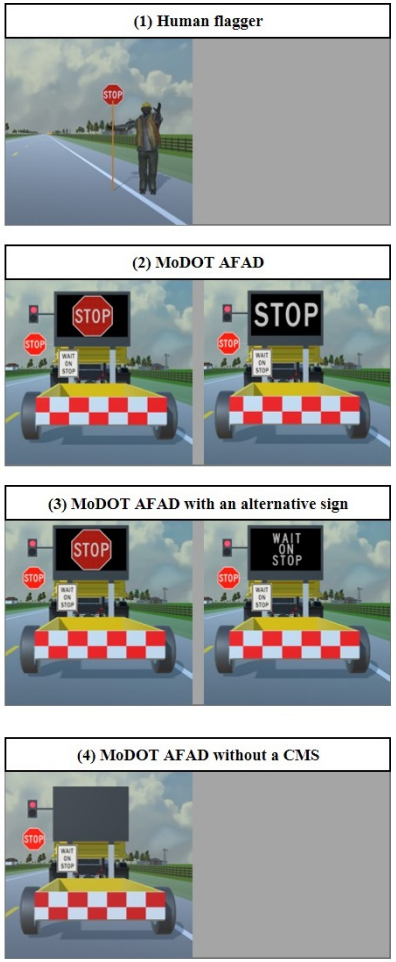
Multimodal Simulator Application

Driving Simulator – Automatic Flagger Assistance Device

Multimodal Simulator Application

Driving Simulator – Automatic Flagger Assistance Devices

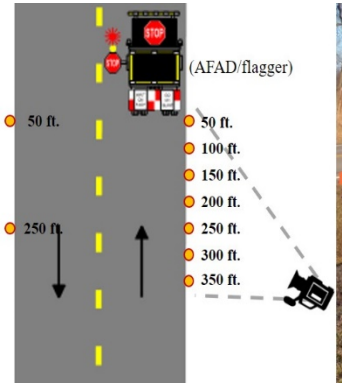


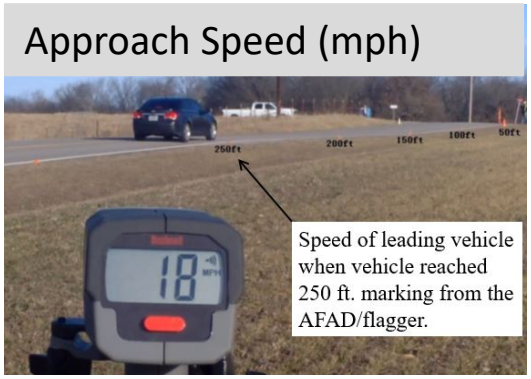


- AFADs lowered vehicles approach speed significantly
- AFADs increased the full stop distance behind AFADs
- AFADs with CMS produced lower intervention rates than the flagger

Multimodal Simulator Application

Driving Simulator – Automatic Flagger Assistance Devices





Conclusions

- AFADs were more effective than human flaggers in terms of stopping distance and speed
- Drivers preferred AFADs over human flaggers

Multimodal Simulator Application

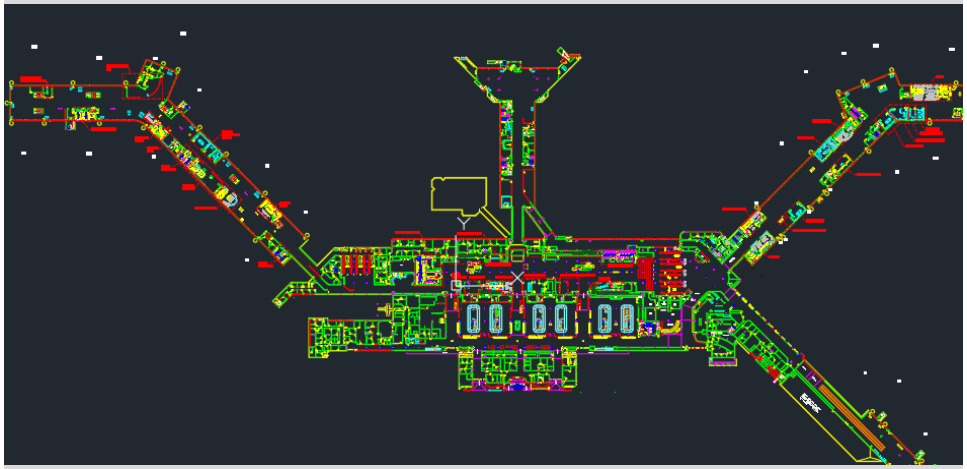
Wheeling Simulator – Airport Wayfinding Accessibility

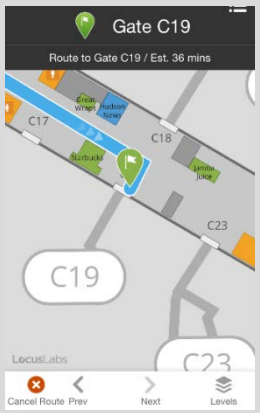
ACRP Research

- Evaluate new assistive technologies
- Better understand / help wheelchair users
- Enhance airport accessibility

Multimodal Simulator Application

Wheeling Simulator – Airport Wayfinding Accessibility





Virtual airport model

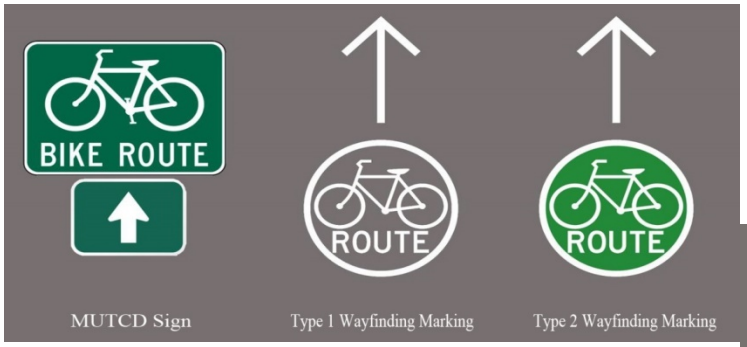
- Virtual airport modeled on STL airport
- Travel paths of similar complexity

Simulator Study

- MU Institution Review Board approved
- human subject trials (30 participants)

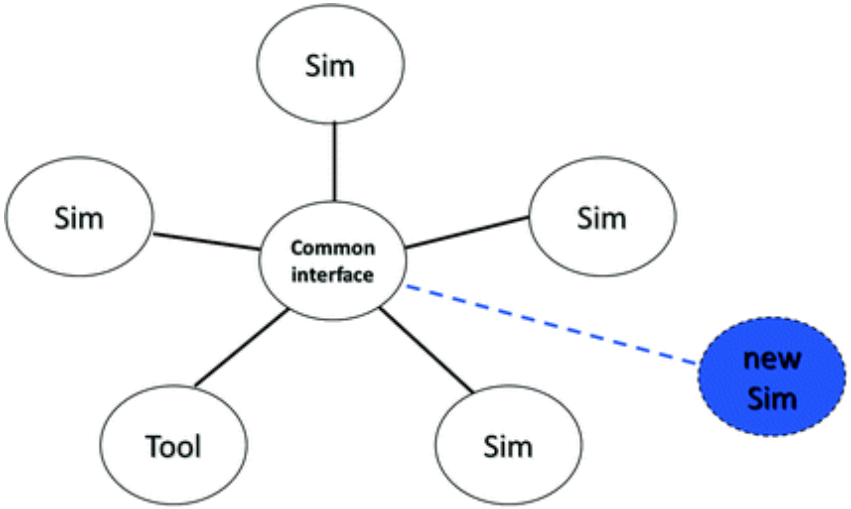
Bicycling Research Examples

- FHWA experimentation
- No current MUTCD standard
- Wayfinding signage/markings
- Detection markings



Federated Simulators

Multiple Modes Interacting Together in Virtual World



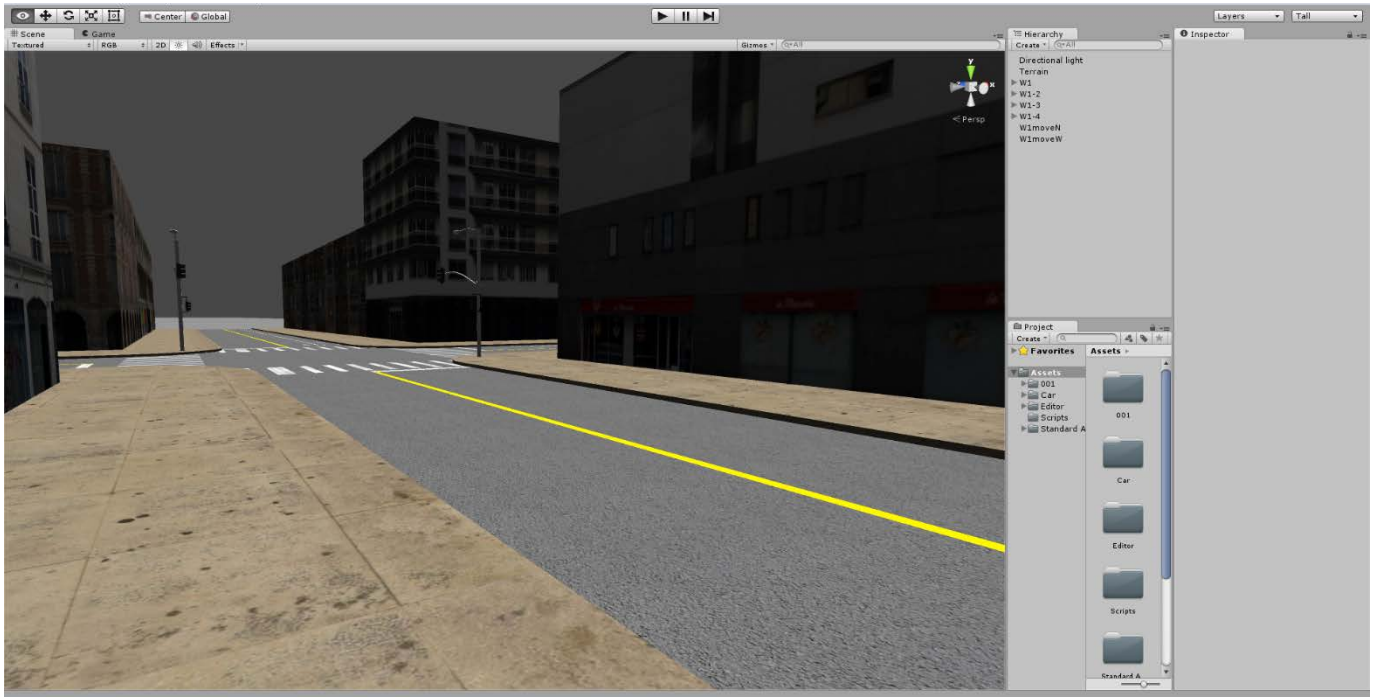
Advantages

- More realistic context
- A broad range of human behavior
- Multiple conflict situations
- Communication and interaction between road users
- Decision-marking process

Federated Simulators Development

Simulation Engine

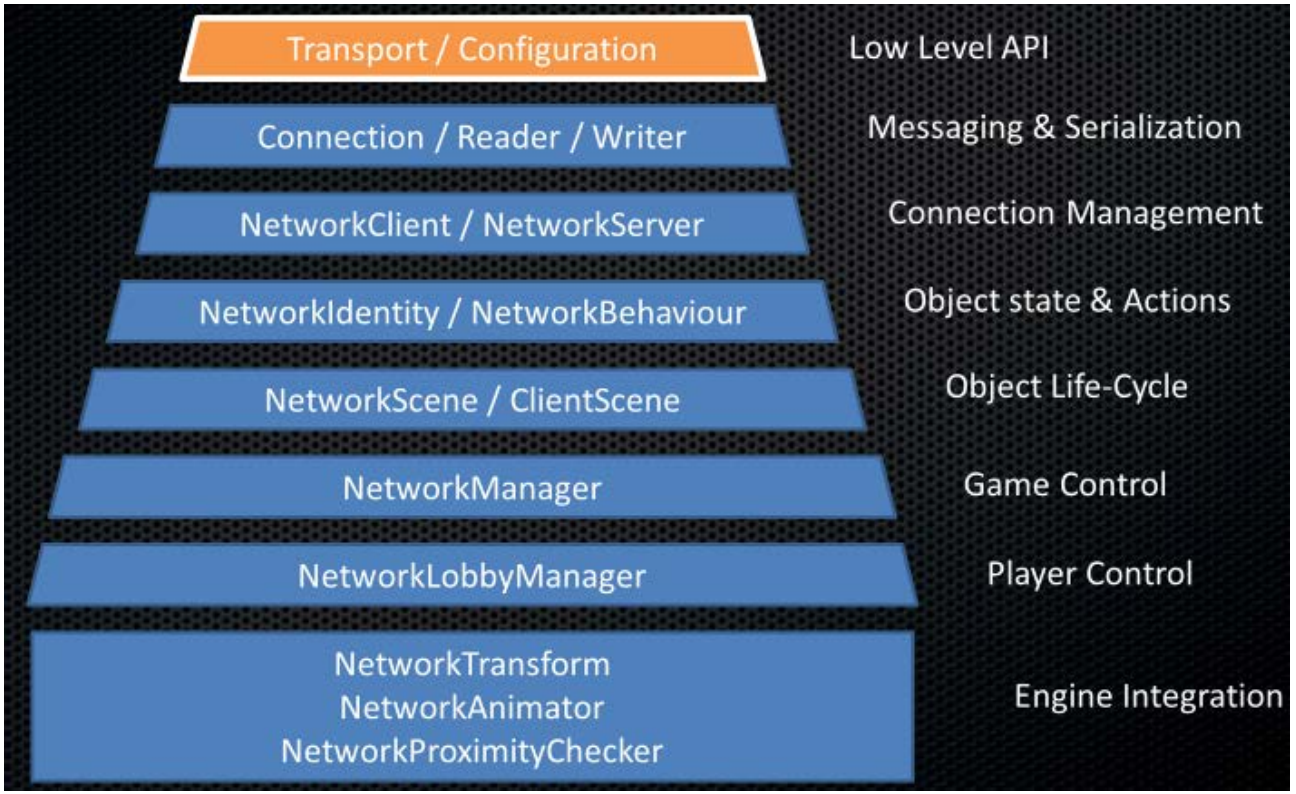
AutoCAD Design + 3D Modeling + Unity Platform (C#)



Federated Simulators Development

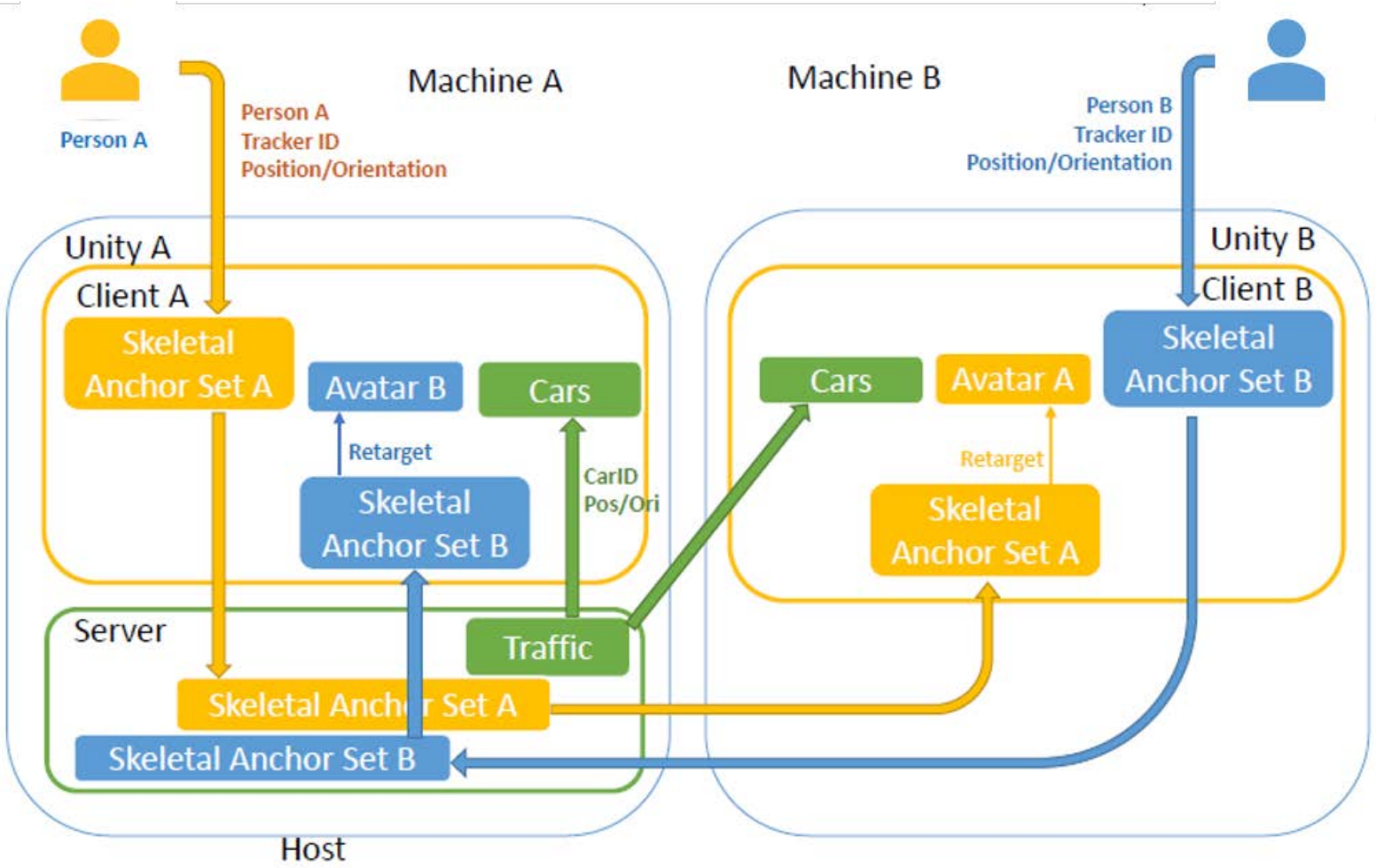
Simulation Engine

Unity multiplayer High Level API



Federated Simulators Development

The integration of different simulators into a real-time interoperable virtual environment



Federated Simulators Application

Autonomous Vehicle-Pedestrian Interaction

Question: how will pedestrian communicate with AVs?

Federated Simulators Application

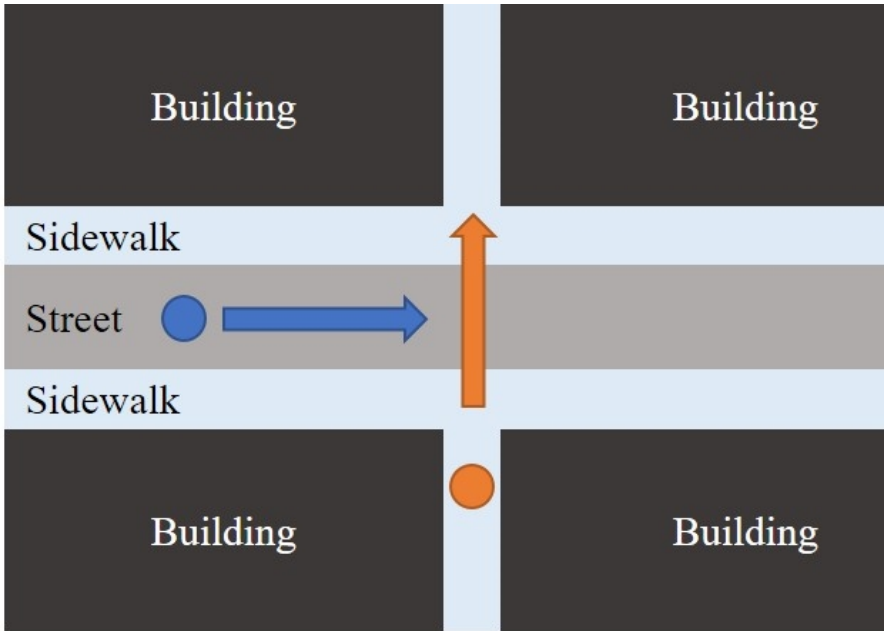
Autonomous Vehicle-Pedestrian Interaction

External Display

Federated Simulators Application

Autonomous Vehicle-Pedestrian Interaction

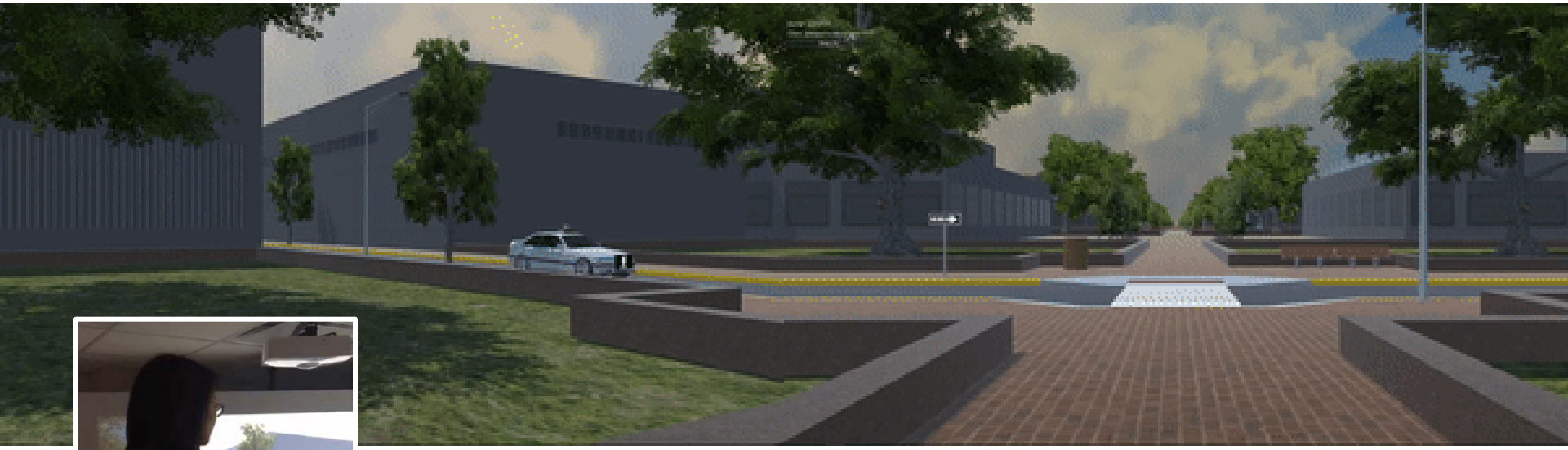
Test Scenarios

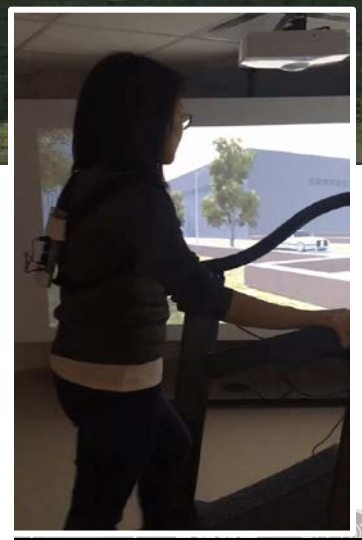


Federated Simulator Application

Autonomous Vehicle-Pedestrian Interaction

Pedestrian simulator view





Federated Simulator Application

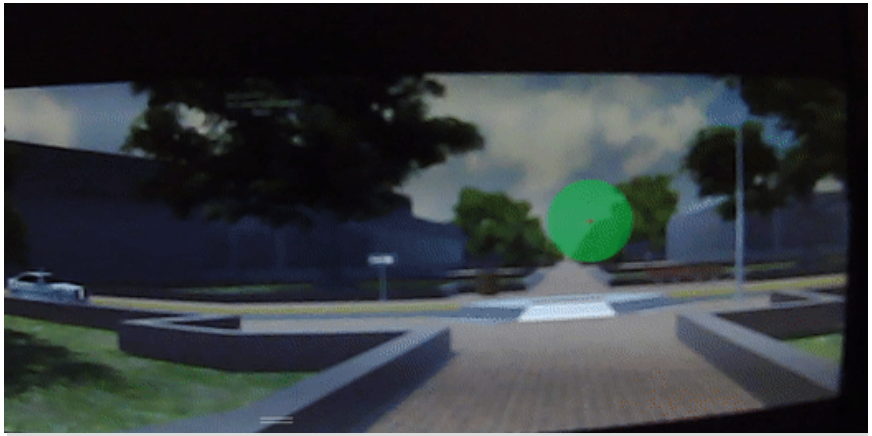
Autonomous Vehicle-Pedestrian Interaction

Car simulator view

Federated Simulator Application

Autonomous Vehicle-Pedestrian Interaction

Results



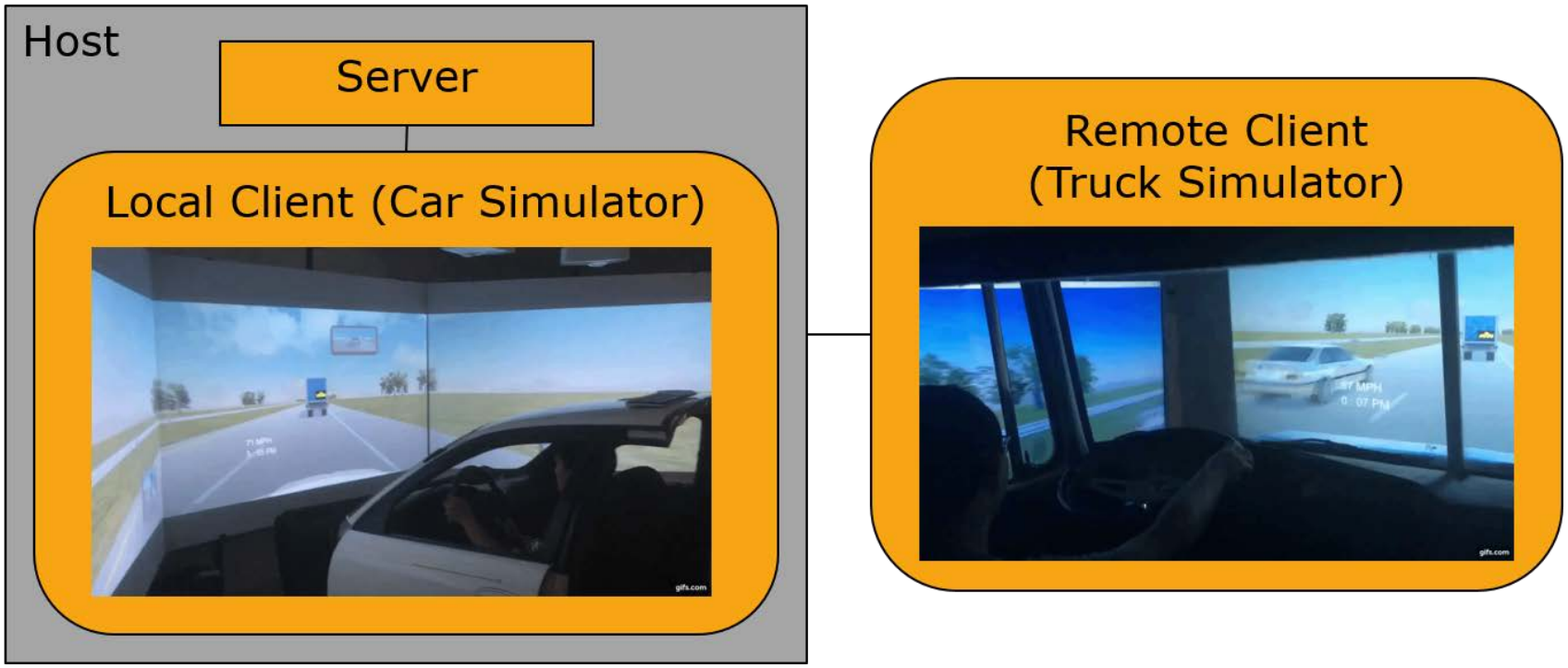
30 participants

- Eye tracking results
- Response time
- Number of critical events

Results

- Text over graphic
- External display over human-driven vehicle
- Prefer placement in front not on windshield

Federated Simulators
Simultaneous Trucking and Driving



Autonomous Truck Platoon Research

Scania Group, 2018

Truck Display Alternatives

How will drivers react to track platooning?

What's the most effective way of communicating truck platooning?

Truck Platoon Communications Results

- No communications performed worst
- Drivers prefer text display to graphics
  - Time to first reaction
  - Gap length at lane change
  - Time to collision
  - Driver survey preference
- Education about truck platooning changed behavior
  - Many drivers not currently familiar with autonomous vehicles or truck platooning

Conclusions

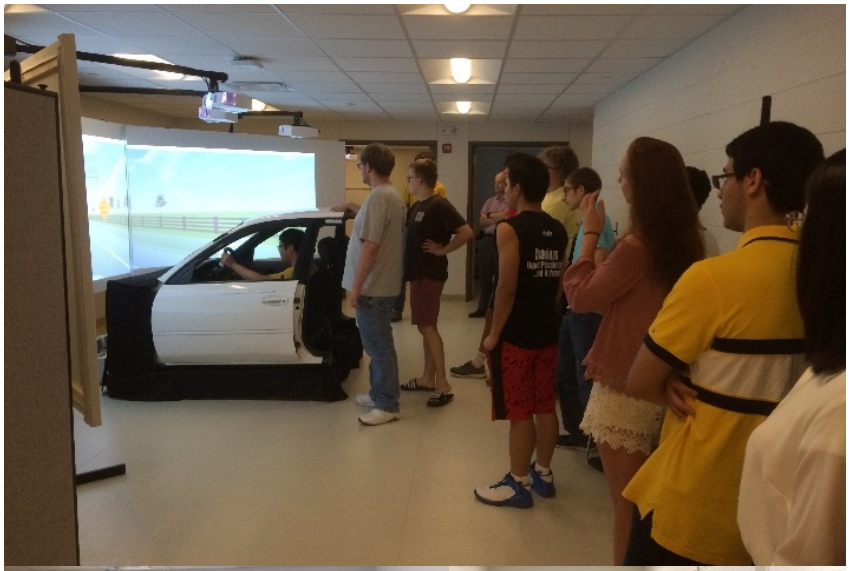
Multimodal simulators useful as a testbed for different applications

- Innovative traffic control devices
- Alternative geometric design
- Signage and pavement markings
- Assistive technology
- Autonomous/connected vehicles

Federated simulators

- Integrating multiple modes
- AR/VR technology
- Cognitive, emotional, and behavior analyses

Beyond Research -> Service



- Public service announcement for texting and driving – Missouri Coalition for Roadway Safety
- STEM outreach – K-12, Boy Scouts, underrepresented minorities

The Future

Could a Bird (e-scooter) simulator be next???

Currently under development