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Advancing Simulation as a Safety Research Tool

Richard Romano

My Early Past (1990-1995)

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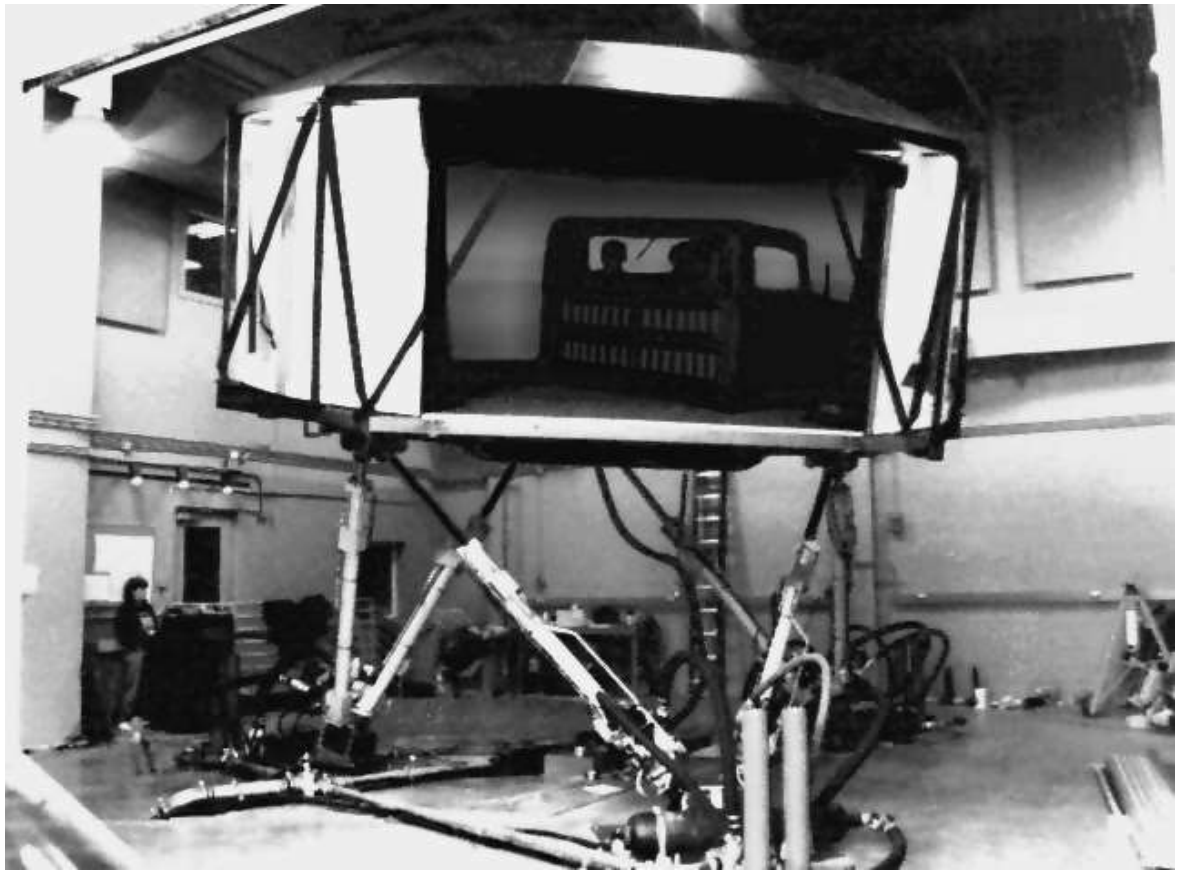
- The Iowa Driving Simulator
- Virtual Prototypes
- Human Factors



What Research We Did
Pretty Much What We Do Now

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Driving Simulation Evaluation of the Effectiveness of Retro-reflective Raised Pavement Markers. (Infrastructure/HF)

Development of Models and Test-Beds for Single Vehicle Roadway Departure Crash Avoidance Systems. (ADAS/HF)

Development of Models and Test-Beds for Rear-End Crash Avoidance Systems. (ADAS/HF)

Assessment of the Safety of Multifocal Intra-Ocular Implants for Driving. (Biomedical/HF)

Human Factors In The Automated Highway System (Automation/HF)

What has changed?

Building Research Simulators

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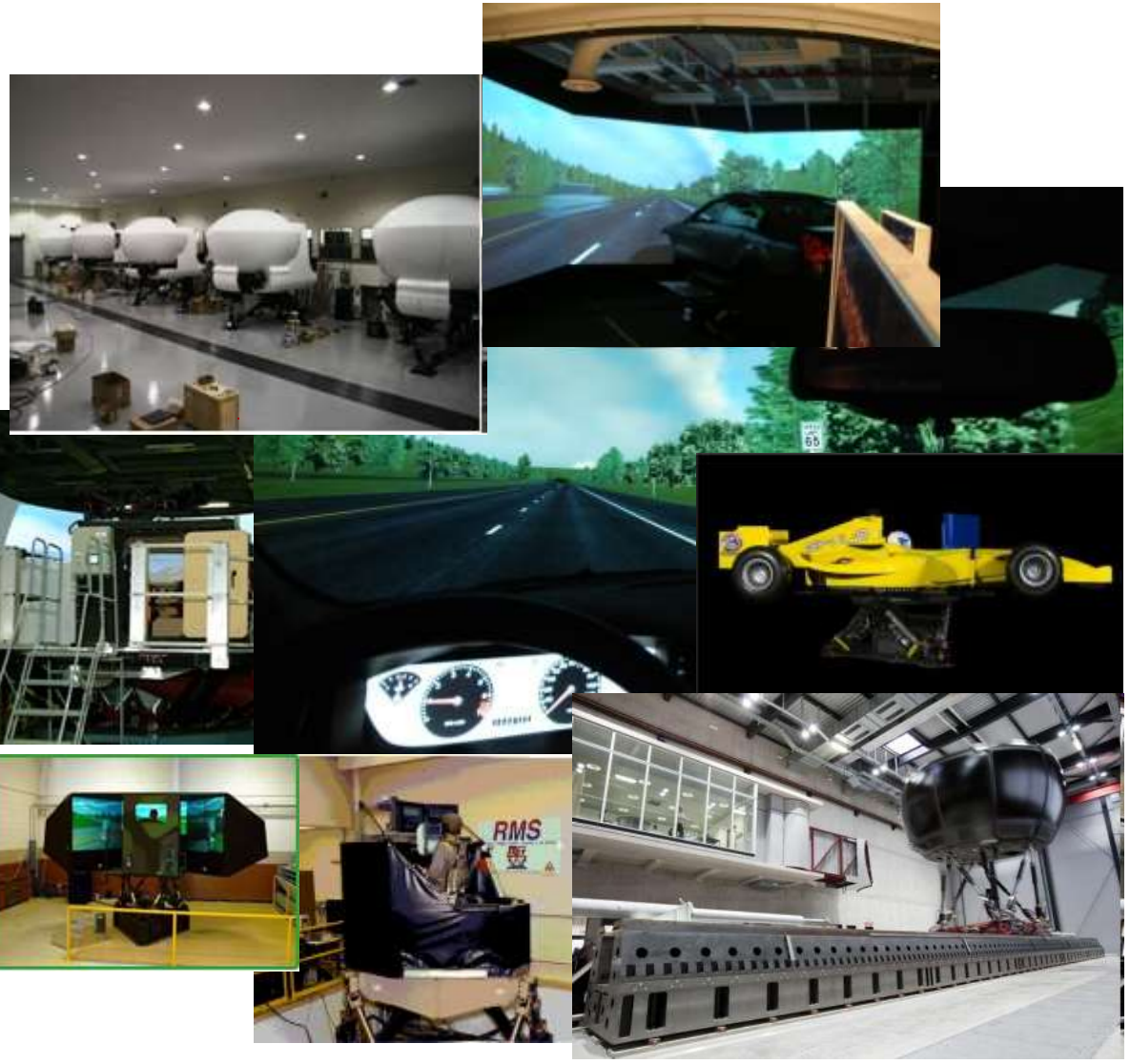
Realtime Technologies, Inc. 1997 and 2015

Realtime technologies, inc



FAAC INCORPORATED real. experience.

My Current Position

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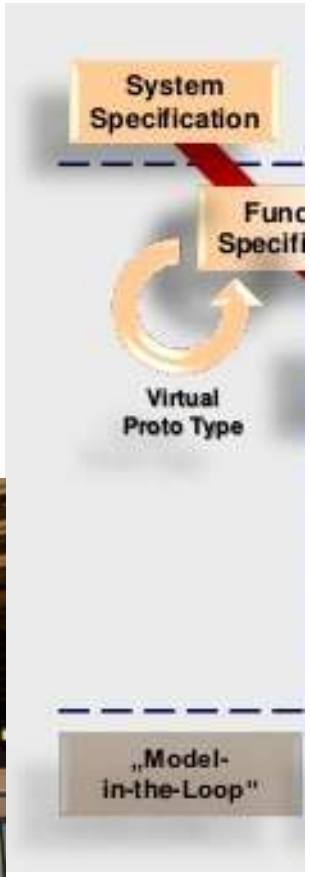
ITS Safety and Technology group is regularly testing the human factors aspects of the Functional Specification and feeding back to the future System Specification.

Must care about human performance.



Can Results from Simulators Be Trusted (vs Naturalistic Studies)

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Hands Free Versus Handheld Cell Phone Usage Versus a Control Group Assessed in Simulators

- Does the experiment really capture the issue?
- Are the demands at the right level?
- Is an externally paced task similar to a self paced task?

Really a Comparison of Laboratory and Field Research

Subtask	Rate Ratio	95% Confidence Interval*
Overall Cell Phone Use	1.32	0.96 – 1.81
Visual-manual Subtask (such as looking at or touching a cell phone, reaching for the phone, dialing, texting, etc.)	2.93**	1.90 – 4.51
Call-related Visual-manual Subtask	3.34**	1.76 – 6.35
Text-related Visual-manual Subtask	2.12**	1.14 – 3.96
Talking/Listening	0.84	0.55 – 1.29
Talking/Listening (Hand-held Phone)	0.84	0.47 – 1.53
Talking/Listening (Portable Hands-free, such as a Bluetooth earpiece)	1.19	0.55 – 2.57
Talking/Listening (Integrated Hands-free, which is built into the vehicle navigation system)	0.61	0.27 – 1.41
Hand-held Cell Phone Use	1.73**	1.20 – 2.49
Portable Hands-free Cell Phone Use	1.06	0.49 – 2.30
Integrated Hands-free Cell Phone Use	0.57	0.25 – 1.31

Efficiencies

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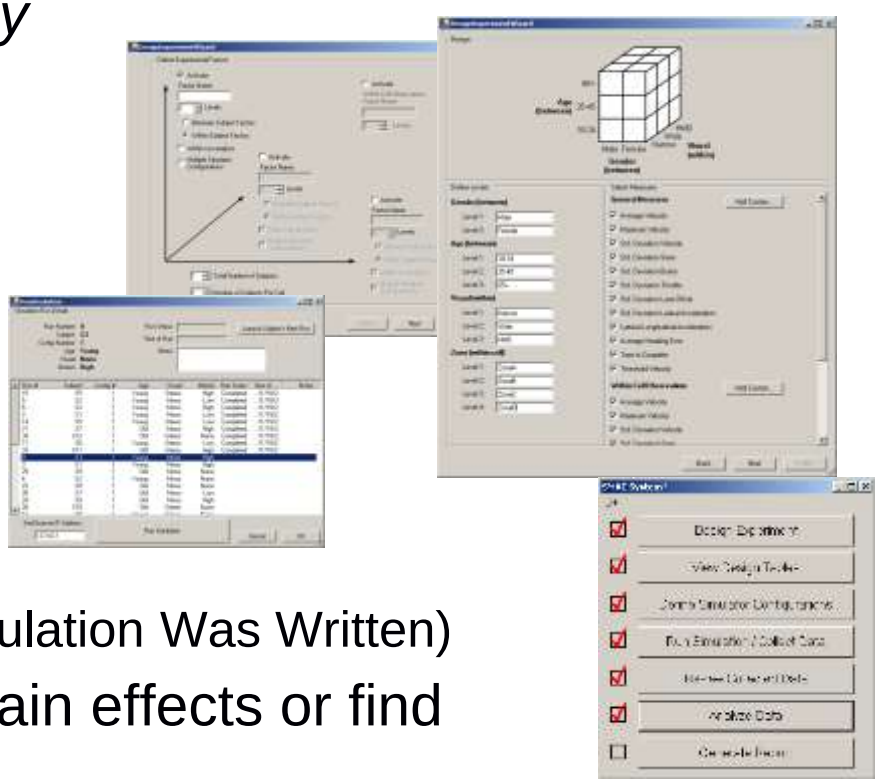
It is always enjoyable to read a paper about a well designed and executed simulator study

The simulator is a testing tool only

Researchers main failures are:

- Wrong simulator for the job
- Poor experimental design
- Too many performance metrics
- Poor statistics
- Small subject pools
- (This is why the Handbook of Driving Simulation Was Written)



We miss out on detecting important main effects or find random ones

We typically tightly control the traffic patterns experience by the driver

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Challenges of Simulator Design

Richard Romano

Eye Relief (Display Distance)

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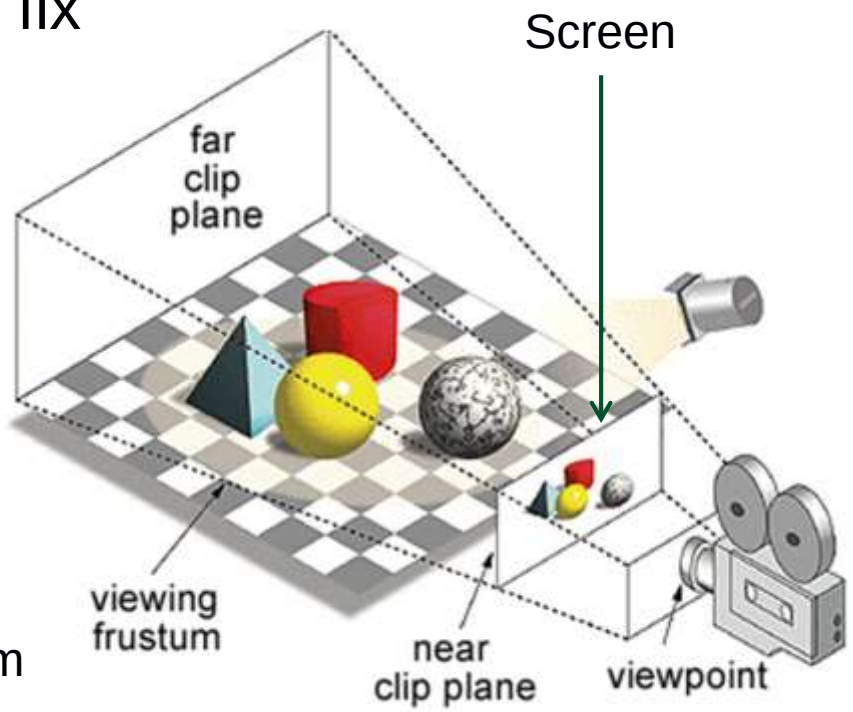
- It is important for visual objects in the simulator to be located “behind/beyond” the screen
- Otherwise they look too big and too far away
- Bring the screen in to fix



Taken from thefreedictionary.com

Eye Relief

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- When screens are too close (inside 4 feet?)
  - Eye strain from accommodation
- Eye strain is worse than computer work
  - The virtual image is further away
  - Fights with accommodation reflexes
- 3D Displays make the interaction more challenging
- Push the screen out to fix

Taken from thefarmersdaughter.com

Vestibular Ocular Reflex (VOR)

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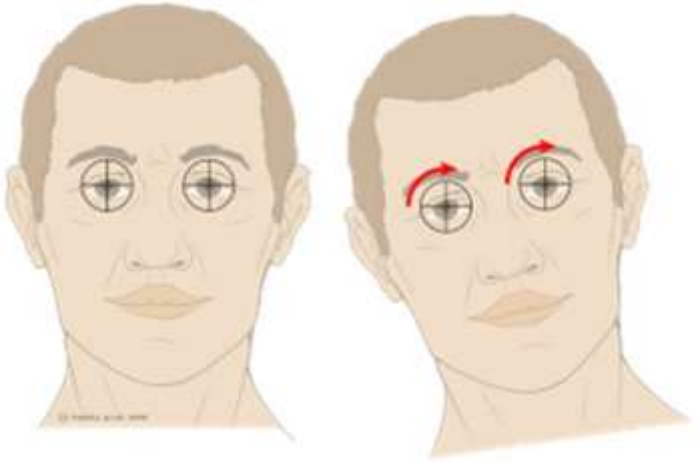
- Vestibular Ocular Reflex (VOR) allows you to track the road
- Without vestibular feedback the driver must rely on the Optokinetic Nystagmus (OKN)
- If motion in simulator is scaled, eyes must use both OKN and VOR
- Motion bases can filter motion so the yaw rate is not constant, which makes it even worse



http://thesymbiont.blogspot.com/2010/08/gyroscopic-eyes-vestibulo-ocularreflex.html

Motion and Sickness (Pitch)

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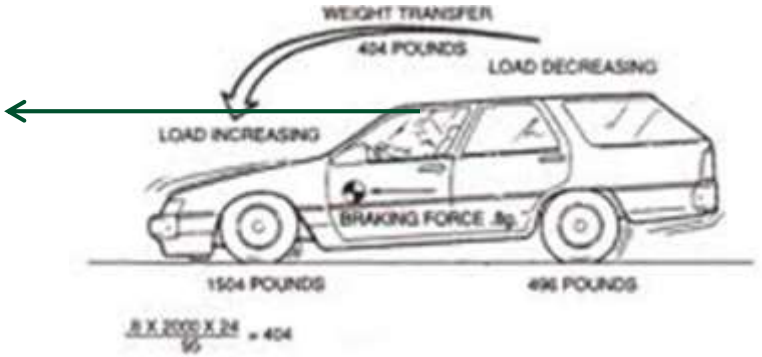
- In real world vestibular ocular reflex makes it so the car pitches around your eyes.



- In a fixed based simulator
  - Horizon just moves up
  - Issues with the car “pitching” too much
- A pitch motion base can support the reflex properly.
- Or turn off pitch motion in the dynamics.

Motion Sickness and Yaw

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- Lack of yaw motion cues makes driving performance worse at intersections
- Causes driver induced oscillations
- People complain about steering wheel and vehicle dynamics
- Therefore simulator users tend to minimize turns at intersections
- The only real fix is an unlimited motion yaw ring

Taken from forcedynamics.com

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The Future of Driving Simulation

Future of Simulation

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What is the future of ground vehicle transportation?

Simulators Need to Move Towards Naturalistic Driving

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Transportation is moving quickly. We need to test future concepts that don't exist. How do we do this in a robust way?

The research is just starting (most of these are very difficult research questions):

- Distributed and massively distributed simulations (humans interacting with humans)
- Real world databases (can't be contrived places, AV developers believe this)
- Advanced traffic models (when we can't get enough humans)
- New experimental designs

Motivation for Distributed Simulators

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Driving simulators are good at A/B comparisons (new design versus baseline).

- How do we compare human drivers interacting with each other with human drivers interacting with automated vehicles?
- How do we test automated vehicles interacting with pedestrians? (Need to compare this with traditional vehicles interacting with pedestrians)

Driving Simulators at Linkopings Universitet, Sweden

Next Steps: Integrate Pedestrian in the Loop

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https://ts.catapult.org.uk/innovation-centre/the-visualisation-laboratory/projects/laboratory-improvements/ Omnideck6

Real World Databases Otherwise We Could Miss Important Design Factors

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Correlated GPS Information

Realtime technologies, inc

Working towards 10 cm accuracy
Used in the real car

Human Factors Autonomous Traffic Controller

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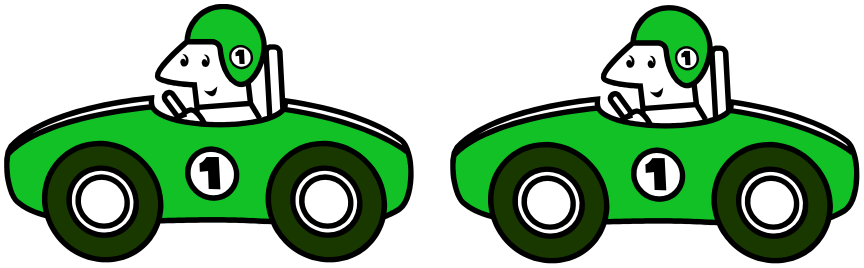
What can we learn?

Original IDS State Machine (1993)

Link list of vehicles on the road. Only compared to the vehicle in front of it O(n).

Similar to current Micro Simulation



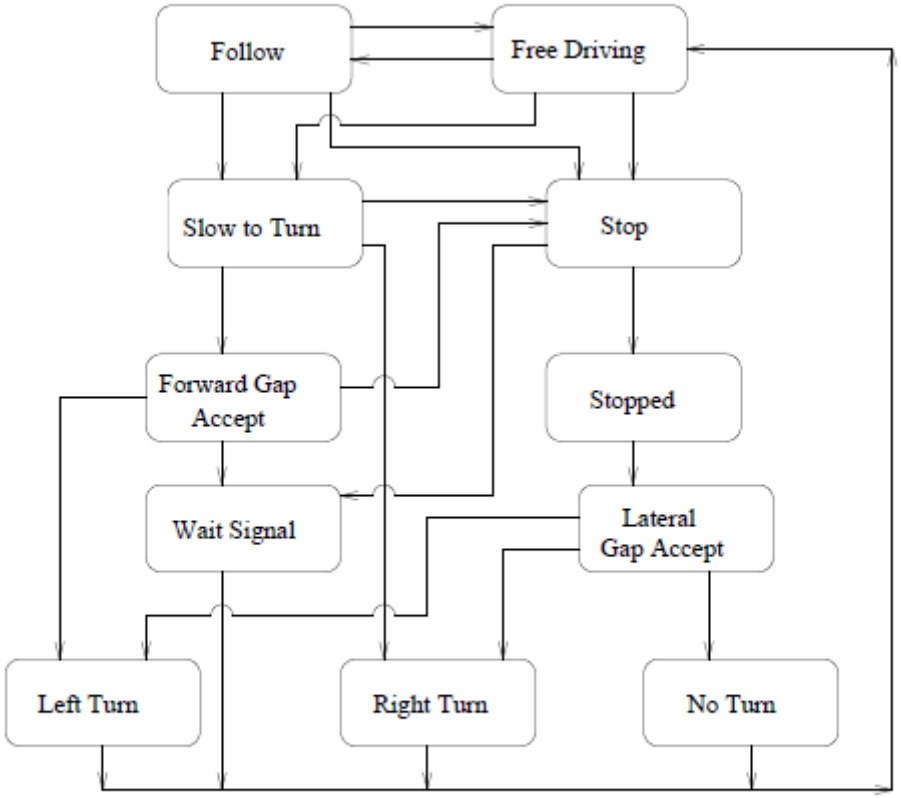


Figure 3: Simplified version of the original vehicle behavior state machine

Scenario Authoring for Virtual Environments J. Cremer and J. Kearney

Thought Experiment

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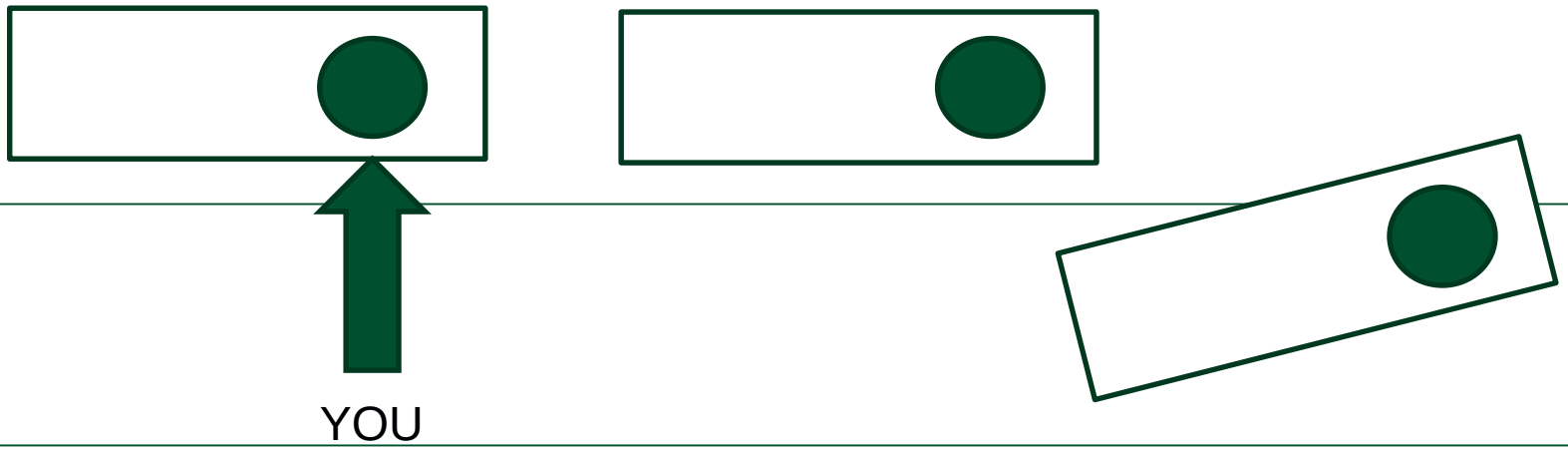
Truck cuts in front of the car in front of you

Do you slow down immediately?



What about the microsimulation that only models car following for the vehicle ahead?
How powerful are experiments if we make the traffic simulation more complex?

Conclusions

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Need Geospecific Databases

- This is important for training also!

Need Inexpensive Motion Bases that Can Address Simulator Sickness (Direct vestibular stimulation for pitch and yaw?)

Can New Displays with Variable Focal Distance Help? Can this be with an inexpensive HMD?

Need More Powerful Interactive Traffic Models

Need Distributed Simulation

Need Multi-Modal Simulation

New Methods for Experimental Design (Bridge between Laboratory and Field Research, will need more subjects)

Rapid Correlated Database Development (Millions of Miles)

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Map Export
- OpenStreetMap

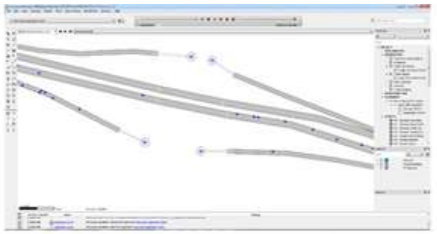
Traffic Simulation Development
- Aimsun

Physical Scene Manipulation
- Trian3D

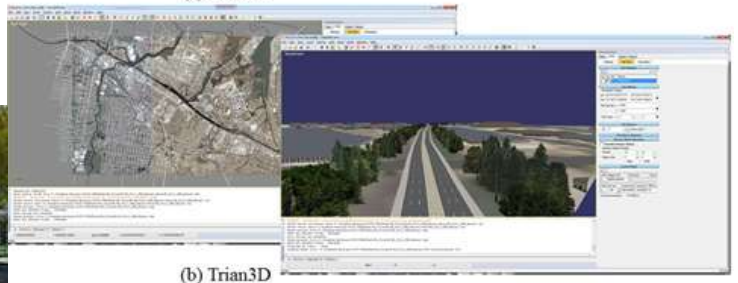
Integrated Simulation

Leverage what s already being developed for AVs

- Civil Maps
- cognata
- Etc.



(a) Aimsun



(b) Trian3D

Motion Base Replacement
Direct Vestibular Stimulation

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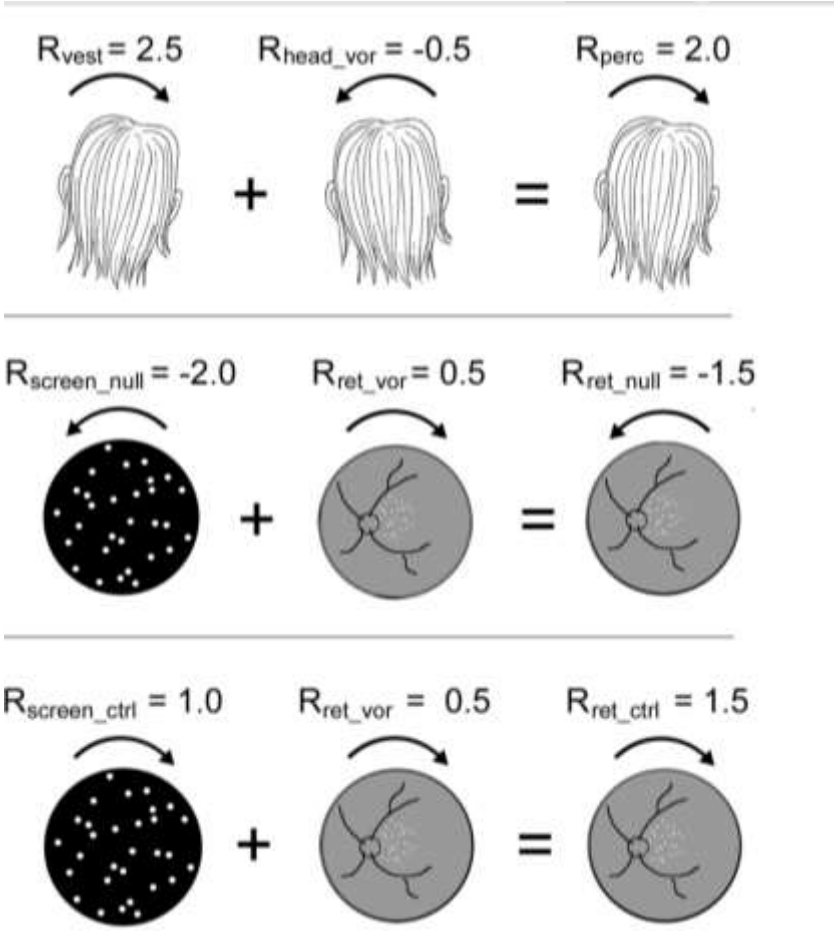
"Using psychophysics, we were able to create, and present to a static person lying in an MRIscanner, visual–vestibular cue combinations that were consistent with natural head rotation in the roll axis (congruent visual–vestibular cues)."



Billington, J., & Smith, A. T. (2015). Neural Mechanisms for Discounting Head-Roll-Induced Retinal Motion. Journal of Neuroscience, 35(12), 4851–4856. https://doi.org/10.1523/JNEUROSCI.3640-14.2015

Displays for HMDs

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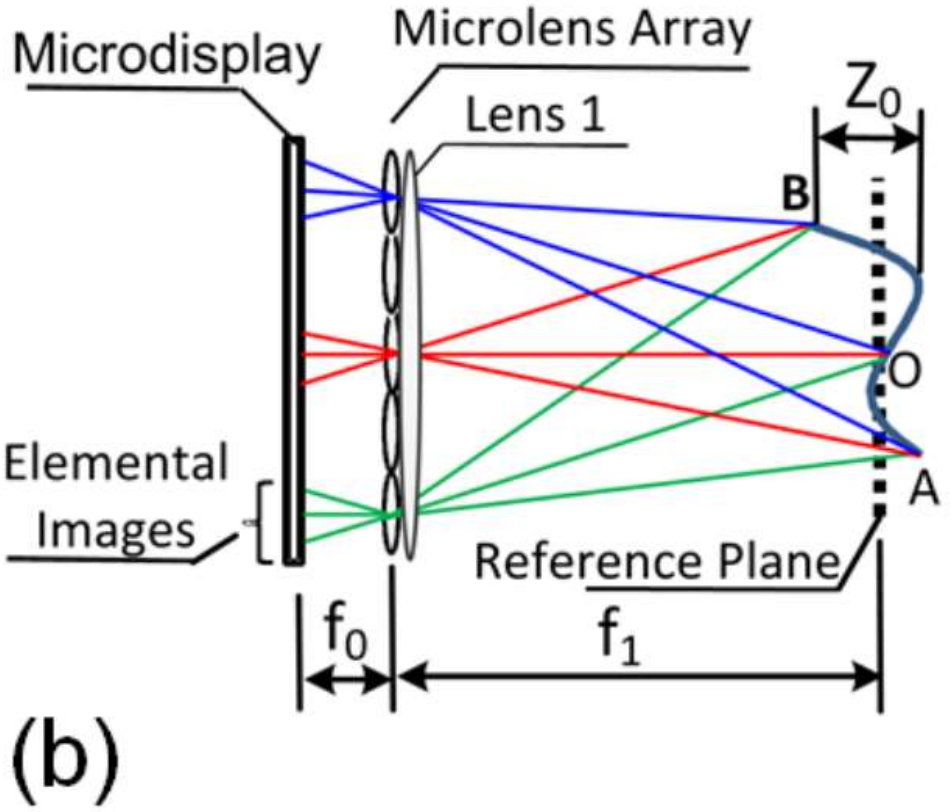
Programmable microlens allows multiple focal distances



H. Hua and B. Javidi: “A 3D integral imaging optical see-through headmounted display”

Traffic Simulation

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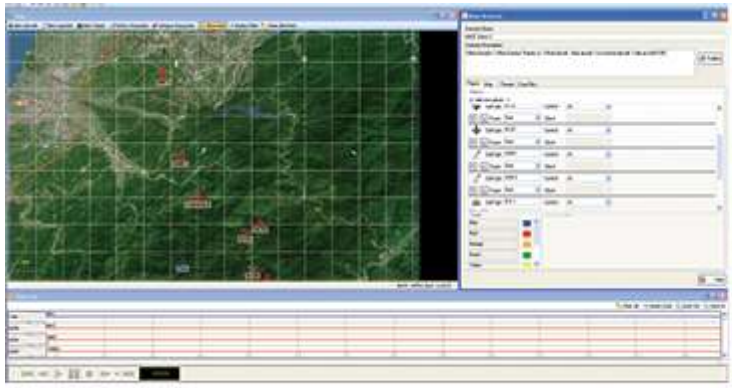
Let's assume in mixed traffic (autonomous and traditional vehicles) that autonomous vehicles should drive like safe humans.

Why shouldn't the same controller be usable in Traffic Microsimulation and in the Real Vehicle?

Wouldn't this lead to better models and controllers all around?



Scenario Building

Hypercopter View

Pilot View

FAAC INCORPORATED real. experience.

Scenario Design

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Formalizing the scenario process

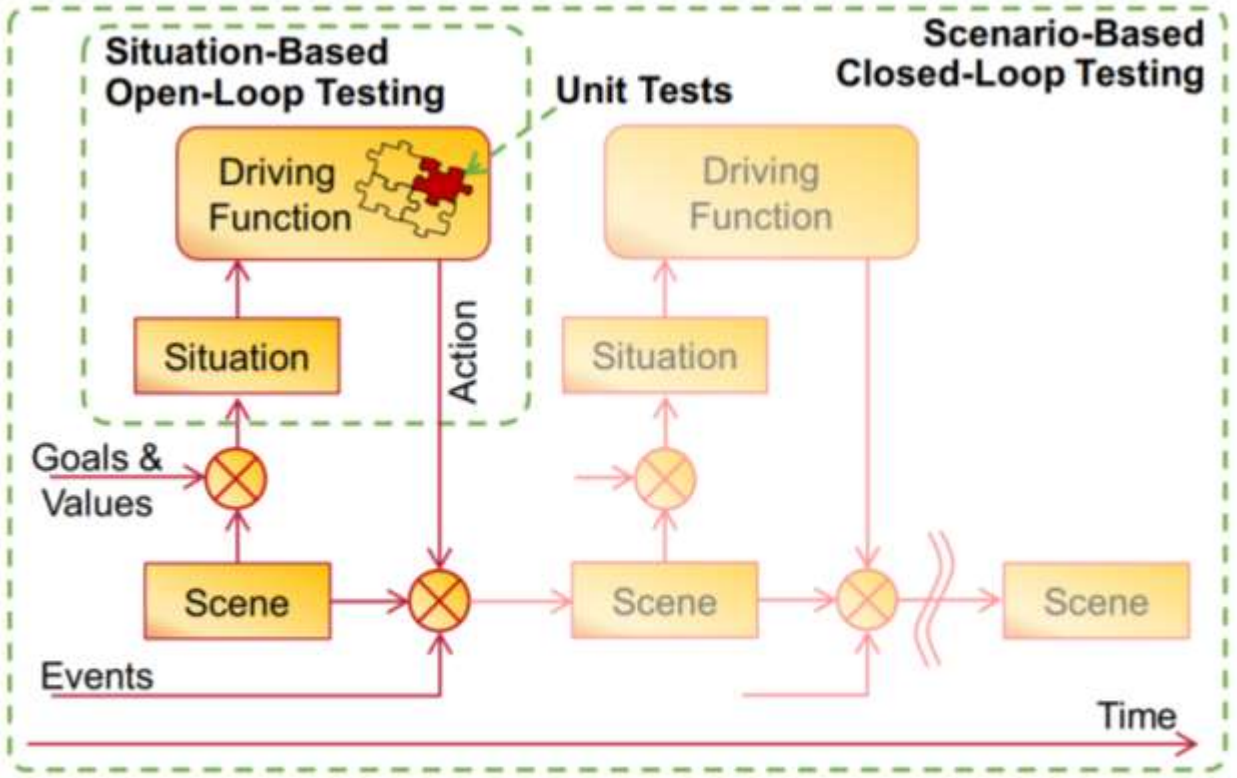

Fig. 10. Illustration of the differences between Unit Tests, Situation-Based Open-Loop Testing and Scenario-Based Close-Loop Testing

"Defining and Substantiating the Terms Scene, Situation, and Scenario for Automated Driving"
Simon Ulbrich ; Till Menzel ; Andreas Reschka ; Fabian Schuldt ; Markus Maurer

Scenario Design

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What is the probability that we can get to the desired scenario configuration?

Can we adapt the scenario dynamically to get there?

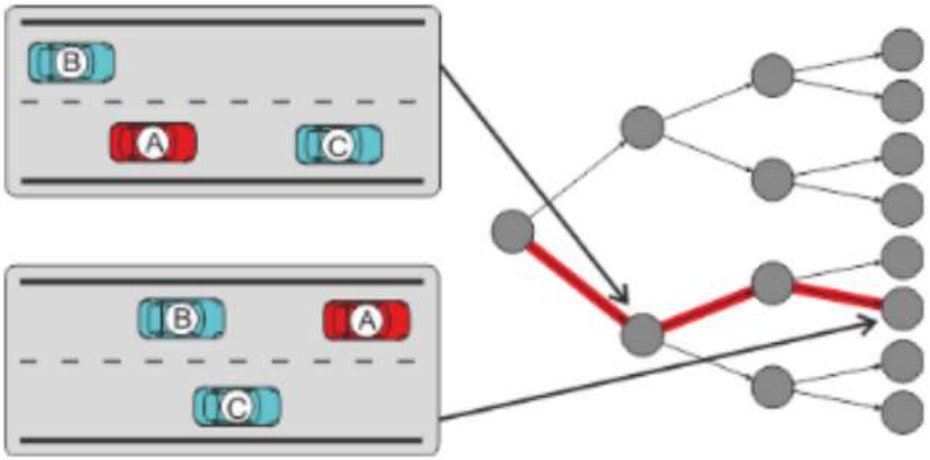

Figure 1. Two example key scenes (on the left) being part of a scenario (red line), which is a sequence of key scenes (nodes) and actions/events (edges). Adapted from [Ulb15].

"A Dynamic and Model-Based Approach for Performing Successful Multi-Driver Studies", Julian Schinler, Frank Koster, 2016

Questions?

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