Simulation-Based Safety Testing
Brake-By-Wire

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TOCSYC
Testing of Critical System Characteristics

SafeCOP

March 13, 2016

Agenda I

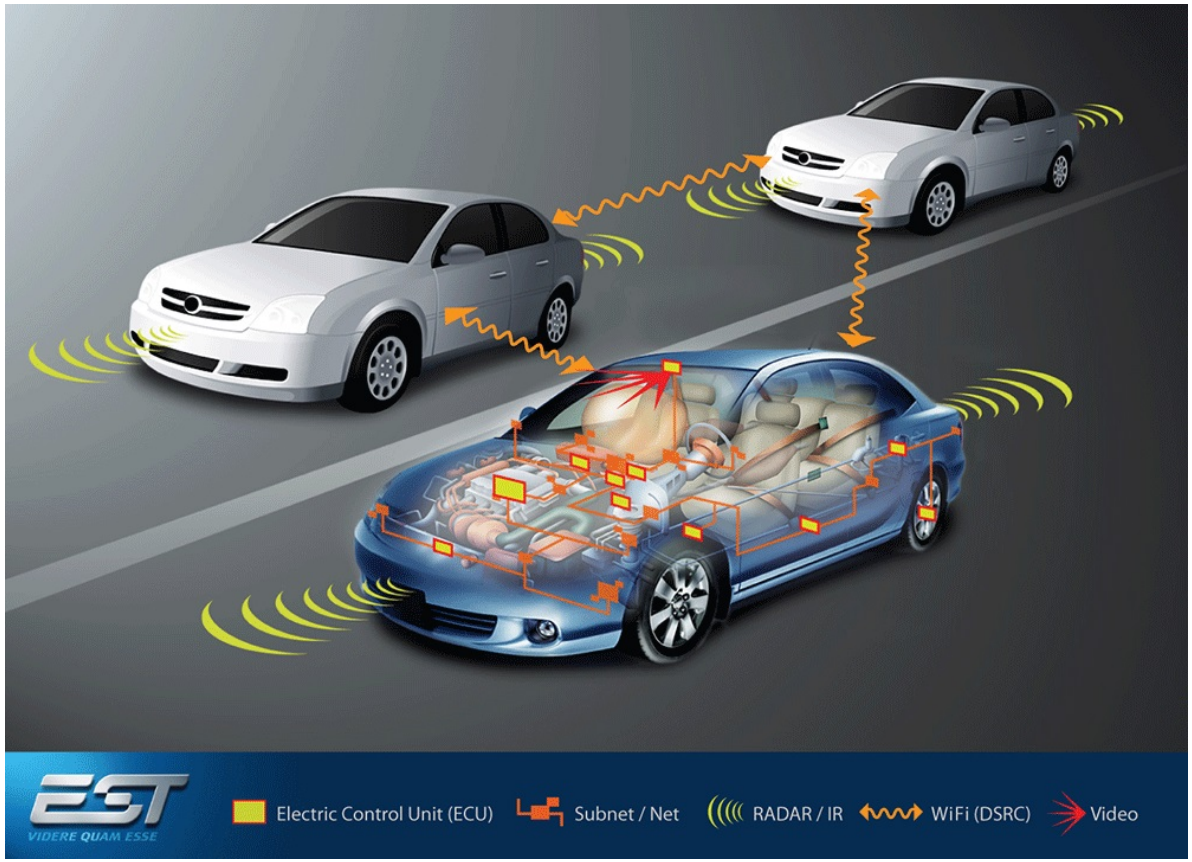


Figure: Communicating Vehicles[1]

[1] source: mathworks.com

- old mechanical systems are replaced
- new electrical system are more efficient
- . . . and connected

We have . . .

- electrical brakes (Volvo BBW)
- connected cars
- orchestrated, synchronized, and collaborative maneuvers

Safety

- safety means: the car brakes *in time* (delay, latency)
- individual for each car
- timebuffer translates to probability for avoiding fatal crash

$\Rightarrow$ **probabilistic safety = time (admissible delay)**

Source of Safety

- the BBW has **delays**
- the cooperative braking (i.e. hazard warning) has **delays**
- both provide safety and feed from the **common source time**

Research Question

How is time optimally divided among both functions?

Methodology

- mathematical
  - Brownian motion too complex too solve,
  - discretization introduces too much error
- real world testing
  - too expensive
- last straw: simulation

Simulation

- BBW
- SUMO
- OmNet++

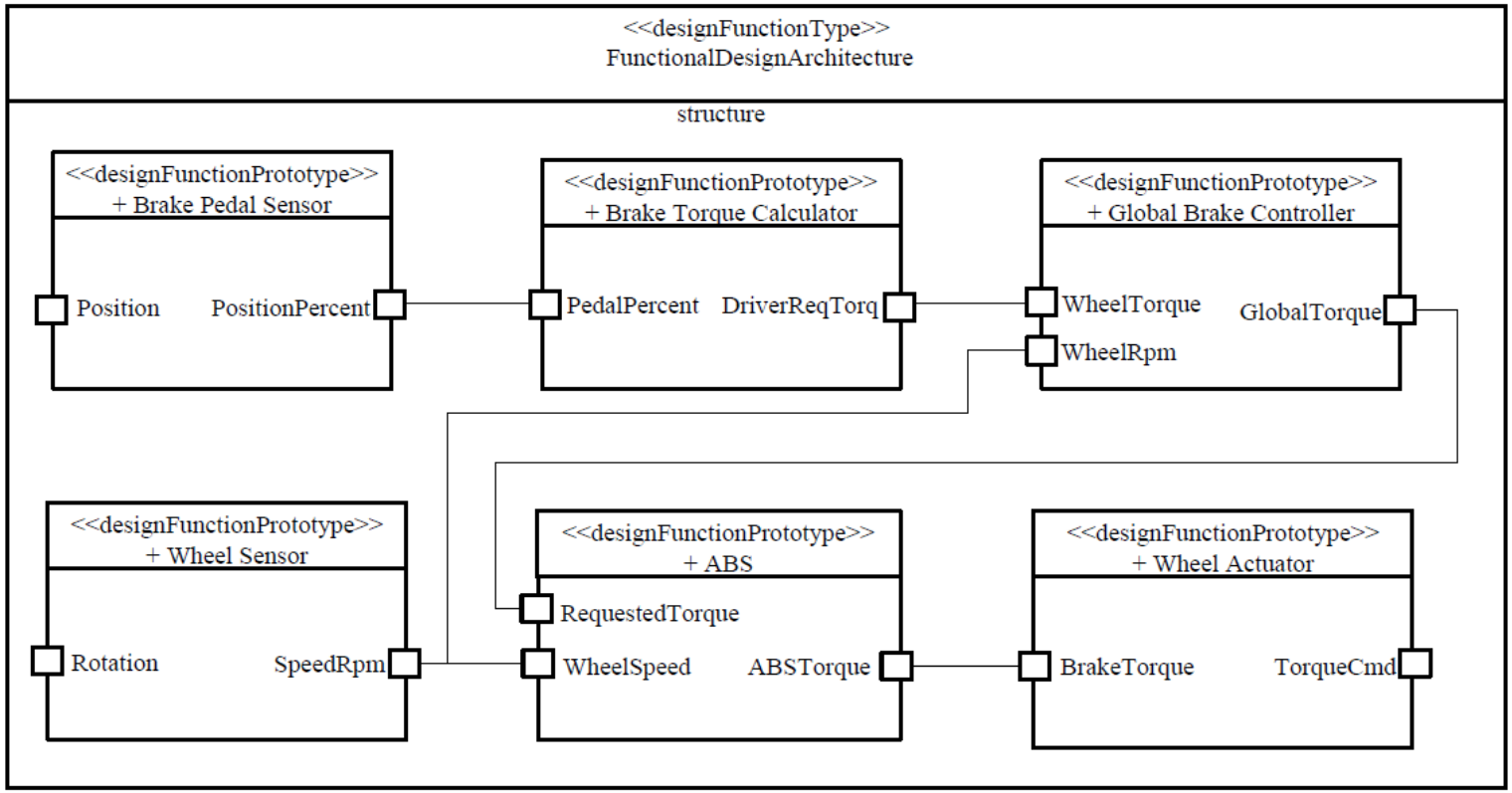


Figure: Volvo BBW

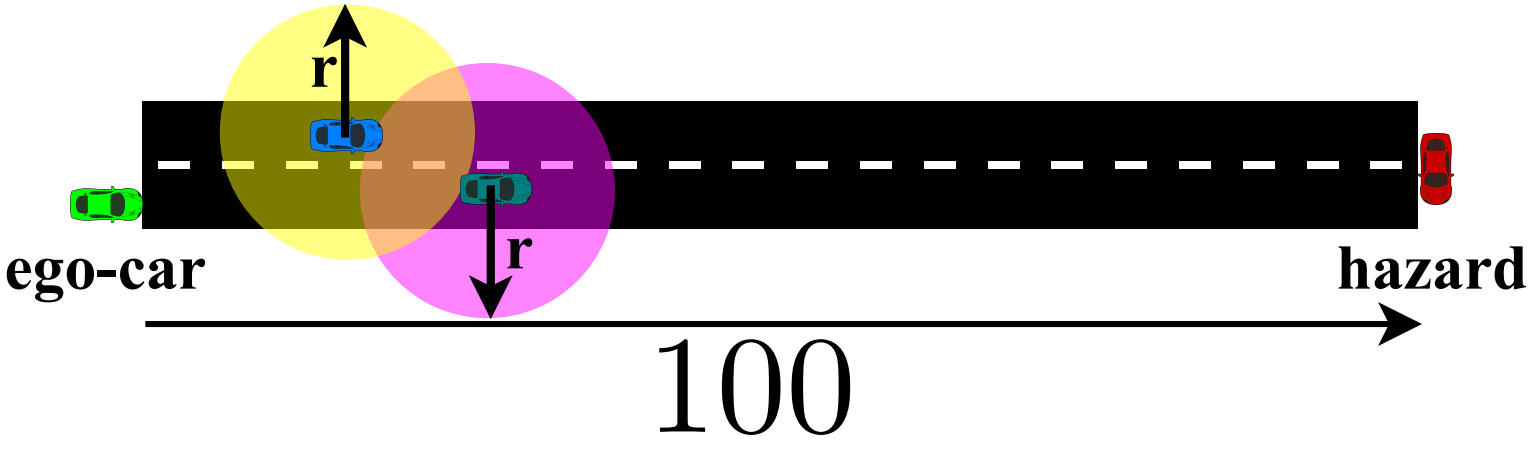
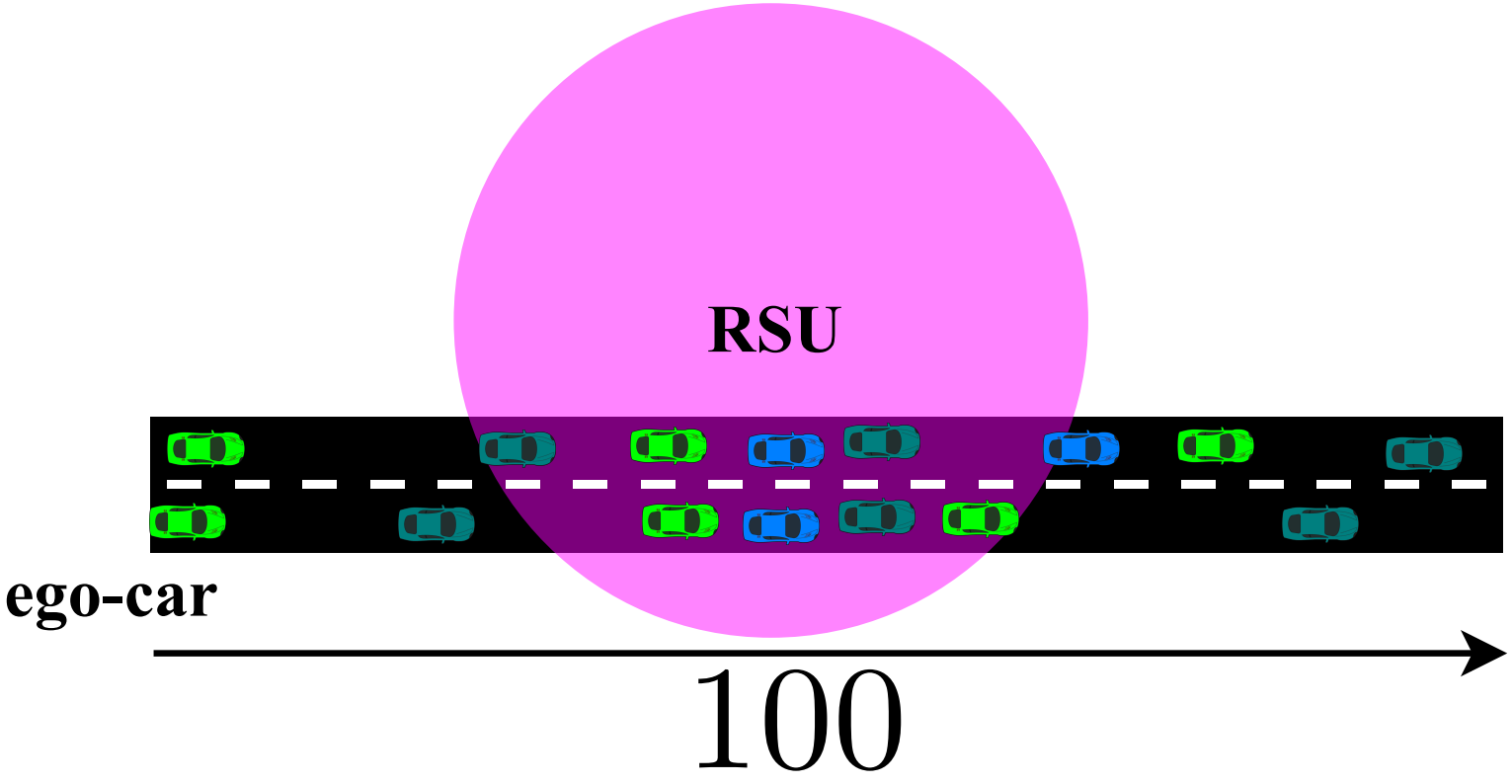


Figure: SUMO/OmNet++



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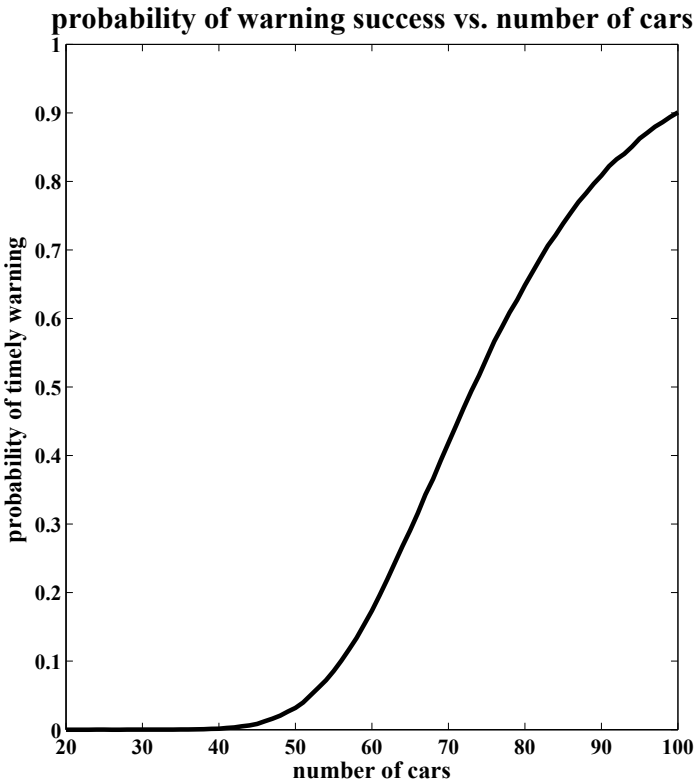


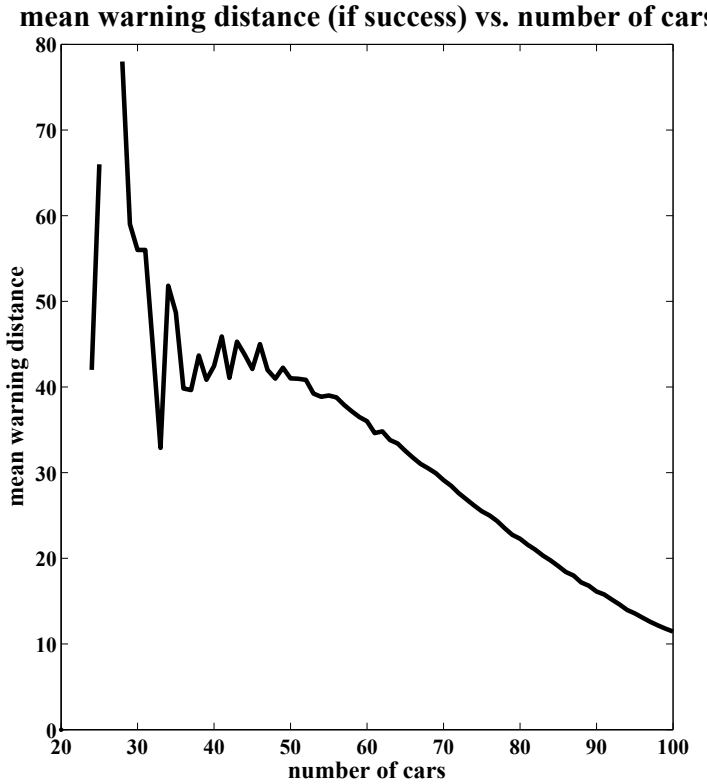
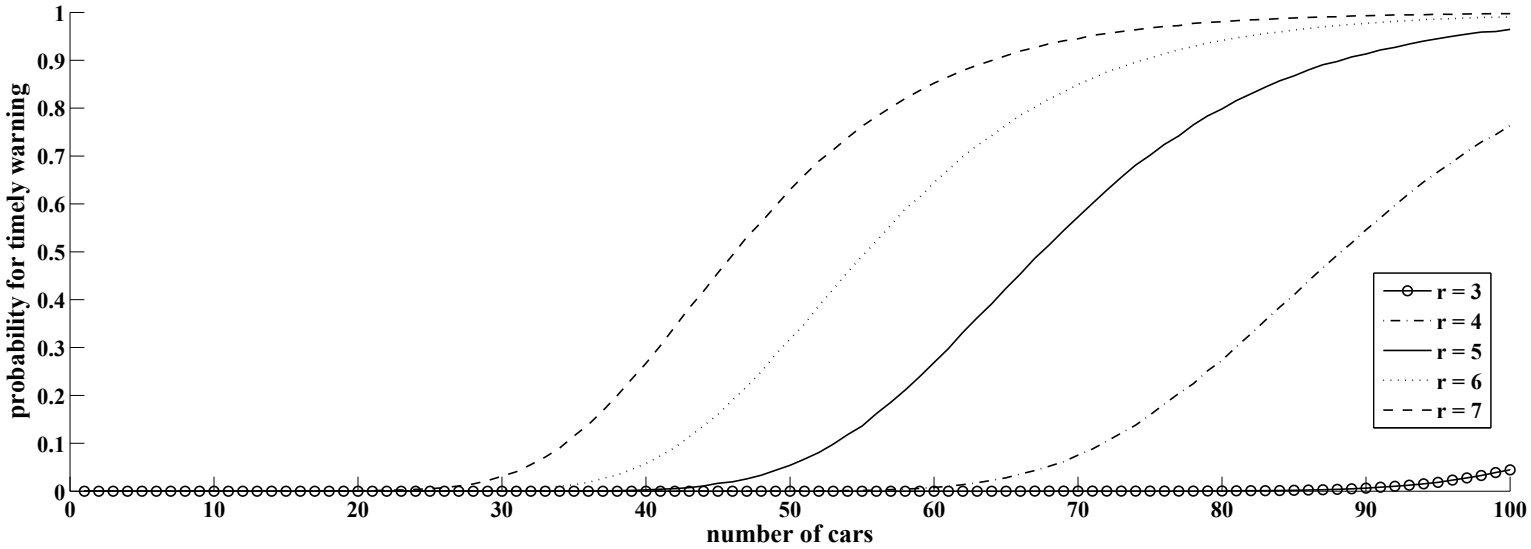


Figure: first results



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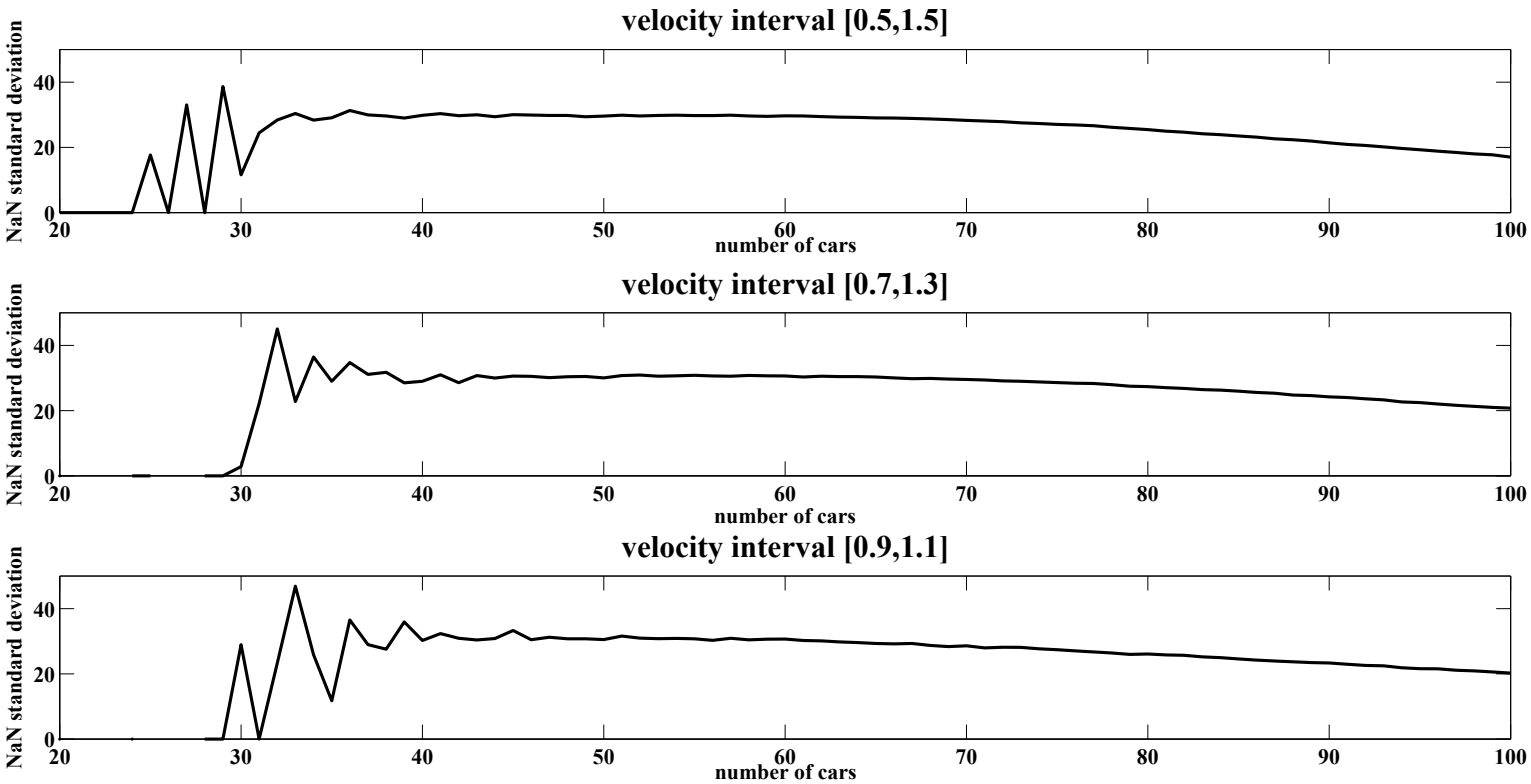

Figure: first results

Wrap-Up

- BBW & communication
- safety
- simulation

Future Directions

- fully integrate BBW into SUMO
- get experience on the protocol level
- platooning
- safety & security

Questions?