CPS: Synergy: Collaborative Research: Collaborative Vehicular Systems

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Introduction

The ongoing research aims to develop rules to study and methods to coordinate a network of fully and partially self-driving vehicles, interacting with conventional vehicles driven by people on a complex road grid, so that overall safety and efficiency of the traffic system can be improved. The potential outcomes of the research can add to the collective understanding of more general systems with hierarchical structures; help create designs with minimal computation and communication delay; and provide mathematical proofs for safety and reliability of a class of systems that combine physical, mechanical, and biological components with purely computational ones.

Researchers at the Control and Intelligent Transportation Research (CITR) Laboratory at The Ohio State University and Cyber-Physical Systems Laboratory (CPSLab) at Arizona State University are collaborating to address a series of vehicular-CPS problems, with applications in the entire range of Cyber-Physical Systems.

CONTACT

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CITR | Control and Intelligent Transportation Research Lab

CPSLab Cyber-Physical Systems Lab

Mission and Focus

Motivated by our earlier efforts:

- "Autonomous Driving in Dense, Mixed Traffic Environments" (OSU, NSF Supported)
- "Model Exploration for Cyber-Physical Systems" (ASU, NSF Supported)

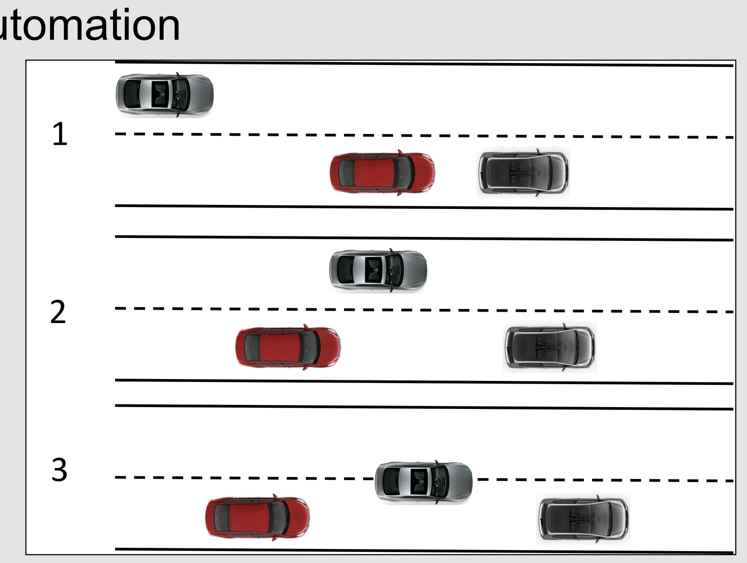
The research project addresses three concerns we developed from our prior experience:

1. **Collaboration:**
   - Autonomous (semi-autonomous) and totally "human-driven" CPS entities in a cohabited world.
   - The setting of semi-autonomous ground vehicles in an environment (street traffic and highway traffic)
   - Some portion of cars make decisions themselves, securely exchange information with others and try to understand the behavior of non-communicating vehicles,.
   - Objective: Safe and reliable traffic flow.
2. **Scalability:**
   - Present research on CPS do not lend themselves well to be scaled to the true applications
   - We address scalability by focusing on hierarchies
   - We consider grouping CPS entities as teams, convoys, regions, etc.
3. **Testability and Verifiability:**
   - Underlying problem for our application area of roadway transportation
   - We are using fully and partially virtual environments to investigate the effect of introducing autonomous entities into a real world, and thus do testing in a safe way.
   - CPS calculus as a modeling and verification tool to prove safety conditions.
   - Automated selection of test parameters and initial conditions through optimization methods

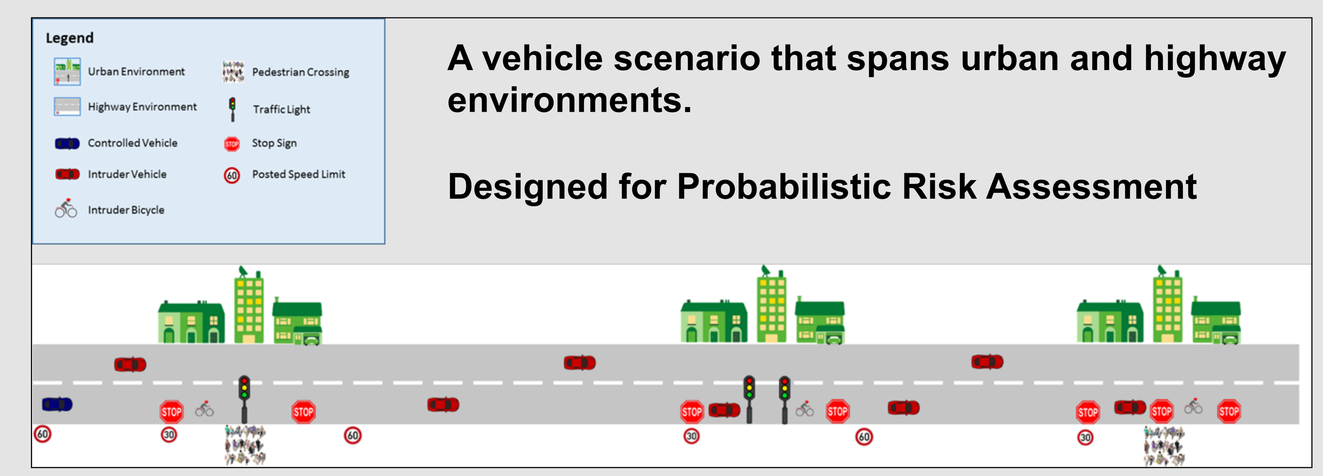
Collaboration

- An experiment for basic forms of collaboration is being developed at OSU
- CACC + Lane Change
- Partial automation in mixed traffic
- Focus areas:
  - Coordination messages (who does what)
  - Information fusion (who knows what)
  - Vehicles with different dynamics
  - Human-in-the-loop automation

Opening up a gap in an automated convoy for a new vehicle, followed by automated gap alignment and human-controlled merge



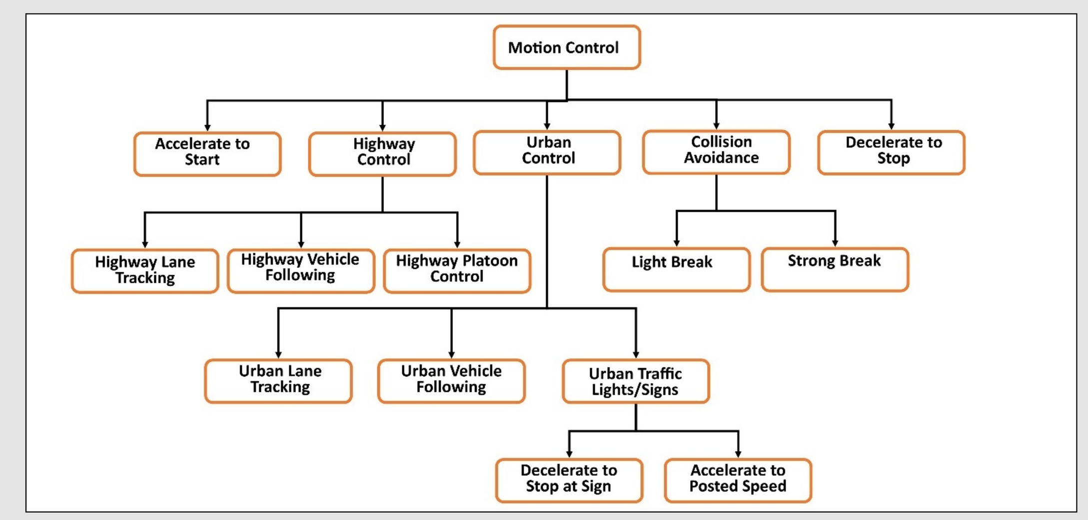
Validation and Verification



•Risk assessment methods for Unmanned Ground Vehicles (UGVs) in an Urban/Highway environments

•Scenarios of interest were identified from the DOT publication "*Pre-Crash Scenario Topology for Crash Avoidance Research*".

•Using functional hierarchies to design autonomous controllers and providing assurance cases in risk prone scenarios



Automatic Test Generation

Problem Description

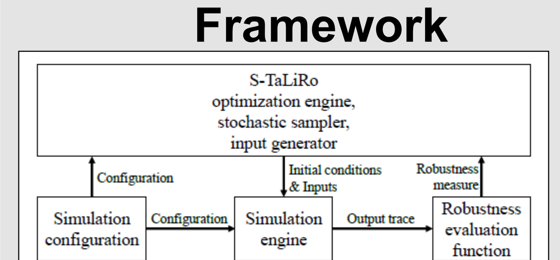
Given

- **A set of Vehicles Under Test (VUT)**
  - High fidelity models (complex dynamics)
  - Full control architecture (in contrast to specific control algorithms).
    Possibilities:
    - Black box systems
    - Gray box systems (in case specific control modes must be targeted)
- **A set of dummy actors**
  - Static or moving actors
  - Simple dynamics or kinematics or non-physics based motion
- **The environment**
  - Parameterized road network

Compute

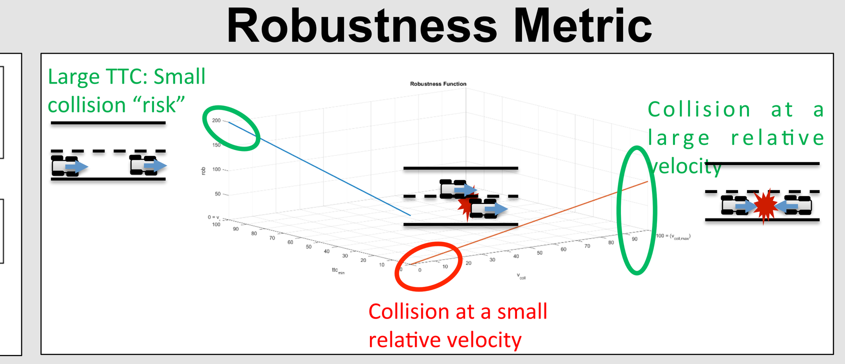
- The initial conditions and vehicle trajectories which lead to a behavior on the boundary between safe and unsafe behavior

Framework



- S-TaLiRo for initial state / input sampling
- Optimization goal: Minimize robustness value
- User selected simulation engine

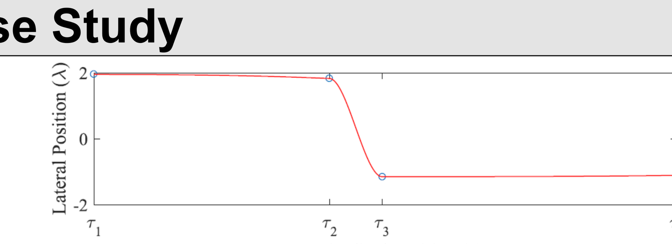
Robustness Metric



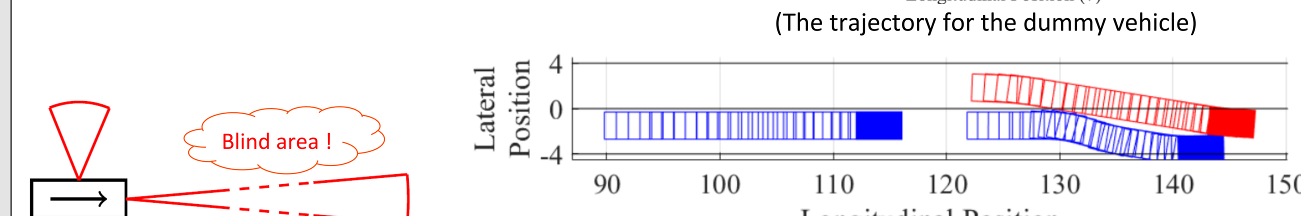
Case Study

Simulation Configuration:

- Two vehicles under test
- One dummy vehicle
- Two-lane straight road



(The trajectory for the dummy vehicle)



(Poor sensor configuration) (A front collision right after avoiding a side collision)

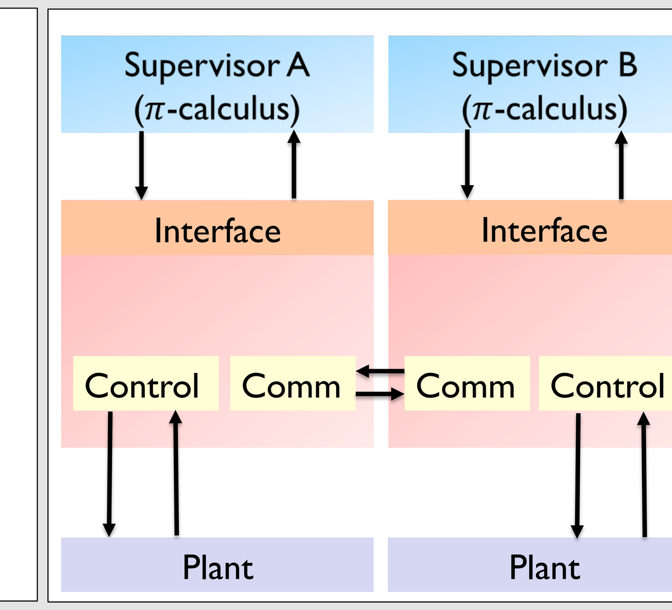
Modeling Concurrency and Reconfiguration

Project Goals

Vehicular system modeling framework that

- Is easy to use
- Provides automatic abstraction for verification
- Does not constrain dynamics
- Enables whole-system simulation

Architecture Overview

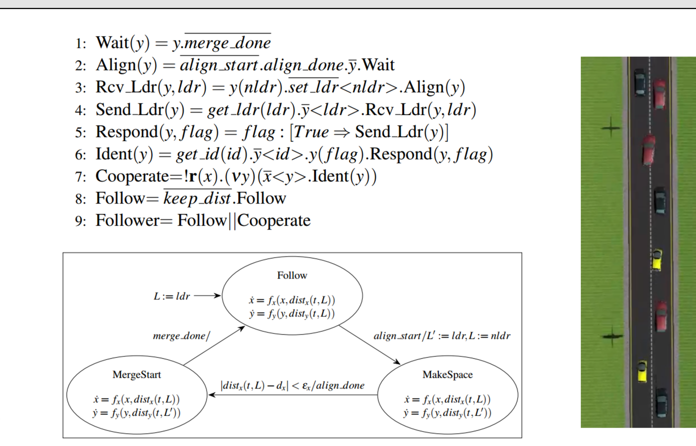


Case Study: Vehicle Platooning

Three behaviors

- Leader
- Follower
- Joiner

Heterogeneous vehicles
Heterogeneous controllers



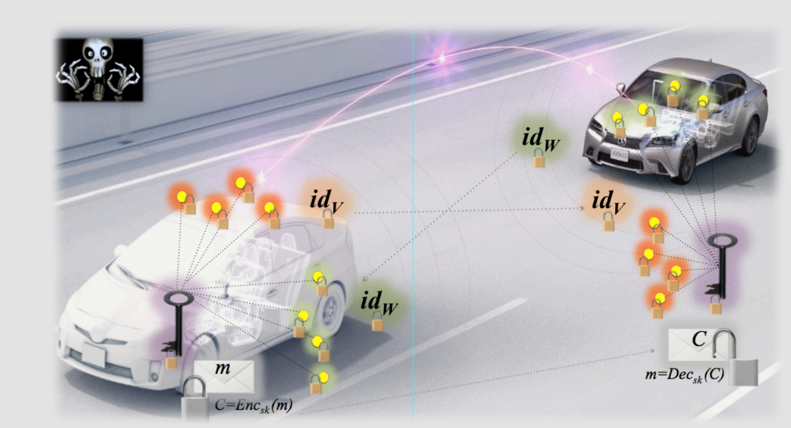
Communication Security

Preserving location privacy using improved anonymous authentication

An extension of public key infrastructure (PKI) methods to manage encryption, while preserving privacy.

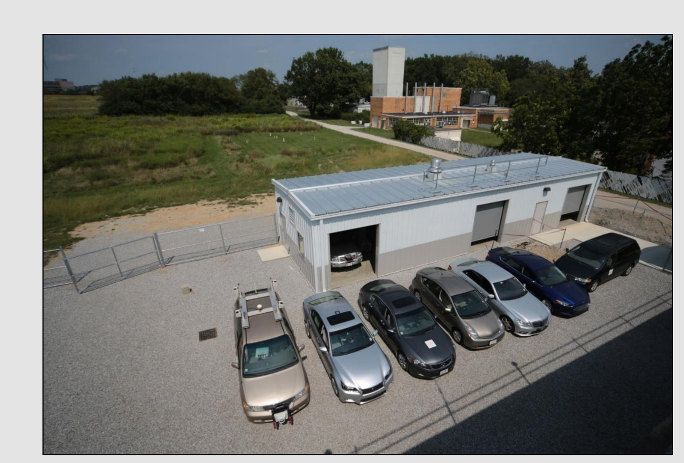
Gains:

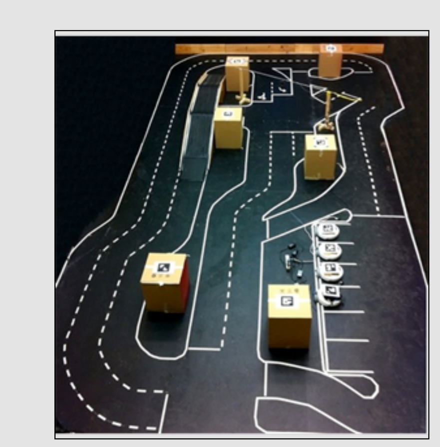
- Computation time
- Storage cost
- Number of handled vehicles



Facilities

Collaborating researchers have access to a range of laboratories and garage facilities through OSU CITR:





References

For a list of references, please contact the PIs using the contact information on the left.