COMBINED LATERAL AND LONGITUDINAL VEHICLE CONTROL USING REINFORCEMENT LEARNING FOR DYNAMIC COLLABORATIVE DRIVING

by

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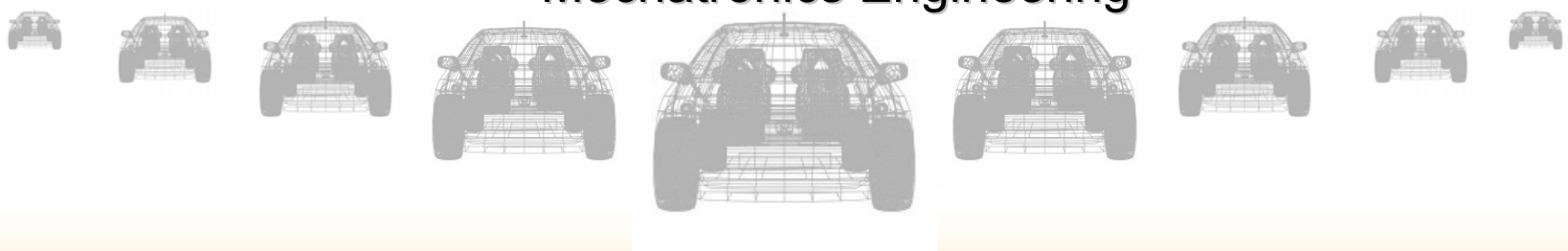
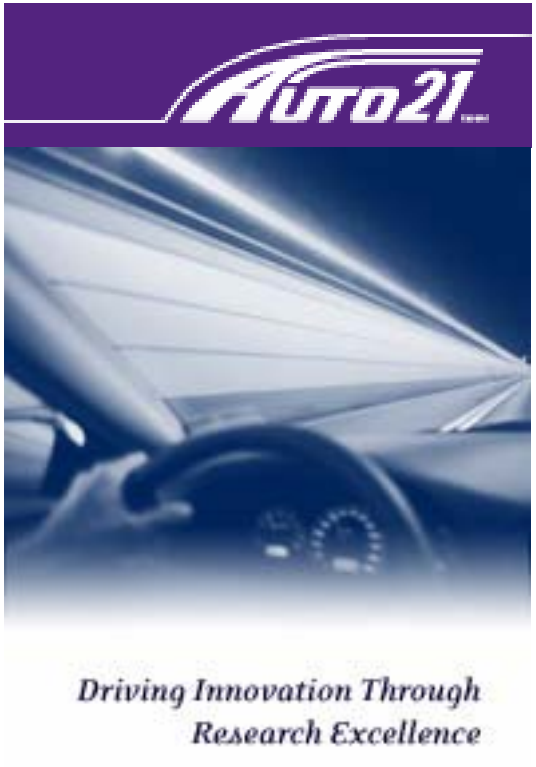


Auto 21

- Canada-wide research initiative
- Membership:
  - 37 Universities, 110 companies
- Objectives:
  - Improve safety
  - Promote R&D in automotive sector
- Research:
  - Intelligent Systems & Sensors Group
    - Dynamic Collaborative Driving
      - University of Waterloo (Dr. Jan Huissoon) and University of Sherbrooke (Dr. Francois Michaud)



Motivation

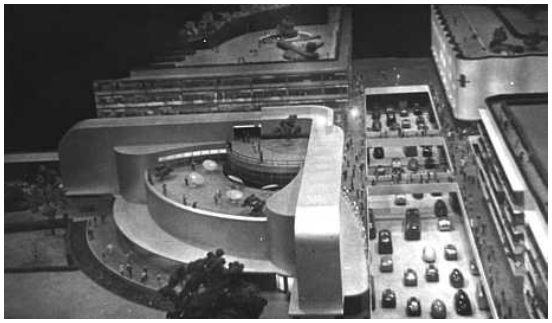
- Problem:
  - Increase of traffic flow due to urban development
- Adverse effects:
  - Traffic congestion
  - Driving Stress
  - Vehicle Collisions
  - Pollution
  - Logistical delays
- Solutions:
  1. Build more roads
     - **Expensive** and **Difficult**
  2. Improve usage on existing roadways
     - Drive **closer** and **faster**
     - Automate the driving

Rush Hour (Los Angeles USA)

Automated Highway System

Rationale

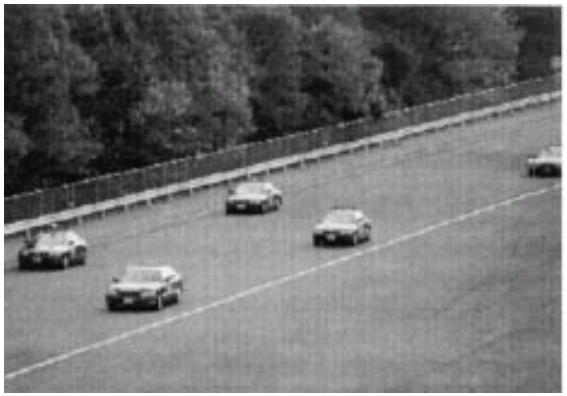
- Idea dates back to 1939 (Norman Geddes)
- Various prototype demonstrations (1994-2000)
- Automated driving remains a concept
- General public does not trust the reliability of automated driving



GM Futurama 1939
(New York, USA)

Promote Chauffeur
(E.U.1994)

Caltrans-Path: Demo 97
(San Diego, USA)

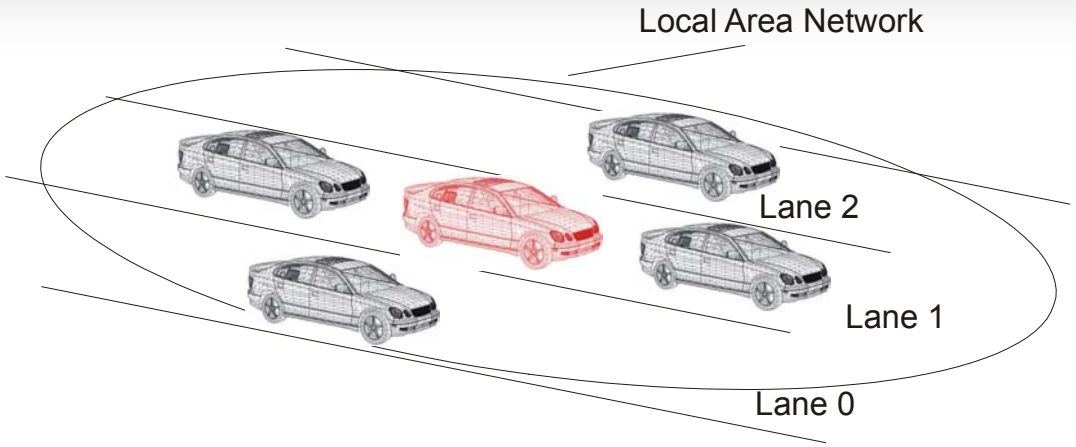


AIST: Demo 2000
(Tsukuba, Japan)

Rationale

- From concept to reality, issues must be resolved
  - Safety
  - Fault-Tolerance, Reliability
  - Coexistence of automated vehicles with human driven vehicles
- Previous prototypes:
  - Identical vehicles
  - Few vehicles
  - Centralized Control
- New Approaches should use:
  - Decentralized Control
  - Use Artificial Intelligence Methods
  - Sensor fusion
  - Inter-Vehicle Communication and
  - Shared Data Representation

Dynamic Collaborative Driving



- Multiple vehicles forming dynamic networks
- Sharing of sensory information to build up a larger shared dynamic data representation of the environment
- Benefits:
  - Multi-vehicle collaboration
  - Improved traffic flow
  - Improved safety
- This research addresses the issue of multi-vehicle collaboration

Research Question

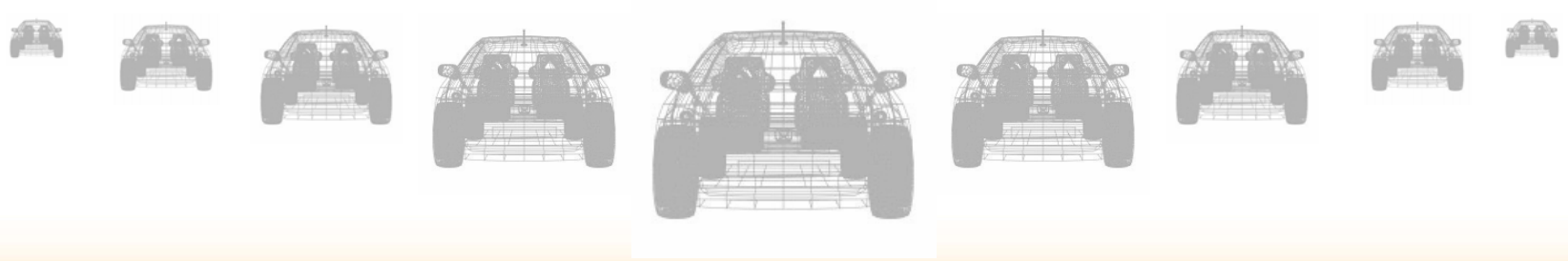
- How does one control the motion of a vehicle within a group of vehicles to share a common roadway?

- What to control?
  1. One vehicle following another (laterally and longitudinally)
  2. The longitudinal inter-vehicle spacing within a lane (formation)
  3. The entrance and exit of a vehicle from lane to another (formation)

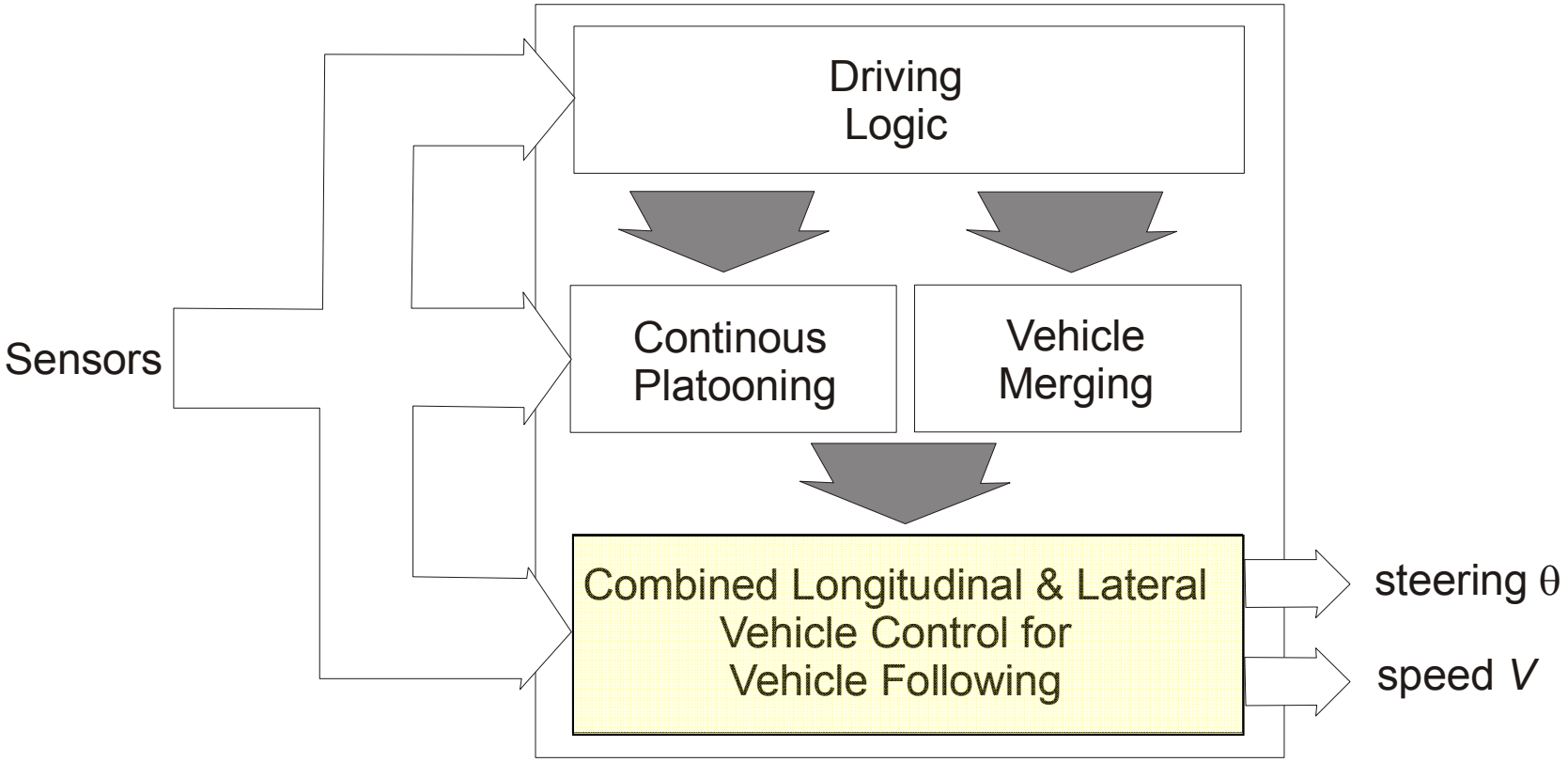
- Desired Solution:
  - General (any kind of vehicle)
  - Robust (under any condition)
  - Scalable (for any number of vehicles)

Proposed Solution

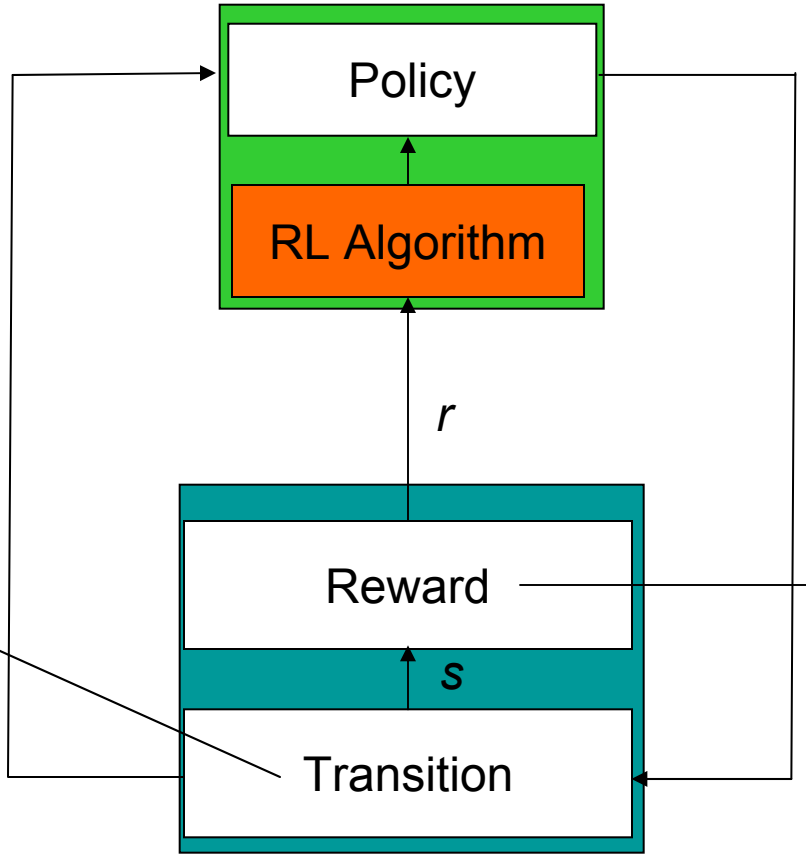
- Solution:
  - Have the machine determine its own controller
  - Assuring a certain level of performance for any situation
- Idea:
  - Applying Reinforcement Learning to achieve dynamic collaborative driving control

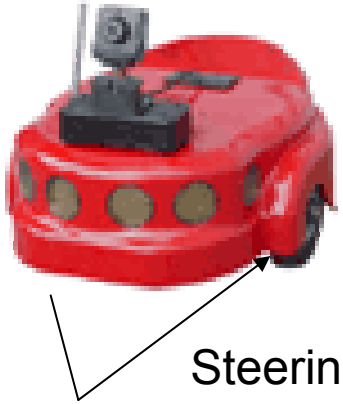


Decentralized Dynamic Collaborative Driving

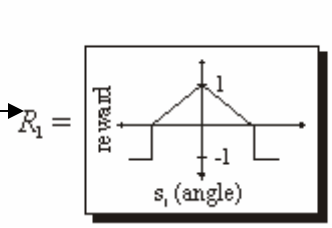


Reinforcement Learning Example





Steering Command



Experimental

Objective:

Show that Decentralized Dynamic Collaborative Driving can be addressed as a collection of reinforcement learning problems, resulting in an adaptive solution that is robust

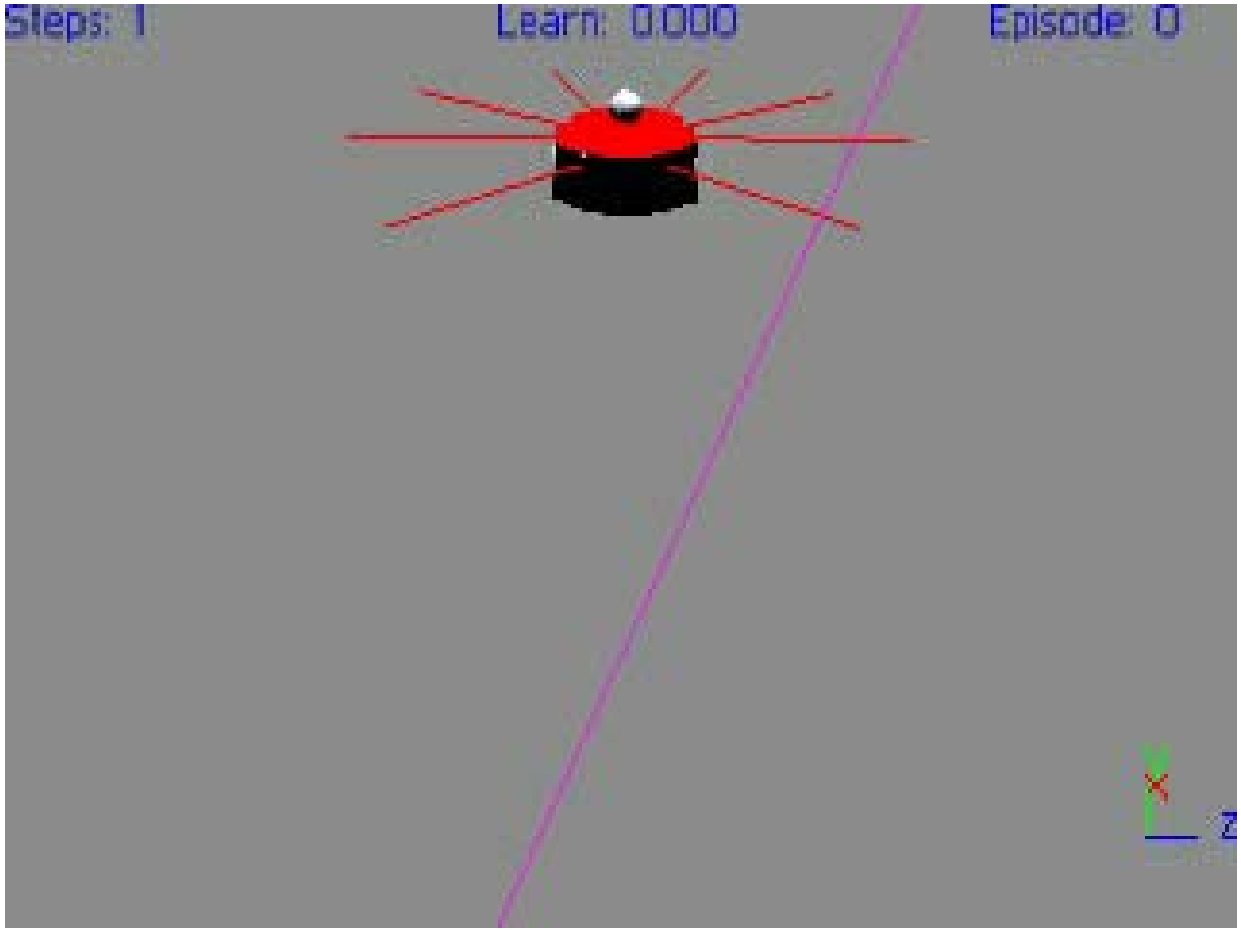
Methodology:

1. Obtain each optimal control policy using the *training environment* (simulated)
2. Evaluate the quality of the optimal policy learned in the *road environment* (simulated)

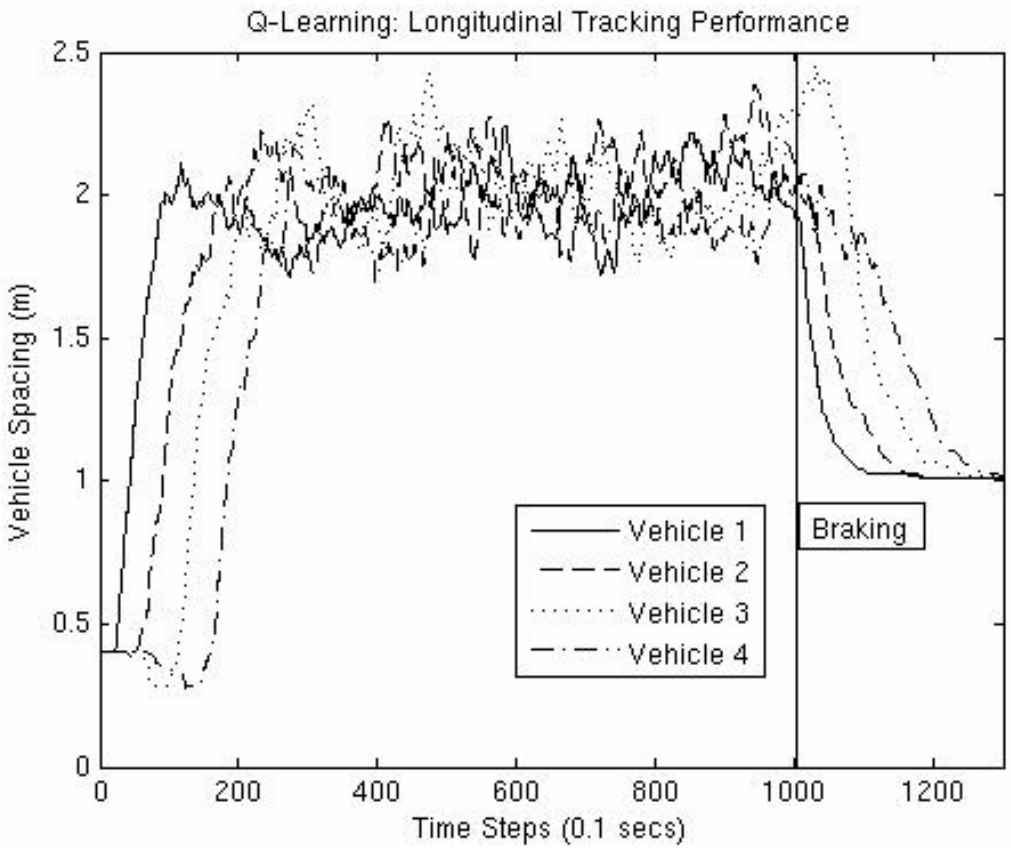
Phases:

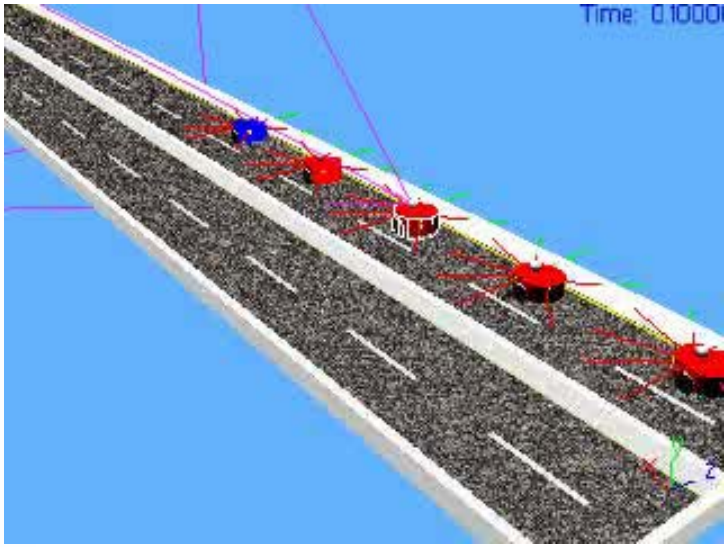
1. Feasibility studies using small mobile robot models
2. Studies using detailed full-scale vehicle models

Training of Combined Lateral and Longitudinal Vehicle Control

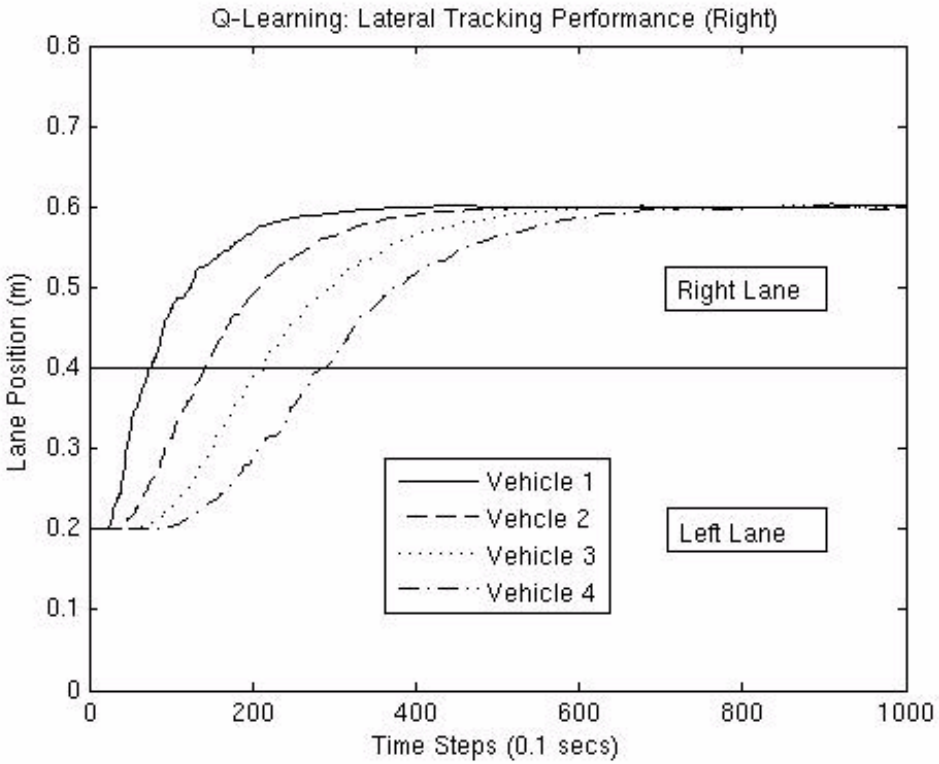


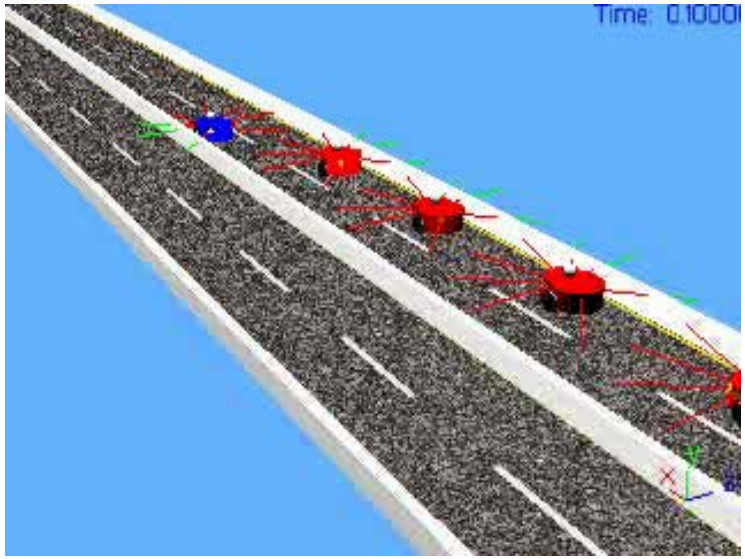
Preliminary Results
Longitudinal



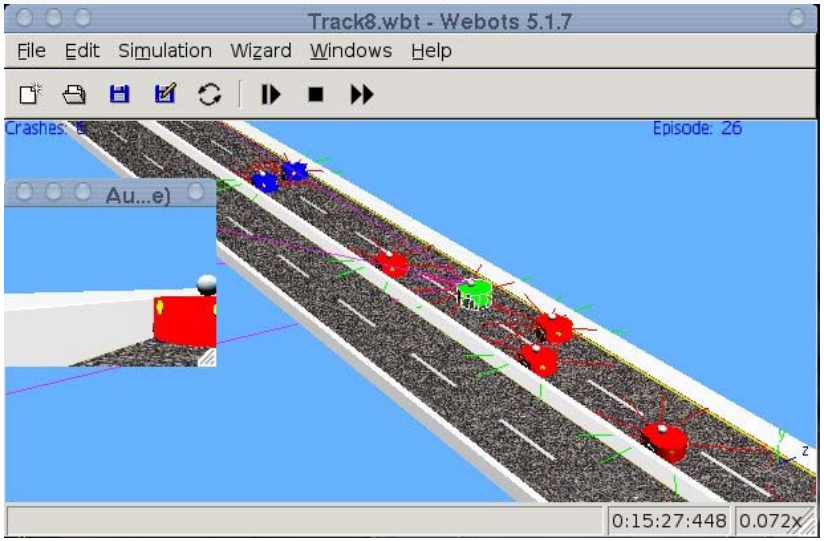


Preliminary Results
Lateral



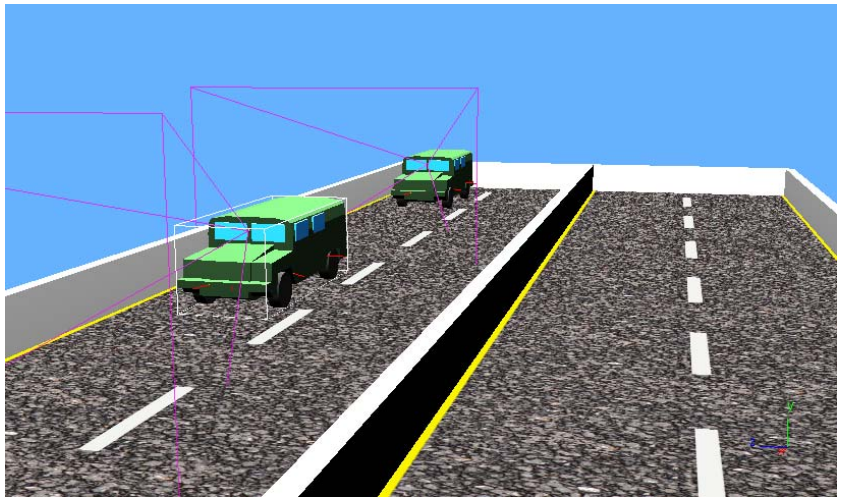


Future Work



- Full-Scale Vehicle Simulation Studies
  - Vehicle Dynamics Modeling
  - Environment Modeling

- Feasibility studies for Formation Controllers
  - Longitudinal Inter-vehicle spacing (platooning)
  - Entry/Exit control into and from platoons (lane changing)



Acknowledgements

Questions?