Department of Computer Science

University of Reading

Integration of Autonomous and Human-Driven Cars

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OpenSource AI Workshop

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LIMITLESS POTENTIAL | LIMITLESS OPPORTUNITIES | LIMITLESS IMPACT

Outline

Introduction

- Driver-less cars are emerging
  - Solve many challenging traffic problems
  - Opened a research area
- A mix of vehicles types coexist
  - AVs - Autonomous Vehicles
  - HVs - Human -Driven vehicles
  - Deployments of AVs is a gradual process
- **How can we deal with the vehicle mix?**

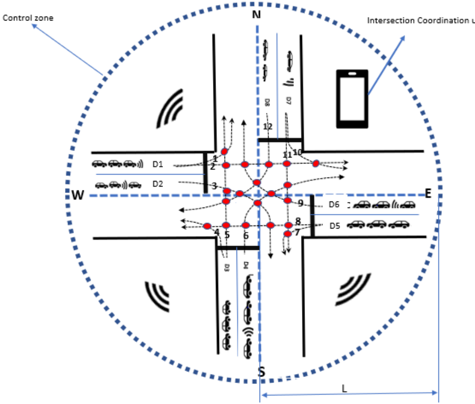

Figure: Cross road intersection with double lanes.

Social Behavior of HVS and AVS

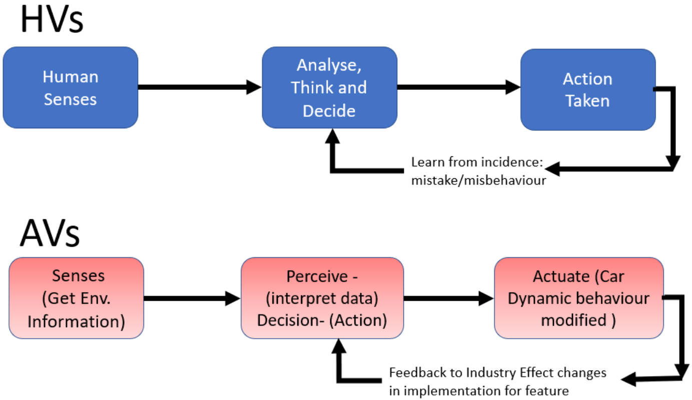

Figure: Social Behaviour of HVs and AVs

Relationship to Artificial Intelligence

The realization of commercial AVs is made feasible by AI technologies:

- Environmental perception
- Map building
- Path planning
- Deep neural networks

Ethical issues associated with AV

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- **Privacy Issues**: Its communication standards are open for hacking
- **Morality issues**: Dilemma of taking decision - Self trolley problem
- **Safety standards**: ISO 26262 is safety standard for HVs, what of AVs? google car test 1m-km, is this ok?
- **Reliability**: What if there is network of sensor(s) failure?
- **Responsibility and Accountability**: in case of accident or incident?
- **Quality Assurance Process**: Overall quality and life time of components?

State-of-the-art in Traffic Intersection Management

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Classification

- Centralized vs. decentralized approach
- Traffic lights vs. alternative flow control

Methods

- Ramp metering for merging roads
- Fuzzy Logic
- Vehicle Platooning
- Agent based system

Open Source and Interface for AVs

- Apollo - simulator engine
- Autoware - open city driving in 3D maps
- EB robinos EB robinos Predictor Elektrobit - combine software's together
- NVIDIA® DriveWorks - Software kIT -goes from detection to localization to planning to visualization.
- OpenPilot - controls break and steering system

Motivation of this Research

- Cost of AVs is higher and not affordable by everyone
- Full enabling environment for AVS are not in place yet
- Constructing roads for AVs might not be feasible
  - Cost of redesign
  - Existing city plan (changes are gradual)
- Intersections are crucial points and complex interactions
  - They need to be accounted for

Research Approach

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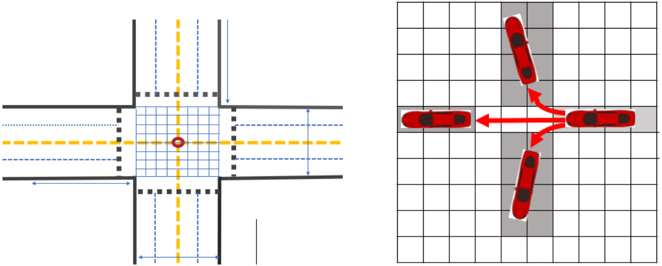
Pricing of Road-Spacetime slot reservations is proposed: Airplanes uses landing slots pricing to avoid conflict, what if AVs and HVs did the same thing in addition to platooning?



(a) Intersection area (b) Reserved slot

Figure: Intersection layout

Approach Considerations

- We model HVs with traffic light, while the AVs is controlled by an MPC.
- The car dynamics is based on Newton law of Physics
- The main measure for safety is the cross-collision point (fig)
- Full behavioural freedom assigned to HVs
- Position, trajectory, speed, time etc are parameters of cars.

Differences between HVs and AVs parameters

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These differences are summarized under the following four heading:

- **Communication**: AVs operates two ways communication loop while HVs is one way
- **Control Efficiency**: AVs observe a set of predefined rules, while human driven vehicles have freedom.
- **Response Time**: AVs response at real-time while HVs response is 2.3 seconds, this delay can be dangerous in emergency.
- **Complexity in the set of rules**: AVs are protocol-based design(movement), while human nature control in HVs.

Algorithm

Two different algorithms for HVs and AVs were developed.

Algorithm for HVs

We modelled human driven vehicle using the convention driving system thus:

- Signal Operation policy
- Simple rule
- Arriving vehicles from an active lane gets automatic reservation slot.

Algorithm for the AVS

This uses:

- Uses Motion protocol
- Communication and sensors
- Permission assignment rule

Coordination Algorithm for AVs and HVS

Vehicle parameters

- Vehicle Identification Number (VIN)
- vehicle length
- maximum and minimum acceleration
- maximum velocity
- maximum steering angle
- Axle distance

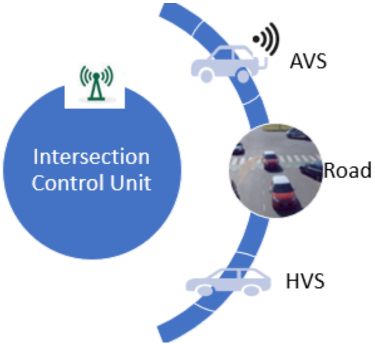

Figure: Intersection Communication platform.

State variables

- Position
- Heading/ direction
- Acceleration and velocity

Early Results

Simulations for intersection efficiency was conducted with random numbers of cars at intersection verses its equivalent crashes as shown

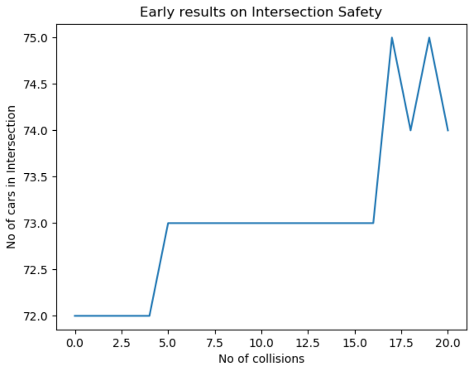

Figure: Graph of no of cars verses no of crashes

Ongoing Research

What we want to achieve:

- A novel intersection management scheme for safe mixed traffic
- HVs and AVs are represented by different physical/driving models
- Formal proof for the safety of the proposed management
- Performance evaluation based on mix ratio of Hvs to AVs

Car Model

This model describes the forces acting on a car based on the principal of Newton's laws of Physics.

Therefore, we model the frictional force as:

$$\mathrm{Fr} = \mu \cdot m \cdot g \tag{1}$$

Vehicle Acceleration

The acceleration a of the vehicle is determined by the net force on the car and the car's mass m:

$$F = m \cdot a \qquad [F] = \left(\frac{m}{s^2}\right) \tag{2}$$

Outline

Summary

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- Pricing of road-spacetime slot reservations could help in a hybrid environment to promote safety
- Vehicle platooning system reduce travel time, breaking and fuel consumption

Ongoing/Future work

- Implementation of a simulator with agents (will be open source)
- Investigation of various performance metrics
- Study of how this system react to failure and mitigation strategies
- Model responding to all road users (e.g., pedestrians, emergency vehicles)

Thank you for listening

Questions