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Welcome!

MPC 590 – Impact of Connected Automated Vehicle on Traffic Safety Under Different Highway Geometric Designs

Presented by:

Dr. Xianfeng Terry Yang

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Impact of Connected Automated Vehicles on Traffic Safety and Efficiency

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MOUNTAIN-PLAINS CONSORTIUM

Outline

- ❖ Background
- ❖ Data Collection
- ❖ CAV & Road Geometric Design
- ❖ Dynamic Signal Control
- ❖ Smart Traffic Signal Control
- ❖ More Discussions

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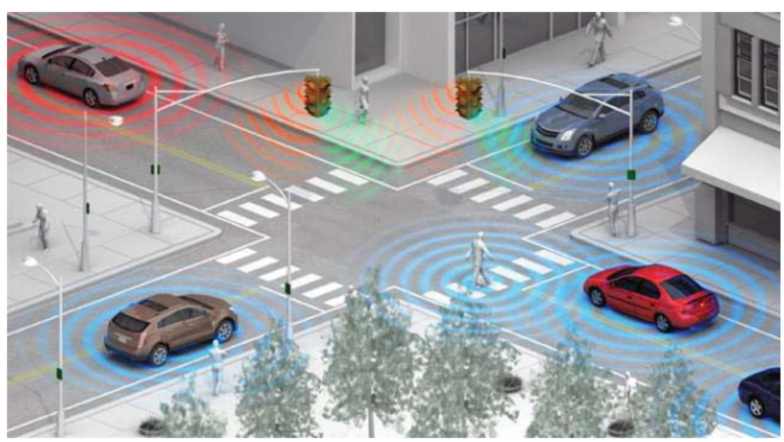
Background: Connected Vehicle (CV)

- Connectivity technologies
  - ~~DSRC~~
  - C-V2X
  - 5G
  - DMB
  - V2X : V2V, V2I, V2P,
  - Etc.



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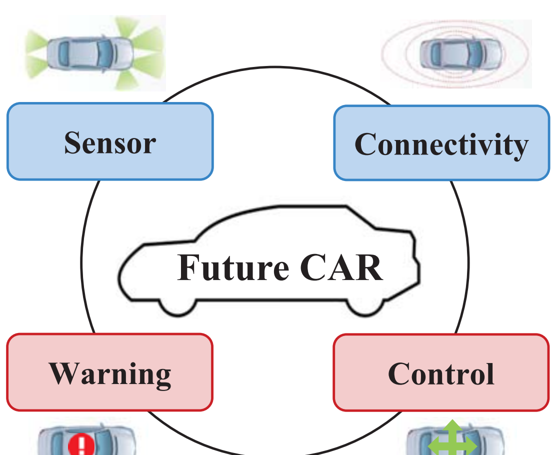
Background: Automated & Autonomous Vehicle (AV)

- Six levels of vehicle automation

SAE Level	SAE Name	Definition	Automation Controls...	Example(s)
0	No Automation	Human performs entire driving task	—	
1	Driver Assistance	Automation controls one vehicle function (steering OR speed)	OR	Adaptive Cruise Control Lane Keep Assist
2	Partial Automation	Automation controls BOTH steering and speed; driver responsible for monitoring and immediate reengagement	AND	Tesla Autopilot Audi Traffic Jam Assistant
3	Conditional Automation	Automation controls BOTH steering and speed and monitors environment; driver may be notified to reengage		Volvo DriveMe
4	High Automation	Automation performs all aspects of dynamic driving task in SOME driving modes; driver not required to reengage		Closed Campus Driverless Shuttle Driverless Valet
5	Full Automation	Automation performs all aspects of dynamic driving task under ALL roadway and environmental conditions		Driverless Taxi

Background: Connected Automated Vehicle (CAV)

- The connectivity technology of CAVs allows the exchange of traffic information between vehicles and infrastructure.
- The automated driving system (ADS) will control the vehicle trajectory based on the real-time data from on-board sensors and CV communication.



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Data Collection: DSRC v.s. C-V2X

At present, there are two very different technologies enabling V2X:

- **DSRC** stands for dedicated short-range communications. It is also called ITS-G5 in Europe. In the US, DSRC is contained in a 75 MHz segment of the 5.9 GHz band. It is often used for direct communications in a local environment.
- **C-V2X** stands for cellular V2X. It utilizes cellular technology to provide the link between the vehicle and the rest of the world, including other vehicles and the traffic control system.

Data Collection: The Engineer's Dilemma

- ❑ In the midst of a platform war, engineers must choose which platform to commit their development time and costs to.
- ❑ Solution: C-V2X won the competition

Data Collection: Other Challenges

Communication Jam/Congestion

- ❑ Imaging all vehicles on the road are CV and CAVs…
- ❑ Some communication priorities may be given to CAVs.

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CAV & Road Geometric Designs

- How CAV safety performance is related to road geometric designs?
- What are the scenarios that CAV can improve road safety?

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Scenario 1: Lane Changing Warning

- Work zones, bottlenecks and lane closures due to incidents
- Warning for driver to change lanes
- Reduced speed area
- Decrease in vehicles conflicts and side collision
- Reduce workers injury risk

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Scenario 2: Red Light Warning

- Send alert to driver approaching intersection (esp. low visibility)
- Prepare driver for intersection to reduce speed

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Scenario 3: Adverse Driving Condition Warning

- Weather data of downstream road and road condition
- Speed limit alert in case of low visibility of signs
- Suitable for curvy roads

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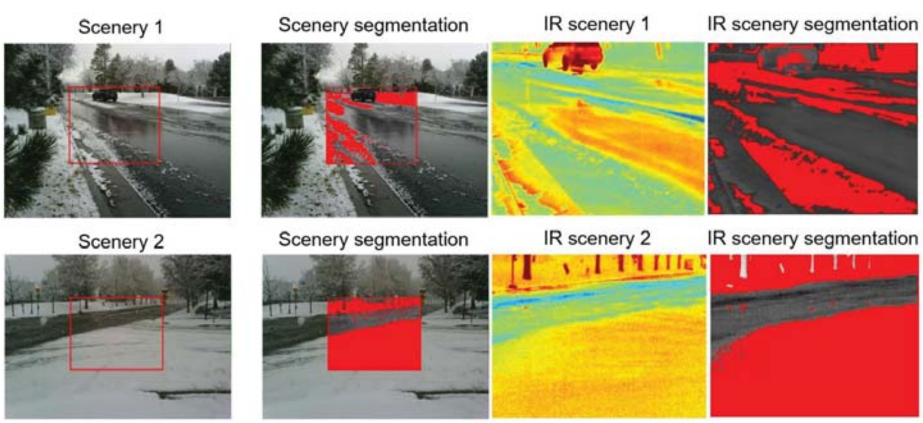
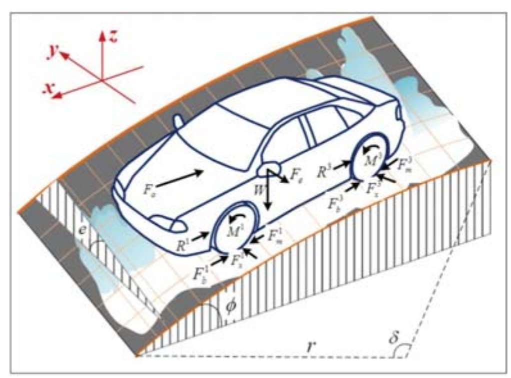
Scenario 3: Adverse Driving Condition Warning

- Road Slippery Condition Detection





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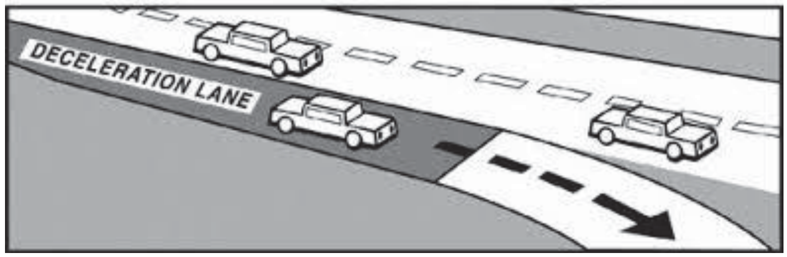
Scenario 4: Ramp Notice

- Road with short exit ramp lane
- Alert to driver to change lane in a suitable time before reaching the ramp
- Lower crash rates due to lane change and travel time



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Scenario 5: Active School Zone Notice

- Based on activation of school zone
- Send alert to reduce speed
- Avoid unnecessary speed reduction in deactivated school zone times

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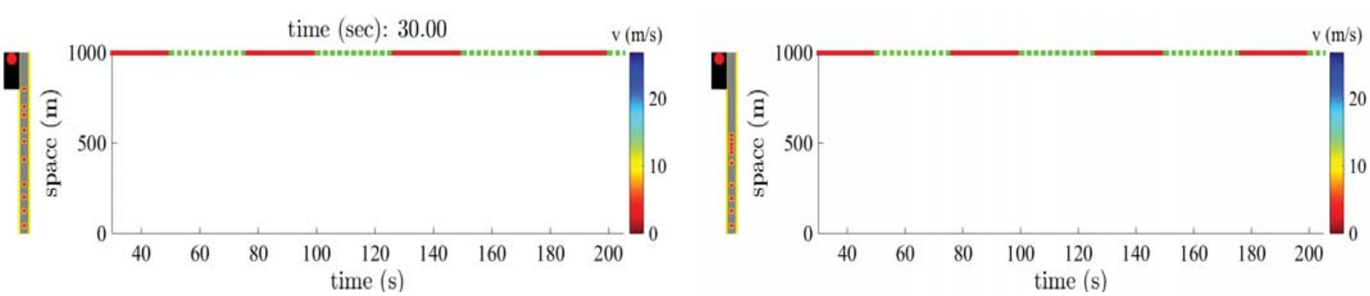
Dynamic Traffic Signal Coordination: Concept

CAV Speed Harmonization

- Design vehicle trajectories and corresponding signal timing (i.e., final boundary conditions)
- Maximize throughput and driving comfort, minimize energy consumption, ensure safety
- Core problem – Trajectory planning + Scheduling



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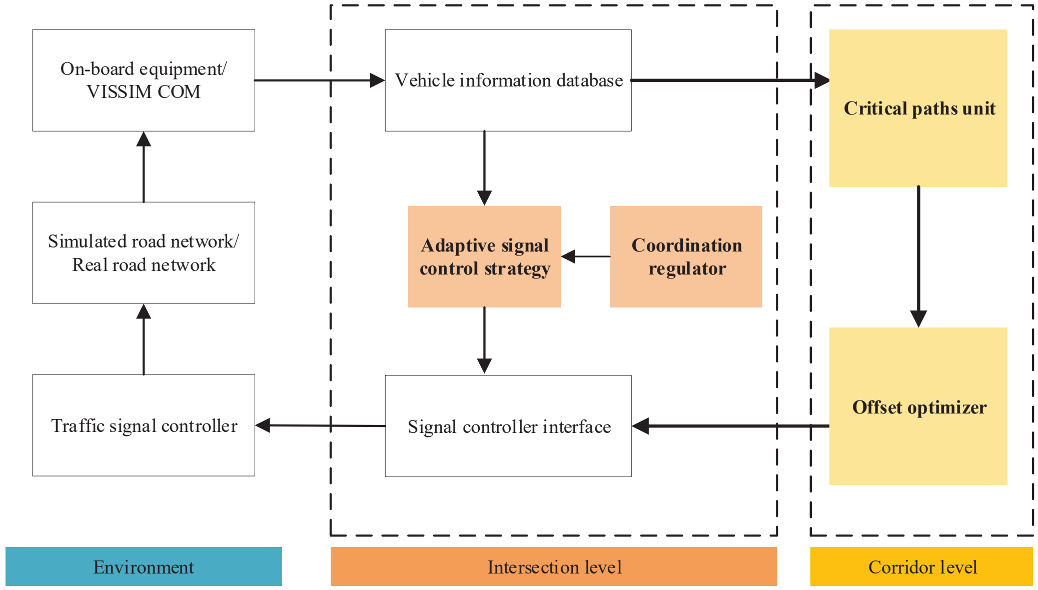
Dynamic Traffic Signal Control: System Design



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Smart Traffic Signal Control: background

Intersection Safety

- Two types of crashes at intersections

Side-Angle Crash

Rear-End Crash

Dilemma Zone Protection System (DZPS) → ✓

Advanced Warning Systems(AWS) → ?

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Smart Traffic Signal Control: background

Intersection Safety & Mobility

- The prevention of rear-end collision at intersections is still an unsolved problem.

- Traffic safety and mobility are usually implemented with different control devices, and thus often compete for the limited available resources.

- Integration of control devices for both operations so as to concurrently achieve the effectiveness on those two regards has not been well-addressed yet.

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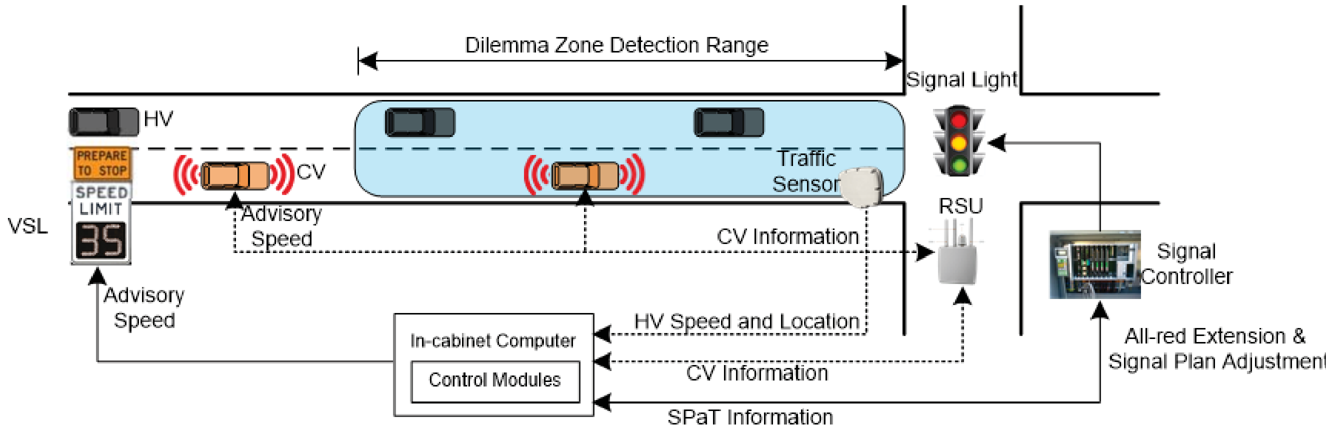
Smart Traffic Signal Control: background

The proposed system



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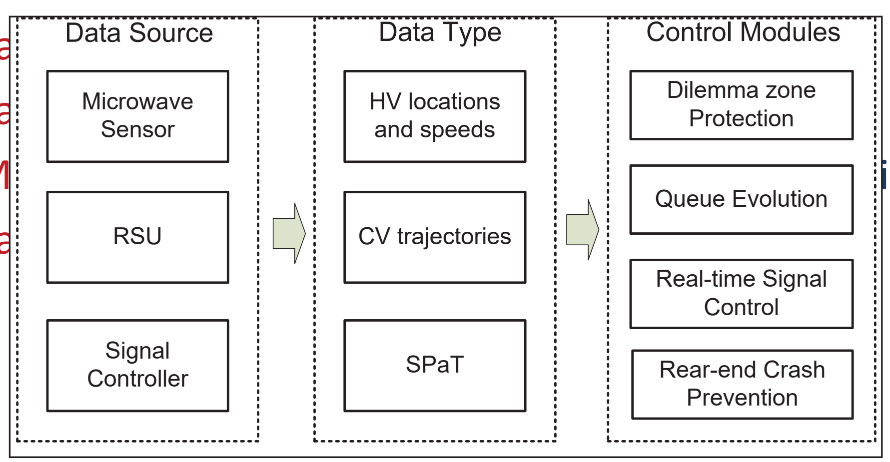
System Data Flow

Modules:

- Module 1 (Sa
- Module 2 (Sa
- Module 3 (M ization
- Module 4 (Sa



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Module 1: Dilemma Protection

This study aims to predict vehicles' passing probability at ε seconds before the end of yellow interval, where ε indicates the time needed for data transition and all-red extension activation:

$$P_{pass}(i,t_\varepsilon) = Max(\frac{1}{1-e^{-\beta_0-\beta_1 v_i(t_\varepsilon)-\beta_2 d_i(t_\varepsilon)}}, \delta_i(t_\varepsilon))$$

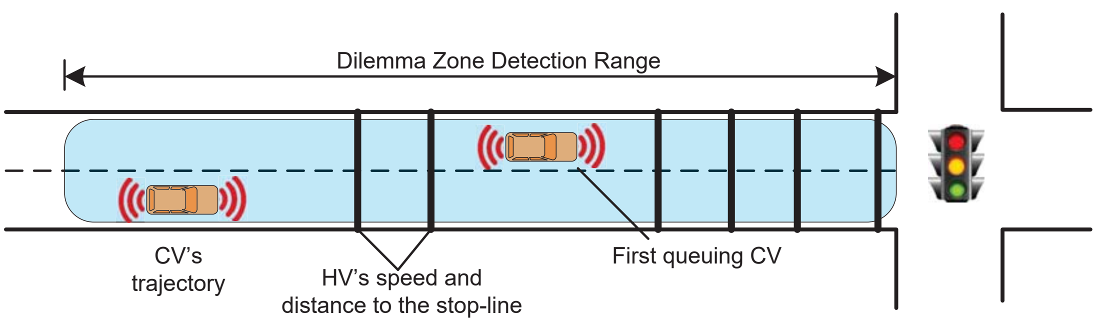
where $\delta_i(t_\varepsilon)$ is a binary variable which indicates whether vehicle i intends to accelerate:

$$\delta_i(t_\varepsilon) = \begin{cases} 1 & if\ v_i(t_\varepsilon) \geq v_i(t_\varepsilon - 1) \\ 0 & o.w. \end{cases}$$

Then the required all-red extension time, ARE, can be calculated by:

$$ARE = \max_i \{\frac{d_i(t)}{v_i(t)} - \varepsilon - AR + \sigma\}$$

Module 2: Queue Length Estimation




: the location of vehicles


: the trajectory of CVs

Module 3: Signal Coordination & CV Speed Harmonization

$$\zeta_{out,i} = \max(\theta_i + \max_{j \in \Psi_{out}(i)} \{\tau_j\} - \frac{L_{out,i} - \max_{j \in \Psi_{out}(i)} \{q_j + \lambda_j \tau_j\}}{v_{out,i}}, 0)$$

$$\zeta_{in,i} = \max(-\theta_i + \max_{j \in \Psi_{out}(i)} \{\tau_j\} - \frac{L_i - \max_{j \in \Psi_{out}(i)} \{q_j + \lambda_j \tau_j\}}{v_{in,i}}, 0)$$

Module 4: Rear-end Crash Prevention

Sub-Modules:

- Submodule 1 – vehicles are arriving with insufficient sight distance while intersection has uncleared initial queue after onset of green.
- Submodule 2 – vehicles are arriving with insufficient sight distance while intersection has uncleared initial queue after onset of red.
- Submodule 3 – some vehicles within the detection zone are predicted to be stopping during yellow and all-red time

System Control Logic and Actions

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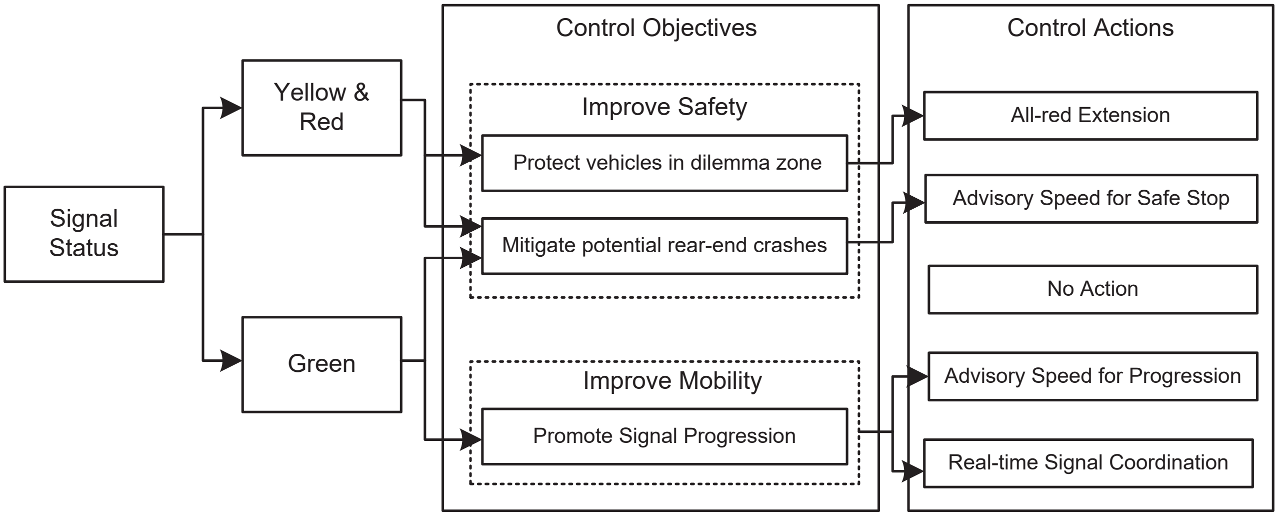

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Numerical Test

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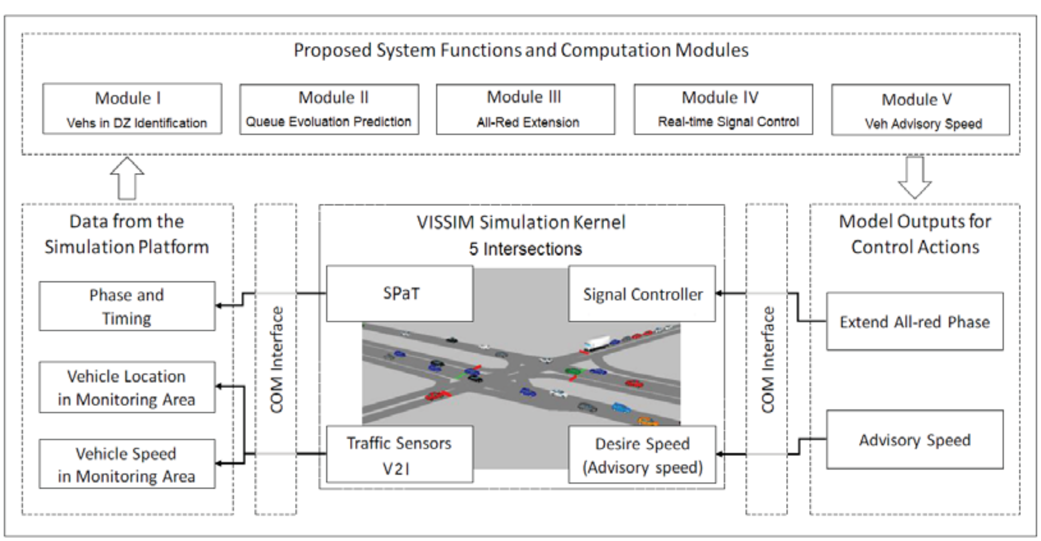
The arterial segment includes five intersections and it is a part of the CV corridor operated by UDOT. All intersections are installed with DSRC RSUs for supporting V2I communications



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Scenario Settings

Basic Settings:

- 40% regular vehicles' compliance rate to VSL
- 10% CV penetration rate

Control Types for Comparison:

- Pre-timed traffic control
- Dilemma zone protection system (safety module only)
- Proposed system (safety module + mobility module)

Performance Evaluations

❑Safety MOEs

- Average number of vehicles trapped in the dilemma zone per signal cycle;
- Average number of potential side-angle crashes per signal cycle measured by vehicle trajectories;
- Average number of potential real-end crashes per signal cycle measured by the number of hard-braking vehicles (deceleration rate > $10 ft/s^2$);
- Average number of red-light running vehicles per signal cycle.

❑Mobility MOEs:

- Average number of stops;
- Average of vehicle delay.

Safety Performance

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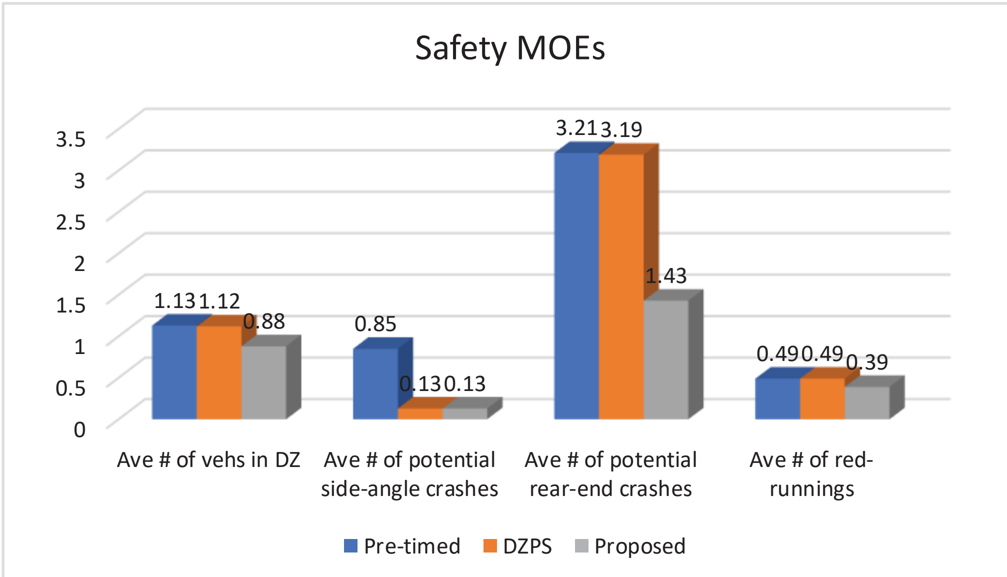

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Mobility Performance

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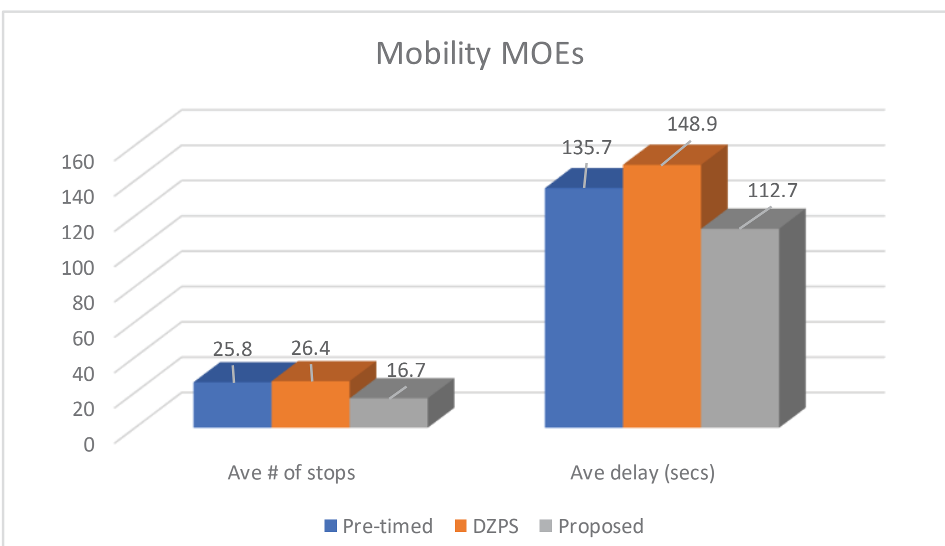

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More Discussions

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Roles of Governments?

- Do nothing – Let the operations of AVs without connection
- Promote CAVs
  - CV pilot program
  - CAV (Connected Vehicles) demonstration grants
  - CARMA platform
  - Utah CV corridor
  - Standard & regulations
- Opportunities vs. liabilities
  - Demonstrate benefits of CAV over AV alone
  - Construct, manage and maintain CV infrastructure
  - Potential liabilities of providing CV data
  - AV/CAV “drivers license”
  - Data management from CAV/AV

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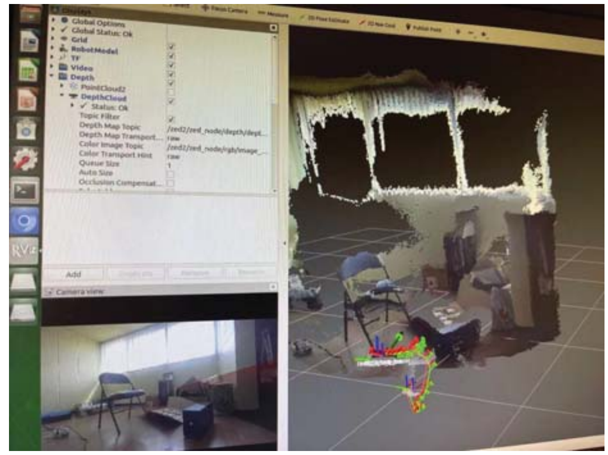
More Discussions

CARMA 1tenth



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Acknowledgement

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UDOT Keeping Utah Moving

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Thanks & Questions?

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