Signalized intersection control in a connected and autonomous vehicle environment

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Acknowledgments and collaborators

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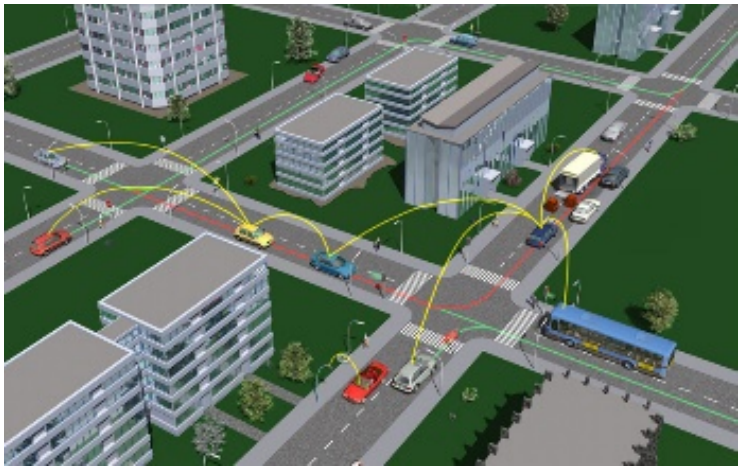
Traditional approaches of traffic signal control

- Fixed-time
  - Not very flexible
  - Unique plan needed for every demand pattern
- Actuated
  - Flexible within a pre-defined range to capture minor variations
  - Relies on information from fixed sensors
- Adaptive
  - Robust to larger variations in travel demand patterns
  - Relies on (aggregated) information from fixed sensors

Connected vehicles offer richer source of information that can be used to inform traffic signal timings…

- Vehicles can provide actual locations and speeds to signal controller

- Information may be transmitted across multiple signals for coordinated control



http://www.dot.state.fl.us/trafficoperations/ITS/Projects_Deploy/CV/Connected_Vehicles.shtm
http://www.automotiveworld.com/analysis/dot-suggests-us-standardisation-of-connected-vehicle-devices-and-roadway-systems/

…and information can be provided back to the vehicles to help further improve operations

- Speed guidance can be provided to human-driven or autonomous vehicles to keep traffic running smoothly (minimize stops)

http://fortune.com/2016/12/06/audi-traffic-lights-vegas/

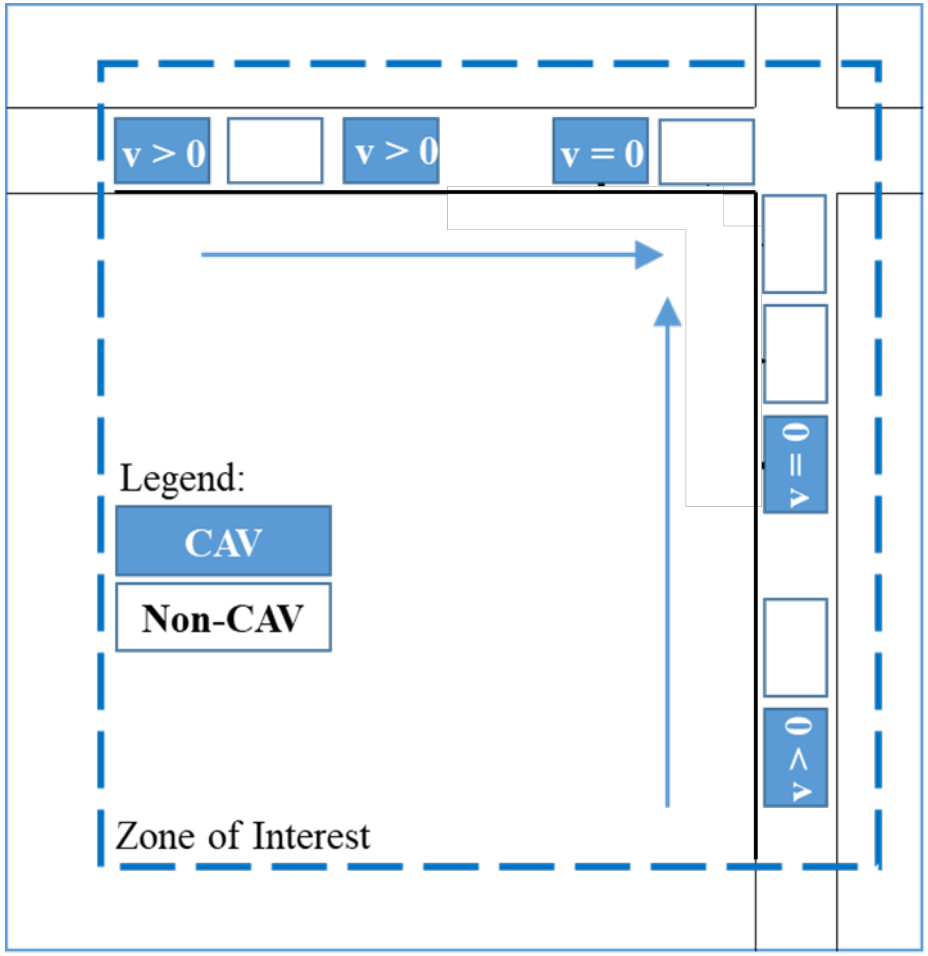
Challenges

- Most existing approaches:
  - Assume 100% CAV penetration
  - Either:
    - Very flexible but do not adhere to traditional signal phasing options (e.g., signal free methods) and are not appropriate when non-CAVs present
    - Adhere to traditional signal phasing options but are not very flexible
  - Assume full compliance with speed guidance
  - Does not account for multimodal traffic

Goal

- Develop a CAV-based signal control algorithm that:
  - Works under <100% CAV penetration
  - Leverages CV information to identify non-CVs
  - Adopts traditional phasing options with flexible phasing sequences
  - Provides speed guidance to both human-driven and autonomous vehicles
  - Can consider multimodal traffic

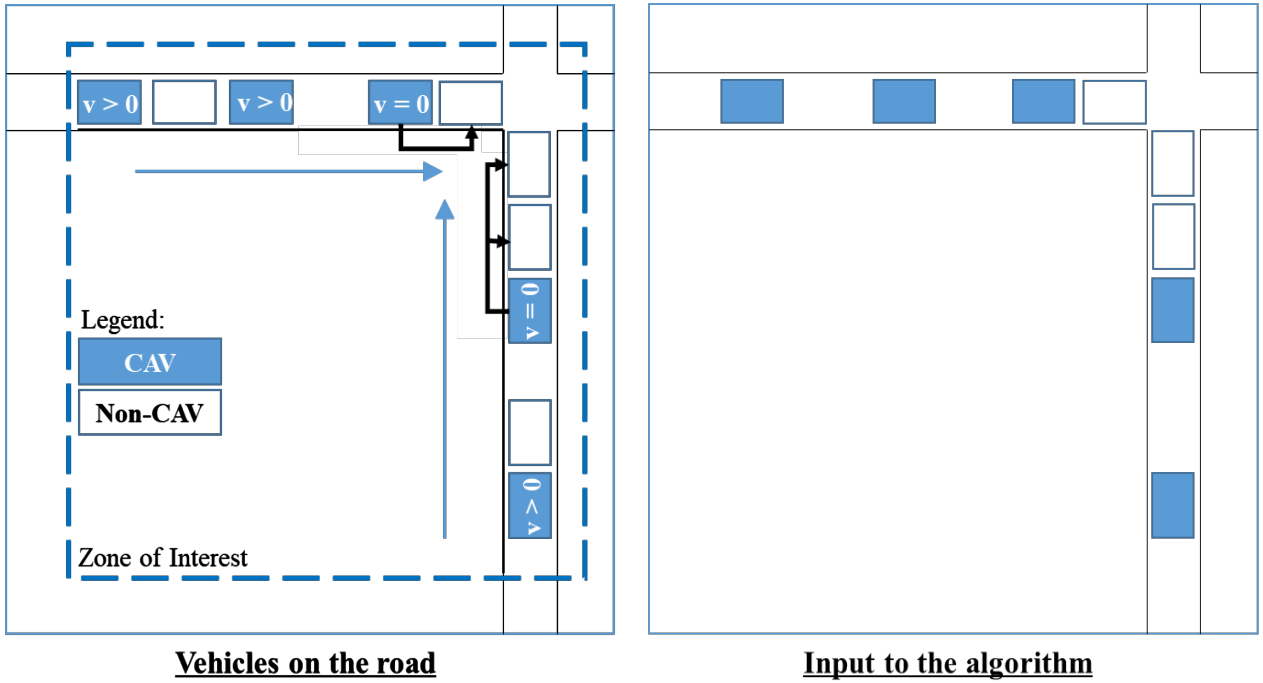
CV information used to understand where CVs are located…



Vehicles on the road

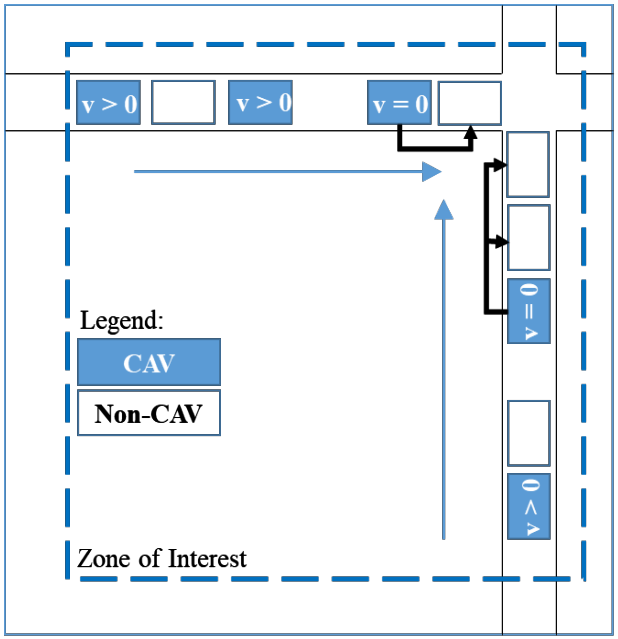
- At regular intervals (e.g., every 10 sec) CVs communicate to signal:
  - Location
  - Speed

…and to identify presence of some other non-CVs

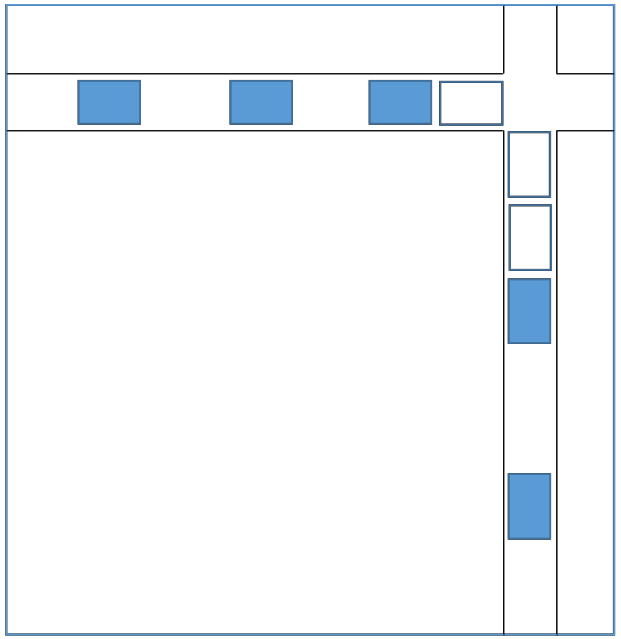


Naturally occurring vehicle platoons are identified

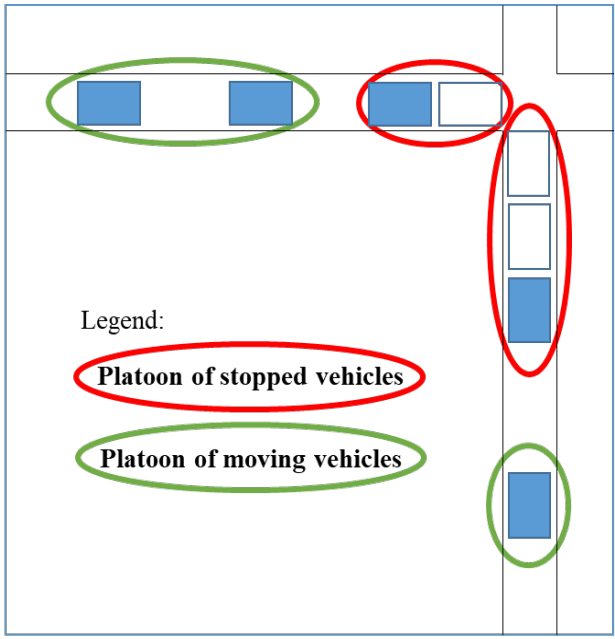
- Platoons are vehicles assumed to travel through the intersection together based on:
  - Headway
  - Spacing



Vehicles on the road

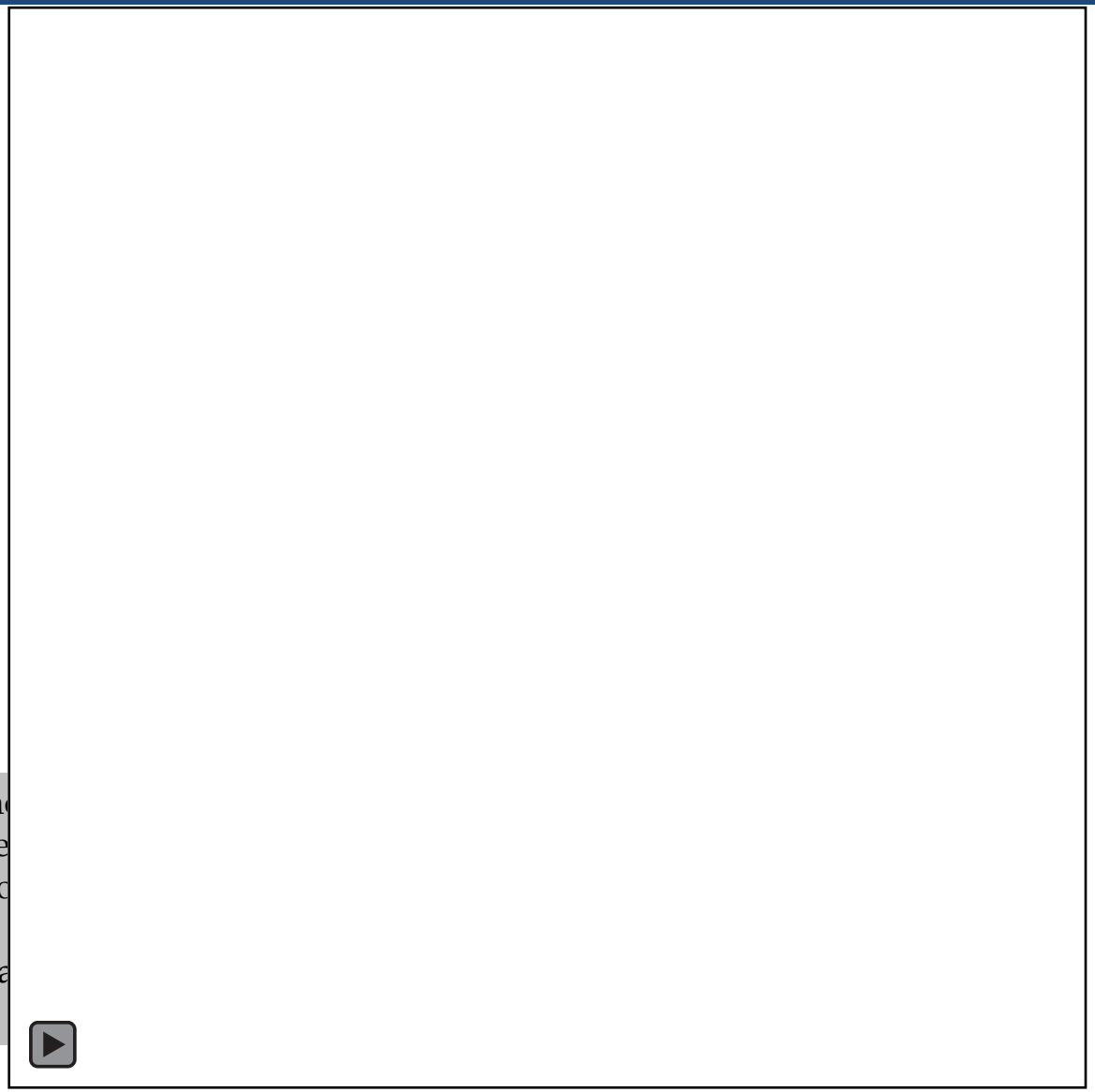


Input to the algorithm



Group vehicles into platoons

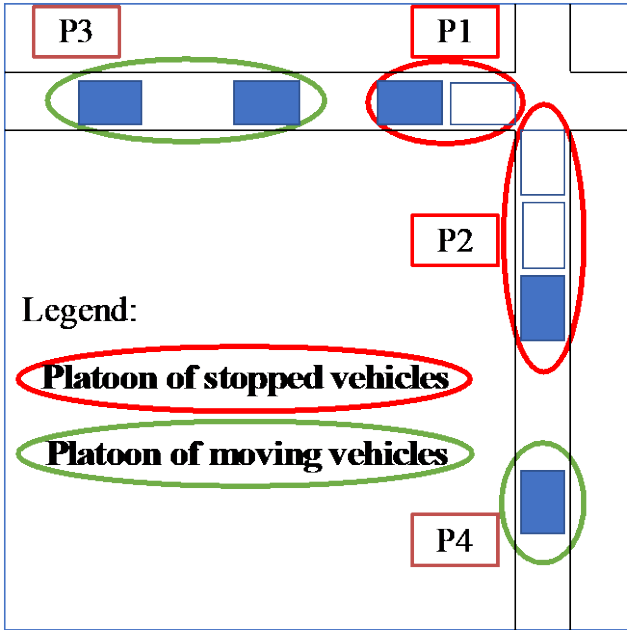
Naturally occurring vehicle platoons are identified

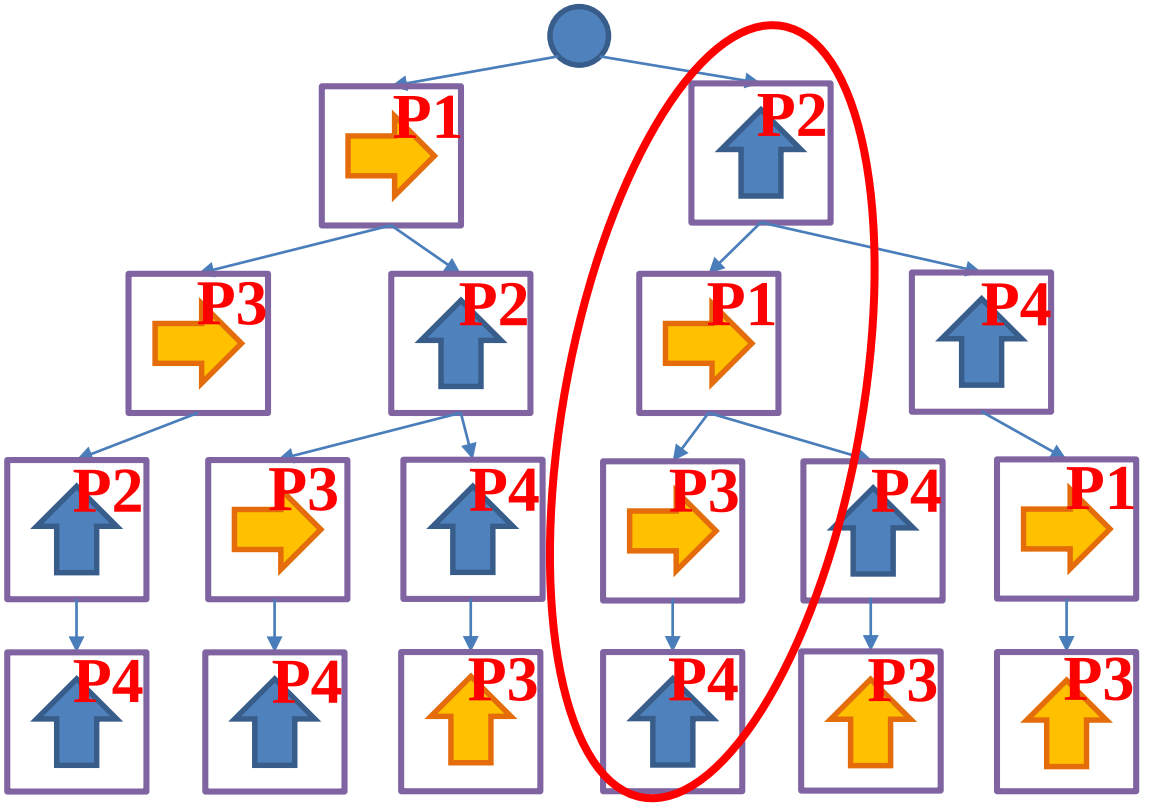


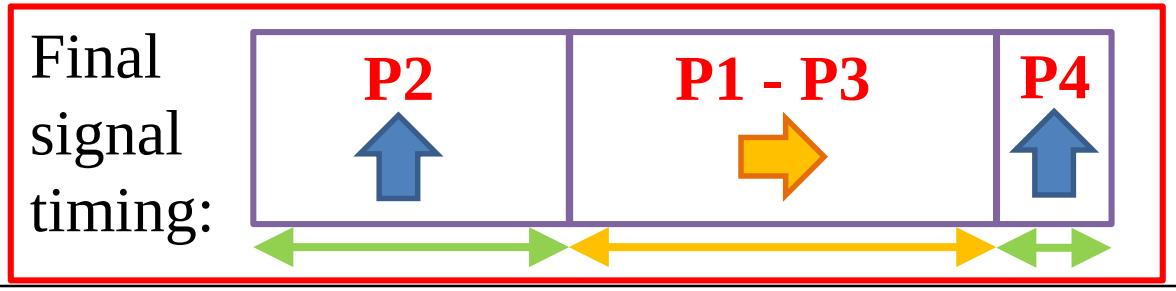
Dark blue: auton
Light blue: conne
Yellow: conventic

Rectangle: No pla
Oval: Platoon

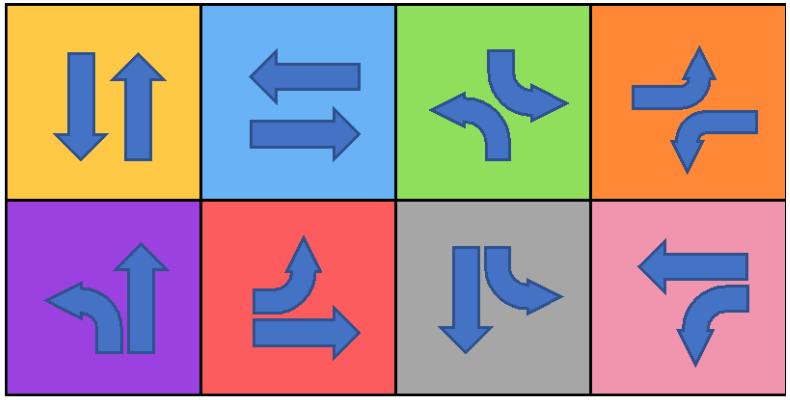
The sequence platoons are allowed to discharge then determines the signal phasing and timing plan

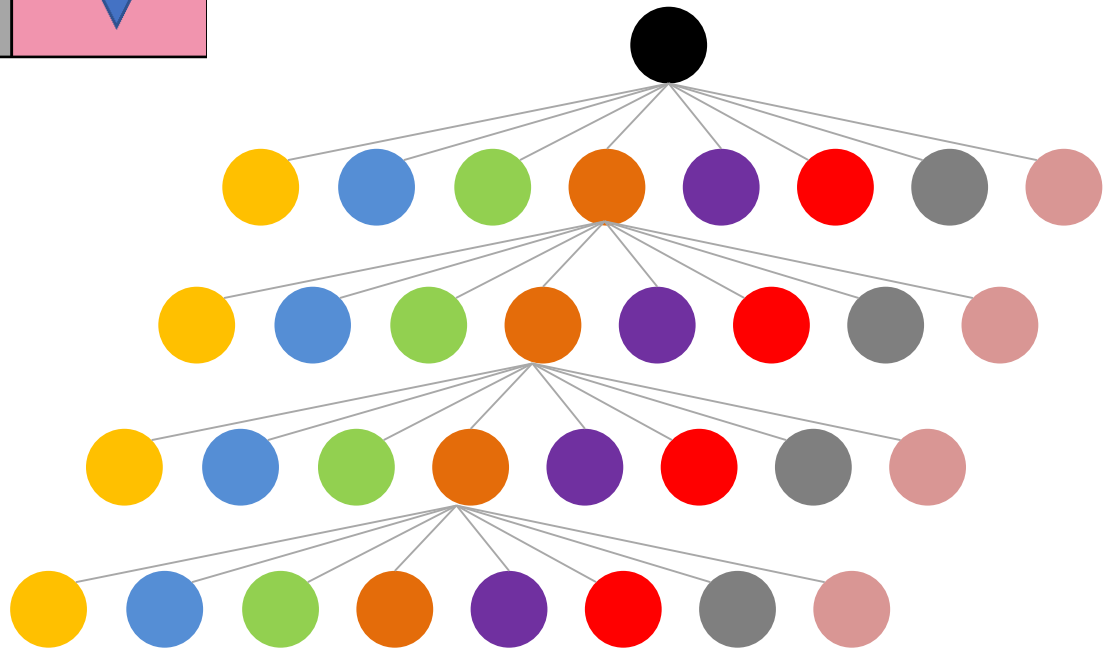




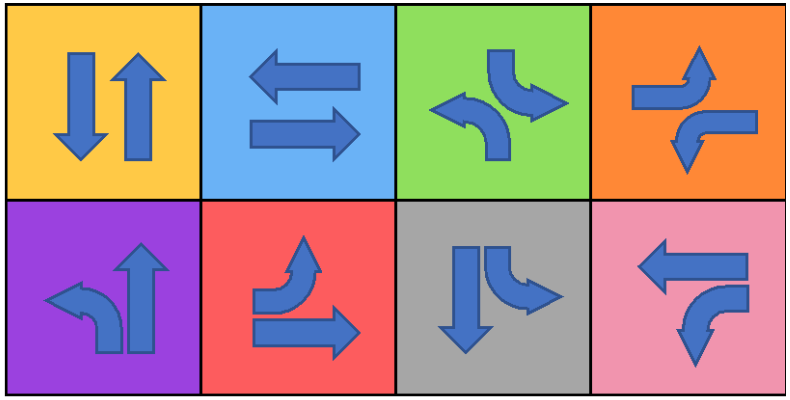


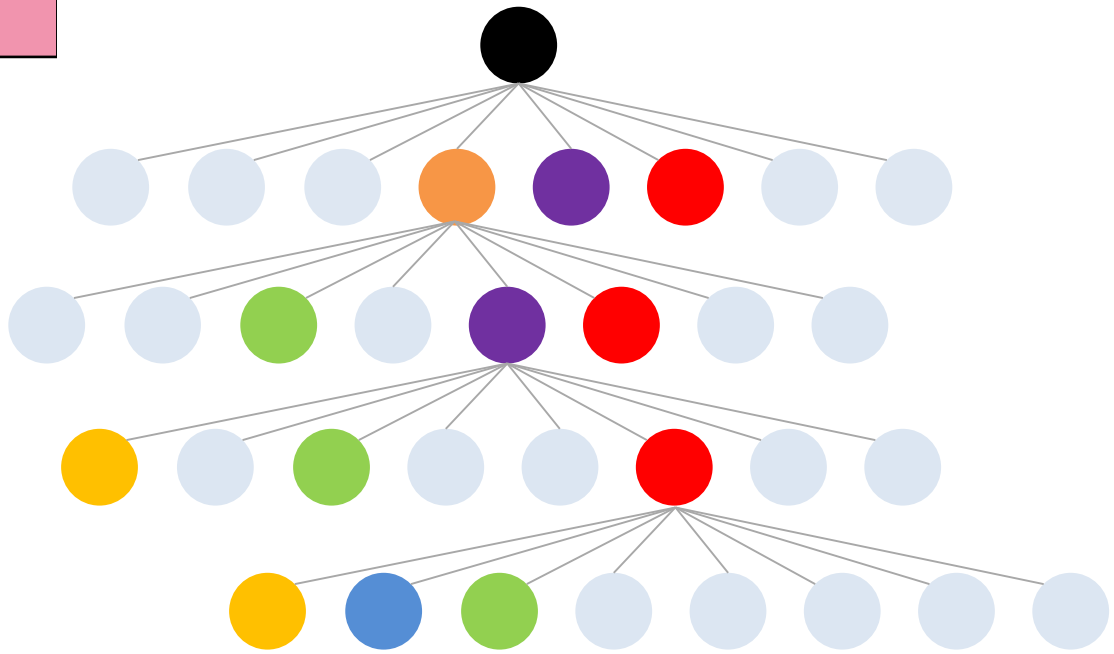
Optimal sequence can be determined by enumerating all options…





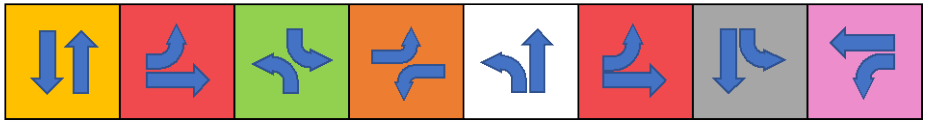
…intelligently enumerating a subset of options…



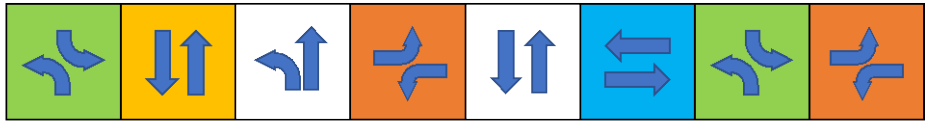


…or by using advanced heuristics like genetic algorithms to find the optimal sequence

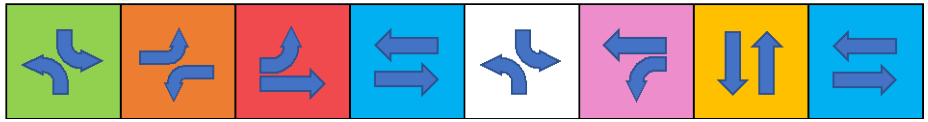
Phase sequence 1

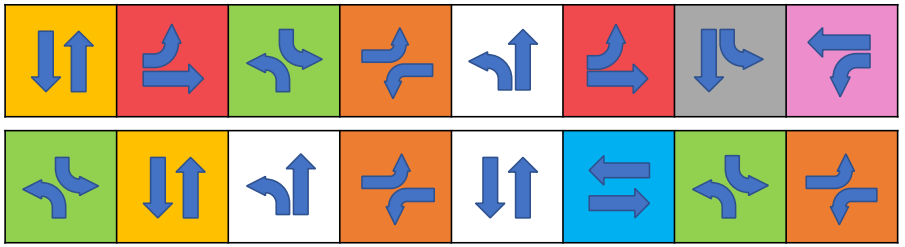


Phase sequence 2



Phase sequence N





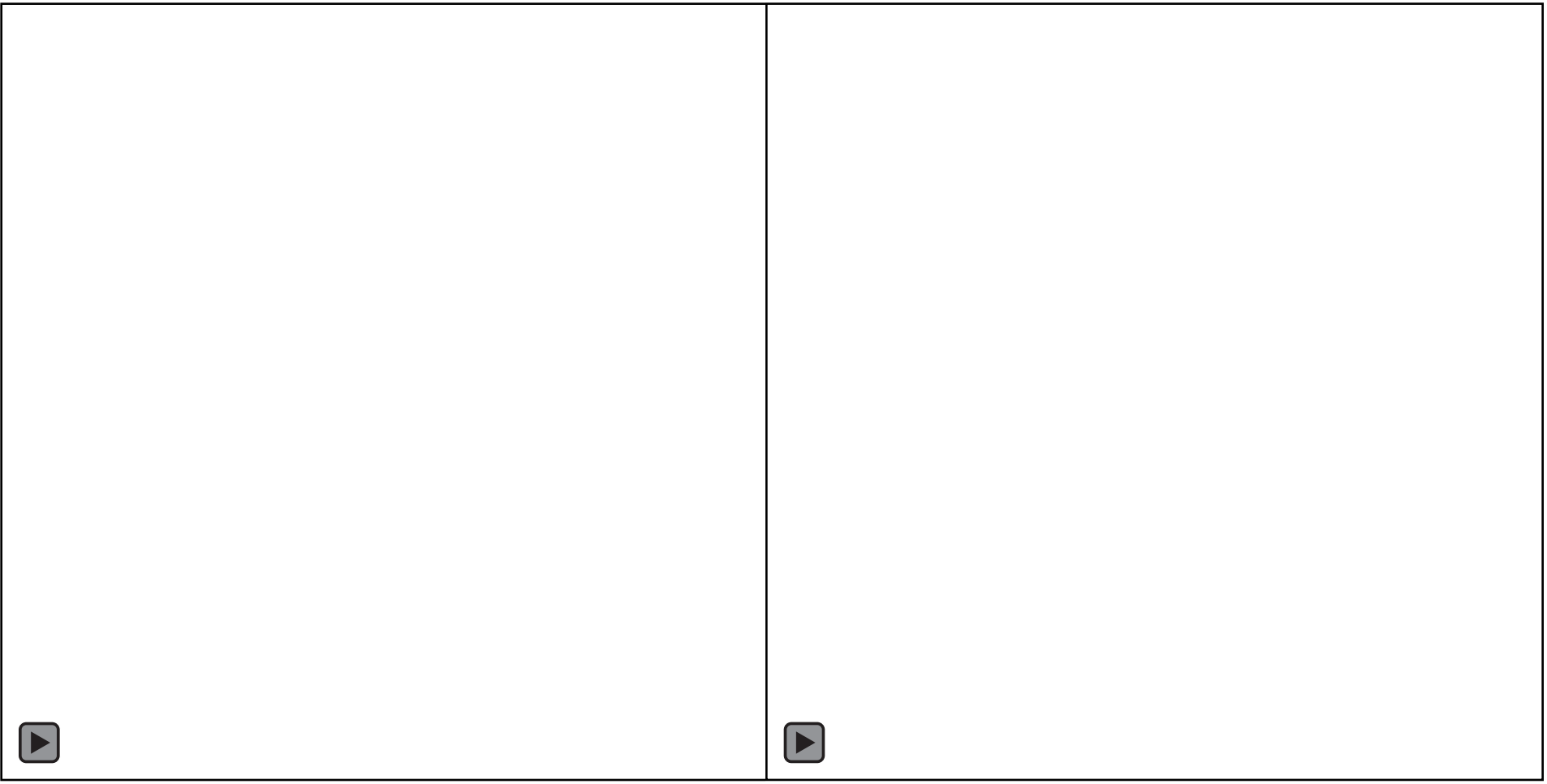
mating

mutation

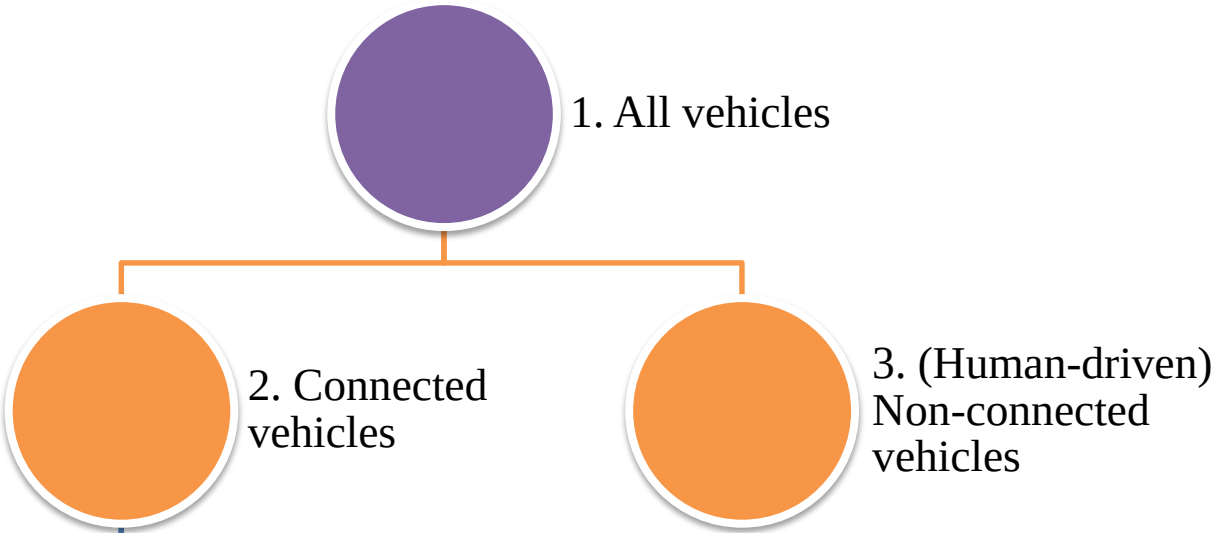
The CV-based control reduces queues and delays at the intersection

Fixed-time control

Flexible CAV algorithm

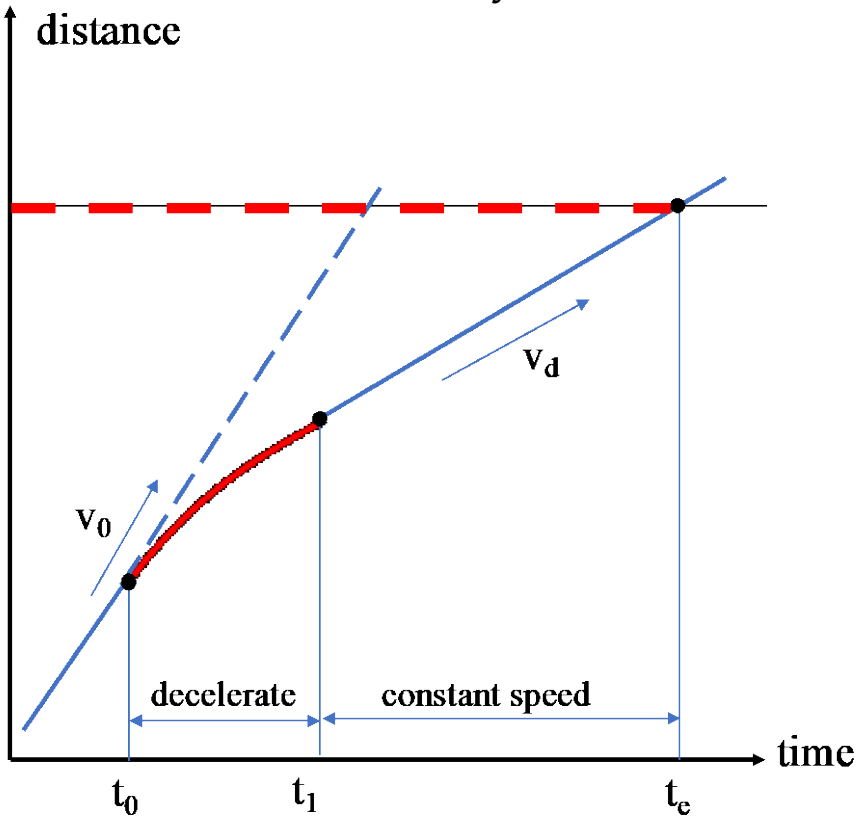


Algorithm can also leverage various vehicle types/technologies to further improve operations

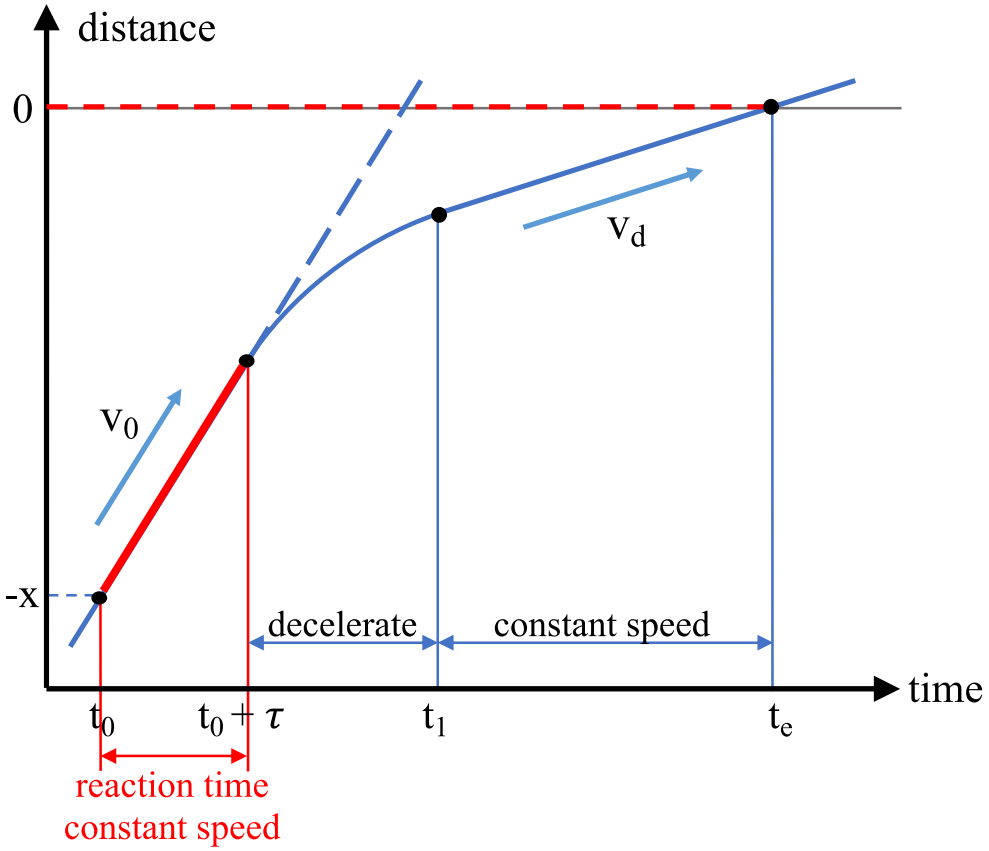


Speed guidance can be provided to help vehicles arrive to intersection only when they can discharge

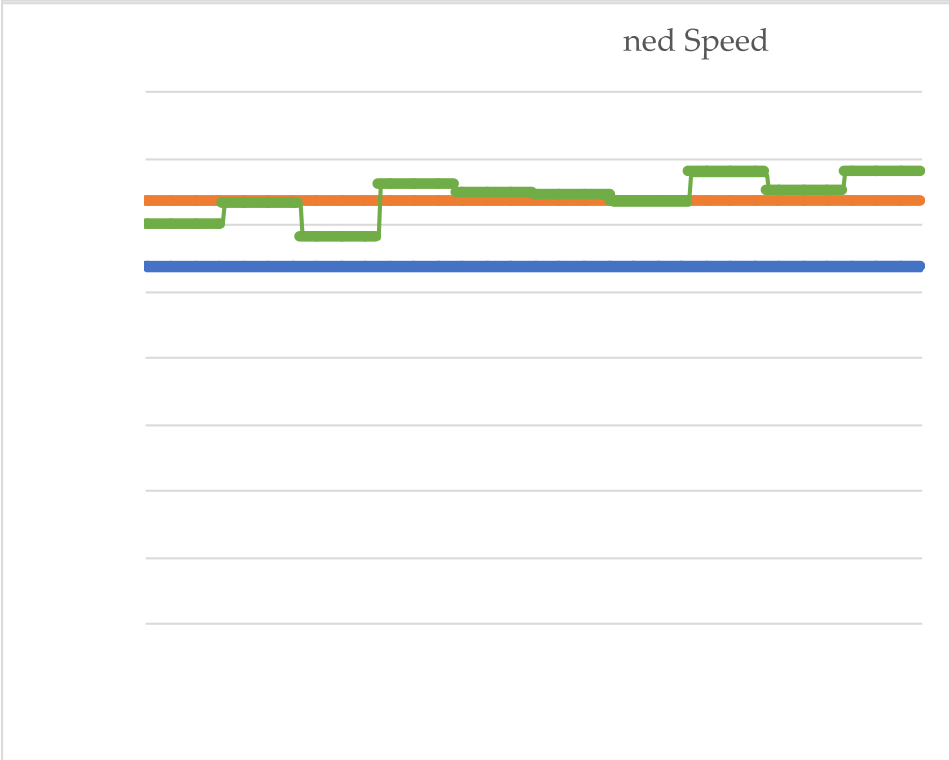
Autonomous vehicles
React instantly



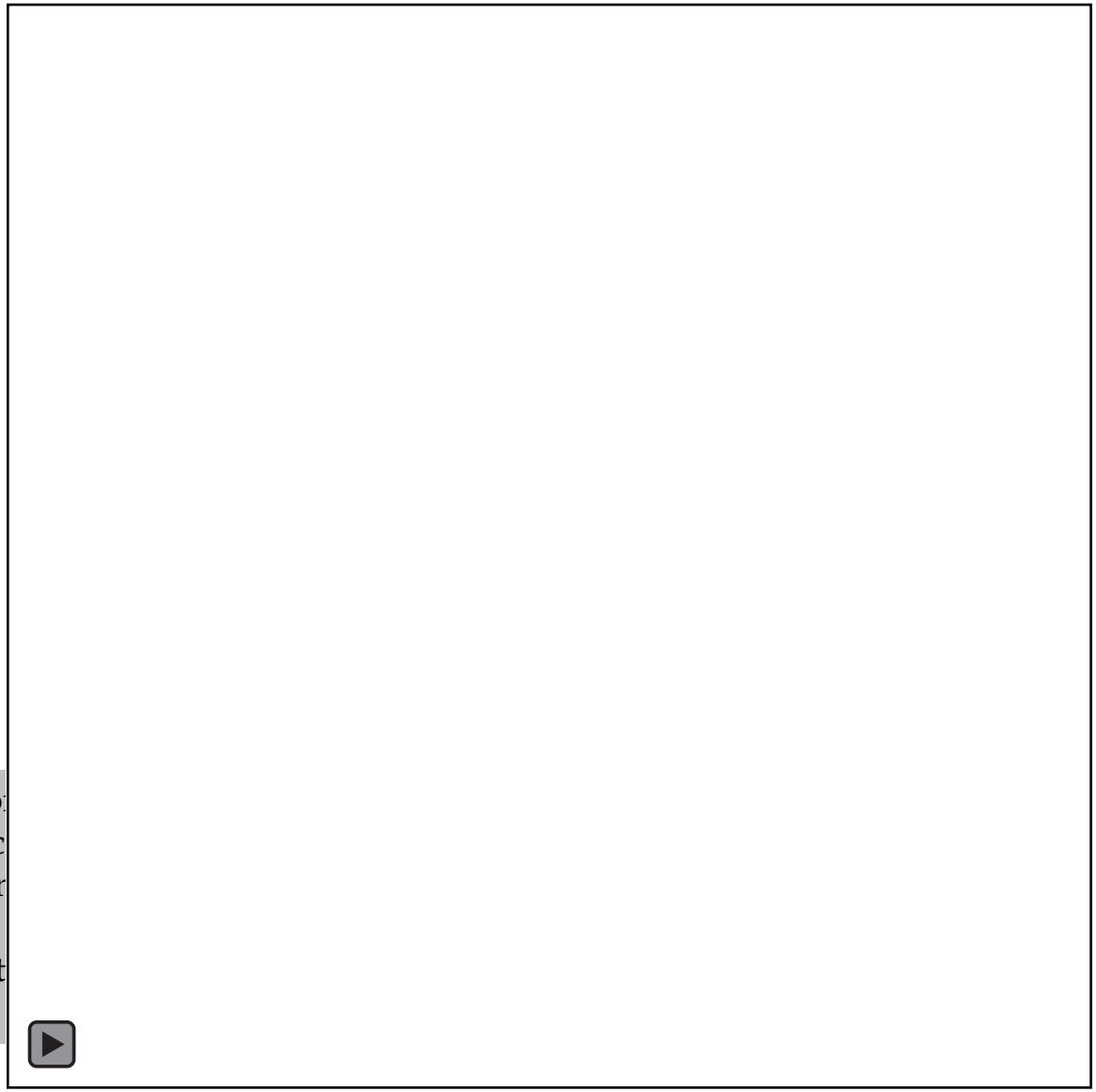
Human-driven vehicles
incorporates reaction time



Simulation accounts for human drivers willingness and ability to adhere to provided speed guidance



Provision of speed guidance reduces number of stopping maneuvers performed



Dark blue: autono
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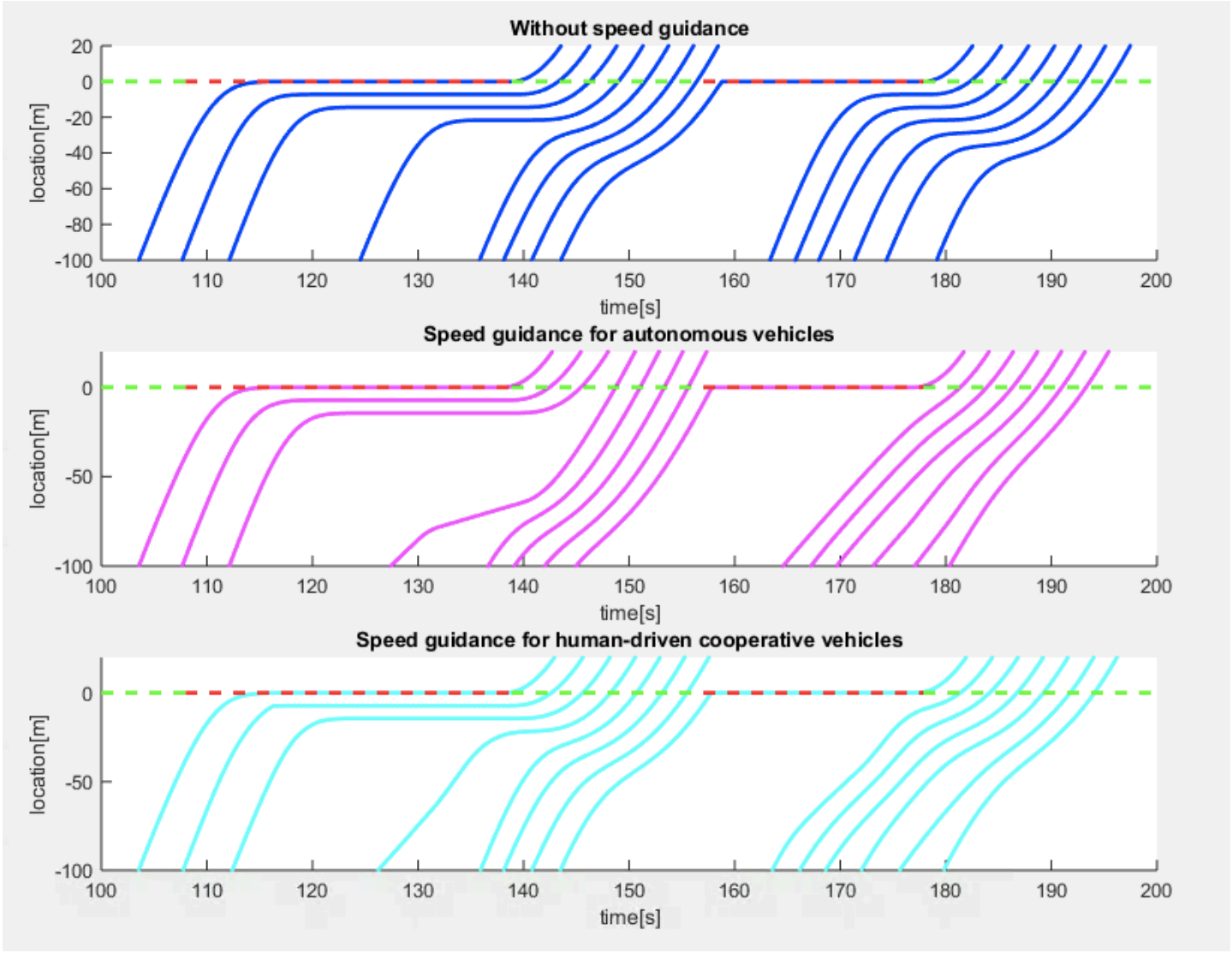
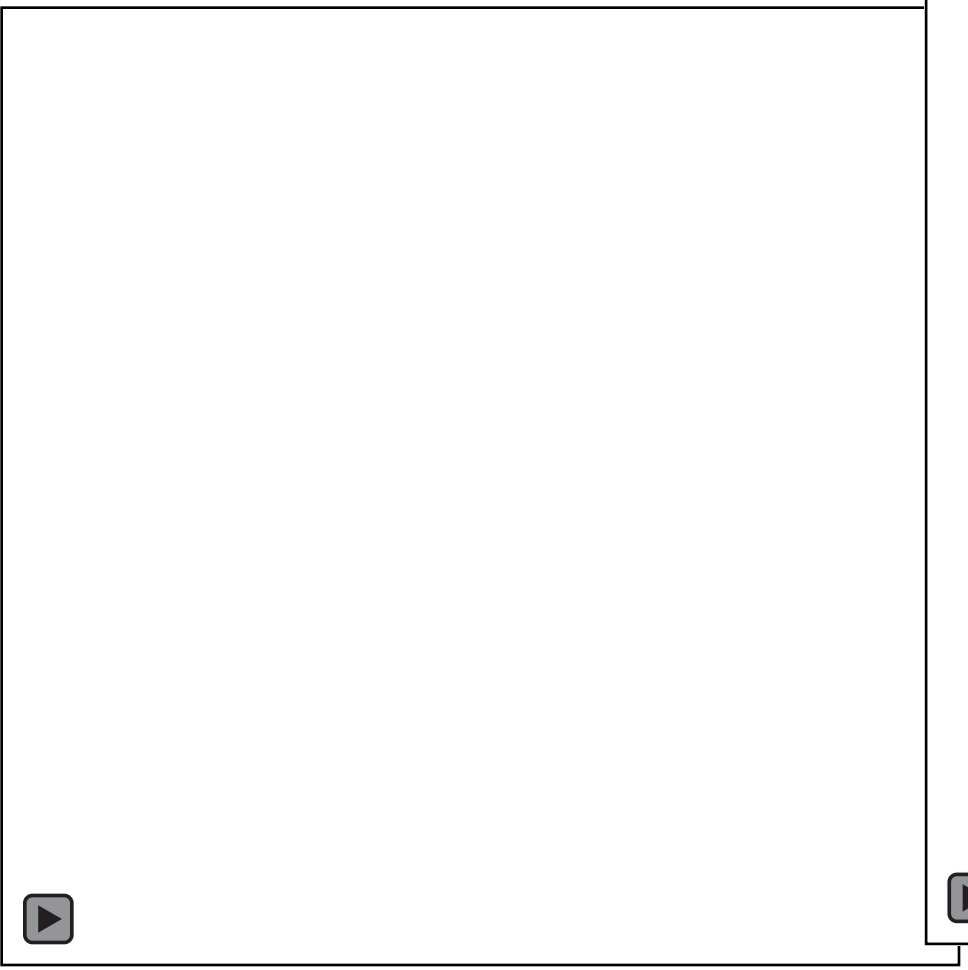
Analysis of trajectories verifies that speed guidance to human vehicles performs slightly worse than to AVs

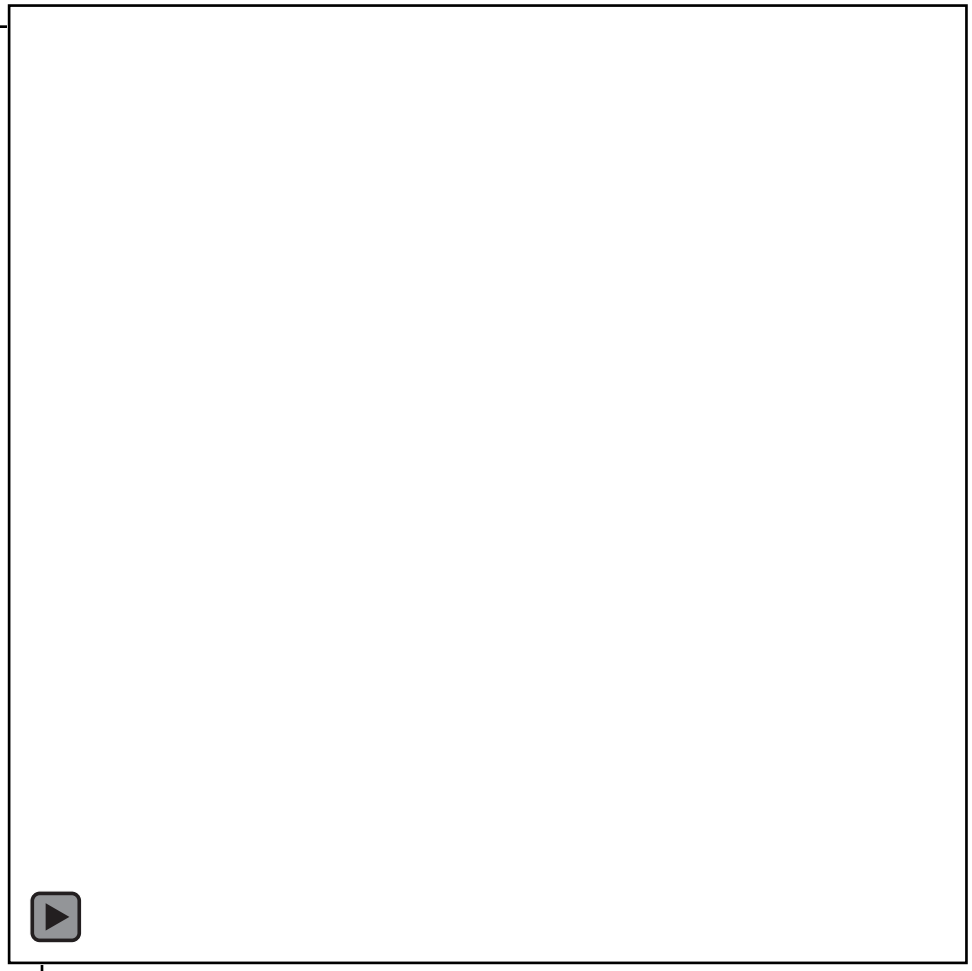


When AVs are present, intersection operates even more efficiently…

Fixed-time control

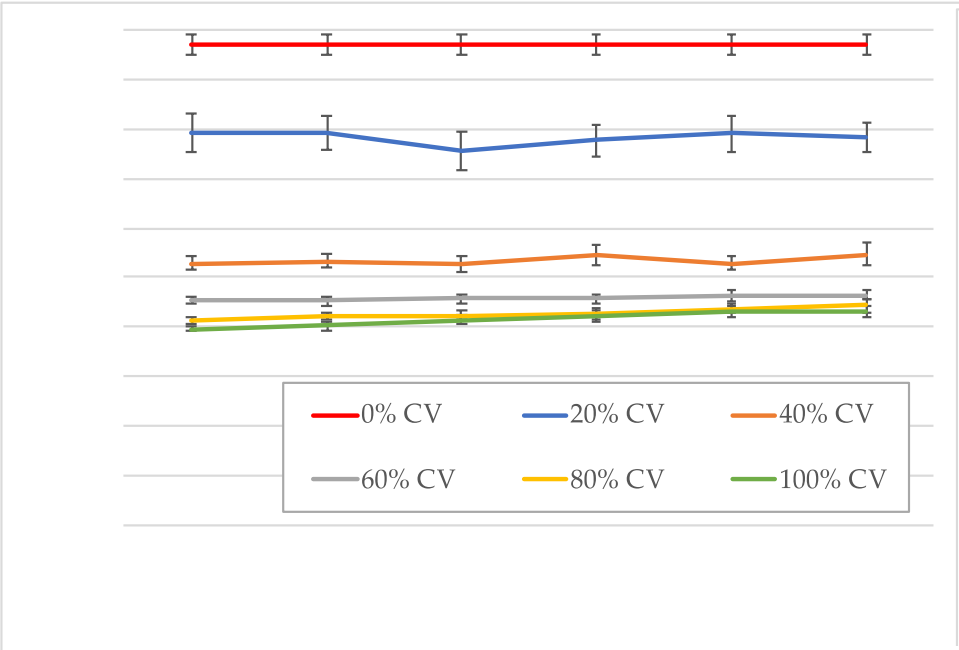


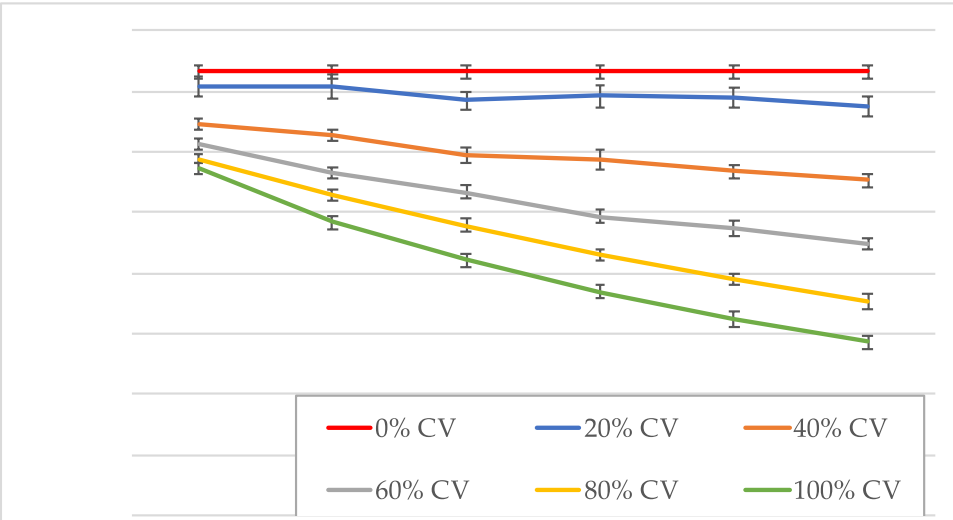
Algorithm with AVs



Results suggest both vehicular delay and number of stops can be reduced using CV-based control…

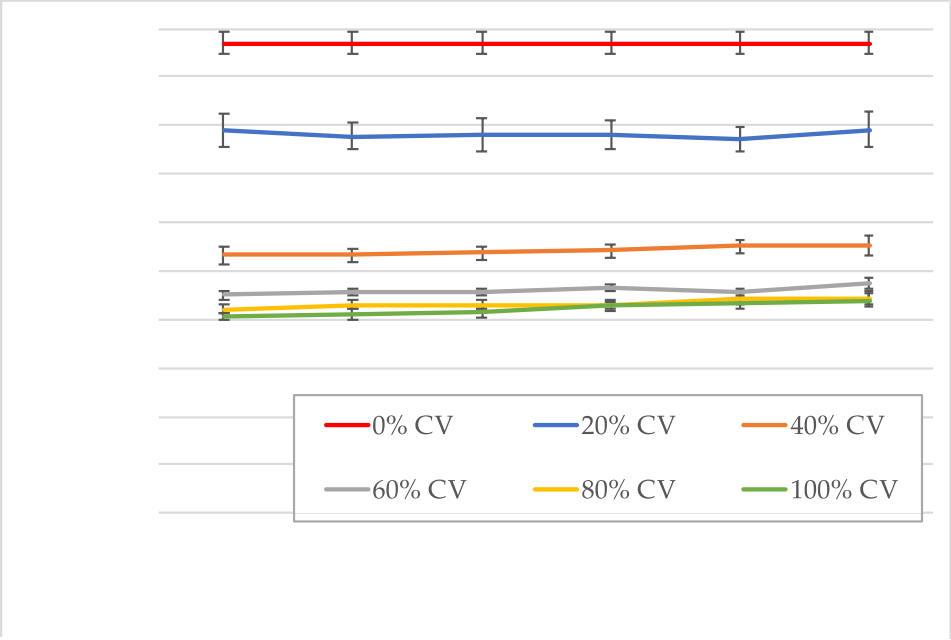
- 0% AVs

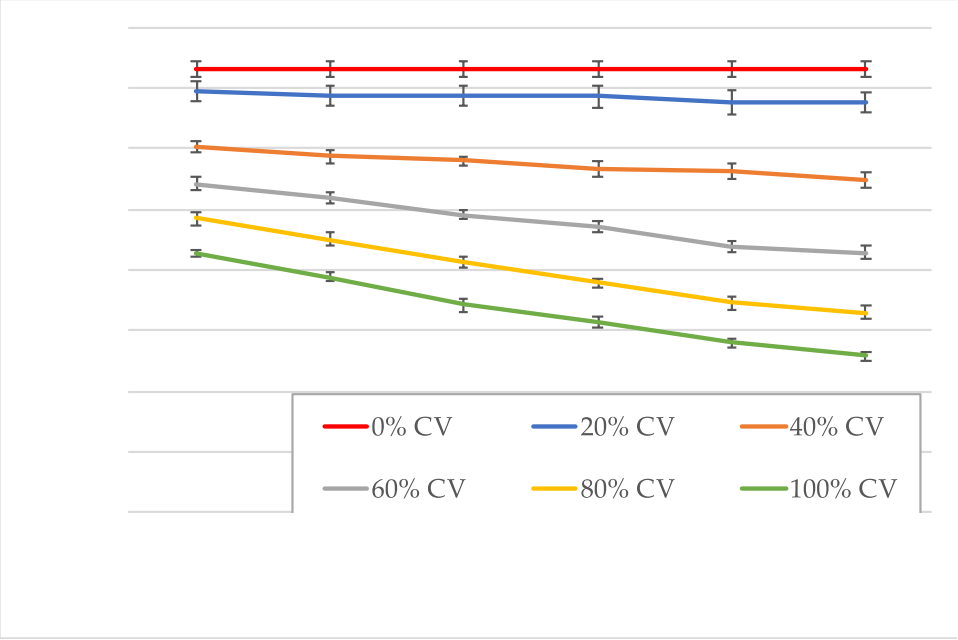




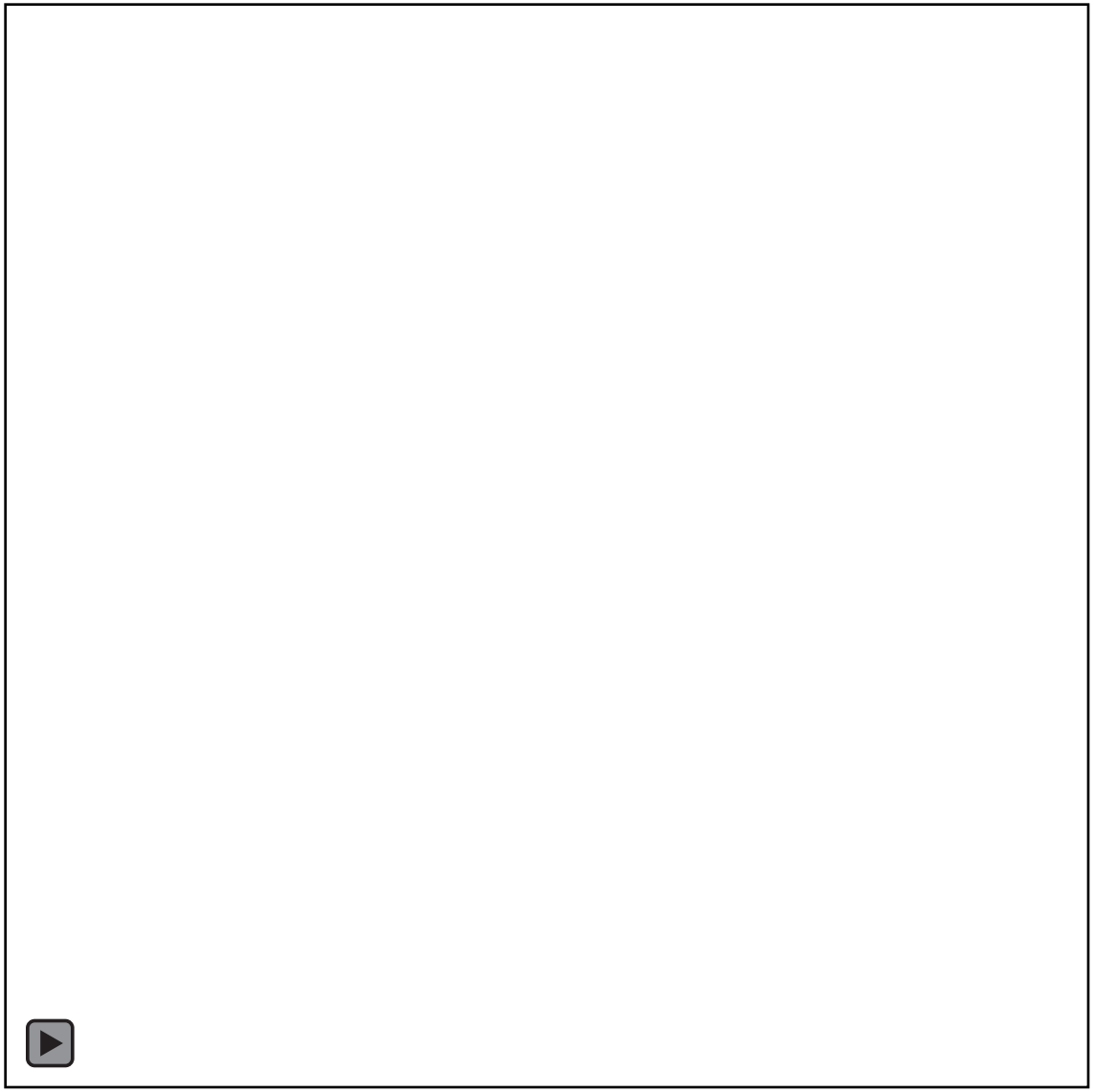
…and the benefits only improve as vehicles become autonomous

- 20% AVs





Current work focuses on adding multimodal traffic, such as pedestrians…



Thank you!

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