San Diego State University

Traffic Operations with Connected and Automated Vehicles

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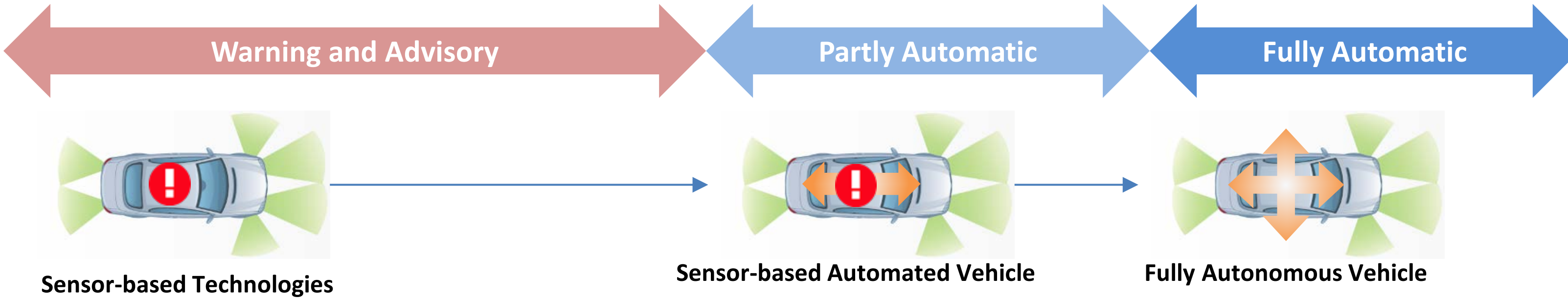
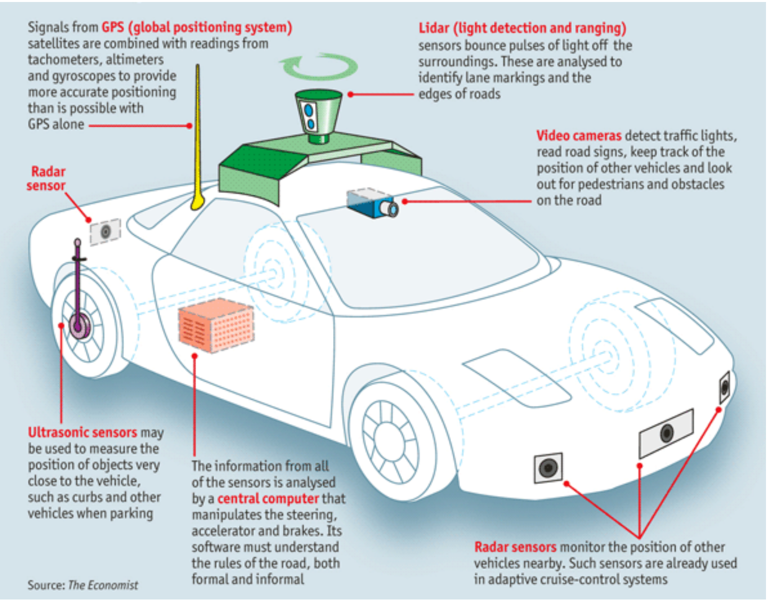
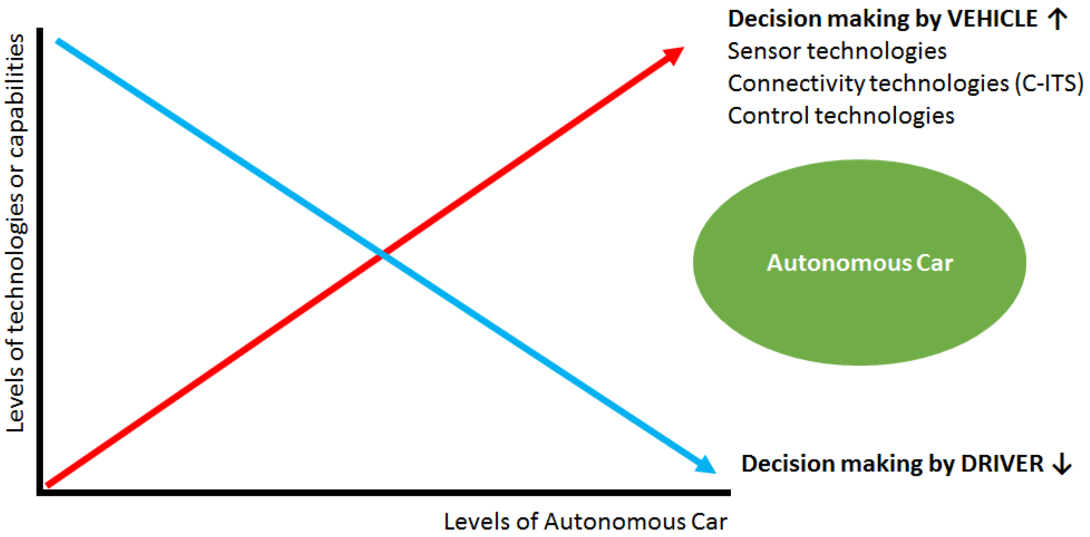
This is a FUTURE CAR

- Automotive control
- Lane changing warning and control
- Self driving
- Vehicle platooning
- Forward collision avoidance
- Providing optimal path
- ECO-Approach and departure at intersections
- Dynamic speed Harmonization
- Advanced traveler information
- Queue warning
- Etc.

Automated Vehicles

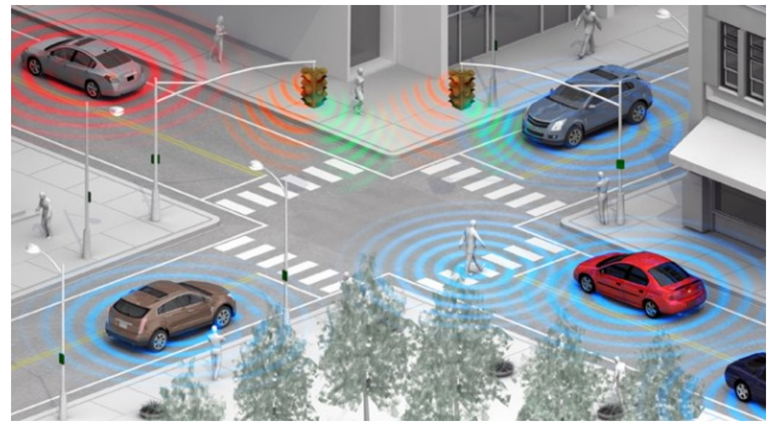


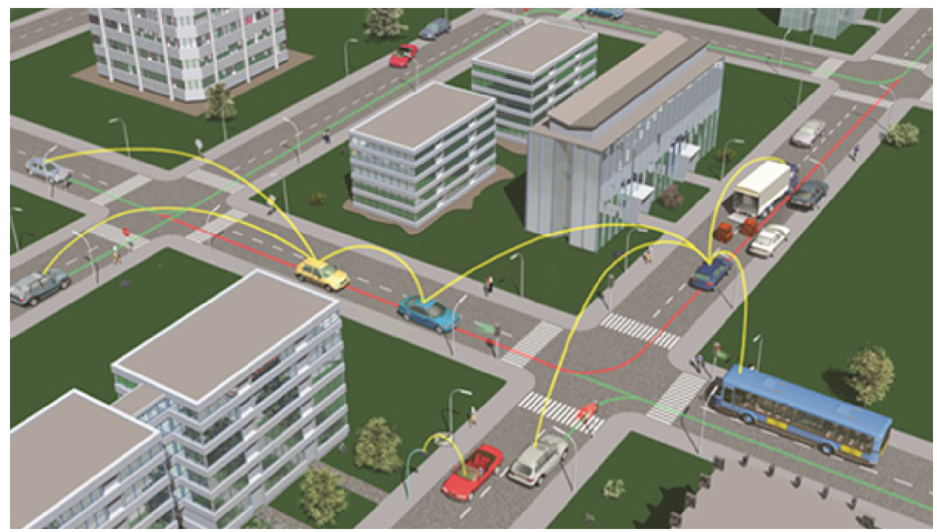




Connected Vehicle

- Connectivity technologies
  - DSRC
  - WAVE
  - 3G / 4G
  - DMB
- Communication types
  - V2X : V2V, V2I, V2P, V2B……
  - Car2X
  - Etc.





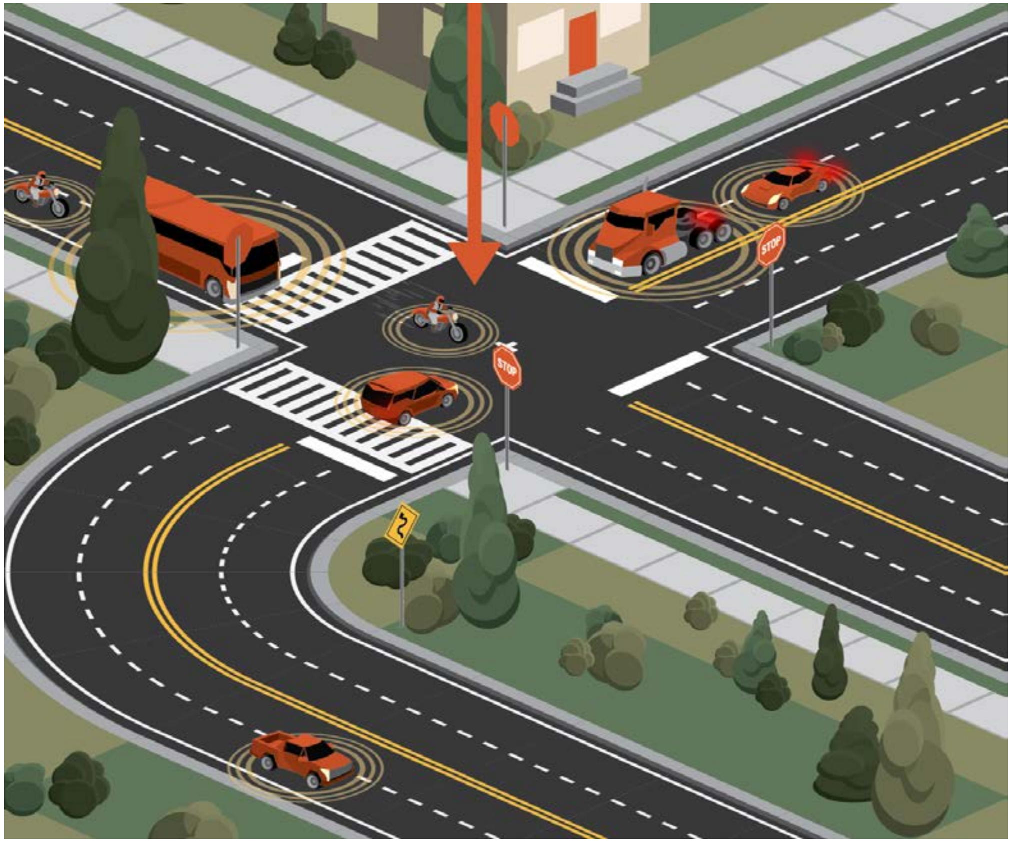
Connectivity Technologies (Connected Vehicle) → **Connected Automated Vehicle**

Why we need Connected Vehicle Technologies?

Why do we need CV technologies

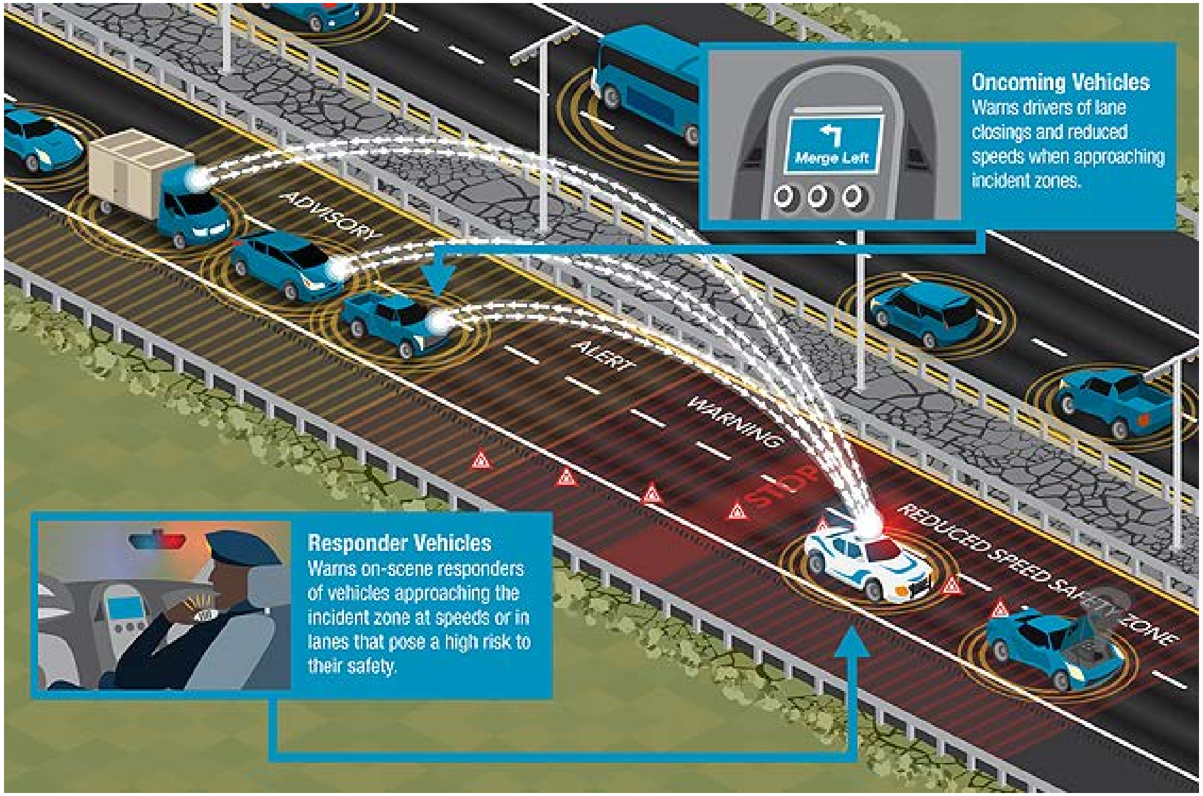
- Safety
  - Intersection Movement Assist

https://youtu.be/q58DzXQ8ae4?t=2m9s
https://youtu.be/2Ac2lgo7Opo?t=37s



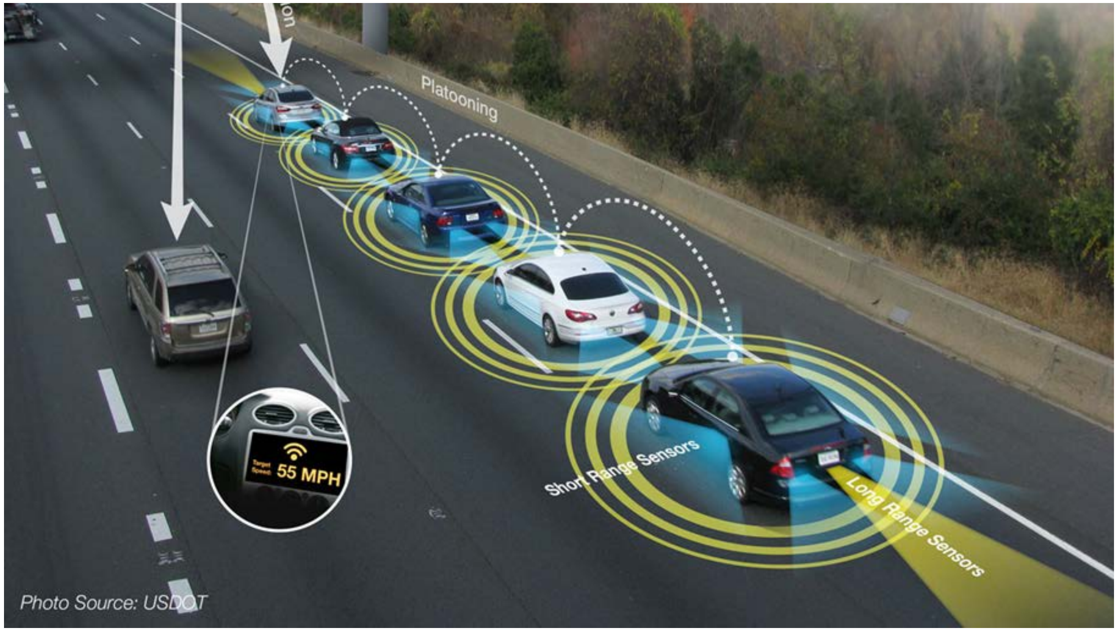
Why do we need CV technologies

- Mobility
  - R.E.S.C.U.M.E
    - Response, Emergency Staging and Communications, Uniform Management, and Evacuation



Why do we need CV technologies

- Mobility
  - Platooning



What will happen with AVs only?

- AVs are often designed with conservative control functions (Safety is always the priority).

- Within mixed traffic flow (AVs and non-AVs), AVs may become the “Moving Bottleneck” which will increase the total network delay and reduce safety performance.

- How about 100% AVs on the roads but without CV technologies?

Cooperative Adaptive Cruise Control

- Adaptive Cruise Control (ACC) technology automatically adjust the vehicle speed and distance to that of a target vehicle. ACC uses a long range radar sensor to detect a target vehicle up to 200 meters in front and automatically adjusts the ACC vehicle speed and gap accordingly.

- Adaptive cruise control (ACC) systems can gain enhanced performance by adding vehicle–vehicle wireless communication to provide additional information to augment range sensor data, leading to cooperative ACC (CACC).

CACC v.s. ACC

Fig. 1. Experimental M56s vehicles.

– Field Test

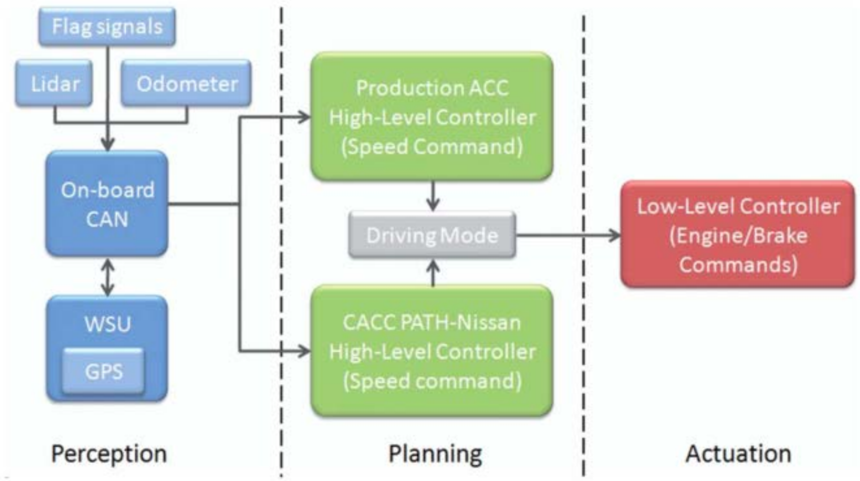
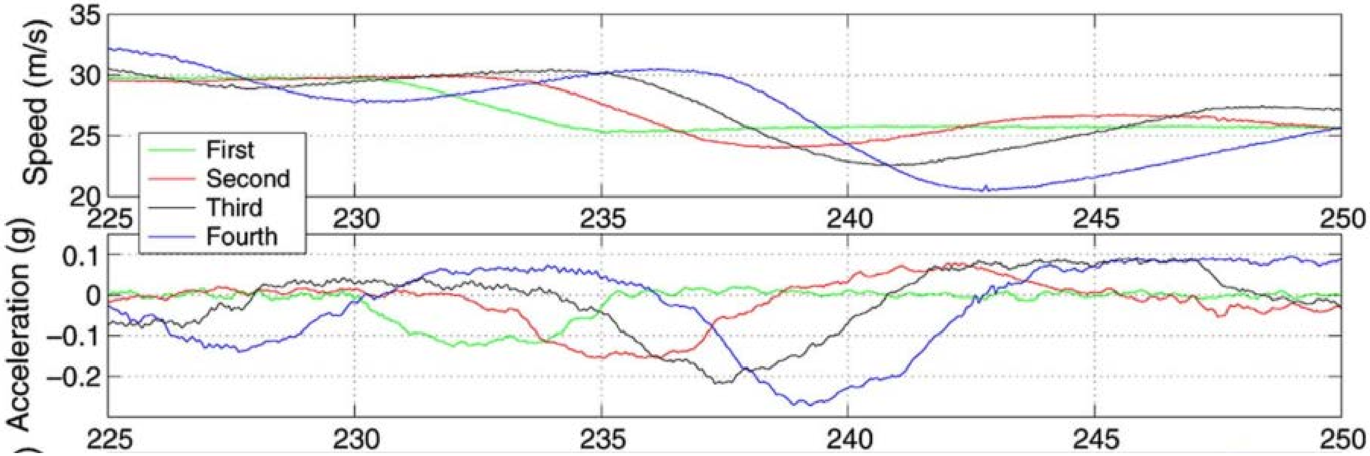


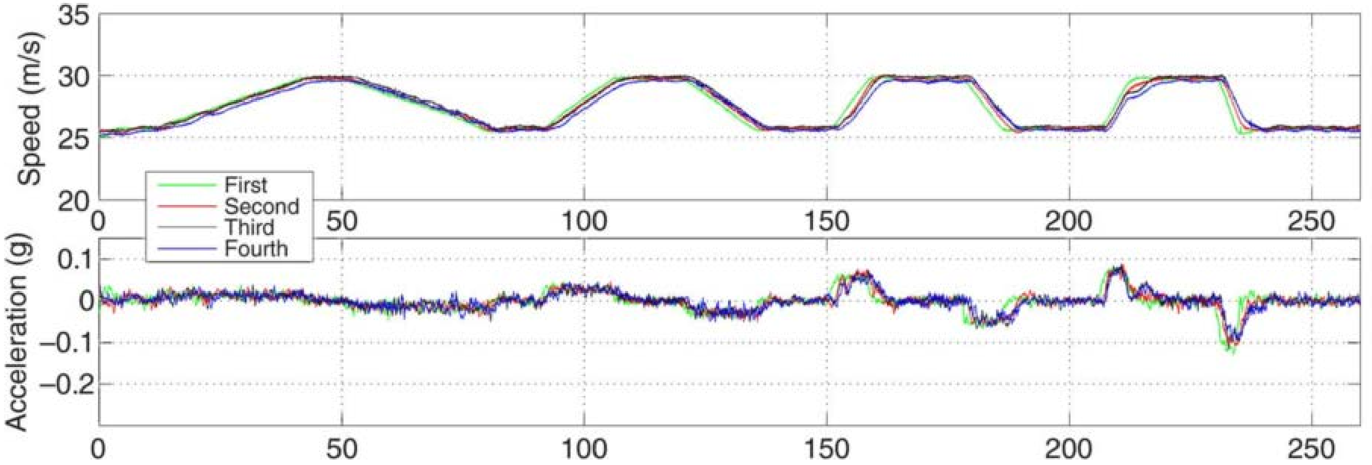
Fig. 2. Control architecture block diagram.

MILANÉS et al. (2014): COOPERATIVE ADAPTIVE CRUISE CONTROL IN REAL TRAFFIC SITUATIONS, IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, VOL. 15, NO. 1, pp. 296-305.

CACC v.s. ACC



ACC



CACC

How to make the CAV-based system more efficient? (e.g., Data Collection)

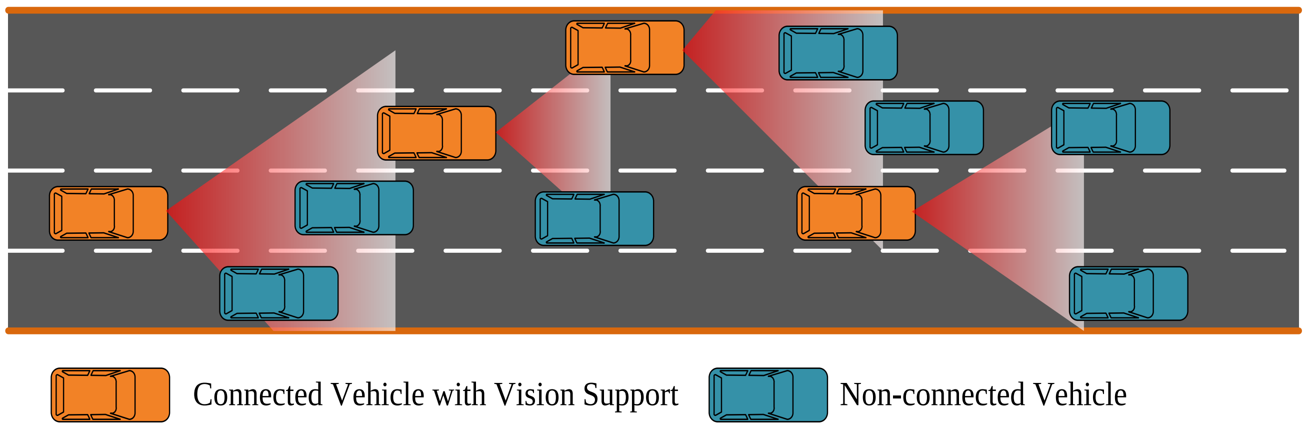
Motivations

- It is still challenging to deploy V2V system in practice, because connected vehicles need to share roads with other isolated (non-connected) vehicles;
- Camera sensors can provide rich imagery descriptions of the surrounding environments of the host vehicles;
- To access the traffic statuses of isolated vehicles, an effective but affordable way is to enhance V2V-equipped vehicles with camera sensors;

System Demonstration

- With camera on connected vehicles, the system will first conduct video processing and extract the information of perceived vehicles such as their speeds, locations, and driving behaviors;

- Through V2V platform, isolated vehicles are perceived and then linked with connected vehicles so as to form a dynamic Ad-Hoc Sensor Network which includes all vehicle information.



Field Demo Test

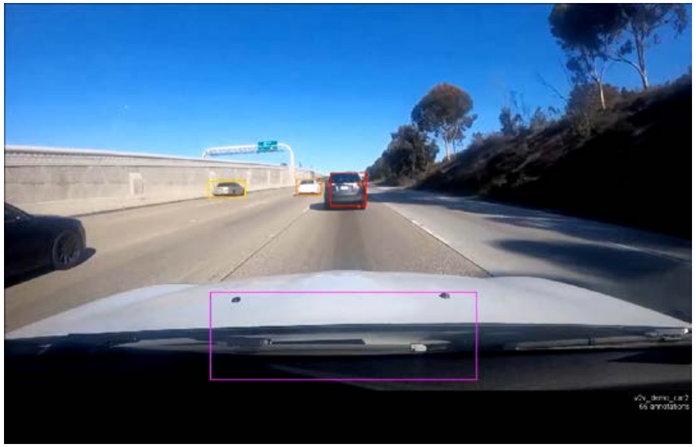
- Four vehicles equipped with camera sensors are tested on I-15, San Diego.

Step 1: Video Processing on each connected vehicle

Step 2: Construction of dynamic Ad-Hoc Sensor Network

Car D

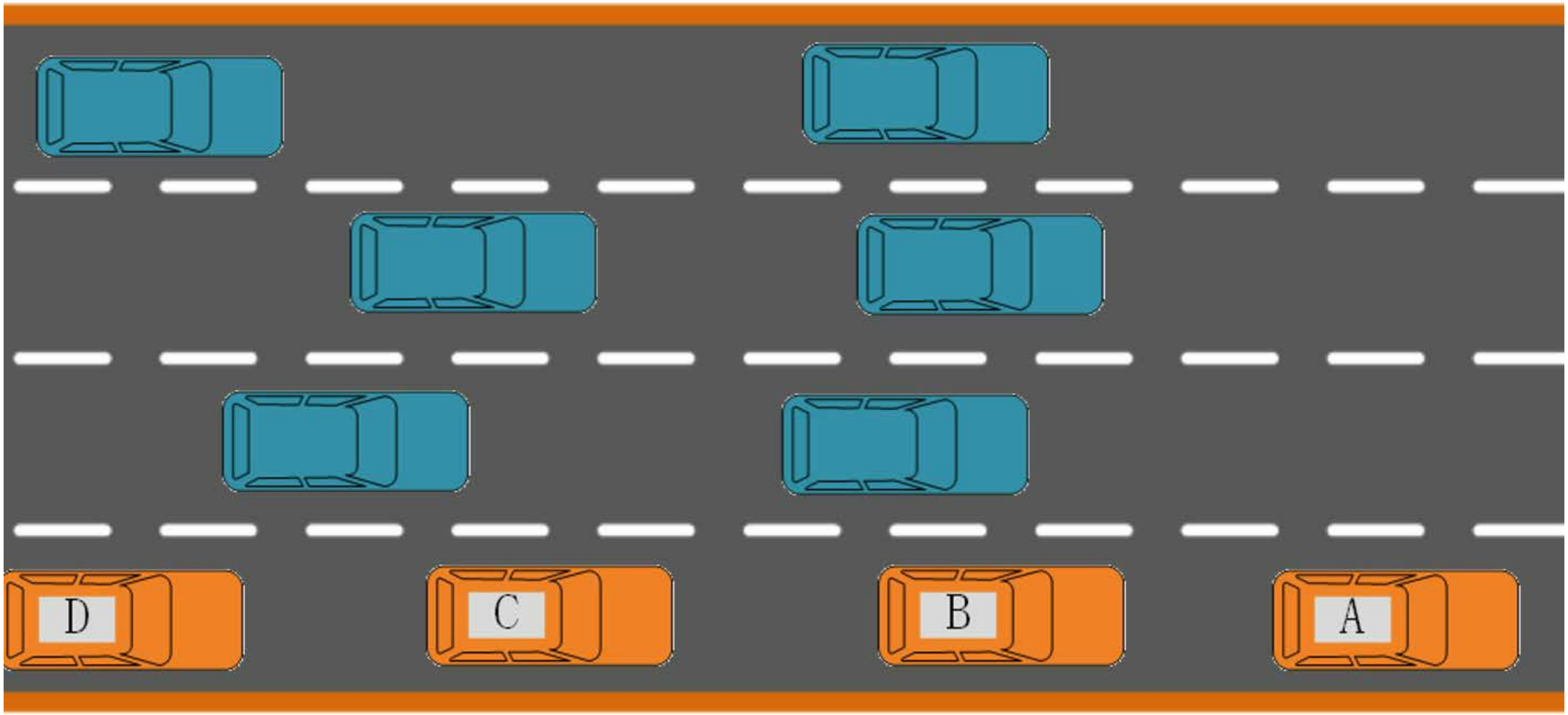
Car C



Car B

Car A

Step 2: Construction of dynamic Ad-Hoc Sensor Network



Traffic Signal Control at Intersections under CAV Environment

The fundamental questions

- **Will we even need traffic signals in the future?**
  - What happens when the volume increases?
  - Do we see emergent behavior that mimics traffic signals?

- **How will we transition during market adoption?**

CAV Traffic Signal Research Needs

- Categories of Research Needs -
  - Network Level Control Considerations
    - More than a collection of intersection, heterogeneous path flows, …
  - User capabilities/characteristics
    - Vehicle, Pedestrians, Trucks, Buses, Bicycles, Motorcycles,…
  - Institutional and Social Issues
    - Culture, cooperative behaviors
  - Traffic flow theory
    - Changes in vehicle behaviors (saturation flow, headway, acceleration, startup lost time, sneakers, …..)
  - Application scenarios
    - Managed Lanes for CAV, Multi Modal, integration of apps – speed harmonization, eco-driving, ….

CAV Traffic Signal Research Needs

- Control algorithms/strategies
  - Trajectory control, multi modal, priority, path based, vehicle dynamics,
- Human factors
  - Passenger/driver limits – acceleration, gaps, …
- Infrastructure adaptation
  - Geometric opportunities (change lane usage/assignment, move the stop bar,….)
- Evolution from today to next generation
  - Levels of Automation (Vehicle Automation, but for signals)
- Impact of shared mobility in traffic control
  - Large fleets of vehicles operating with a common goal
  - Transportation network service providers

Thanks for your attention

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