Case for Connected Autonomy and Implications for 5G Systems

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Question of connectivity

Do real-world autonomous vehicles need to be connected?

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Historical precedence

- There have been various conceptual approach toward driverless cars:
  - Smartification of roads/infrastructures
  - Smartification of vehicles
  - Combination of both

- Smartification of roads
  - California Partners for Advanced Transit and Highways (PATH) program, the “DEMO 97” program demonstrated the platooning of eight AVs guided by magnets embedded in the highway and coordinated with vehicle-to-vehicle (V2V).

Autonomous System

An “autonomous system” has the authority/capability to make decisions on its own.

According to the dictionary definition of autonomous systems, at the first glance, for many, “Connected Autonomous Vehicles” sounds like an oxymoron!

But, can autonomous vehicles actually operate without **interaction (i.e., Communications)** with their environment?

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Autonomous Vehicles – Key Functions

1. Where am I (positioning of ego-vehicle)?

2. What are the objects around me (perception)?

3. What should I do next (control)?

Even most radical opponents of CAVs do not object that all the above functions require some form Communication (passive or active) with the outside entities. The controversial questions is whether active communication can play a bigger role?

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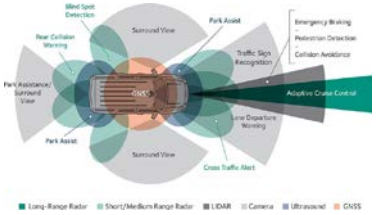
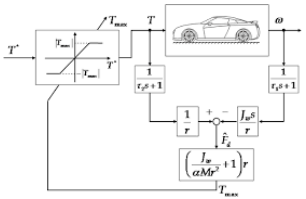
Generic Implementation of Autonomous Function

Sensing



Perception (own state and environment)

Control



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Implemenation Localisation and Perception

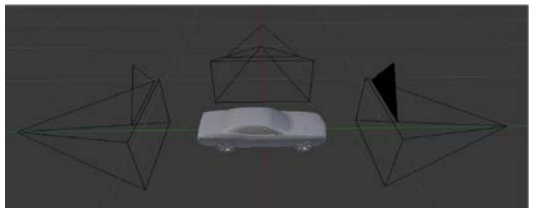
Observation

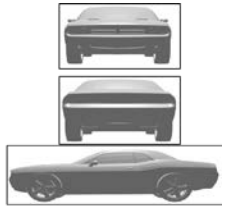
Estimation (semantically called perception)

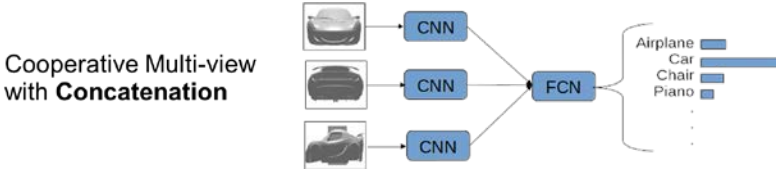
It is known from estimation theory that the accuracy of estimation algorithms significantly improves when the number of independent observations.

Example: Cooperative object classification

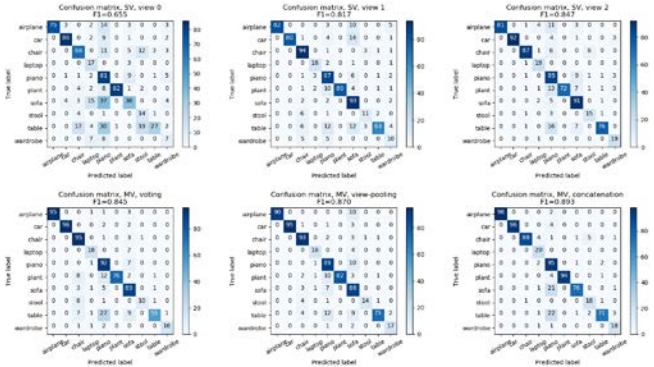
- Comparison of the performance of cooperative perception with the state of the art demonstrate very promising results on synthetic data





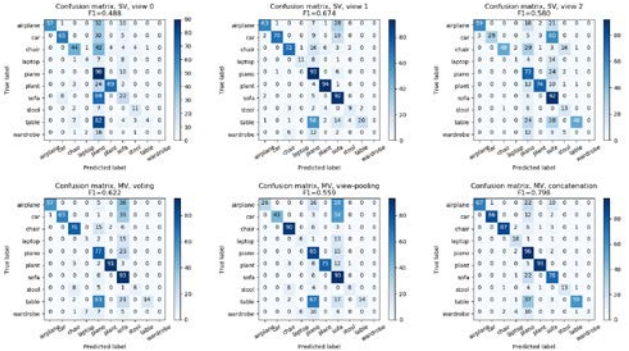


Experiment 1



Cooperative performance Improvement: ~15%

Experiment 2



Cooperative performance Improvement: ~37%

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Control

Safe and efficient control requires not only passive sensing, but also interactive communications (for example for coordination with other road users (Predictive Control).

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Addressing the Misconception

Connected/Cooperative Autonomy
IS NOT about control of ego-system from the outside.

Connected/Cooperative Autonomy
Is mainly about creating platforms and frameworks for autonomous vehicles to assist each other and benefit from the support of infrastructures to significantly improve accuracy of sensing, quality of perception and robustness of autonomous control.

The right question is perhaps, what level and horizon of communications is sufficient/helpful for autonomous vehicles?

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Performance of Existing Technologies (1)

Nominal Performance of Existing Technologies

Feature	IEEE 802.11p	WiFi	UMTS	LTE
Bit Rate	3-27 Mbps	6-54 Mbps	2 Mbps	Up to 300 Mbps
Latency	10ms	10ms	50-100ms	10ms
Setup Time	0	3-5 seconds	100ms up to seconds	50 – 100ms
Coverage	Intermittent	Intermittent	Ubiquitous	Ubiquitous
Mobility Support	Medium	Low	High	Very High
V2V Broadcast	Native	Native	Through server	Through server
I2V Broadcast	Native	Native	MBMS	eMBMS

Performance of Existing Technologies (2)

- Existing wireless communication technologies demonstrate a nominal latency in the range of 5-10ms in load free conditions excluding service setup time and hand-off delay.

- The average latency in moderately loaded conditions is reported to be about 1s for 802.11p and 200ms for LTE networks with the spikes of well above 1-2s.

Implications for Communication Systems

Connected Autonomy Aspect

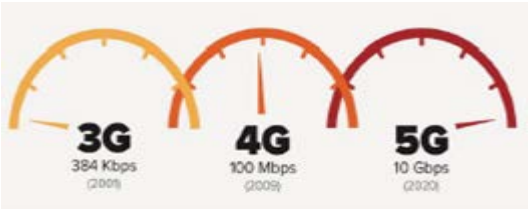
Enabling Cooperative Driving

Supporting Perception Systems

Figure source: Qualcomm

Supporting Cooperative Sensing

Technical requirements



Capacity

Low Latency
High Reliability

Good Coverage

Constraints

Cost Effective

Environment Friendly

Safe/Secure

Thank you for your kind attention.

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