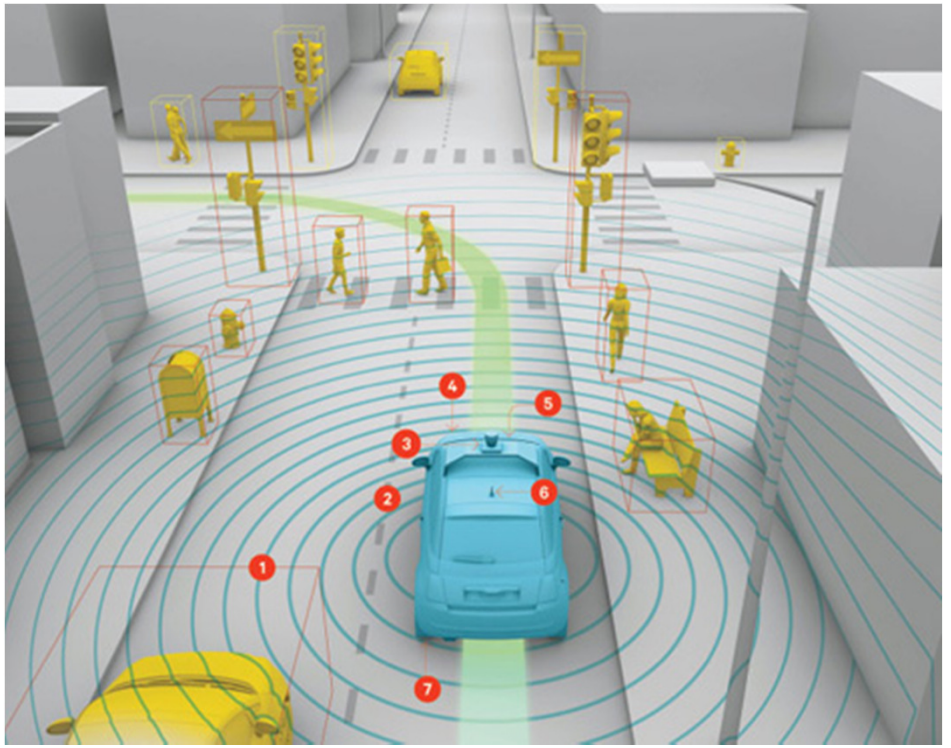

Autonomous Driving

by

Wael Farag

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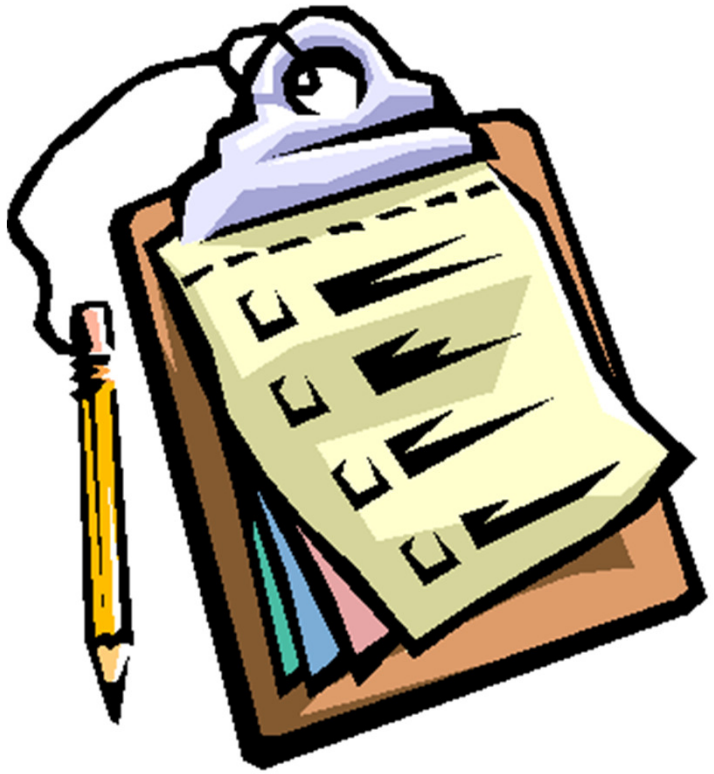
Outline

Goal: to spot light on the technological, market and research trends of Autonomous Driving.



- **What is Autonomous Driving?**
- **Why Autonomous Driving?**
- **Technological Trends.**
- **Market Trends.**
- **Obstacles.**
- **Challenges / Research Opportunities.**
- **Demo Videos**
- **Q & A**

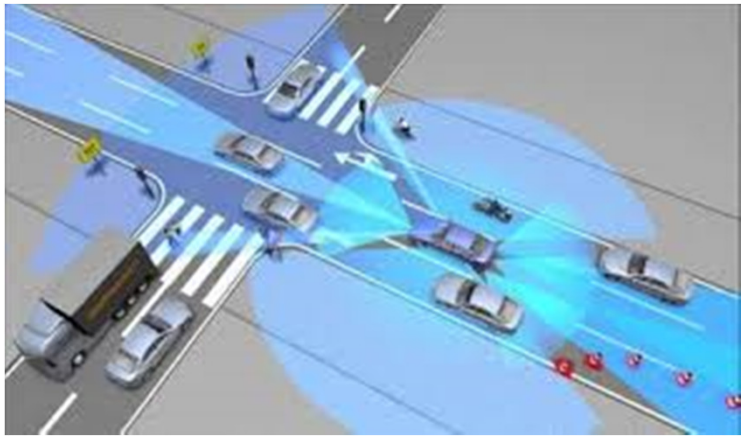
What is Autonomous Driving?

- Driverless Car / Self-driving Car / Robot Car.
- It is a fully automated vehicle capable of fulfilling the main transportation capabilities of a traditional car.
- It is capable of sensing its environment and navigating without human input.

Junior, a robotic Volkswagen Passat, at Stanford University in October 2009.

Why Autonomous Driving? (1)

- Fewer traffic collisions, due to an autonomous system's increased reliability and faster reaction time compared to human drivers.
- Increased roadway capacity and reduced traffic congestion due to reduced need for safety gaps and the ability to better manage traffic flow.
- Relief of vehicle occupants from driving and navigation chores.
- Higher speed limit for autonomous cars.



Why Autonomous Driving? (2)

- Alleviation of parking scarcity, as cars could drop off passengers, park far away where space is not scarce, and return as needed to pick up passengers.
- Reduction of physical space required for vehicle parking.
- Elimination of redundant passengers.
- Reduction in the need for traffic police and vehicle insurance.
- Smoother ride, more comfort.
- Reduction in car theft, due to the vehicle's self-awareness.
- Autonomous car follows highways speed limit better than human drivers.

Why Autonomous Driving? (3)

Predictions:-

- By 2016, Mercedes plans to introduce "Autobahn Pilot", the system allows hands-free highway driving with autonomous overtaking of other vehicles.
- By 2016, Mobileye expects to release hands-free driving technology for highways.
- By 2018, Mobileye expects autonomous capabilities for country roads and city traffic.
- By 2018, Nissan anticipates to have a feature that can allow the vehicle manoeuver its way on multi-lane highways.
- By 2020, Volvo envisions having cars in which passengers would be immune from injuries. Volvo also claims vehicles will effectively be "crash free".

Why Autonomous Driving? (4)

- **Predictions**:-

- By 2020, GM, Mercedes-Benz, Audi, Nissan, BMW, Renault, Tesla Motors and Google all expect to sell vehicles that can drive themselves at least part of the time.

- By 2024, Jaguar expects to release an autonomous car.

- By 2025, Daimler and Ford expect autonomous vehicles on the market.

- By 2032, ABI Research forecasts 10 million new autonomous cars would be rolling out on to US public highways every year.

- By 2040, expert members of IEEE have estimated that up to 75% of all vehicles will be autonomous.

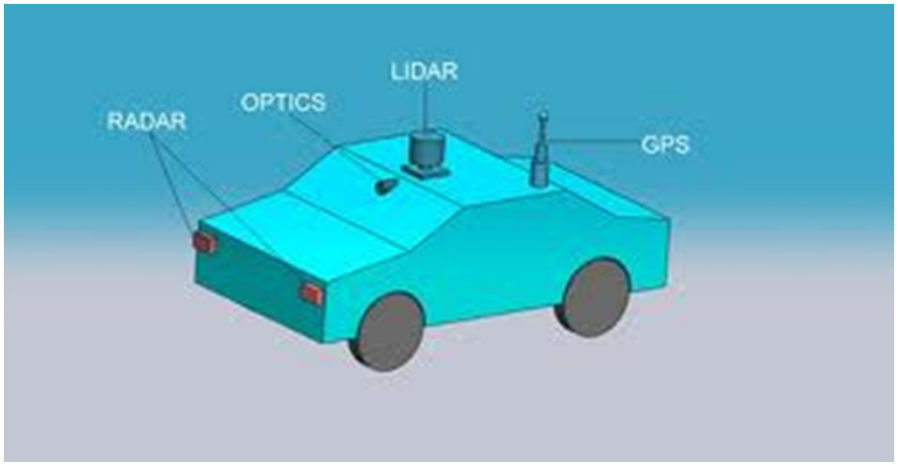
Why Autonomous Driving? (5)

Perspectives:-

- Columbia University's The Earth Institute forecasts the reduction of United States' fleet of vehicles by a factor of 10.
- PricewaterhouseCoopers forecasts a reduction of traffic accidents by a factor of 10 and it concludes that the fleet of vehicles in the United States may collapse from 245 million to just 2.4 million.
- Morgan Stanley estimates that autonomous cars could save the United States $1.3 trillion annually by lowering fuel consumption ($169 billion), reducing crash costs ($488 billion) and boosting productivity ($645 billion).

Technological Trends (1)

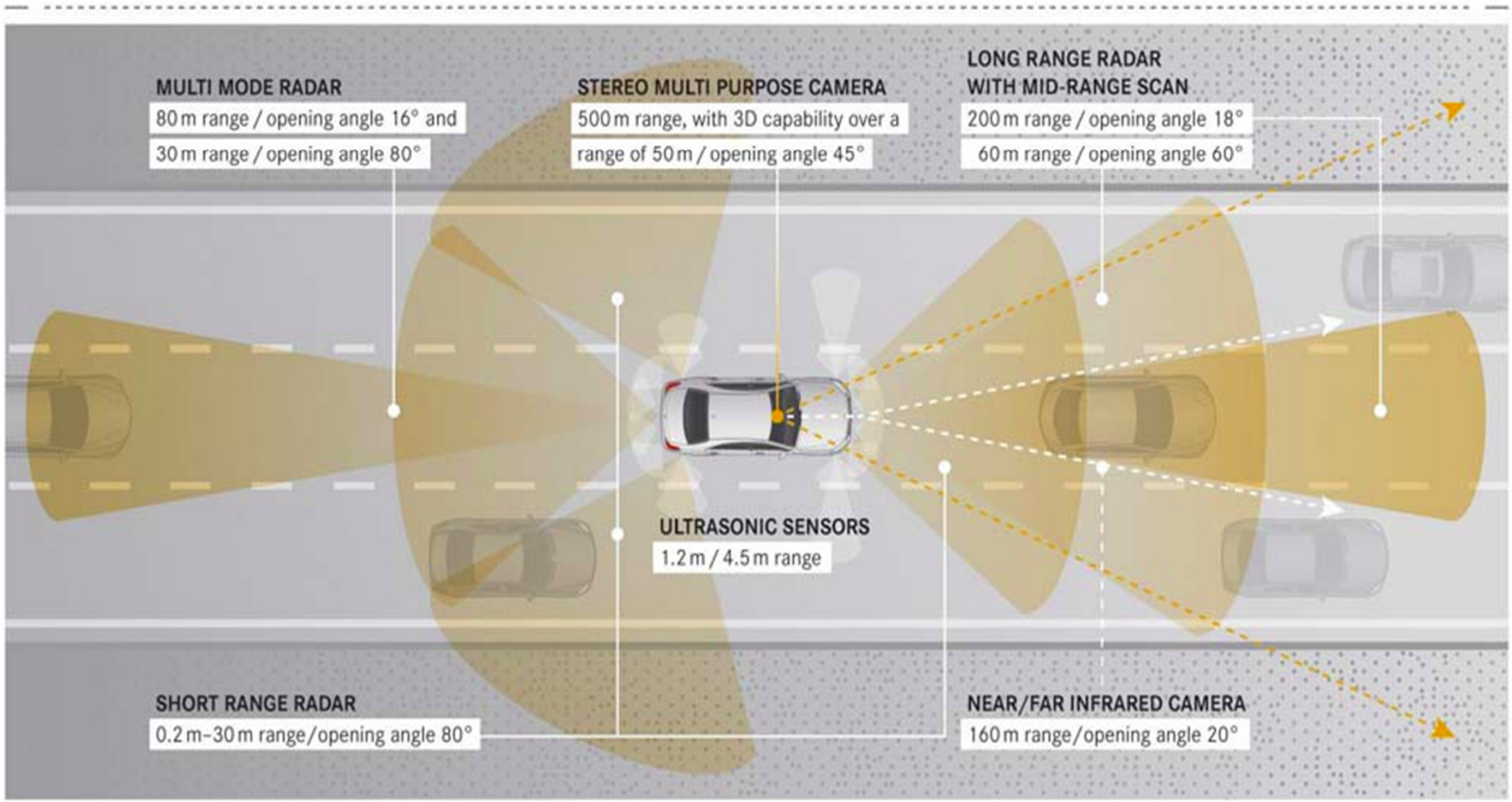
- Autonomous vehicles sense their surroundings with such techniques as radar, lidar, ultrasonic, GPS, and computer vision.
- Advanced control systems interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage.
- Autonomous vehicles are capable of updating their maps based on sensory input, allowing the vehicles to keep track of their position even when conditions change or when they enter uncharted environments.



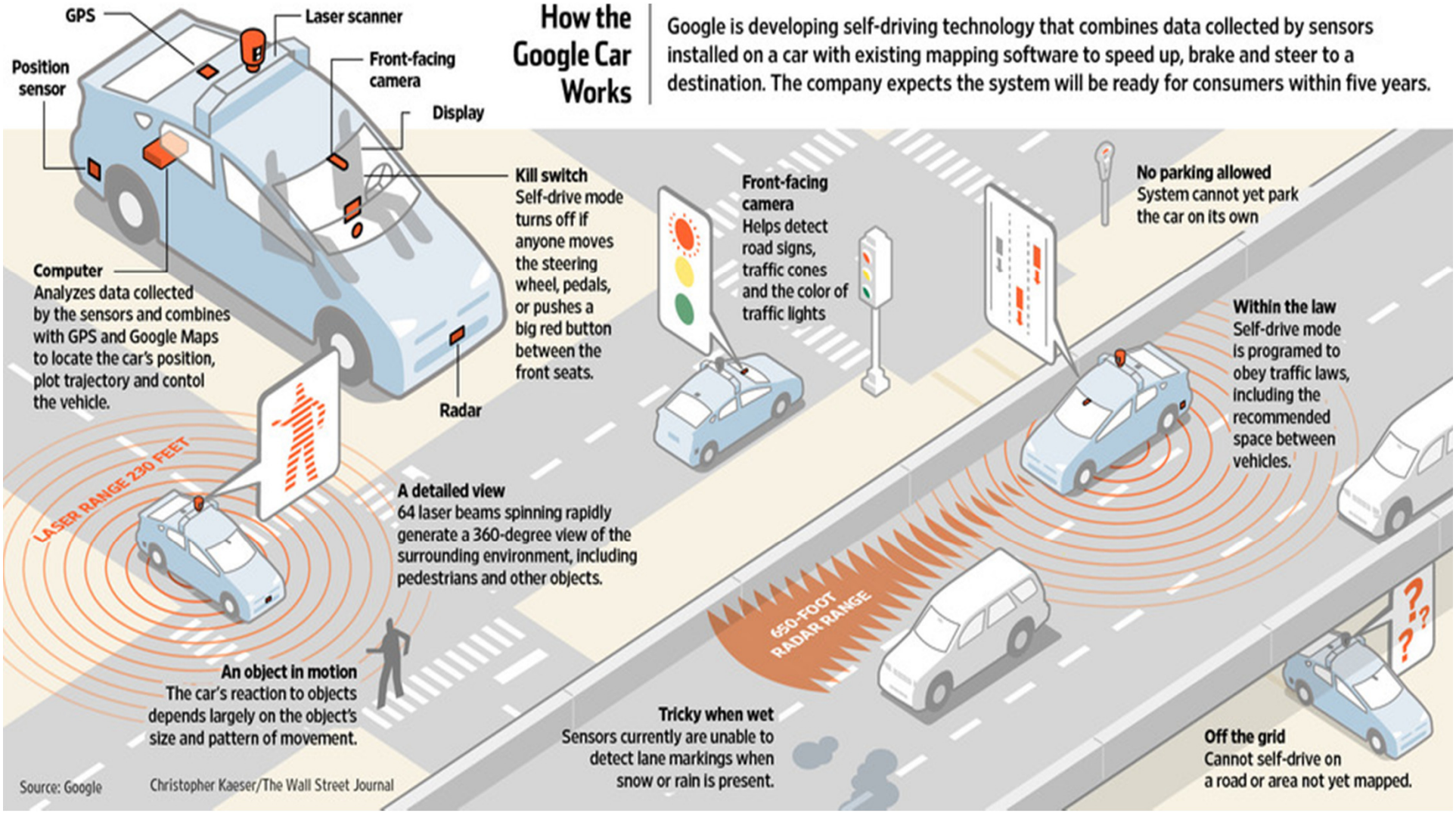
Technological Trends (2)

Radar, stereo camera and ultrasonic systems

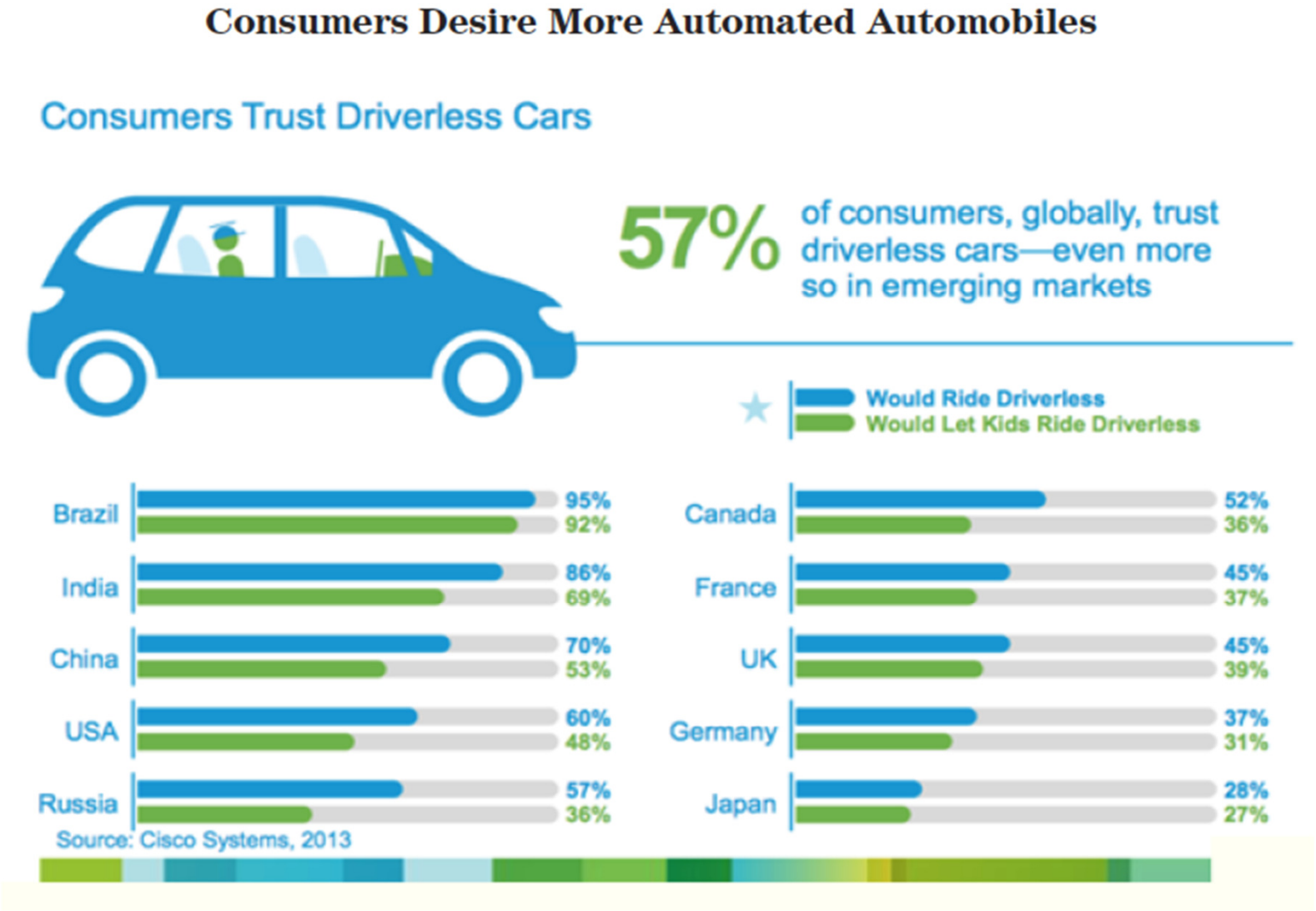
More sensors – more protection



Technological Trends (3)



Market Trend (1)

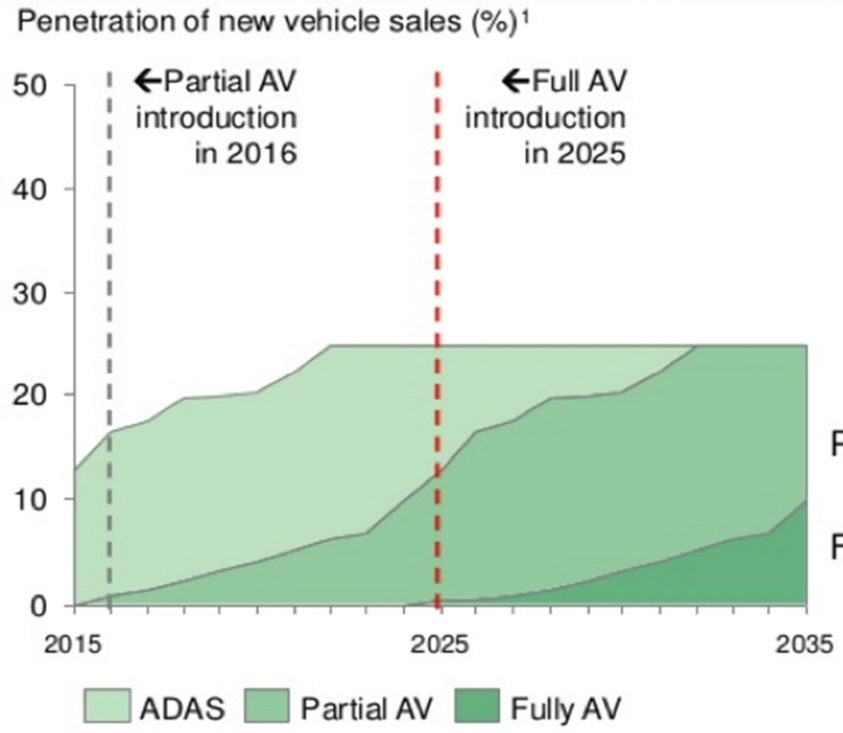


Market Trend (2)

By 2035, 12 million full AV units could be sold a year globally

Market for partial and full AV features expected to grow from ~$42B in 2025 to ~$77B in 2035

In 2035, 25% of market to be AV sales with 15% partial and 10% full AV systems



Represents 12M full AVs and ~18M partial; ~$77B market for AV features in 2035

	2025 global sales			2035 global sales		
	Share (%)	Volume (M)	Sales[3] ($B)	Share (%)	Volume (M)	Sales[3] ($B)
	Estimated global new light vehicle sales: ~111M[2]			*Estimated global new light vehicle sales: ~122M[2]*		
Partial	12.4%	13.9	36	15.0%	18.4	38
Full	0.5%	0.6	6	9.8%	12.0	39
Total			$42bn			$77bn

Obstacles (1)

- Current road infrastructure may need changes for autonomous cars to function optimally. Like traffic and street light upgrades that communicate with autonomous vehicles.
- Liability for damage.
- Implementation of legal framework and establishment of government regulations for self-driving cars.
- Loss of driving-related jobs.

Challenges / Research Opportunities (1)

- **Research in Sensor Technology**:-

- Lowering the cost of sophisticated sensors (e.g. long range radar ~ 1000 US$, Cameras ~ 500 US$).

- Combining different types of sensors readings to eliminate error accumulation and increase accuracy.

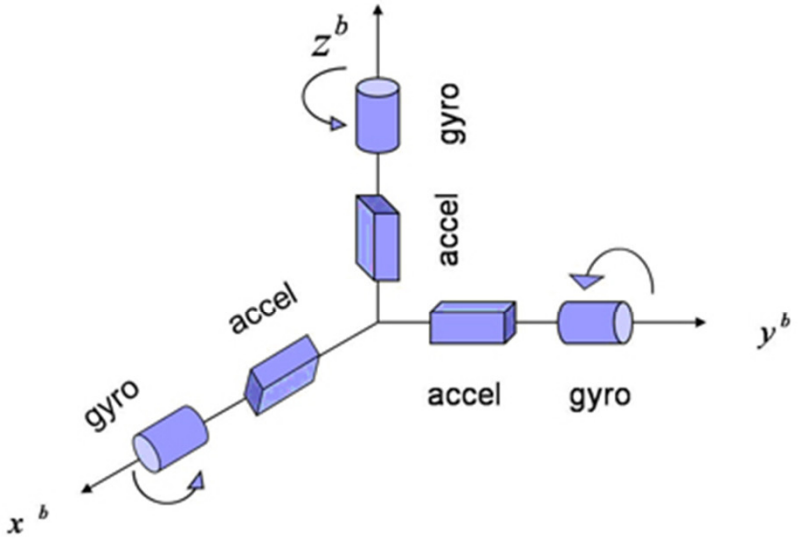
- Investigating new ways of using camera data (real-time image processing?).

Challenges / Research Opportunities (2)

- **Research in Sensor Technology**:-

  - Investigating the Inertial measurement units (IMU) in measuring acceleration and rotation combined with GPS signals.

  - Spinning LIDAR sensor mounted on top of the roof - Velodyne sensor used on the first Google Car ~ $70,000.



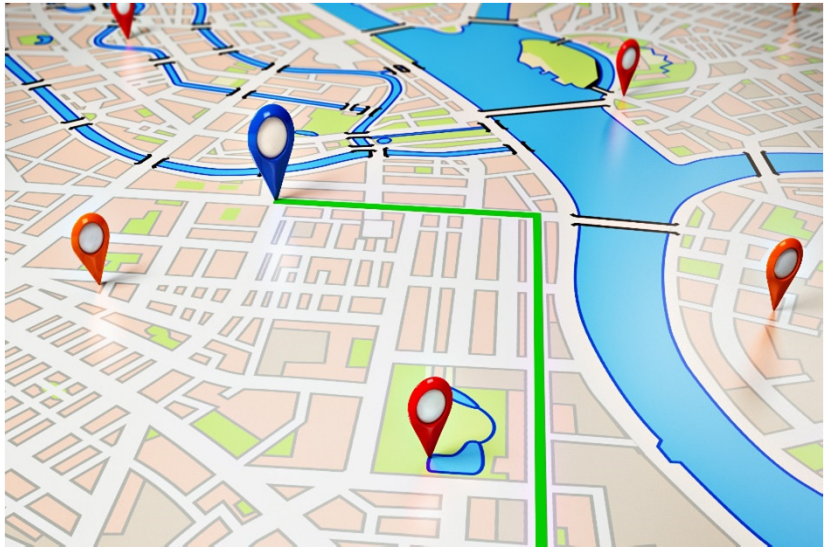
Inertial Measurement Unit
3 accelerometers, 3 gyroscopes

Challenges / Research Opportunities (3)

- **Research in Sensor Technology (cont.)**:-

  - Dedicated Short Range Communication (DSRC) transceivers at 5.9 GHz to receive information about surrounding vehicles as well as from the infrastructure.

  - Digital Maps are essential components of on-road autonomous vehicles and allow navigation planning activities to occur.

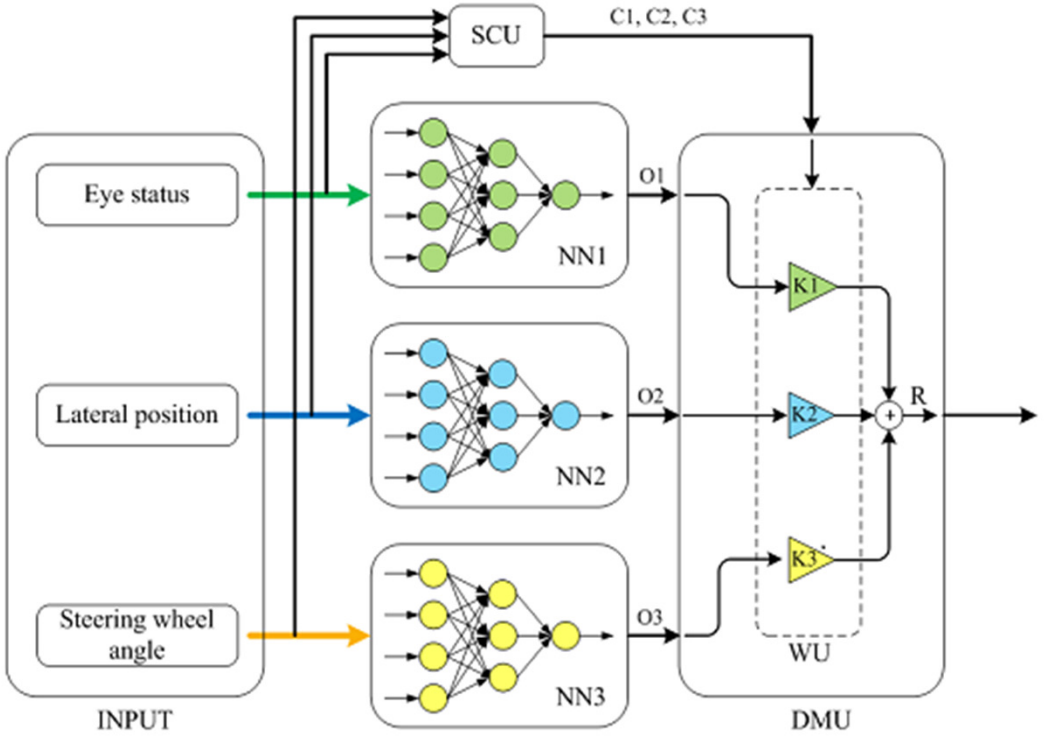


Challenges / Research Opportunities (4)

- **Research in Localization**:-

  - Data fusion is a cornerstone of multi-sensor localization systems.

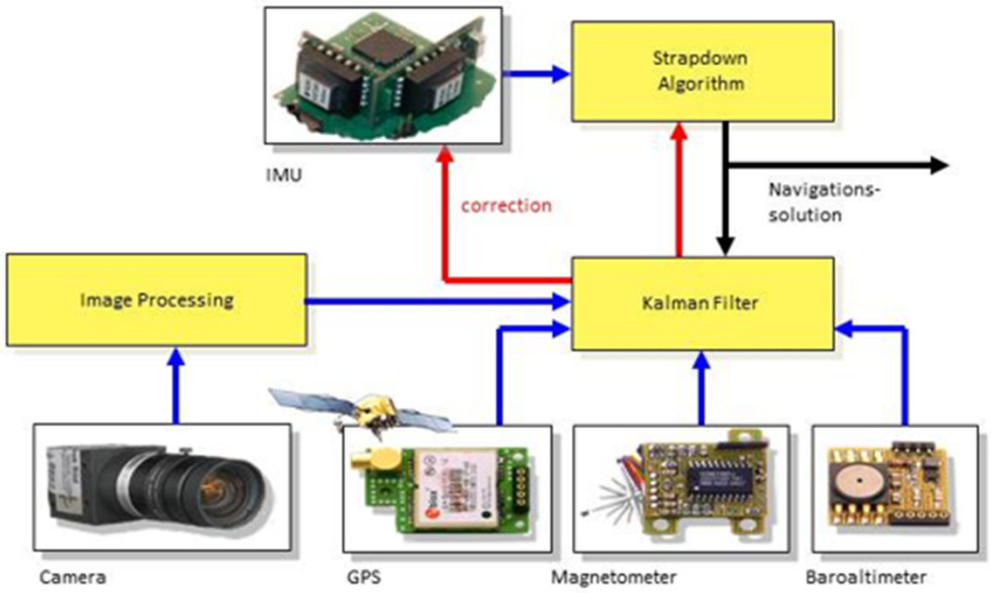
  - The problem is that each sensor has its own unique kind of noise, its own calibration settings, and its own distinctive fault modes.



Challenges / Research Opportunities (5)

Research in Localization:-

- An effective data fusion strategy checks for consistency, recognizing when one sensor is in an error state.
- Using techniques that are able to deal with noisy and uncertain measurements, effective localization is possible (*Kalman Filters*?)



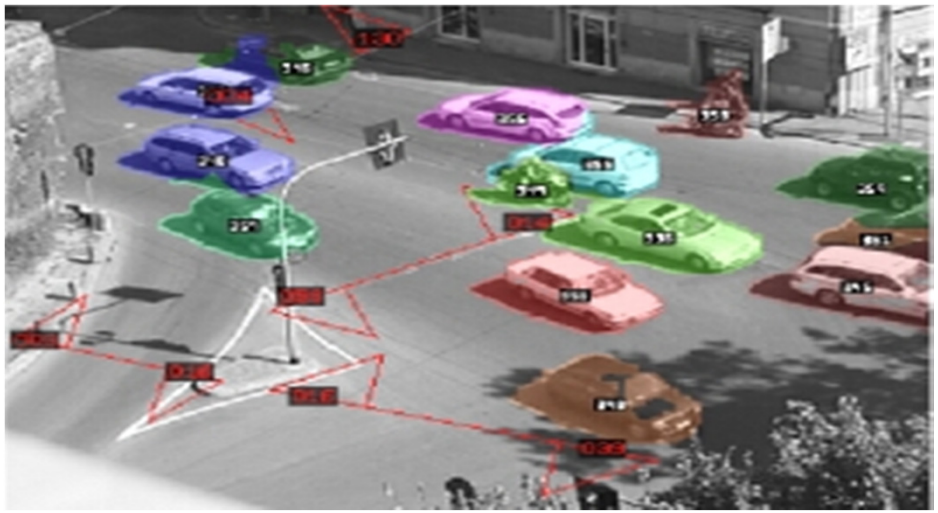
Challenges / Research Opportunities (4)

- **Research in Object Detection**:-

  - Autonomous Cars must know where other obstacles, both moving and stationary, are located and where they're headed.

  - How Moving Objects are being detected using laser scanners and odometry?

  - How Object detection is done in busy urban environments using cameras?



Challenges / Research Opportunities (4)

- **Research in Object Detection**:-

  - Probabilistic methods if used to detect and track moving objects.

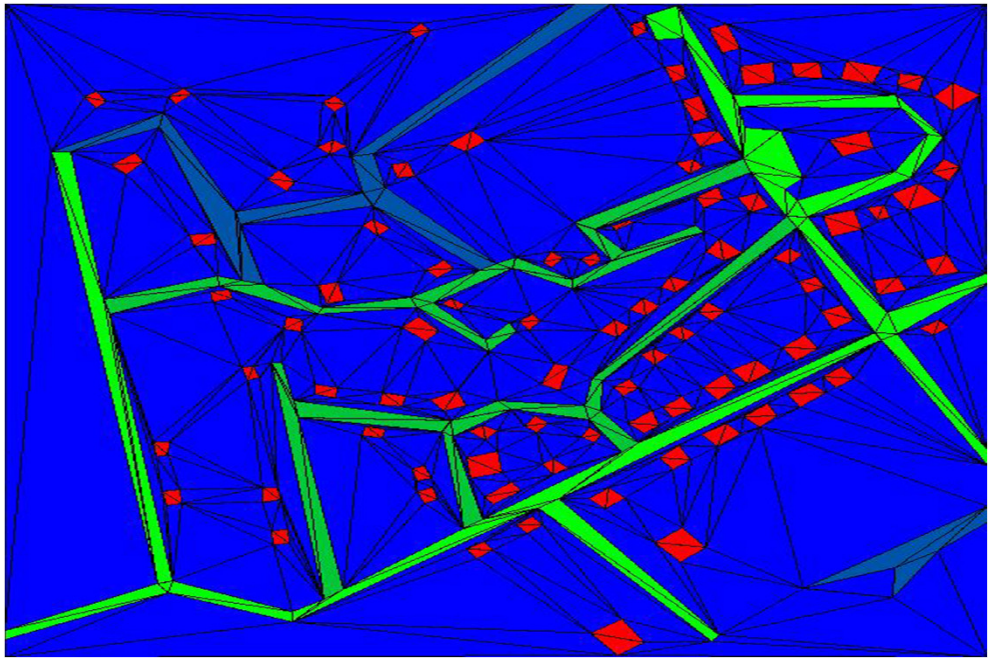
  - Data Association is a problem in which the algorithm defines objects (cars, pedestrians, etc.), and then tries to associate a sensor image with its appropriate object.

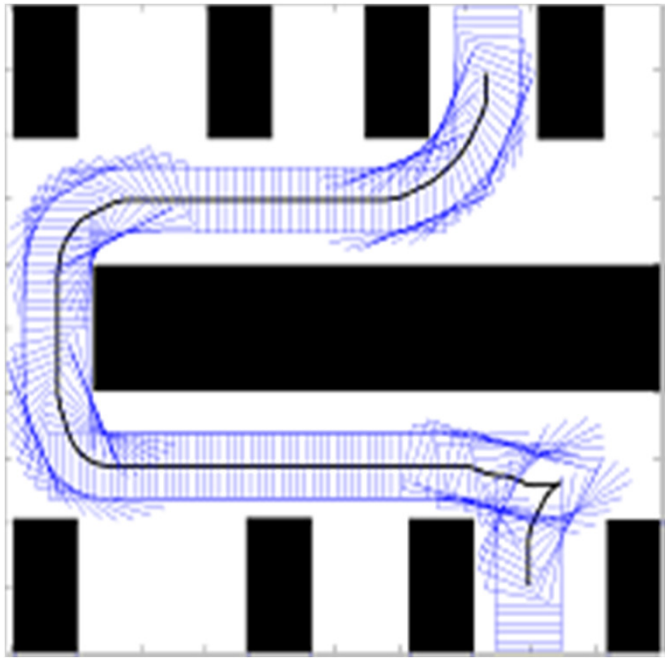
Challenges / Research Opportunities (5)

- **Research in Path Planning**:-

  - How to generate the shortest routes to the desired destination?

  - The path planning problem for autonomous vehicles is more complicated than the basic navigation problem.





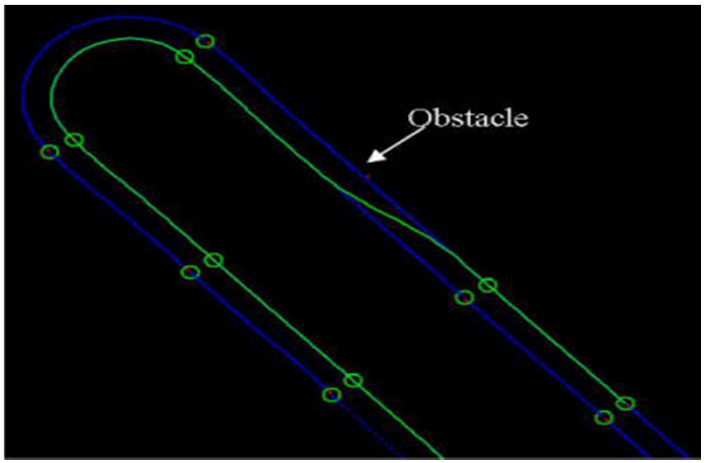
Challenges / Research Opportunities (6)

- **Research in Path Planning**:-

- Autonomous vehicles must also plan detailed and smooth paths, such as for lane changes and turns, and they must be able to plan paths in semi-structured and unstructured environments.

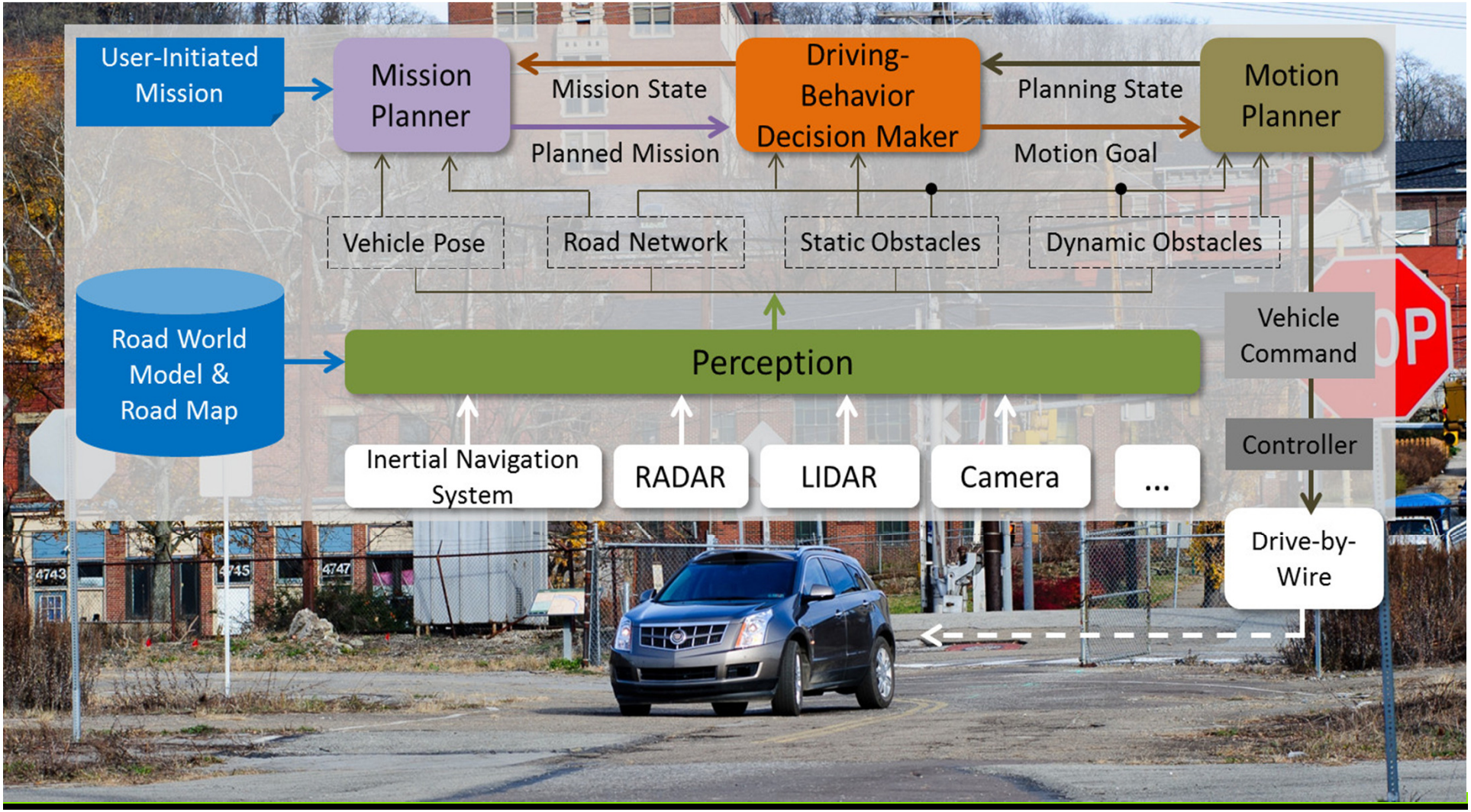
- Plans must be able to take dynamic obstacles into account.

- Self-parking cars have recently been demonstrated and show that this kind of path planning can be quite useful and is ready for commercialization.



Challenges / Research Opportunities (7)

- **Research in Decision making**:-



Challenges / Research Opportunities (7)

- **Research in Decision making**:-

- Control systems for complex machines often take on a hierarchical structure.

- Low-level control of the steering and pedals to regulate speed and lane placement at the bottom.

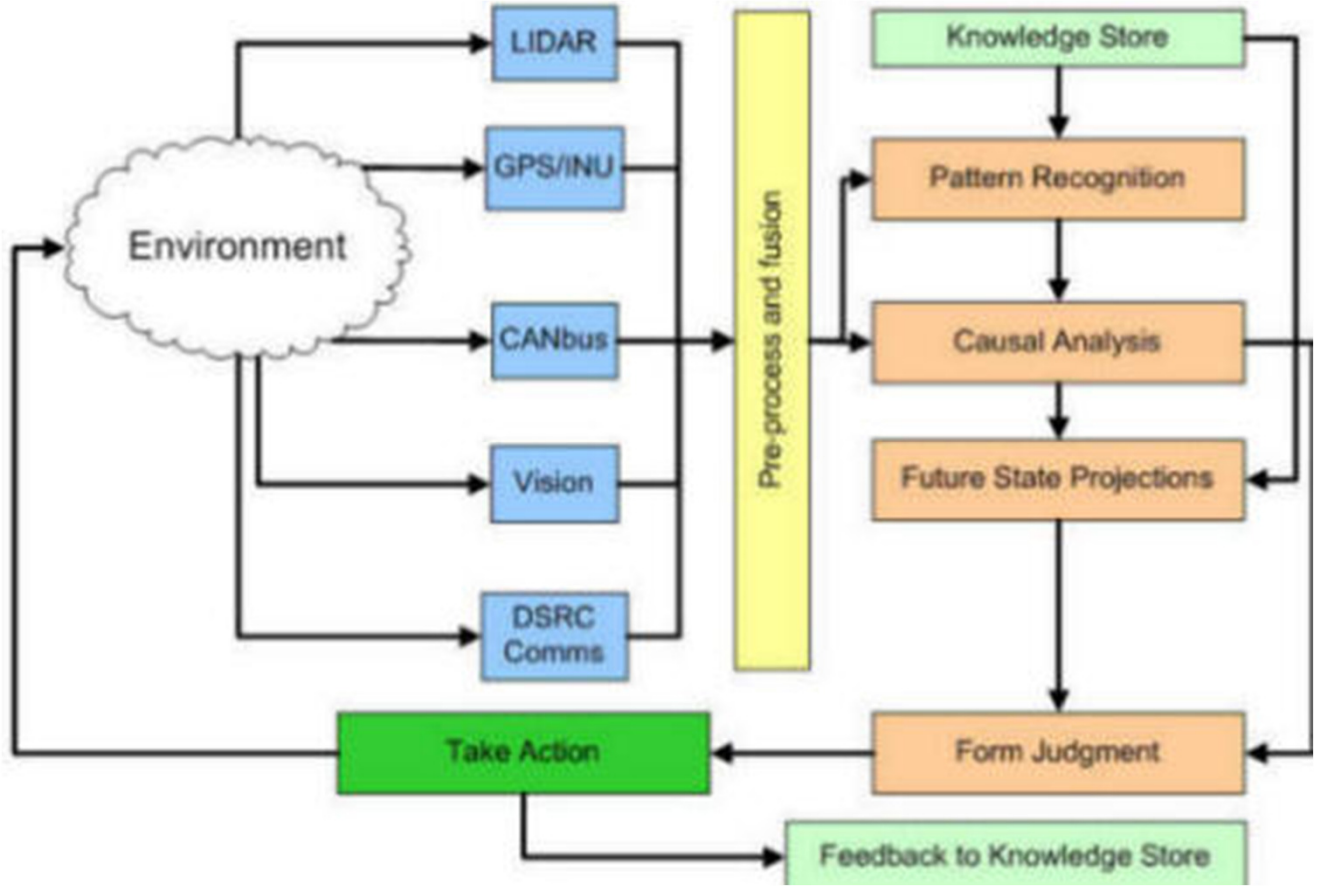
- Mid-level controllers might handle a whole host of specific situations, such as imminent collisions, lane changes, and the like.

- High-level controllers would contain the “brains” of the vehicle, that part of the system that is responsible for behaviors and decision making.

Challenges / Research Opportunities (8)

- **Research in Decision making**:-

  - The highest level of control is what we usually equate with Artificial Intelligence (AI).



Challenges / Research Opportunities (7)

- **Research in Decision making**:-

- Example: Overtaking another vehicle is a rather complicated maneuver, requiring several decisions to be made, and has been successfully automated by AI.

- Schemes must be able to take data from the low-level systems and abstract it into symbolic knowledge for consumption by decision-making systems.

- Human driver and the automation must able to cooperate and function as an effective team (US approach).

- Employing cognitive modeling in automation to make the vehicle “think” more like a human.

Demo Videos

Thank you
for your attention

Q&A

Biography

- PhD in Electrical and Computer Engineering – University of Waterloo – Ontario – Canada.
- Specialization: Controls, Automation, Embedded Systems and Power Electronics.
- 9 Years in Automotive Industry (R&D).
- 5 Years in Construction & Agricultural Machines Industry (R&D).
- 3 Years in Oil & Gas industry (R&D).
- In parallel: Equivalent of 12 Years of University Teaching & Research Experience.
- Interests: Swimming, Running, Reading (Tech/History), Chess.