Autonomous driving revolution: trends, challenges and machine learning

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Outline

- **Vehicle revolution**
- **Challenges: when Big Data meets Machine Learning in the car**
  - **Sensor System** collects Big Data
  - **Machine Learning** perceives the real world
  - Car is a **Digital Agent**
- **Conclusions**

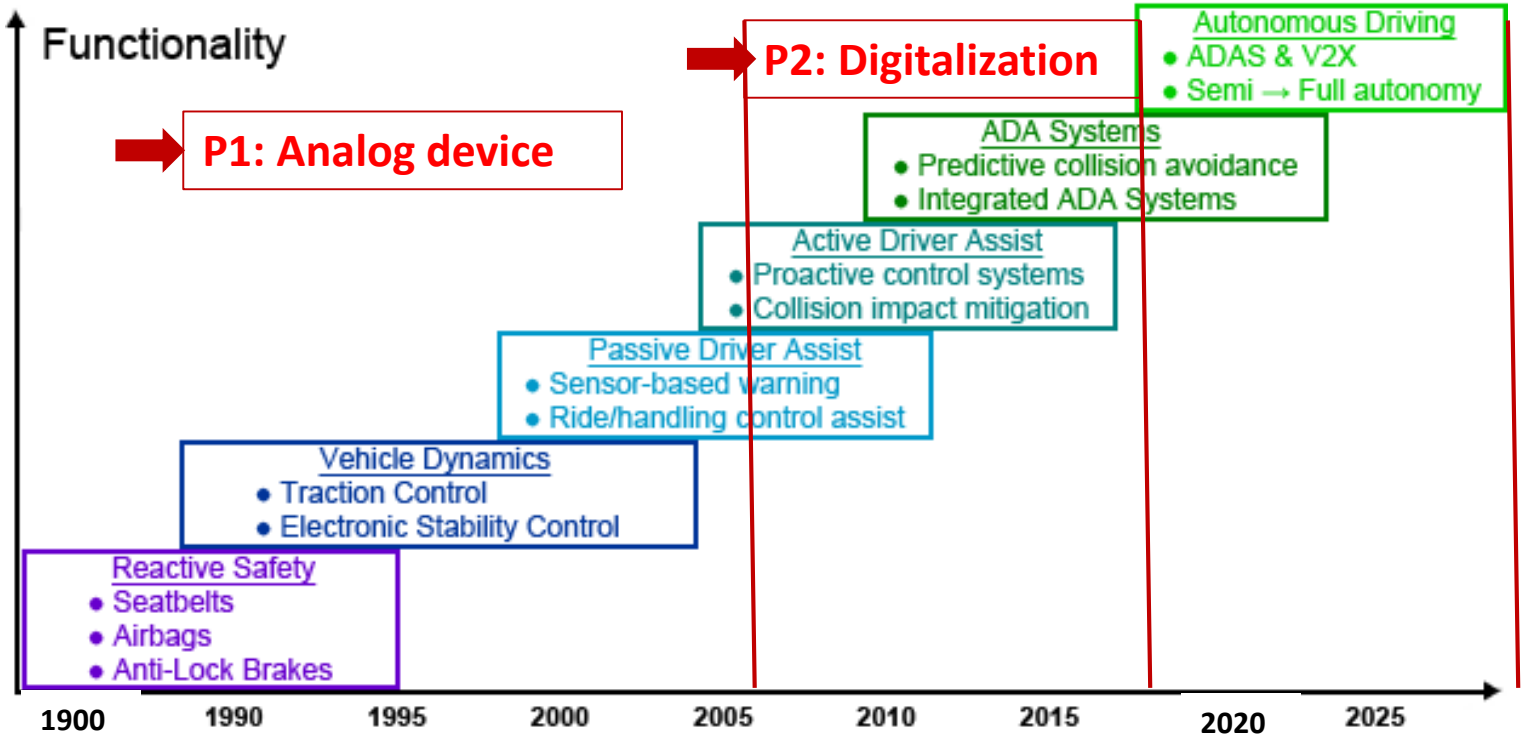
Transportation evolution history

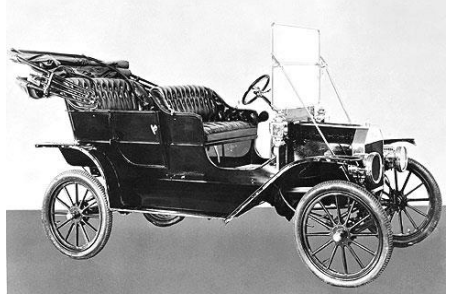
P0: Primitive

P1: Analog device

P2: Digitalization

P3: Intelligence

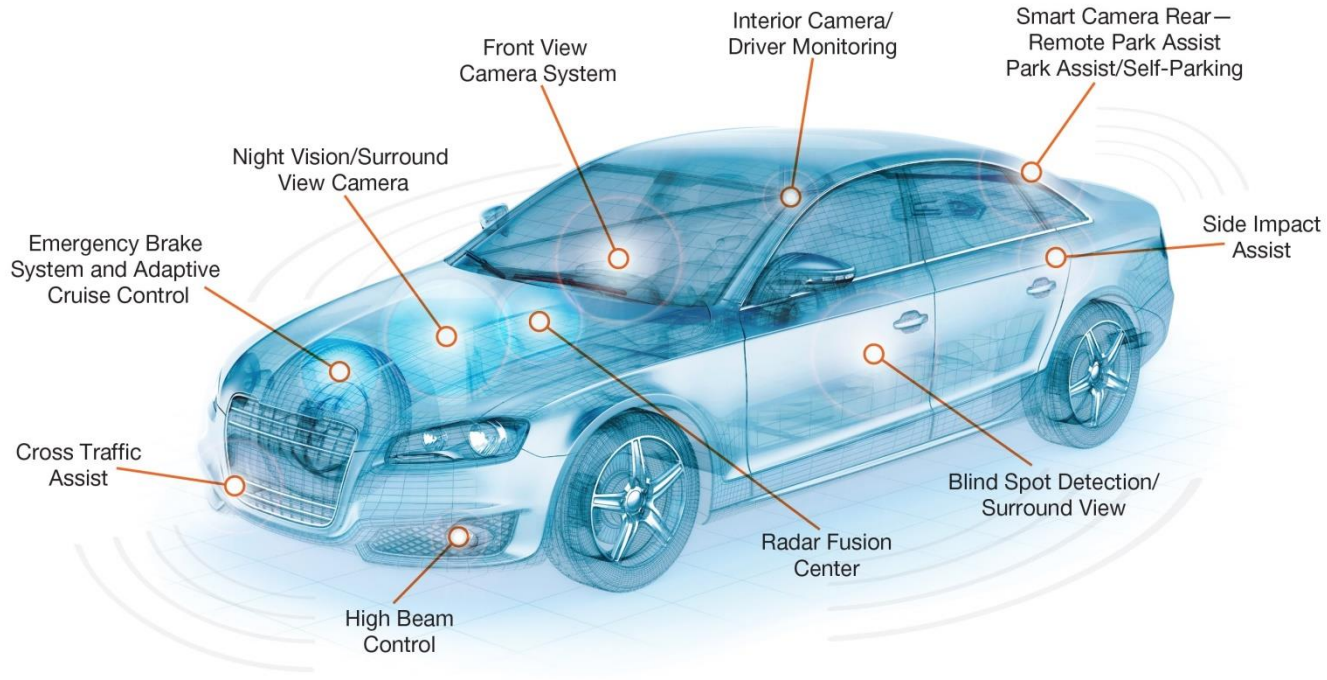




A revolution from analog to digital to intelligence

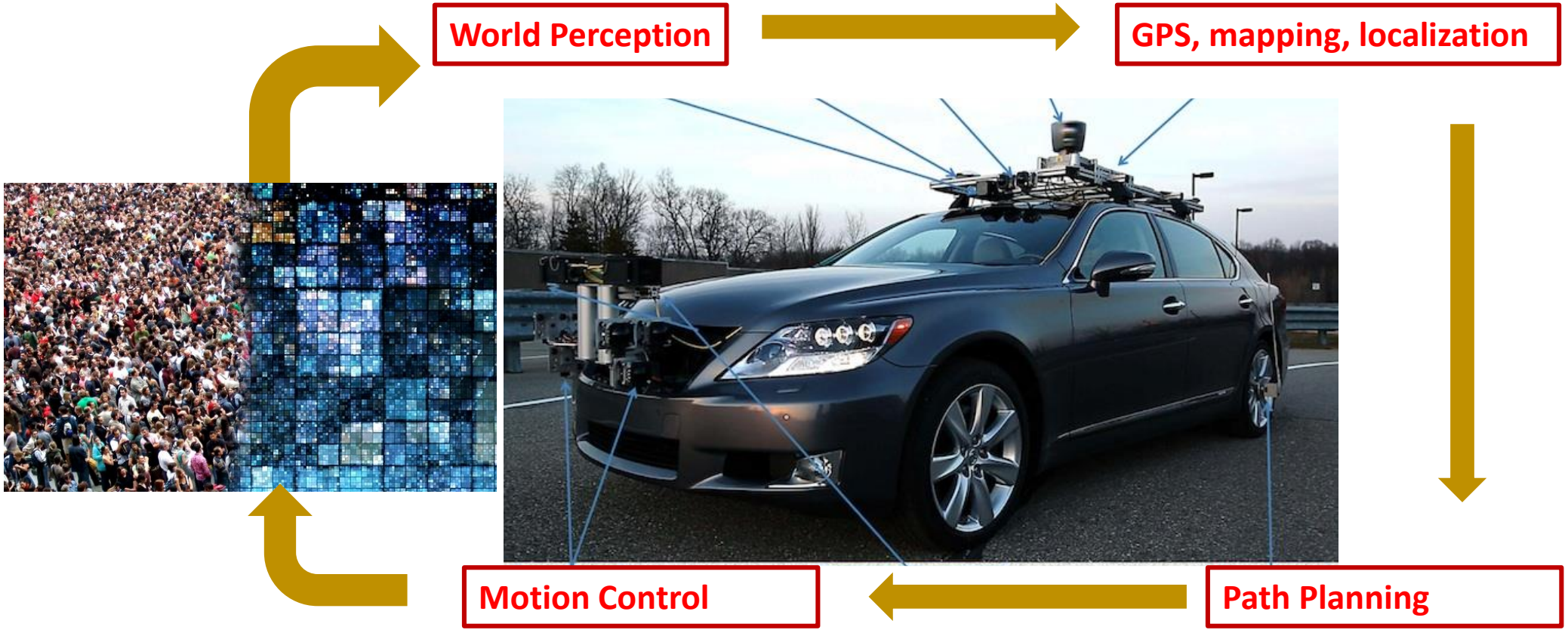
- **All parts are digital controllable**
- **Complex sensor systems**
- **Driving through perception**
- **Controlled by computers**

- **A car will become an agent**
  - **With autonomous behavior**



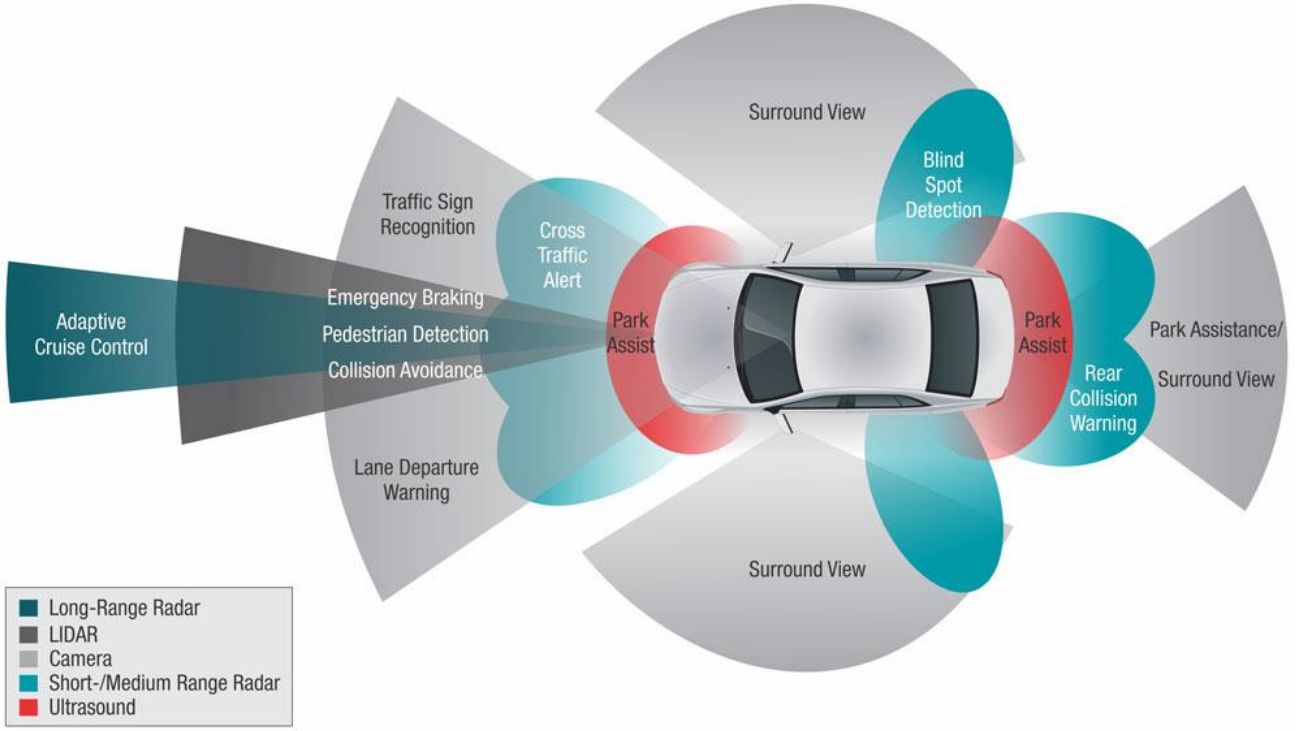
Big Data meets Machine Learning in the Car

- **Real world is a Big Data problem**
- **Driving in human world required intelligent perception of the world**



Hybrid sensor system collects Big Data

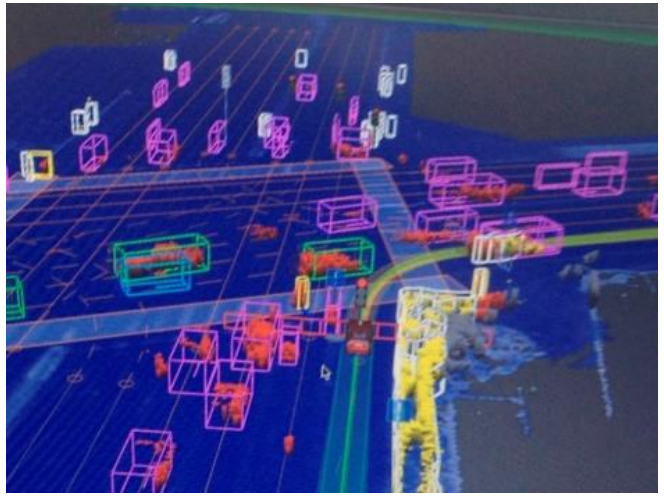
- A sensor system composed of Cameras, Radar, Ultrasound, Lidar
- Sensor fusion technology is not mature yet
- Different sensor data is mostly computed separately



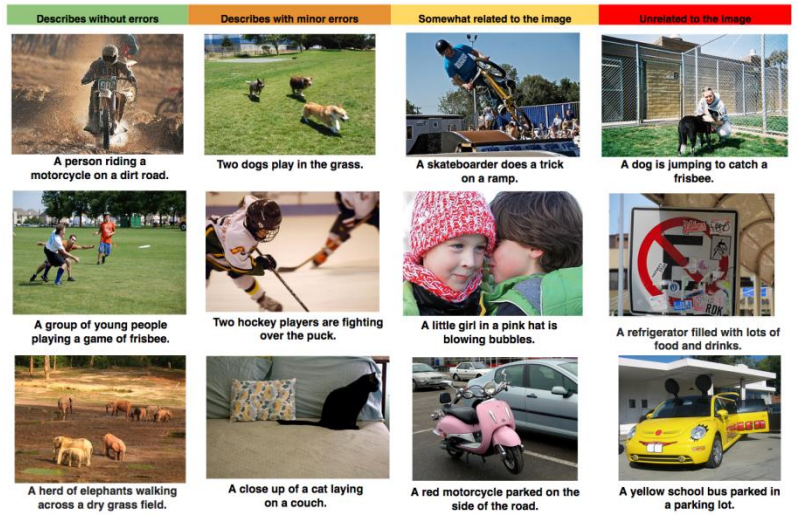
Case study in combining sensors

- Google self driving cars
  - Velodyne 64-beam laser + 4 radars+ 1 camera+ GPS
  - generates a 3D geometry map of the environment
- Radar info is too thin to differentiate objects of same size, same speed
- Cameras see rich semantics. What you see is what you get. But no depth

What radar sees



What camera sees



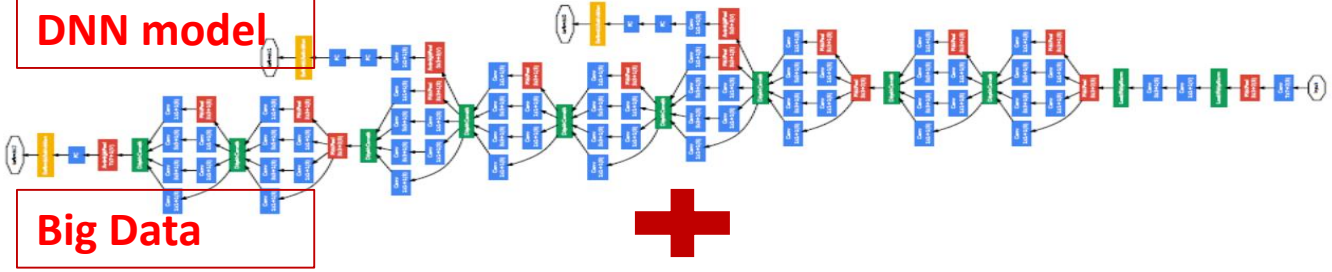
Machine learning perceives the real world

- **Large scale of 2D object recognition is better than human**
  - **What** objects are around
- **3D scene understanding and modeling**
  - **Where** is the object
- **Semantic segmentation**
  - **Extent** of the obstacles
- **Reinforcement learning**
  - **Policy** (**reward or penalty** based learning)
- **End to end learning**
  - From raw data direct to behavior, like a robot

Deep learning based 2D image recognition

- **Large scale object recognition 97% accuracy**
  - Lane detection, pedestrian detection, vehicle detection
  - Animal detection, and road surface detection etc.
  - Case: Mobile eye from traditional algorithm => Deep learning

DNN model



Big Data

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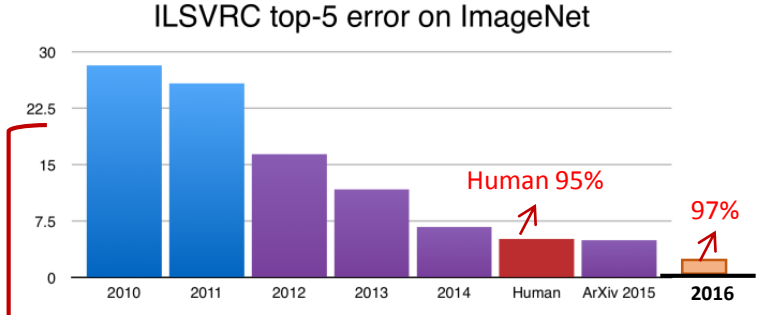
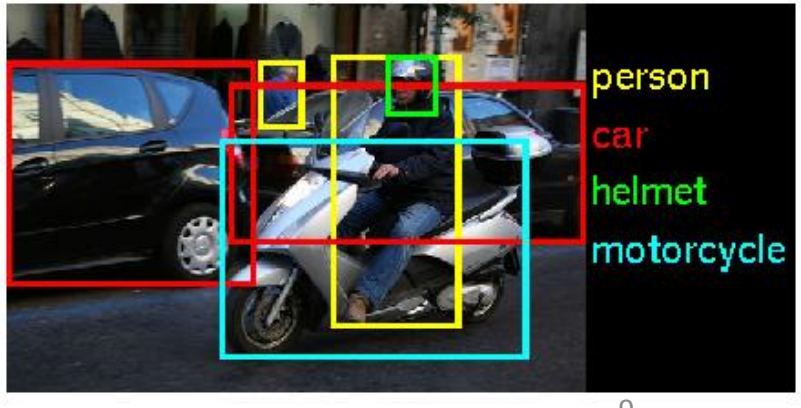
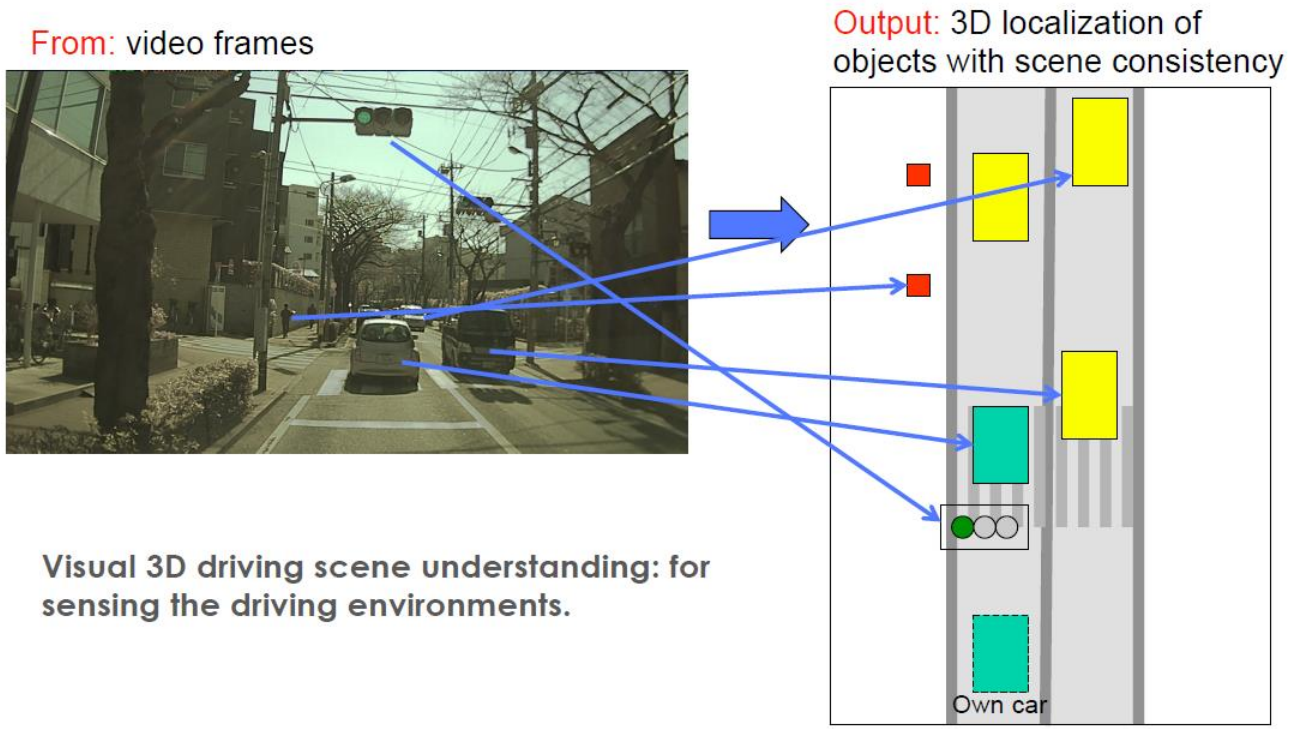




3D scene understanding

- **Real world is not flat. It is 3D.**
- **Depth information is critical for driving.**
- **3D model is far more complicated.**

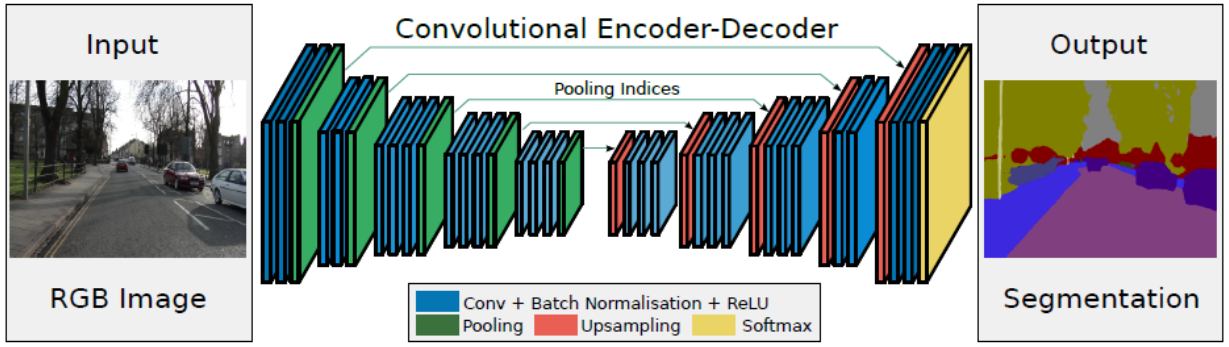
Reference: Lin Yuanqing,
"Building Blocks for Visual 3D Scene Understanding towards Autonomous Driving"

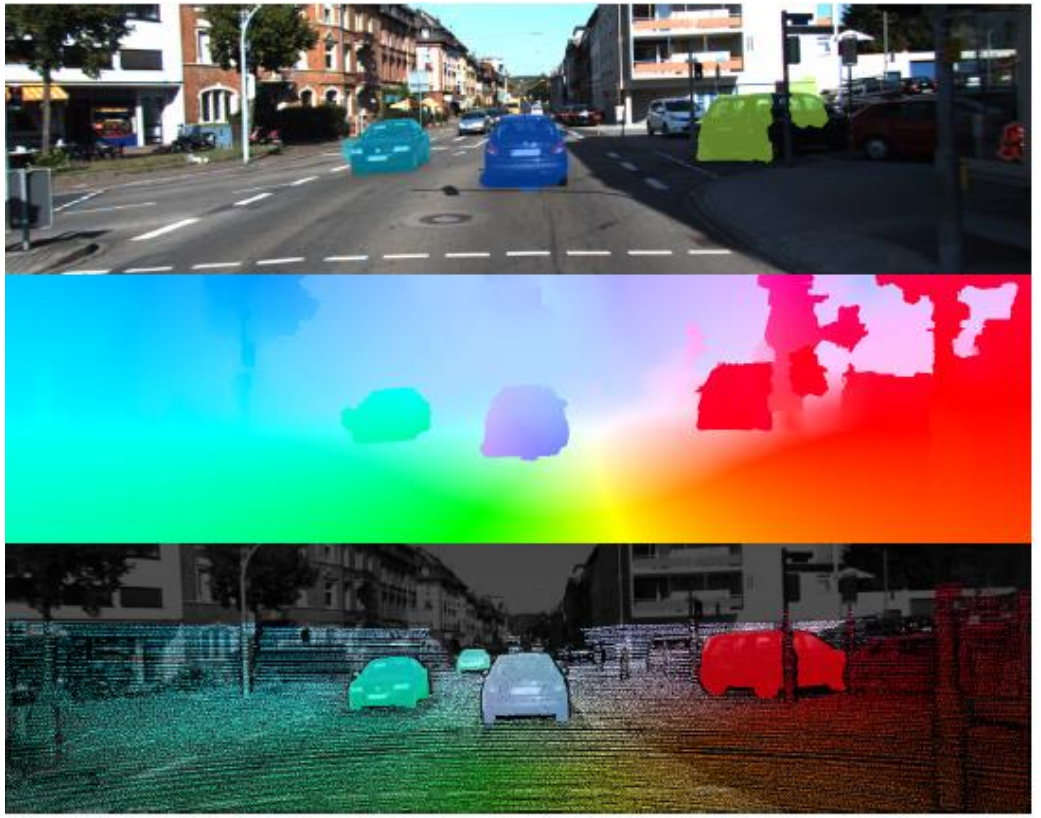


Visual 3D driving scene understanding: for sensing the driving environments.

Semantic segmentation

- Understand **the extent of the object** and each pixel of it
- Advanced requirement based on recognition and detection
- Eventually 3D world segmentation





Above: “SegNet: A Deep Convolutional Encoder-Decoder Architecture for Image Segmentation”
Right: “Object Scene Flow for Autonomous Vehicles”

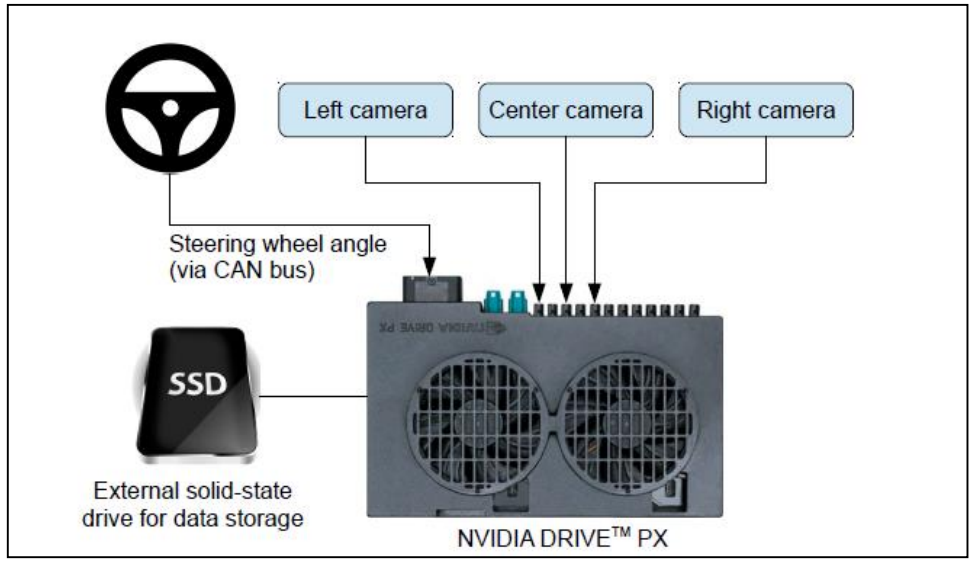
Reinforcement learning

- Goal: to **win**
  - **Policy** based learning
- Learning task: next move at **arbitrary** states
- Algorithm: reinforcement learning + DNN
- Similar methodology can be applied to driving
  - Driving Policy: Given safety, spend least time to get to destination

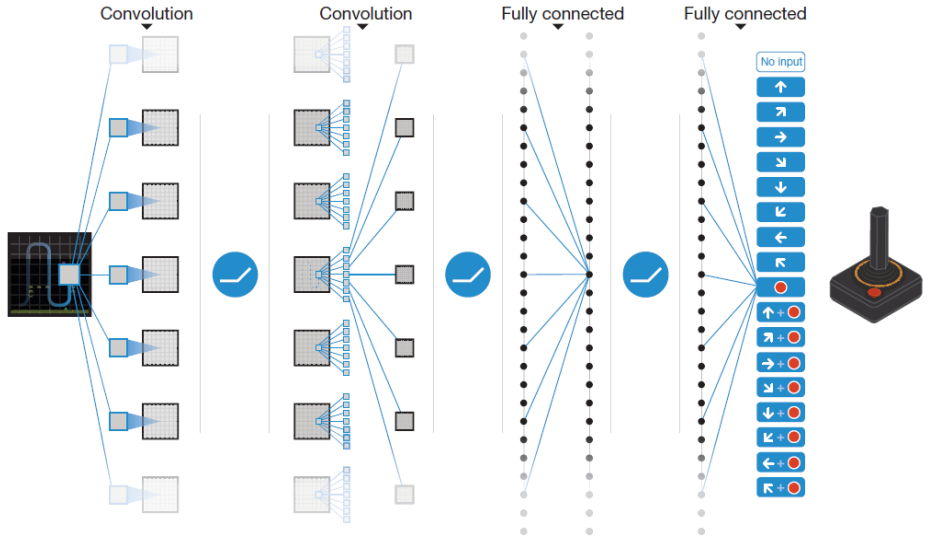
End to end learning

- Use machine learning as the only step from raw data to control
  - Without human interference noise in the middle steps
- DaveNet: AI teaches the car how to drive
  - NVidia GTC 2016 "**after 3000 miles of supervised driving**, their car can navigate safely on **freeways and country roads, even on rainy days.**"

"End to End Learning for Self-Driving Cars", arxiv.org ;



Google "Human-level control through deep reinforcement learning"

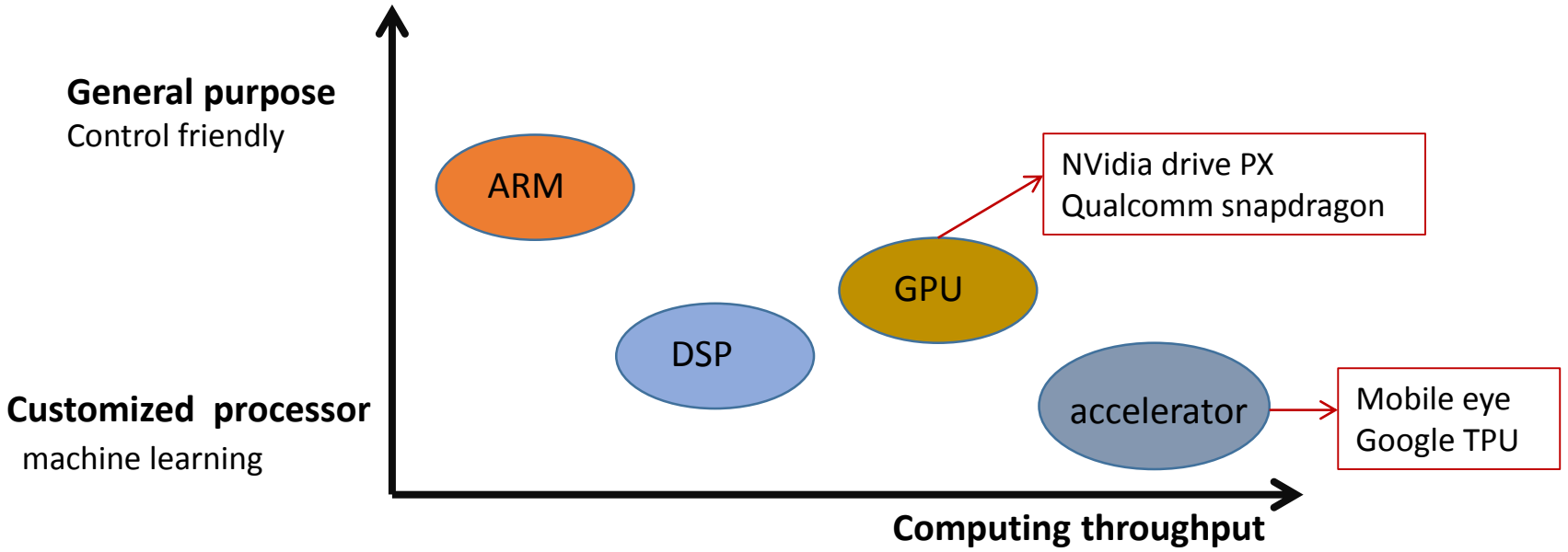


Other challenges in the Car

- **Embedded computers in the car**
- **Cloud solution**
- **Vehicle external connections (V2E)**
- **Vehicle internal connection**

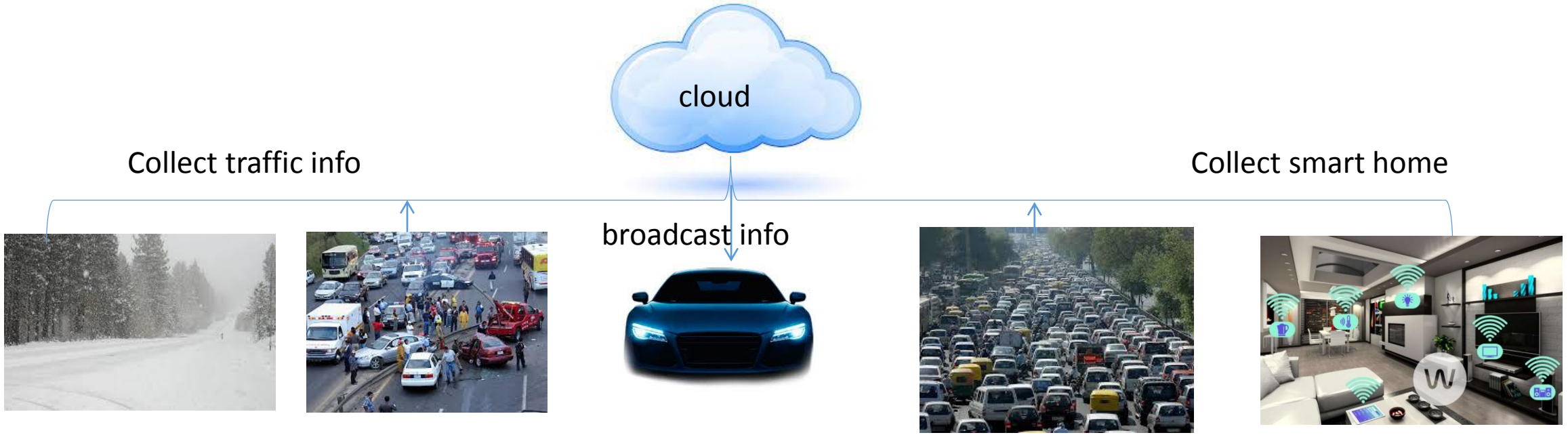
Embedded computing systems

- Real time computing for the sensor array's Big Data input
- Heterogeneous SoC + HPC level computing (Tera flops)
- Reliability is another key



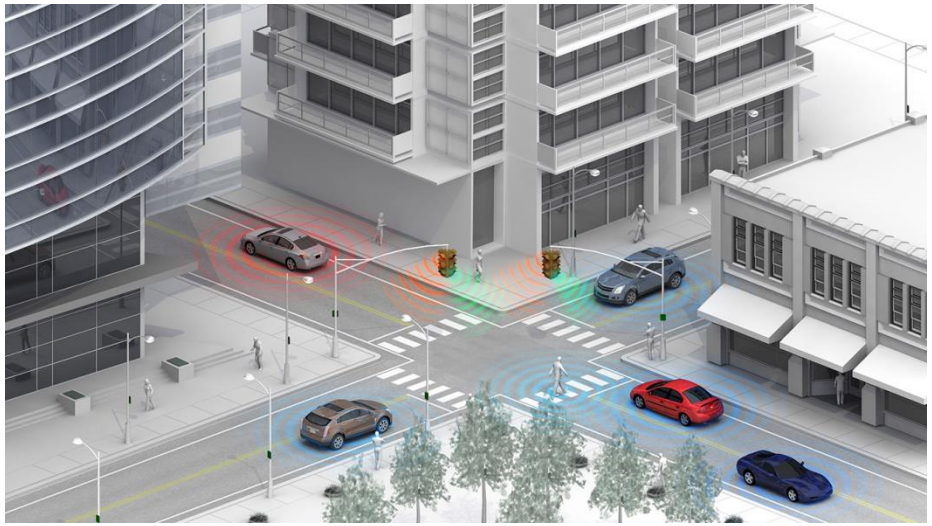
Cloud based solution

- **Agent+** system: cloud updates with traffic condition, bad weather, etc. (Toyota)
- Connect smart home with car (Volks Wagen, with LG software)
- Challenges: network reliability and real time response



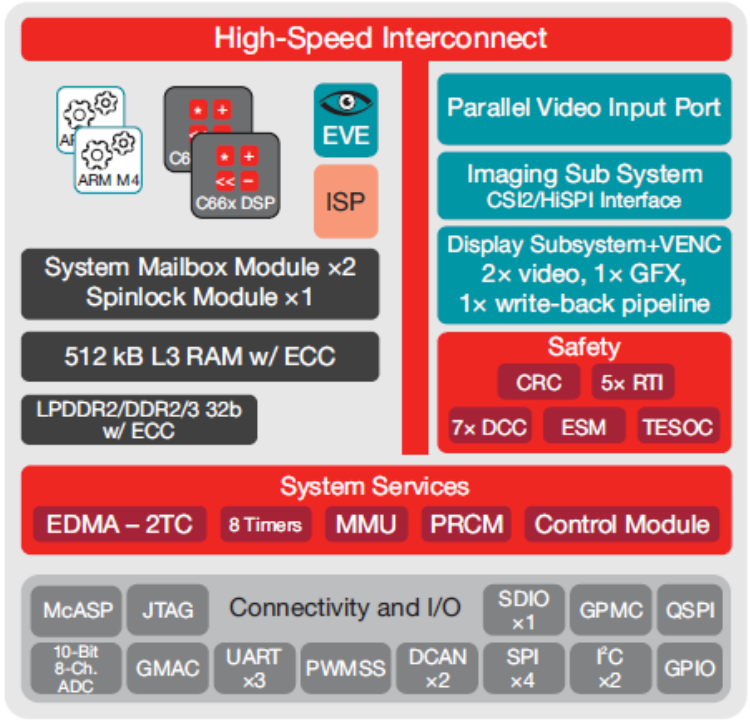
V2E (vehicle to everything) network

- **Collectively become smarter**: share learning on the network
- Dephi: V2V(vehicle), V2B(building), V2P(pedestrain)
- Tesla: fleet learning. Baidu: vehicle to traffic lights



High speed internal interconnect

- All digital components communicate
- High speed due to many sensor
- Reliability and redundant design



Conclusions

- Cars are transforming from analog to digitalization and intelligence
  - Future cars are a digital autonomous device, similar to Robots

- When Big Data meets Machine learning in the car
  - Complex sensor system collects the Big Data info
  - Machine learning algorithms will be the key to perceive the real world
  - Computing in the car is another challenge
  - Cars will be connected to each other and the cloud

- Whoever addresses the technical challenge will harvest the influence.