

Sensors and Computing Hardware

Course 1, Module 2, Lesson 1



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FACULTY OF APPLIED SCIENCE & ENGINEERING

In this module ...

- Sensors for perception
- Self-driving computing hardware
- Designing hardware configurations *sensor configurations*
- Software architecture, decomposition
- Environment representation for self-driving

In this video ...

- Sensors types and characteristics
- Self-driving computing hardware

Sensors

- Sensor: device that measures or detects a property of the environment, or changes to a property
- Categorization:
 - **exteroceptive**: extero = **surroundings**
 - **proprioceptive**: proprio = **internal**

Sensors for perception

- Essential for correctly perceiving environment

- Comparison metrics:

len selection →
zoom ↗

- Resolution # of pixels that create the image
- Field of view: horizontal & vertical angular extent
- Dynamic range that is visible to the camera

- Trade-off between resolution and FOV?

wider FOV
→ larger viewing region of environ
→ fewer pixels that absorb light in one object → low resolution

exteroceptive

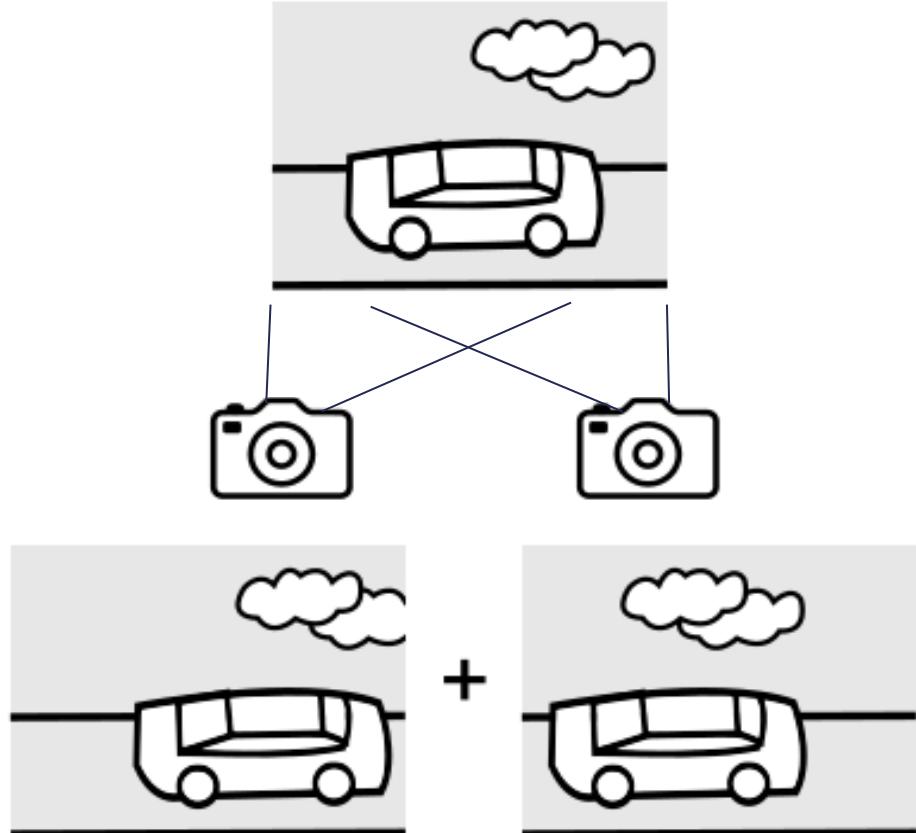
Camera



FOV
→ ↑ resolution
→ same image quality

Sensors for perception

- Enables **depth estimation** from image data

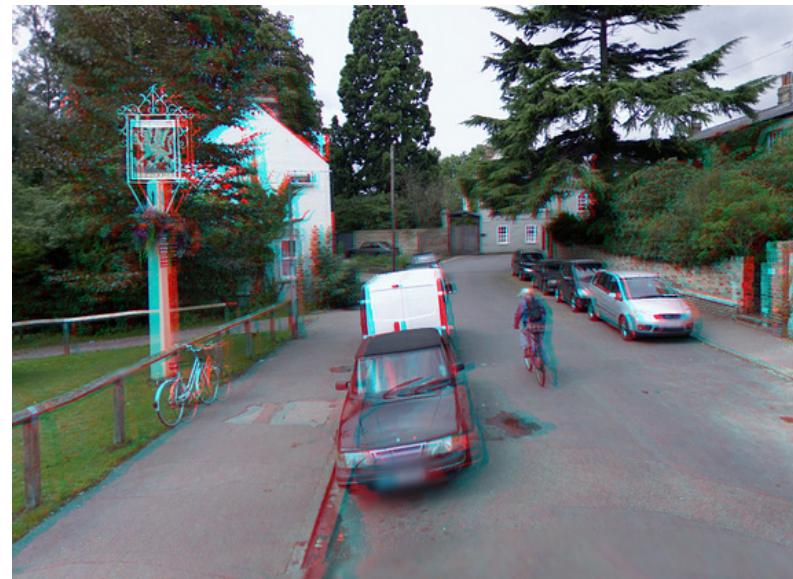


exteroceptive

Stereo



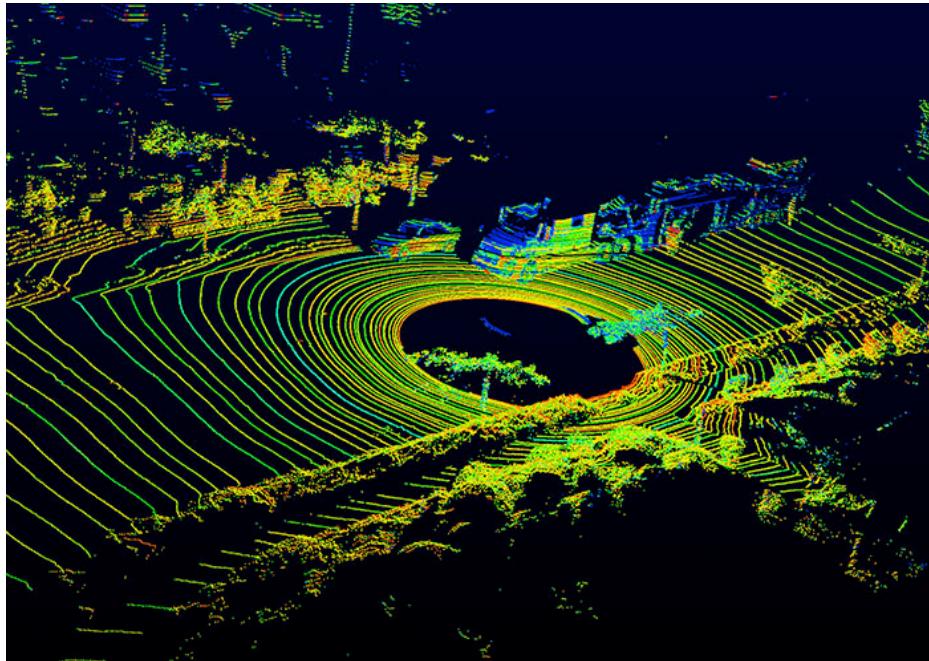
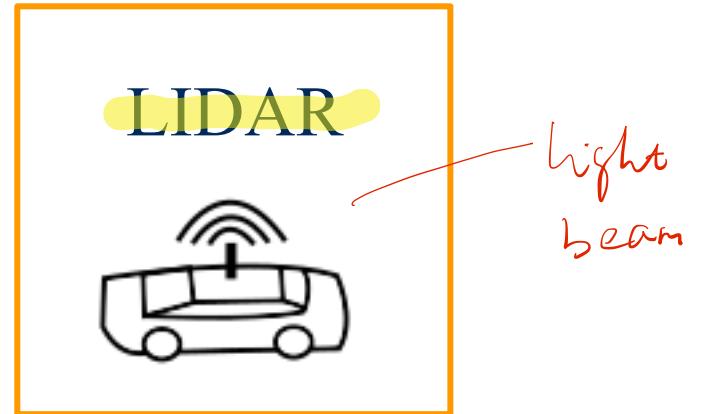
Left and right images



Sensors for perception

- Detailed 3D scene geometry from LIDAR point cloud *its own light source* → *not affected by environmental lighting*
- Comparison metrics:
 - Number of beams 8, 16, 32, 64
 - Points per second ↑ → *more details*
 - Rotation rate faster → ↑ point cloud update
 - Field of view
- Upcoming: Solid state LIDAR!
HD high-resolution no rotational component

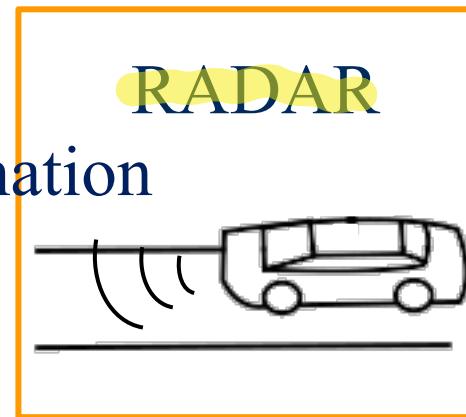
exteroceptive



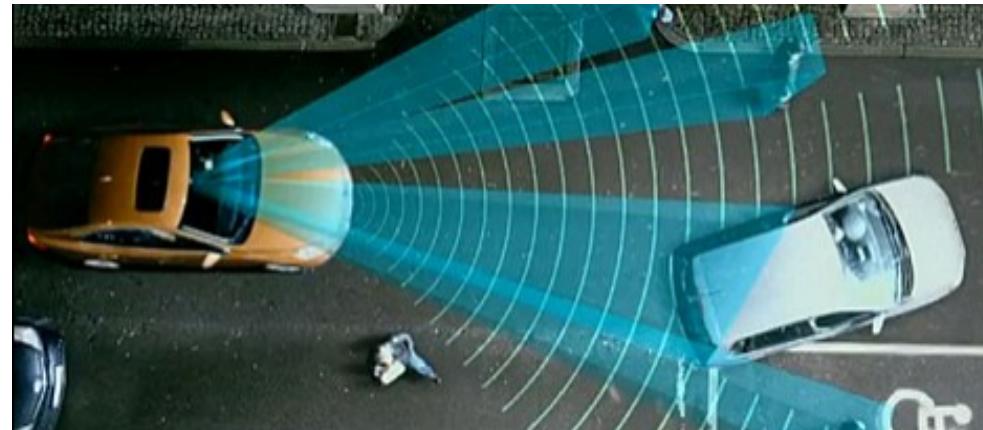
Sensors for perception

- Robust Object Detection and Relative Speed Estimation
- Comparison metrics:
 - range
 - field of view
 - position and speed accuracy
- Configurations:
 - wide ◦ WFOV, short range
 - narrow ◦ NFOV, long range

exteroceptive



radio detection
in ranging
(radio wave)



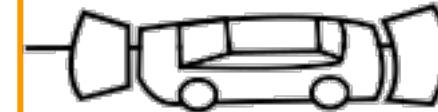
Works in poor visibility like fog and precipitation!

Sensors for perception

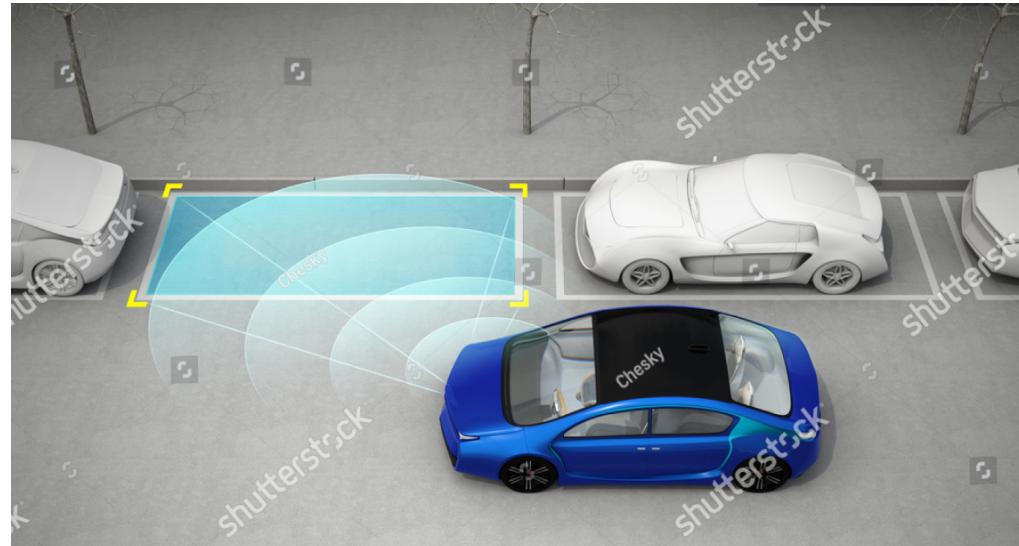
- Short-range all-weather distance measurement
- Ideal for low-cost parking solutions
- Unaffected by lighting, precipitation
Just like radar & lidar
- Comparison metrics:
 - Range
 - Field of view
 - Cost

exteroceptive

Ultrasonics

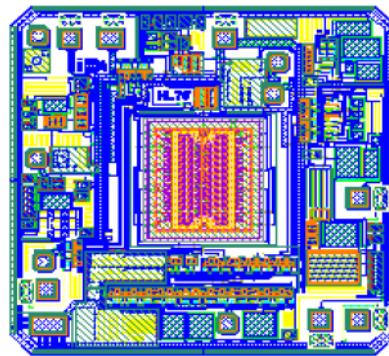


Sonars
sound wave



Sensors for perception

- Global Navigation Satellite Systems and Inertial measurement units
- Direct measure of **ego vehicle states**
 - position, velocity (GNSS)
 - Varying accuracies: RTK, PPP, DGPS
 - angular rotation rate (IMU)
 - acceleration (IMU)
 - heading (IMU, GPS)



proprioceptive

GNSS/IMU



Sensors needed for perception

- Tracks wheel **velocities and orientation**
- Uses these to calculate overall speed and orientation of car
 - speed accuracy
 - position drift

proprioceptive

Wheel
Odometry



Sensors needed for perception: Summary

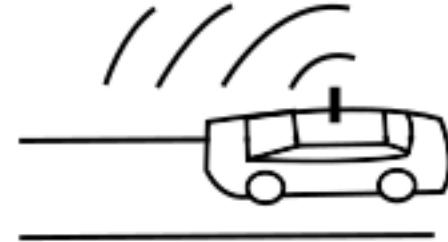
Camera



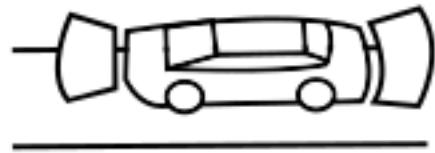
LIDAR



RADAR



Ultrasonics



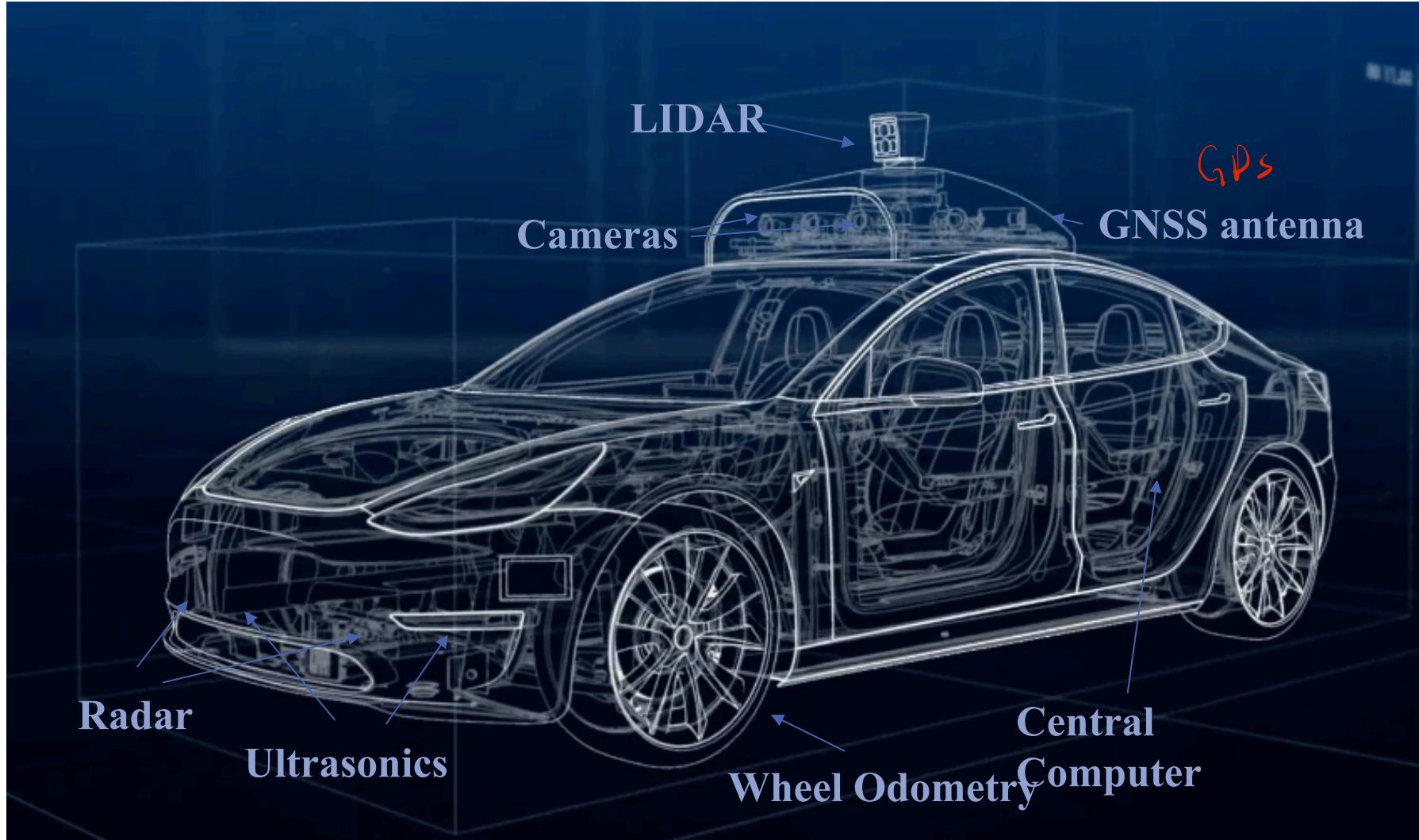
GNSS/IMU



Wheel
Odometry

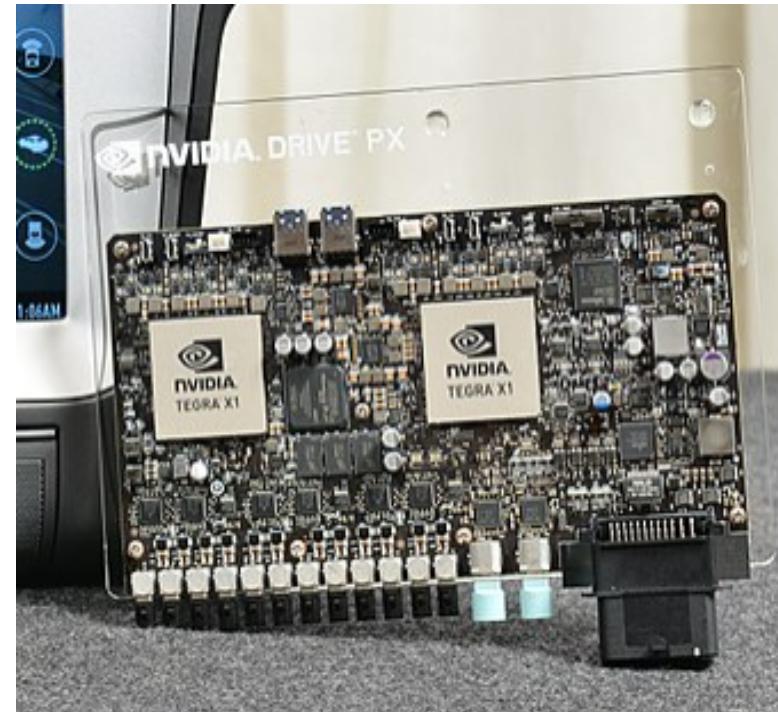


Sensors needed for perception



Computing Hardware

- Need a “self-driving brain”
 - Takes in all sensor data
 - Computes actions
 - Already existing advanced systems that do self driving car processing (e.g. Drive PX/AGX, Intel & Mobileye EyeQ)
 - Nvidia Multi GPUs
 - FPGAs



Computing Hardware

- Need a “self-driving brain”
- Image processing, Object detection, Mapping
 - GPUs - Graphic Processing Unit
 - FPGAs - Field Programmable Gate Array
 - ASICs - Application Specific Integrated Chip

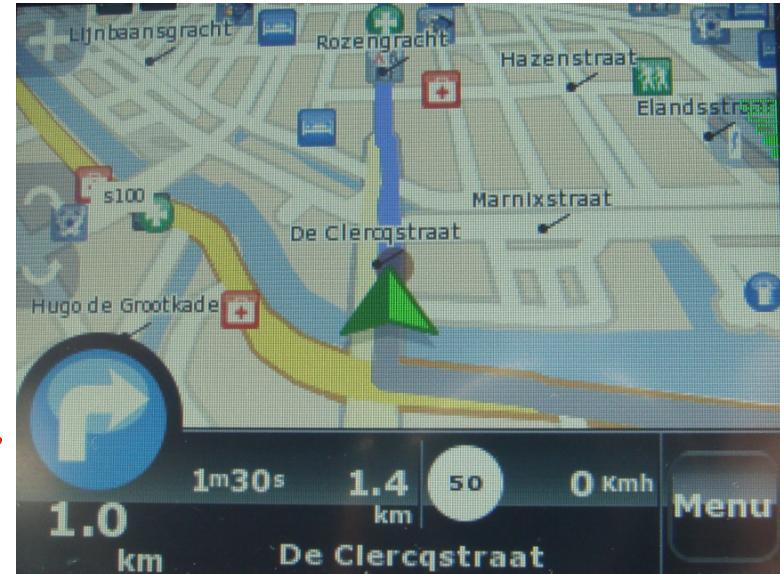
serial & parallel compute modules
*parallelized
compute tasks.*
~~*ex. image processing &
NN inference*~~



Computing Hardware

- Need a “self-driving brain”
- Image processing, Object detection, Mapping
 - GPUs, FPGAs, ASICs
- Synchronization Hardware
 - To synchronize different modules and provide a common clock

GPS
accurate time
at a
reference



Summary

- Sensors - exteroceptive and proprioceptive
 - camera, LIDAR, RADAR, ultrasonics, GNSS, IMU, wheel odometry
- Self-driving computing hardware