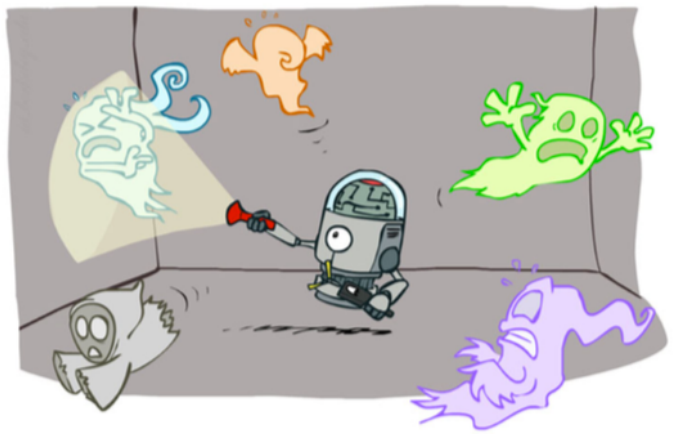
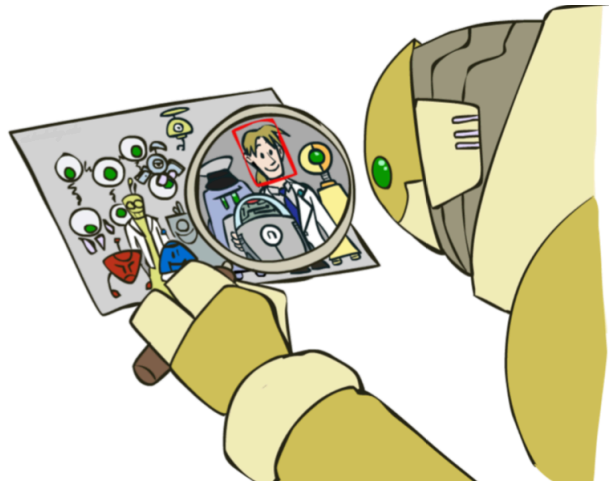
CS 1501: Intro to Robotics

Autonomy, AI, and Applications



Sensors



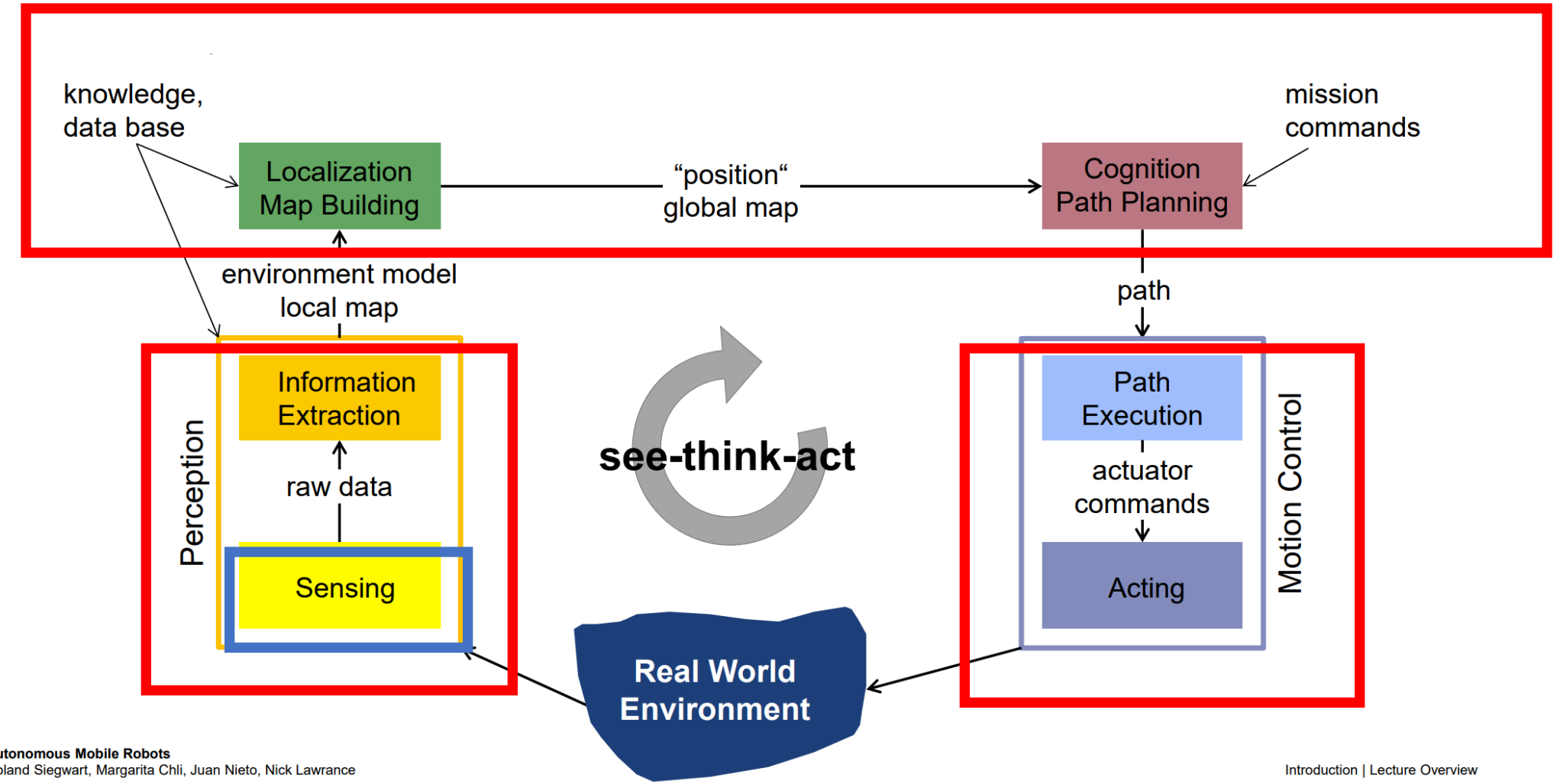
Rohan Raval

Monday 1-1:50pm, MEC 213

Logistics

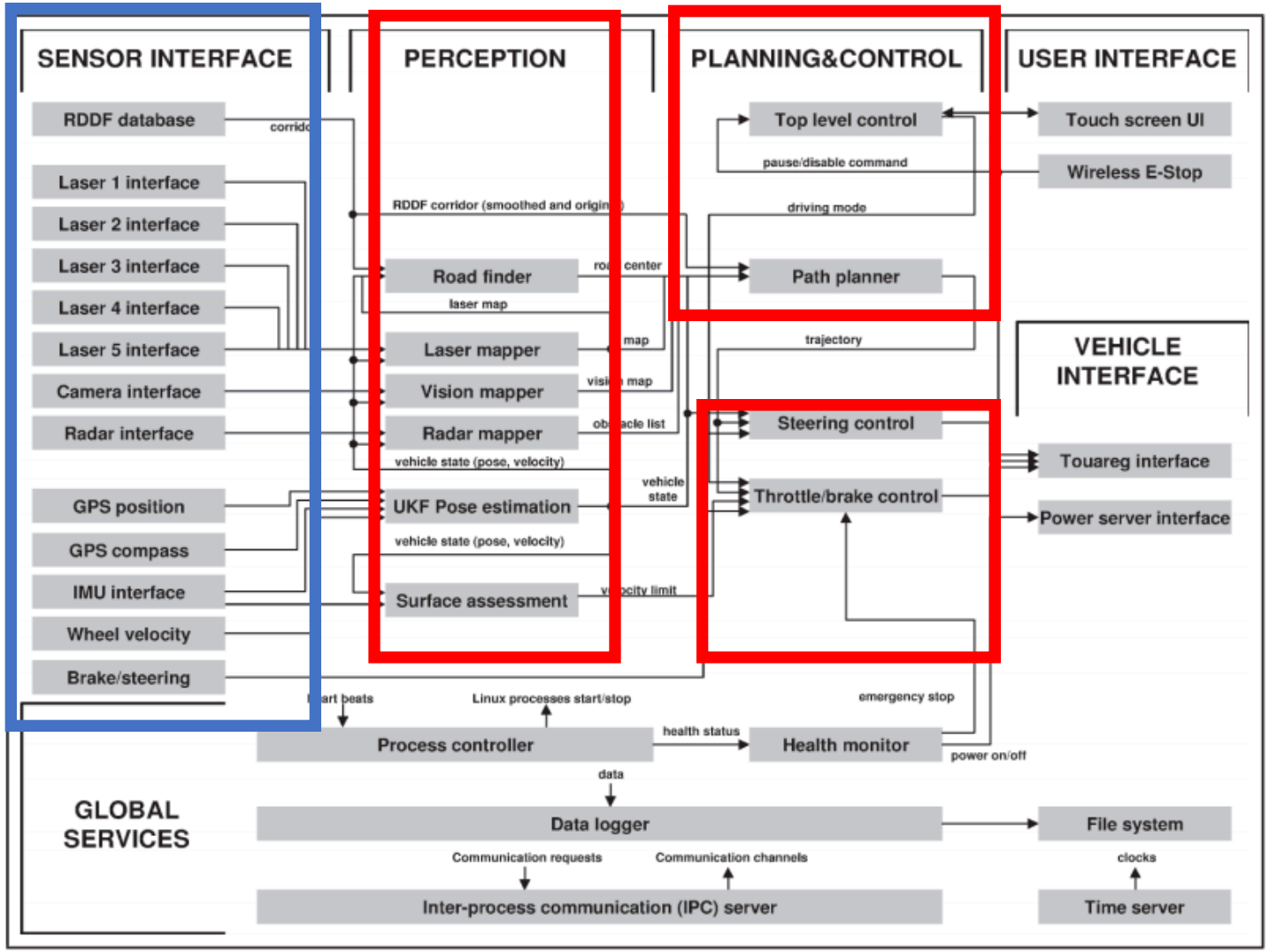
- Access to Collab / website?
- Better way to do Reading Responses?
- Lecture Feedback
  - Too technical? Too fast? Let me know!
  - Anonymous Feedback on Collab!

Recap: See-Think-Act



Recap: See-Think-Act

- "Toward Robotic Cars" – Sebastian Thrun
- Software Architecture for Stanley
  - Stanford's autonomous car that won the 2005 DARPA Grand Challenge



Definitions

- **Robot** = *sensors* + actuators

- **Sensors** = components that provide *measurements*

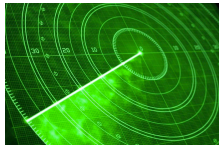
- **Measurement** = information about the *state* of a system

- **State** = "whatever we care about"... parameters of interest
  - Pose
  - Other objects

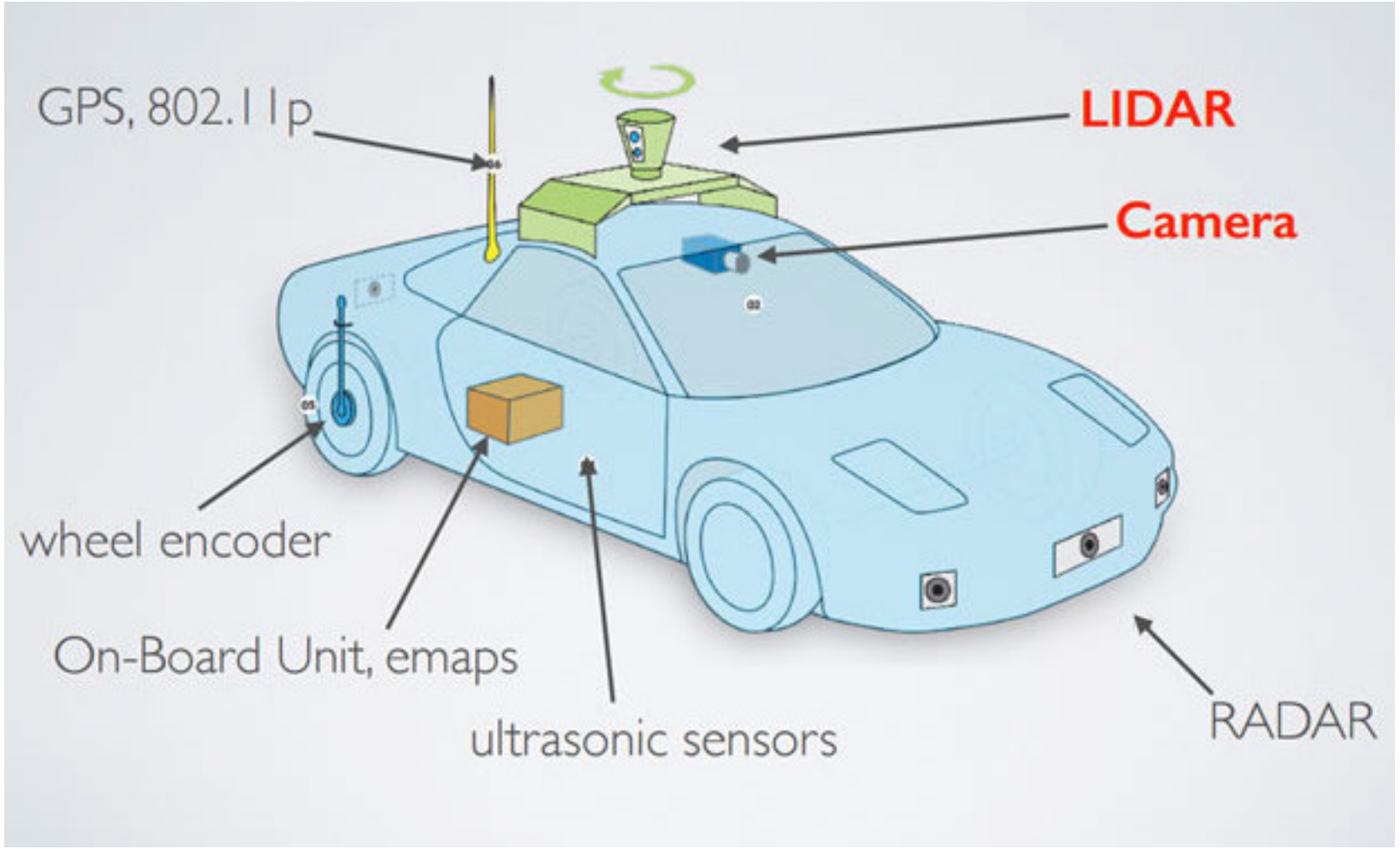
Human Sensors

Sense	Sensor
Sight	Eyes
Sound	Ears
Smell	Nose
Touch	Skin
Taste	Tongue

Robot Sensors

Sense	Sensor
Sight →	Camera 
Sound →	Sonar 
Depth/Range →	LiDAR, Radar 
Position →	GPS, Encoders 
Inertia →	IMU, Accelerometer, Gyroscope

Robot Sensors



Types of Sensors – What?

External

- Measures information from the robot's **environment**
- Measures state of world *with respect to* robot
- E.g. distances to objects, features of images,...
- Job security: "Exteroceptive"

Internal

- Measures values **internally** to the robot
- Measures *state of robot itself*
- E.g. motor speed, heading, wheel revolutions,...
- Job security: "Proprioceptive"

Types of Sensors – How?

Passive

- Measure data coming from environment
- E.g. Camera, GPS

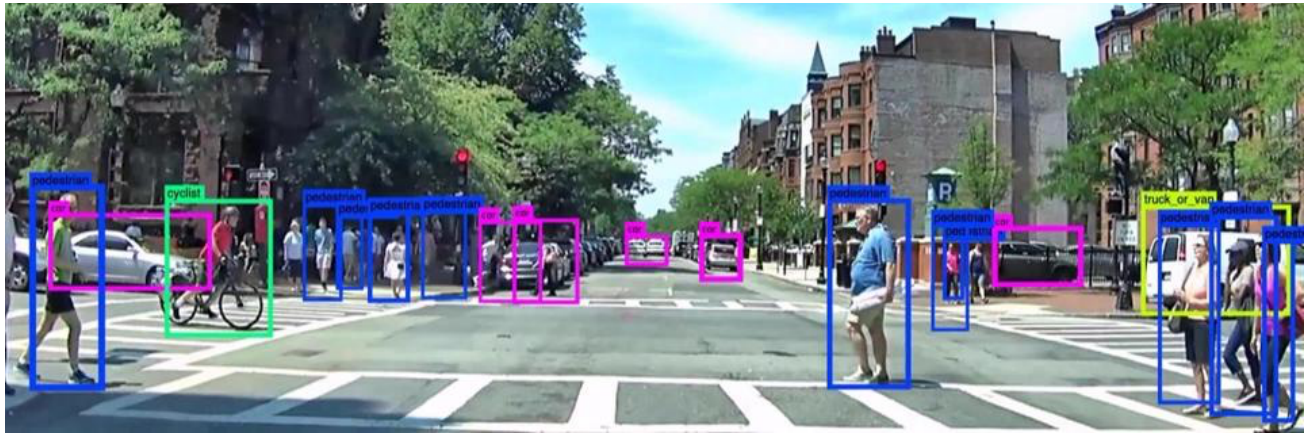
Active

- Emit “something”, measure its reaction with environment
- E.g. LiDAR, Sonar, Radar, etc.

Camera

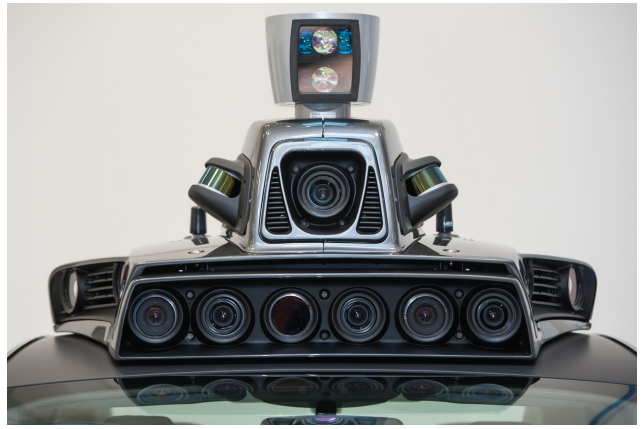
- Passive, exteroceptive

- Computer Vision
  - Object Recognition
  - Segmentation
  - Classification

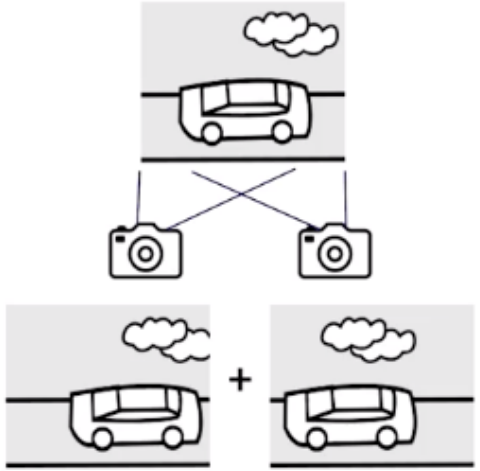


Camera

- Metrics:
  - Resolution
  - Field of View
  - Dynamic Range



- Stereo cameras = better depth estimation!



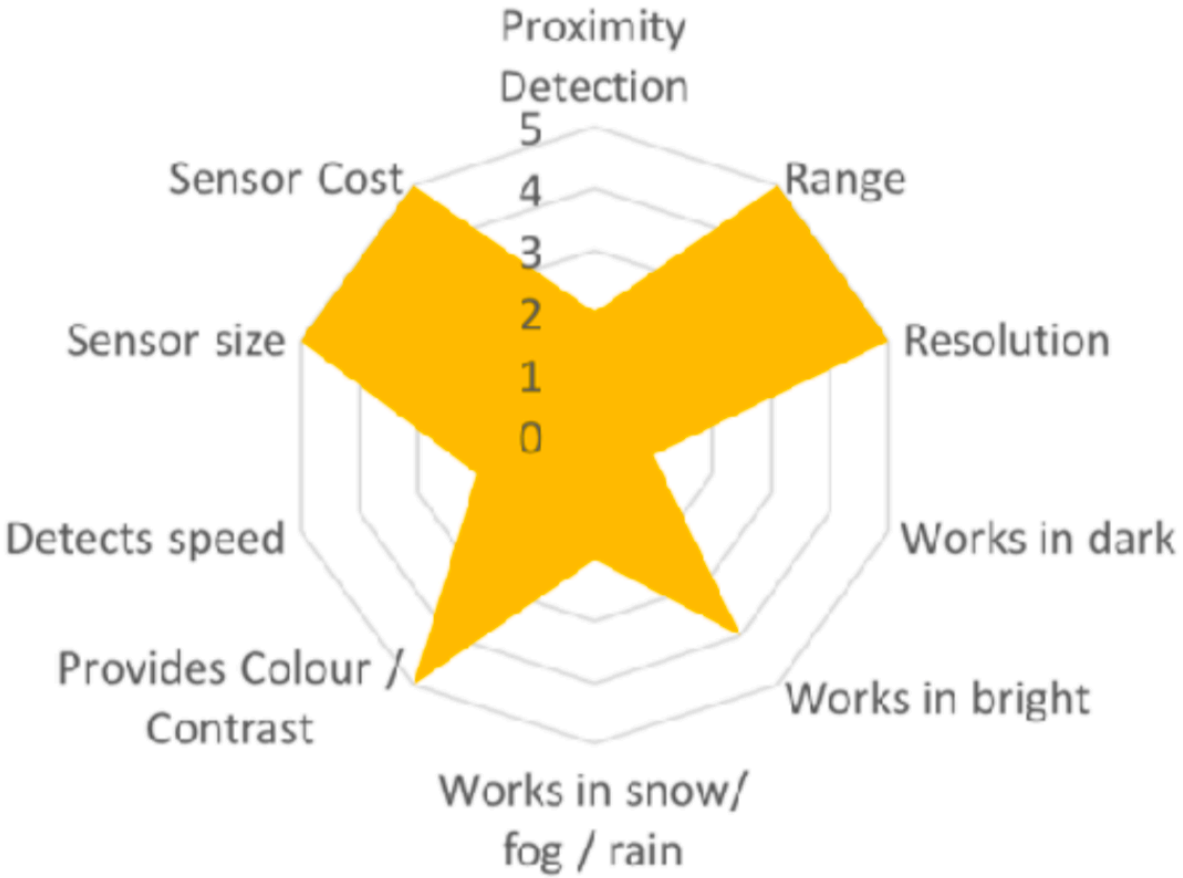
Camera

Pros

- Cheap
- Very high resolution
- Lots of data → lots of learning!
- Like how humans see

Cons

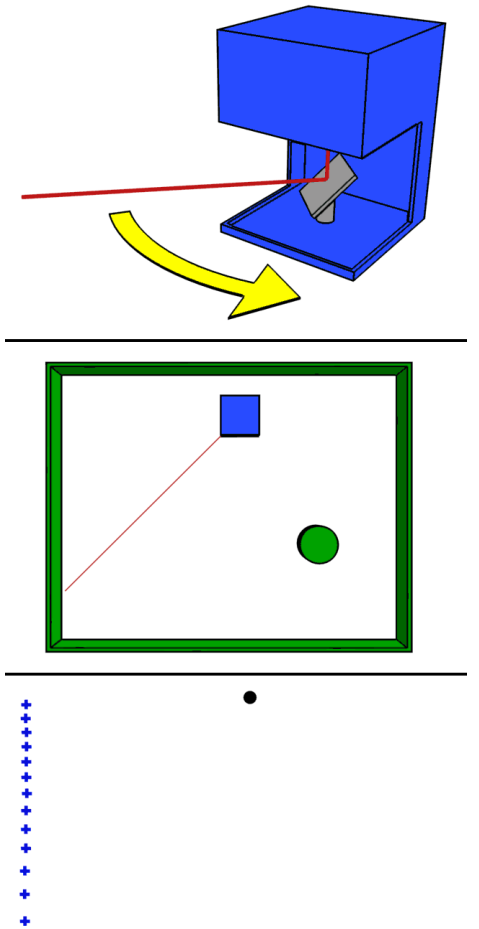
- Bad at Depth Estimation
- Bad in extreme weather



LiDAR

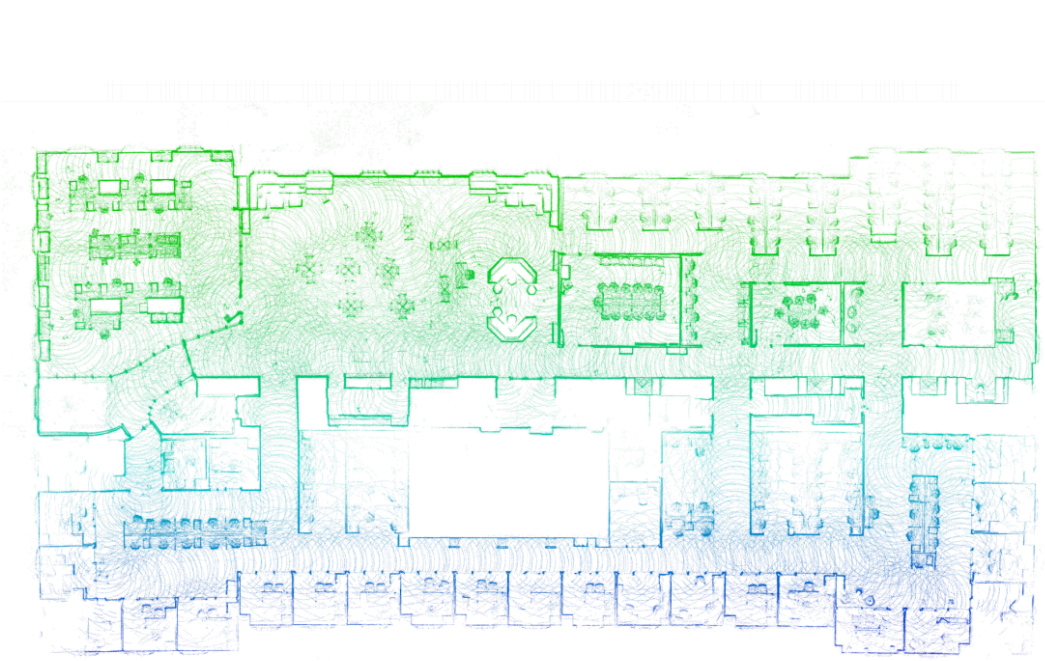
- Light Detection And Ranging
- Active, exteroceptive
- Measuring *time of flight*

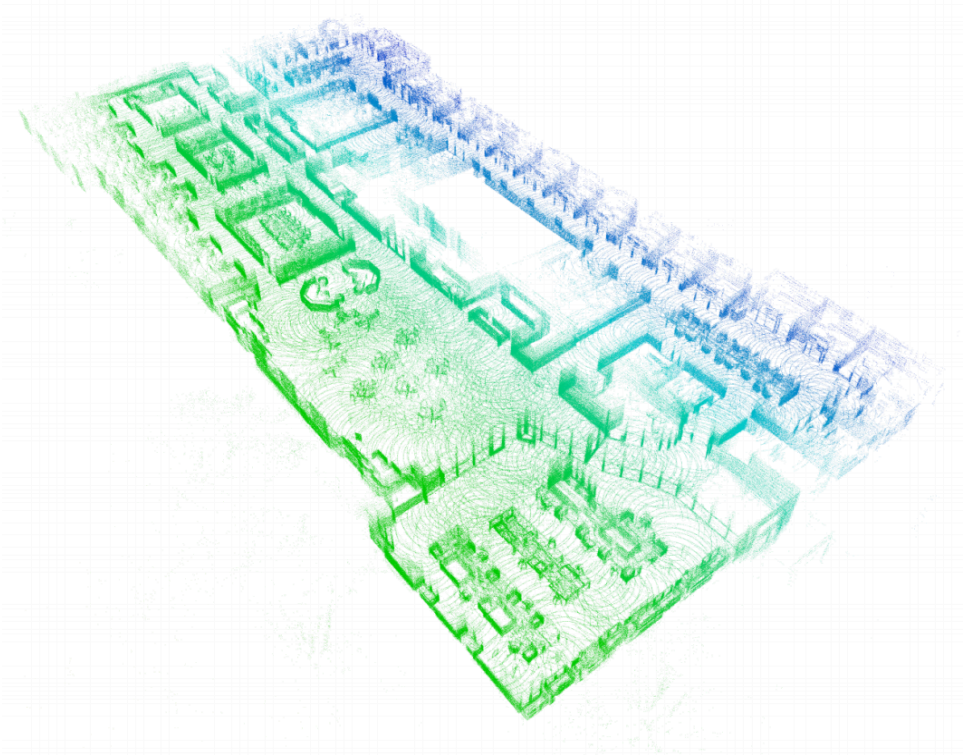
$$\frac{d = (Et \times c)}{2}$$ Where c = speed of light



LiDAR

- Output = **Point Cloud**

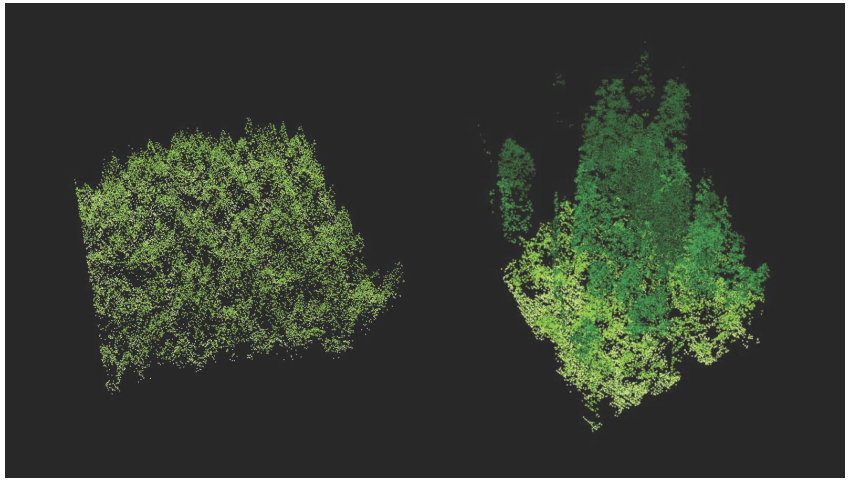




LiDAR

- Metrics:
  - Number of Beams
  - Points per Second
  - Rotation Rate (Hz)
  - Field of View

- Applications
  - Agriculture
  - Archaeology
  - Geology
  - Conservation and Forestry
  - Astronomy (distance to moon!)
  - Surveying and Atmospheric Science
  - Law Enforcement

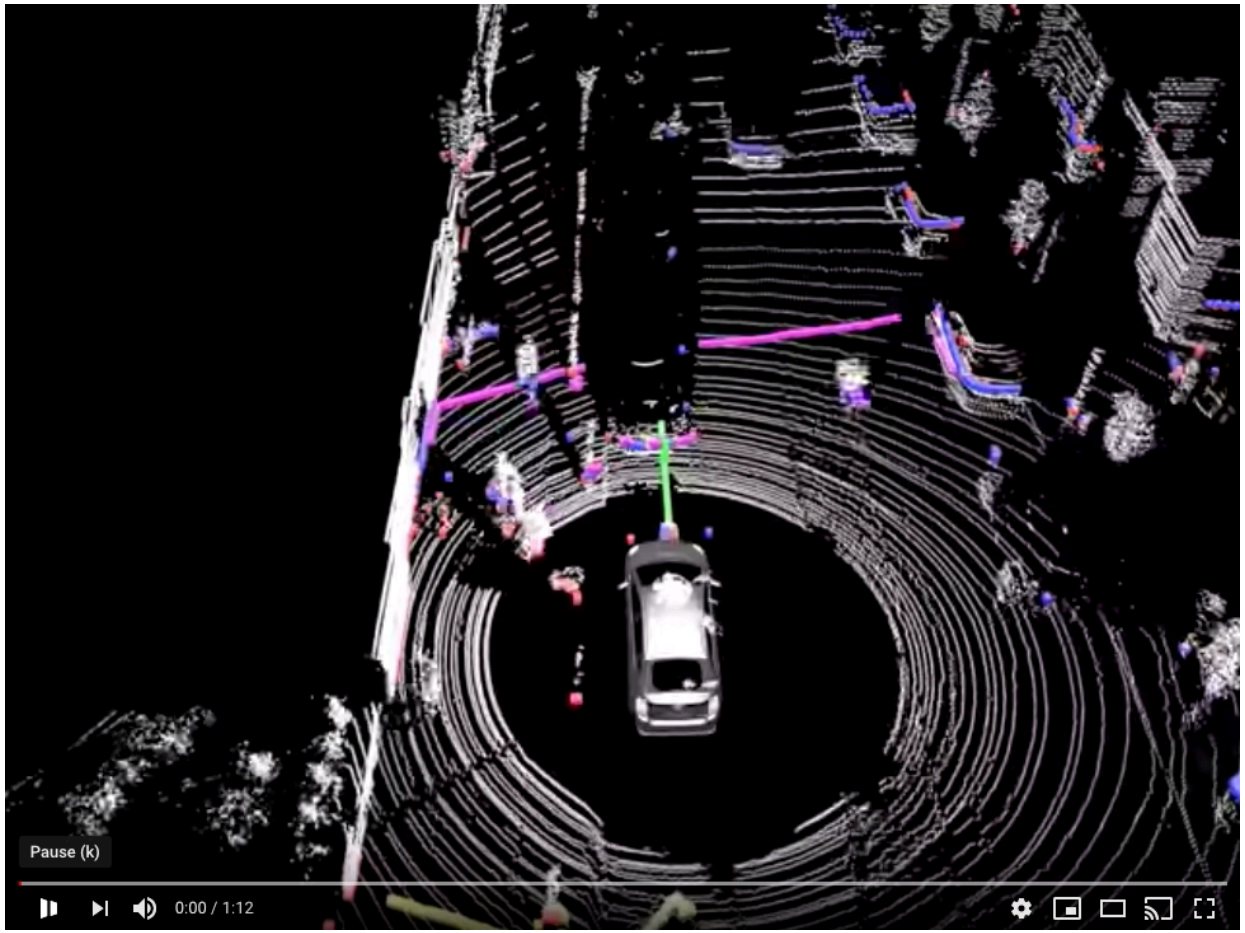


LiDAR

LiDAR Gun

LiDAR

LiDAR in Self Driving Car



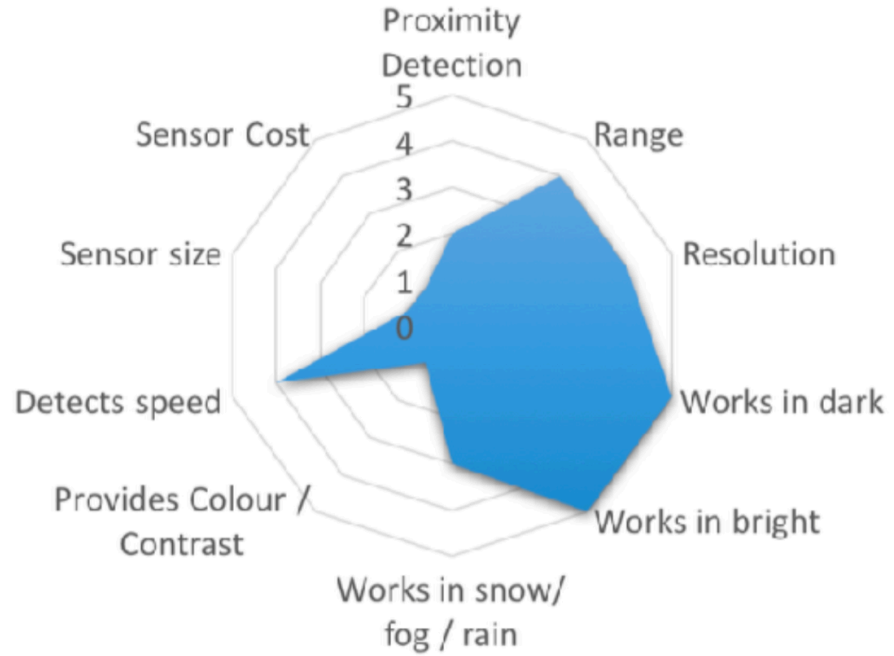
LiDAR

LiDAR in Self Driving Car

LiDAR

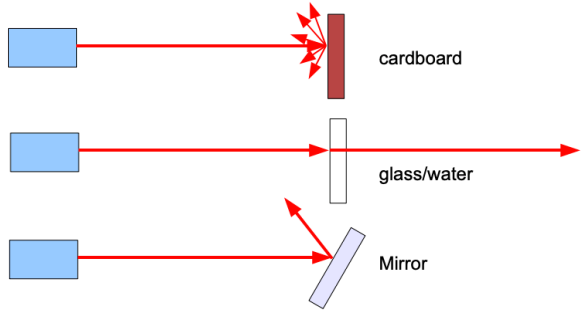
Pros

- VERY accurate depth information
- Good Resolution
- Long Range (400m-ish)
- Large Field of View (360°)



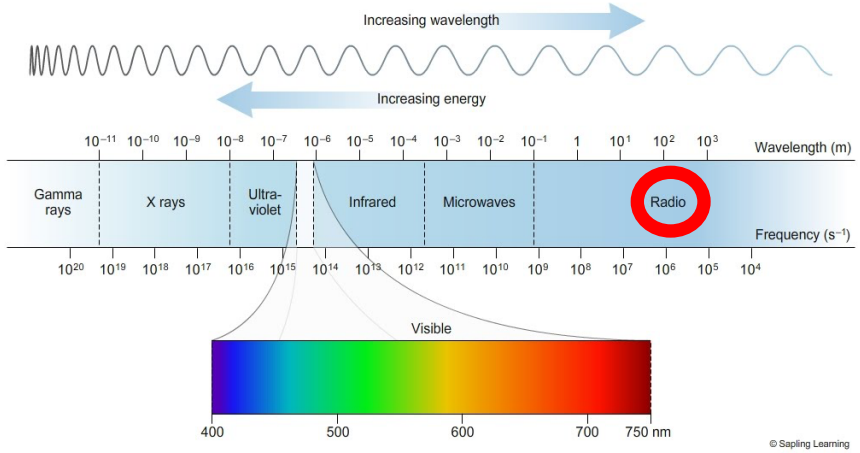
Cons

- Expensive!!
  - Commercial-grade LiDAR can cost upwards of... $75,000!
- Reflections
- Bad in extreme weather (rain and snow)



Radar

- Similar to Lidar, except with radio waves
- Object Detection and Speed Estimation

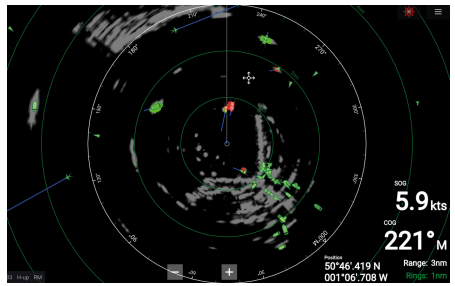


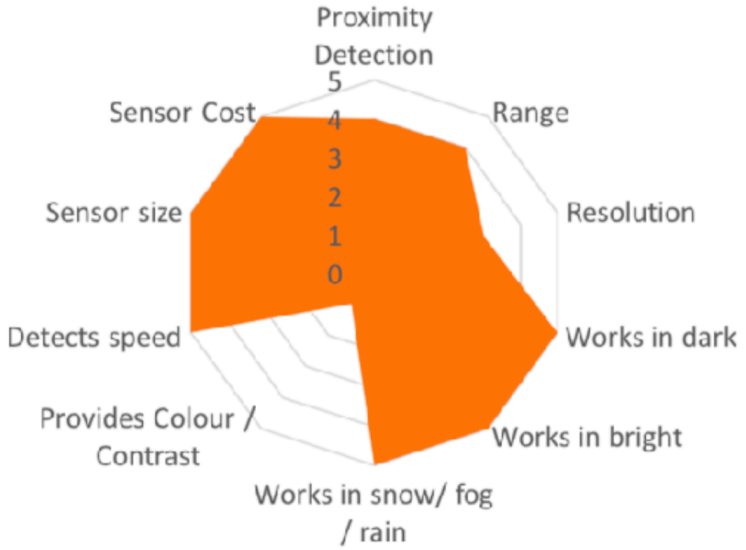
Pros

- Long range
- Better for big objects
- Cheap
- Does well in extreme weather

Cons

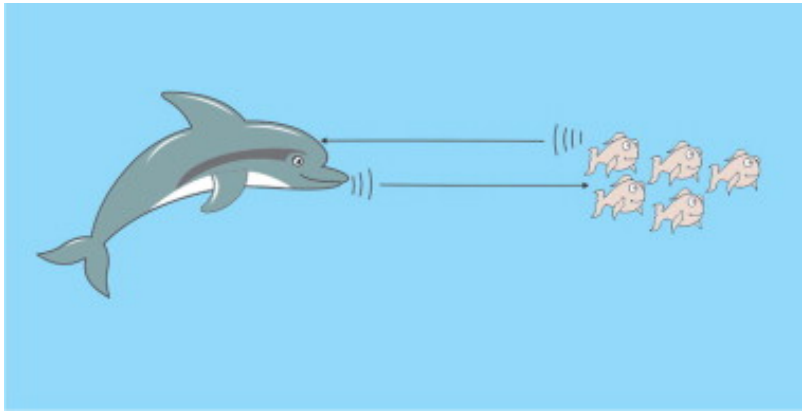
- Low Resolution





Ultrasonic

- Sonar (based on sound)

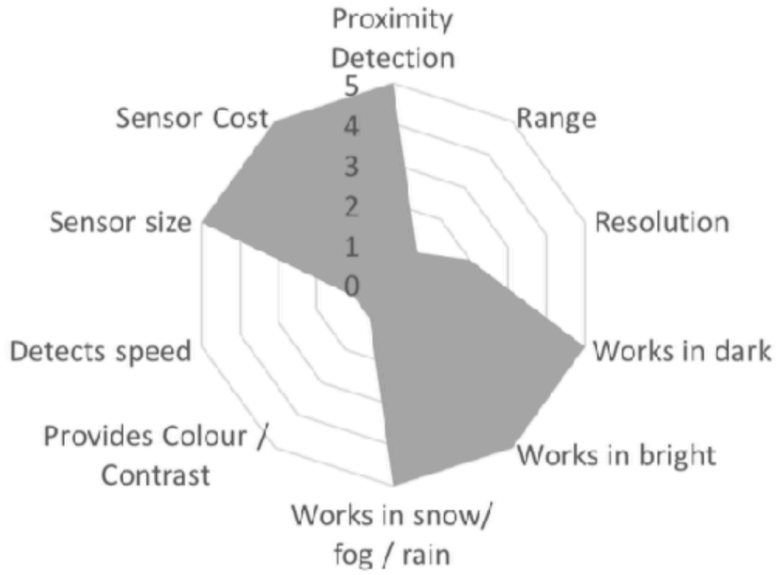


Pros

- Low cost
- Impervious to weather

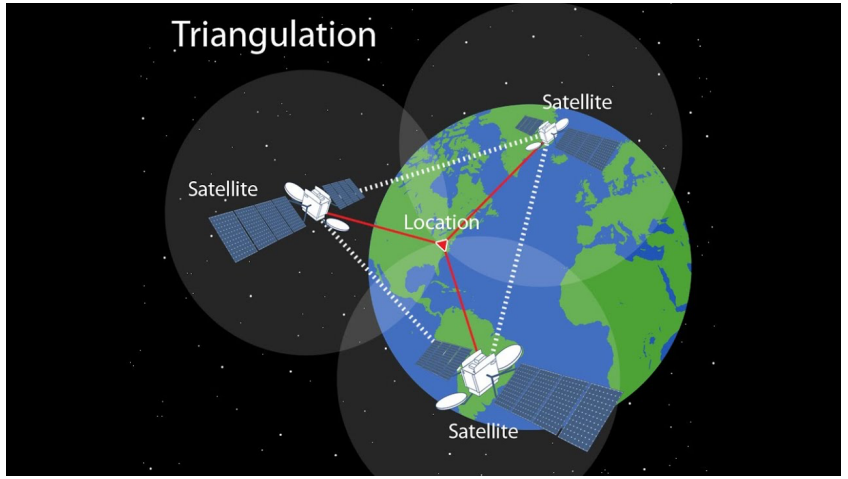
Cons

- Short range
- Better for proximity sensing
- Bad resolution



GPS

- Global Positioning System
- Proprioceptive (internal)

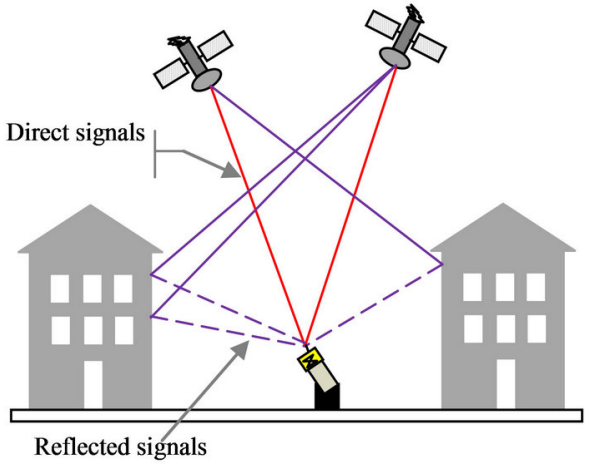


Pros

- *Decent* positioning
- Cheap and readily available

Cons

- Accuracy!
  - 10m vs 10cm accuracy
- Errors!
  - Atmospheric
  - Multipath Problem
- Low Update Rate

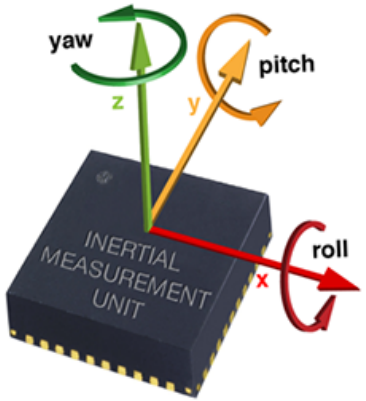


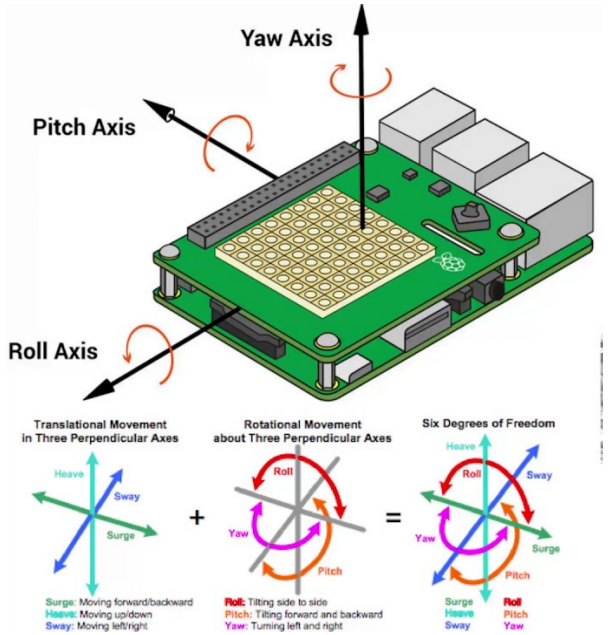
IMU

- Inertial Measurement Unit
- Proprioceptive (internal)

- Combo of Accelerometer and Gyroscope

- Used to calculate position and orientation of robot
  - How is your robot moving?
  - Heading = IMU + GPS
- Can be used independently if other sensors fail





Camera vs LiDAR: The Future

Camera

- Better / more available data
- Better Computer Vision algorithms (active area of research)

LiDAR

- Cheaper
- Increased range
- Upcoming... *Solid-State Lidar*??

Tradeoffs

You don't need <u>all</u> these sensors!

- E.g. Roomba
  - Lidar?
  - Cameras?
  - Pressure/Contact Sensors?

- E.g. Autonomous Drones
  - Agility vs Weight
  - Energy Consumption

- Who makes the tradeoffs?

And they lived happily ever after...

SENSOR FUSION!!

And they lived happily ever after...

SENSOR FUSION!!