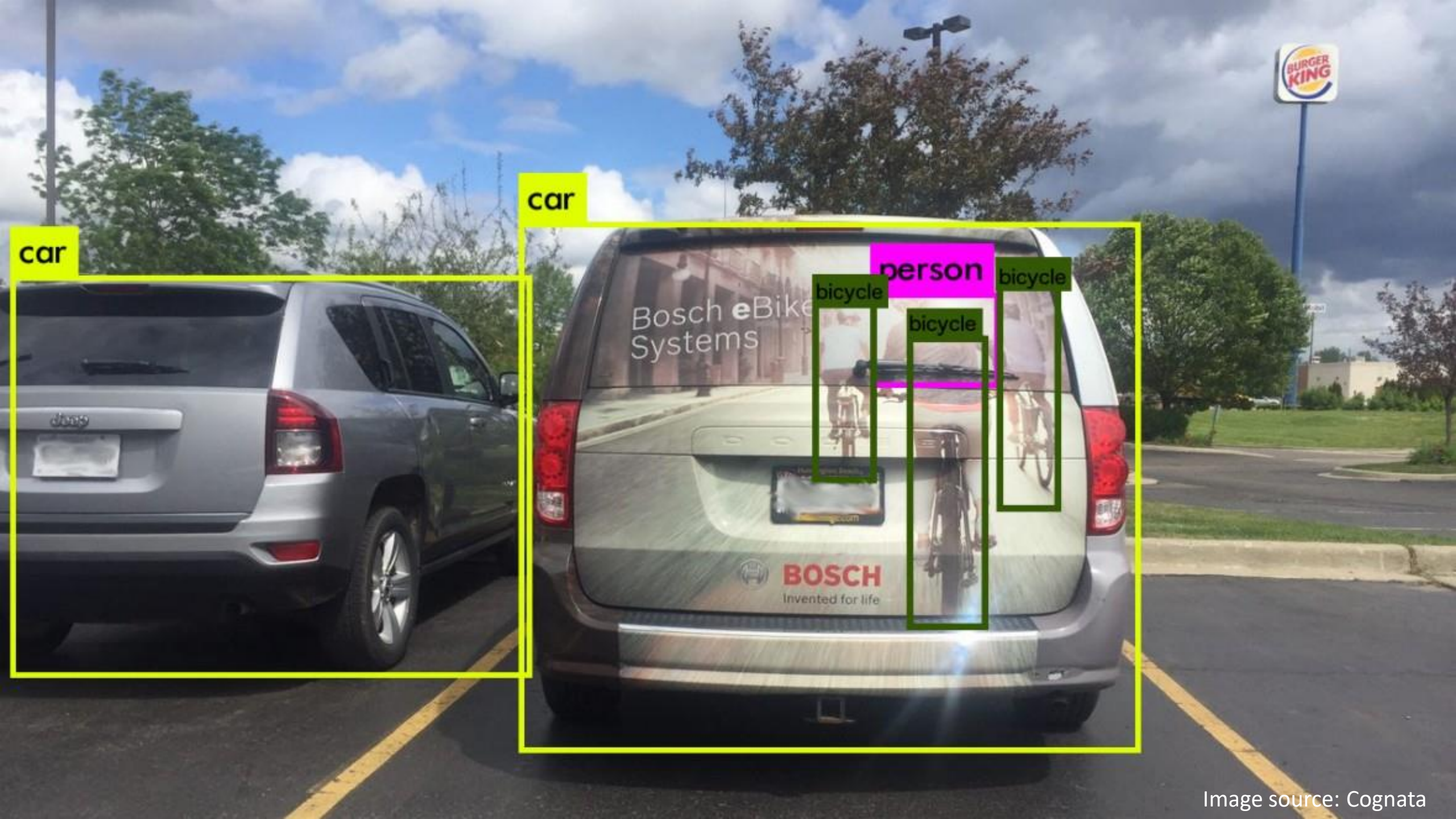
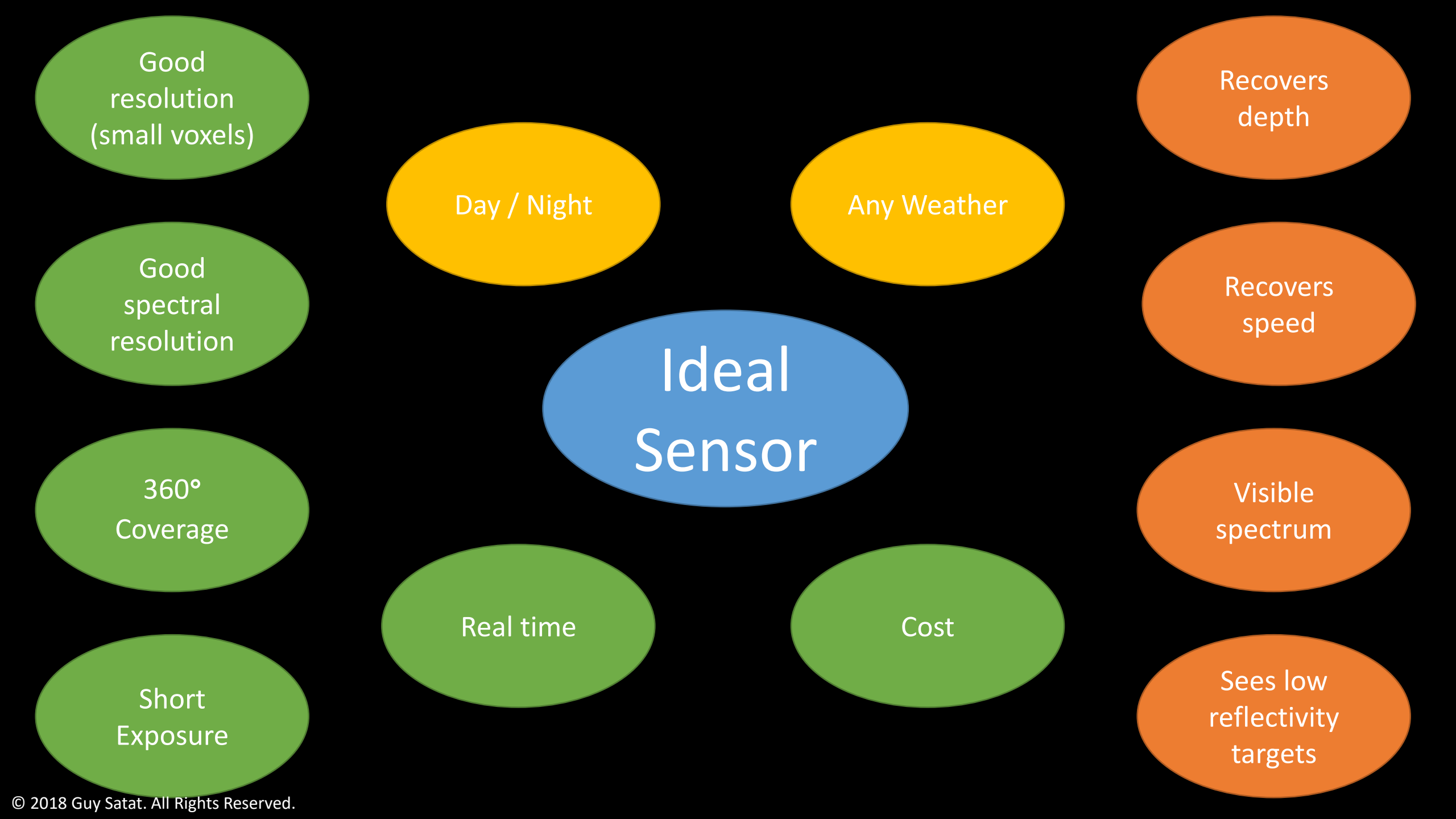
mit media lab

Autonomous Vehicles – Sensors and Limitations

Guy Satat

Computational Imaging for Self-Driving Vehicles @ CVPR 2018


car
car
person
bicycle
bicycle
bicycle
Bosch eBike Systems
BOSCH
Invented for life
BURGER KING
Image source: Cognata



Common Sensors on AVs

- Ultrasonic
- RGB Camera
- Stereo Camera
- LiDAR
- RADAR

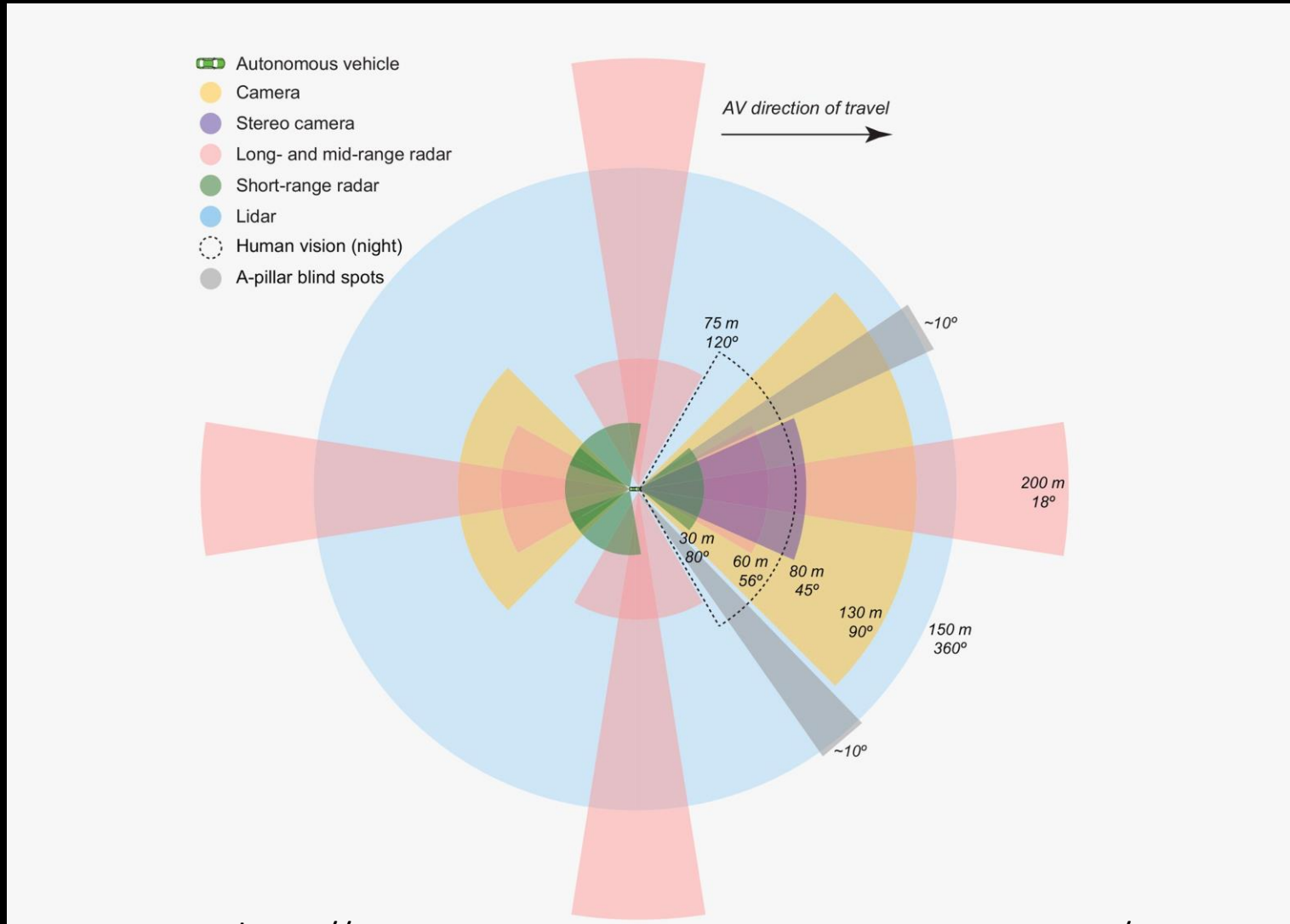
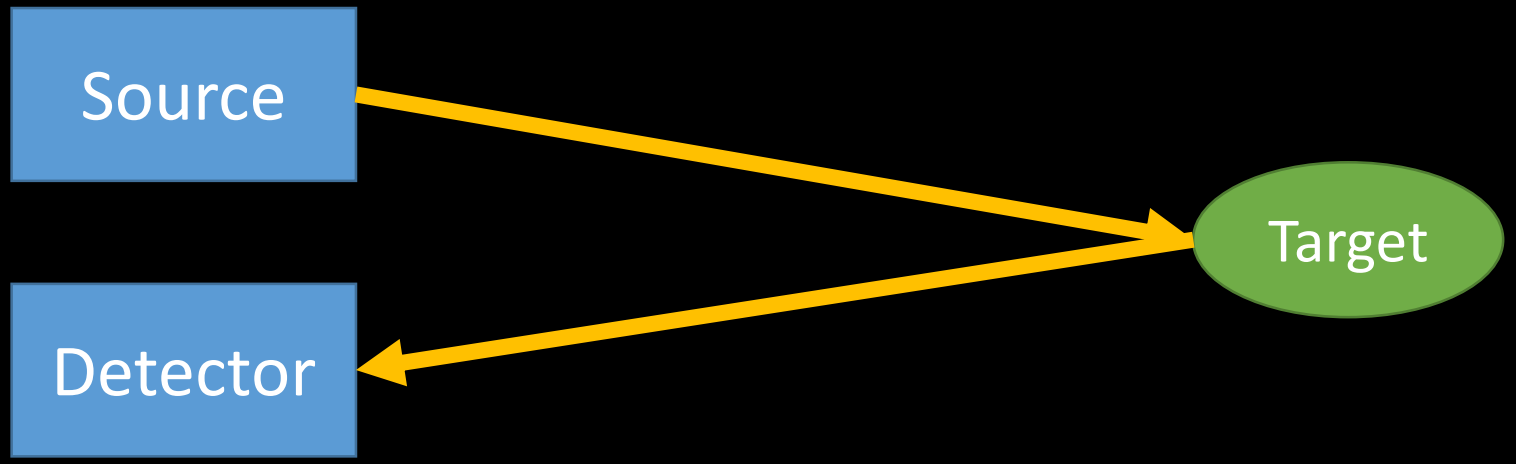
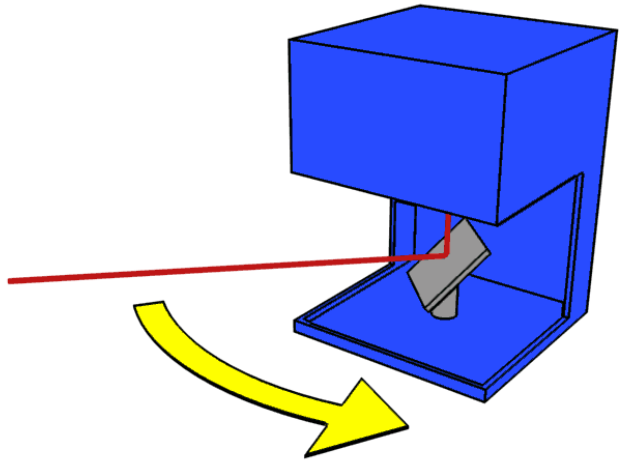


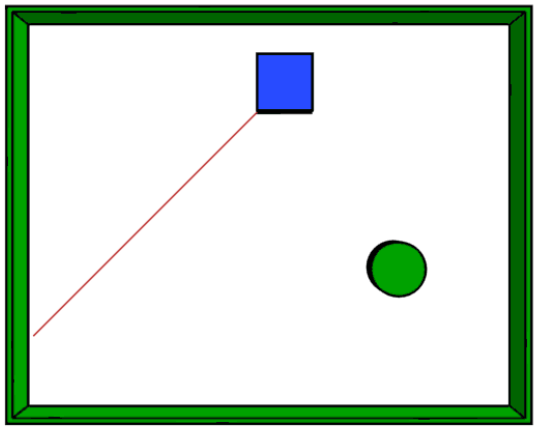
Image source: https://www.wired.com/story/self-driving-cars-perception-humans/

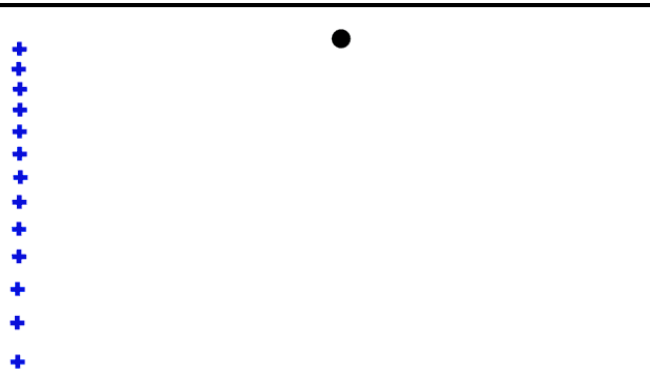
RADAR / Ultrasonic / LiDAR



$$d = \frac{1}{c}\frac{T}{2}$$







Ultrasonic Sensor

- Short range (~cm – few meters)
- Low cost
- Mostly for parking assist
- Being replaced by RADAR

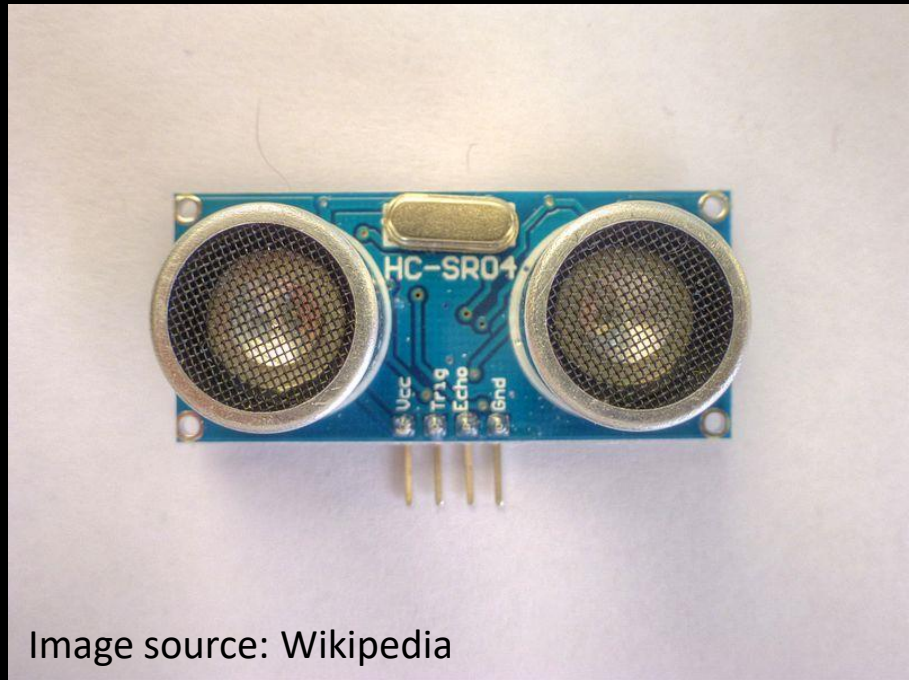


Image source: Wikipedia

RADAR

Image source: Wikipedia

Short Range	Long Range
24 GHz	77 GHz

RADAR

Image source: Wikipedia

Short Range	Long Range
24 GHz	77 GHz
Smaller antennas	More accurate

RADAR

Image source: Wikipedia

Short Range	Long Range
24 GHz	77 GHz
Smaller antennas	More accurate
360 (complements blind spots)	Forward facing

RADAR

Image source: Wikipedia

Short Range	Long Range
24 GHz	77 GHz
Smaller antennas	More accurate
360 (complements blind spots)	Forward facing
Used for: • Lane change assist • Parking assist • Cross traffic monitoring	Used for: • Break assist • Adaptive cruise control

LiDAR

- Raster Scan
  - Multiple beams / detectors
  - MEMS
  - Solid state
- Limited optical budget
  - Eye safety
- Usually NIR (905 / 1550nm)
- Cost
- Low reflectivity targets
- Interference

Image source: Wikipedia

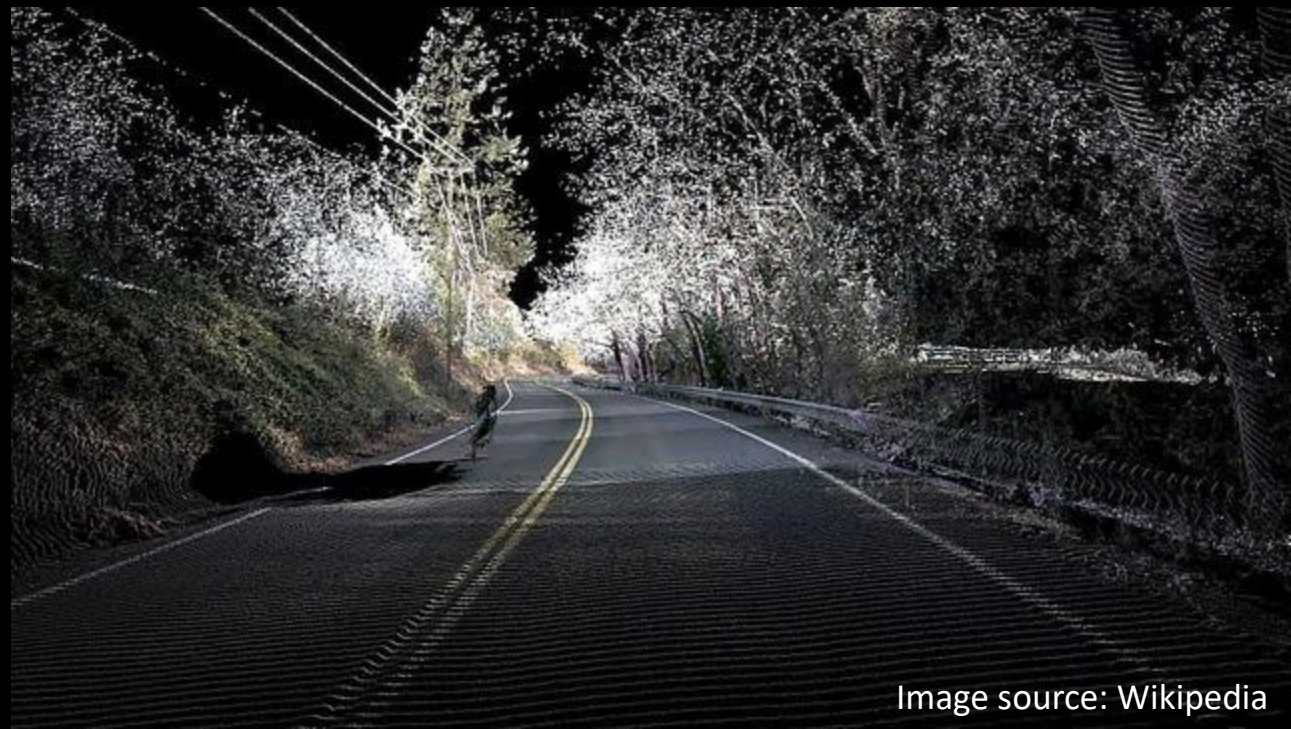
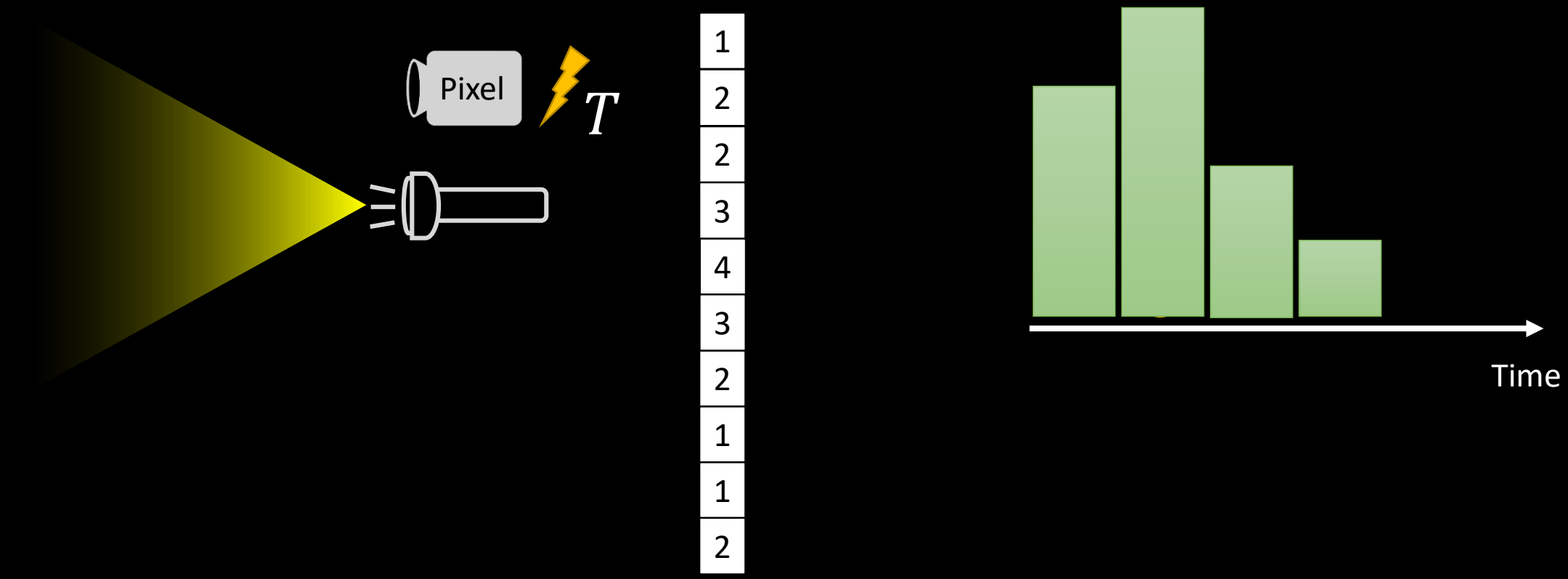
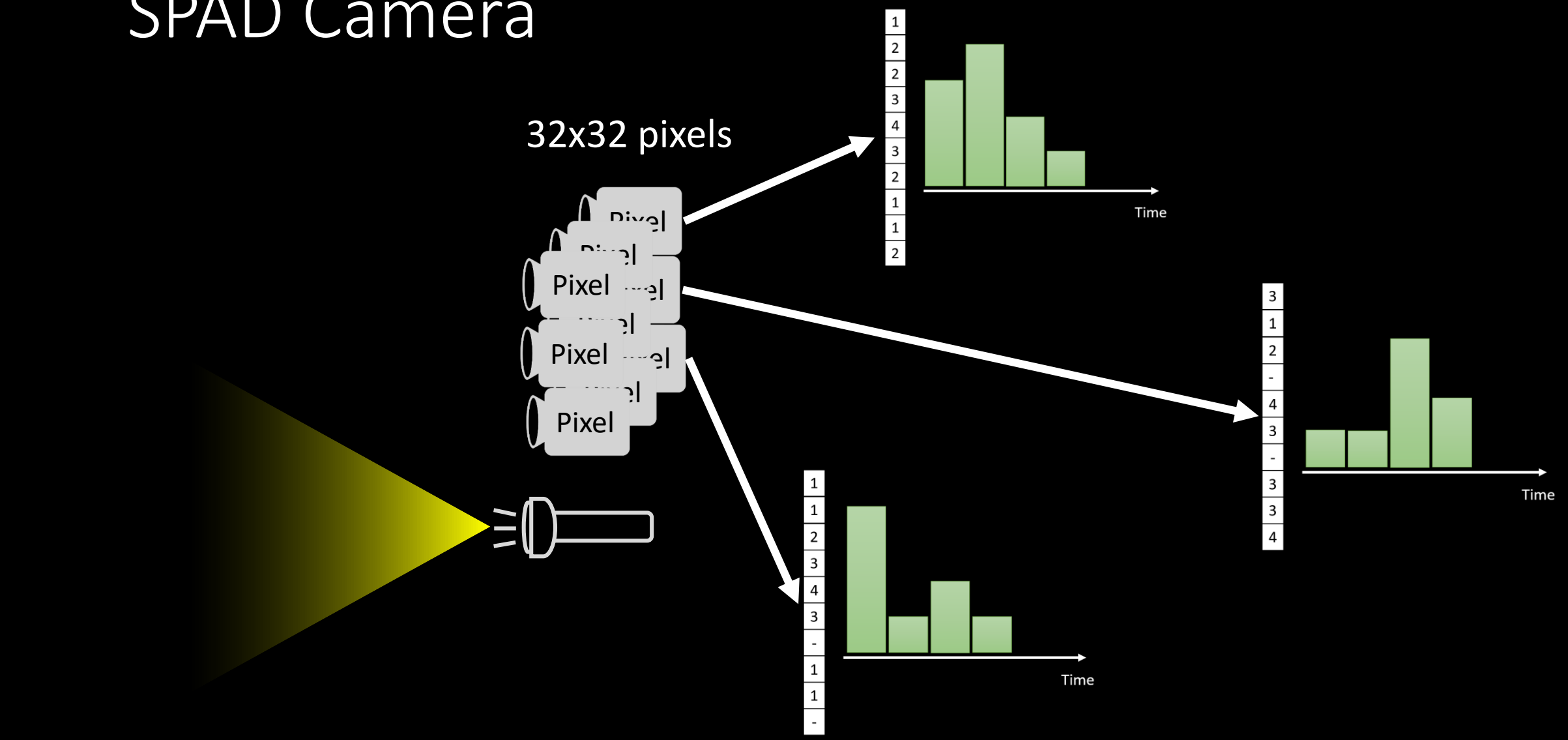


Image source: Wikipedia

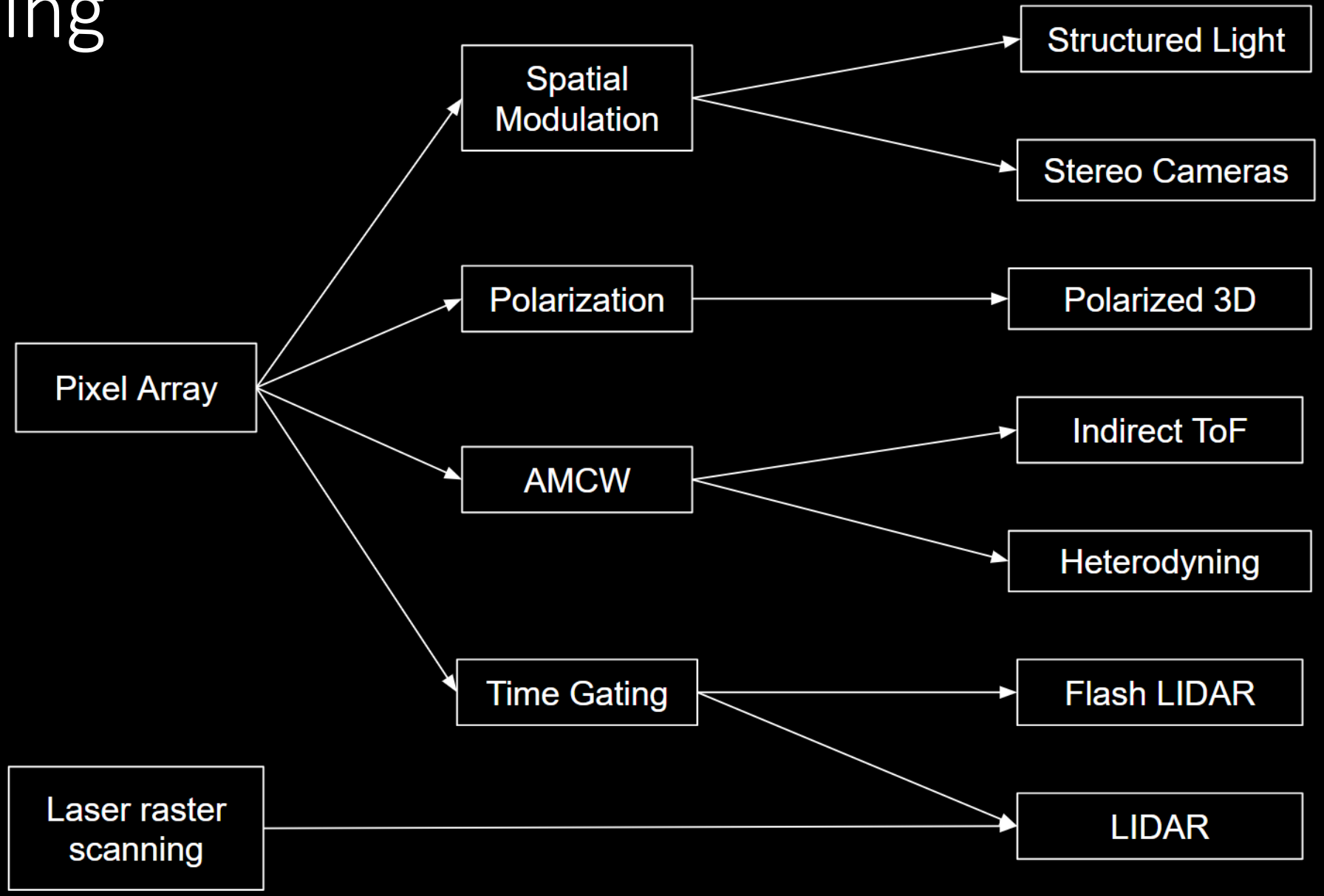
SPAD Pixel



SPAD Camera



Depth Sensing



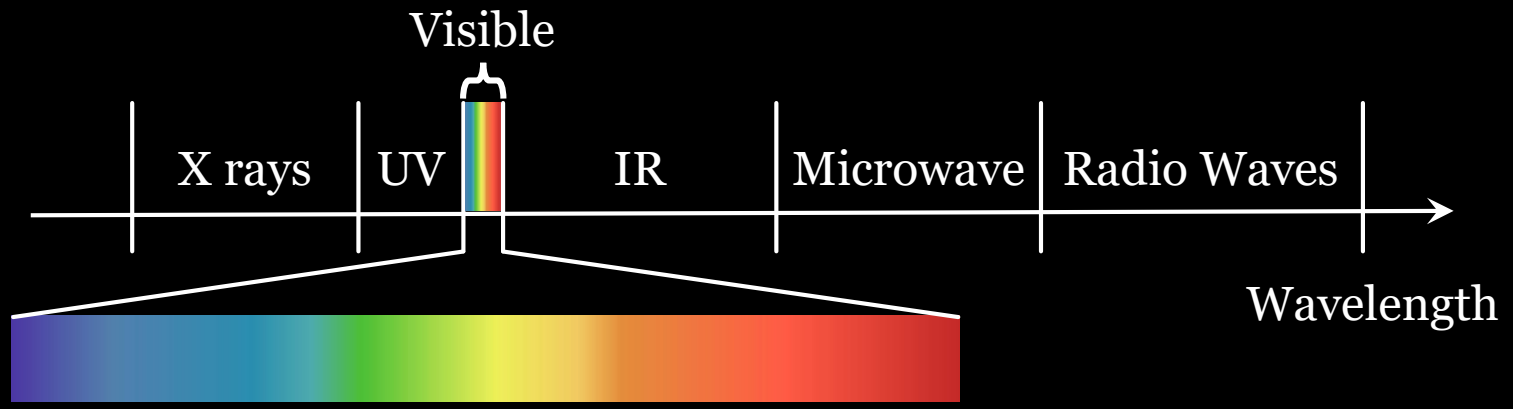
Camera

- 360 / Rear
  - Shorter range
- Front facing
  - Long range
  - Traffic lights / signs
- Challenges
  - Dynamic range: direct sunlight / tunnels
  - Night time

Image source: Wikipedia

	Classification	Localization	Night	Availability	Any Weather
Radar	✗	✗	✓	✓	✓
Ultrasonic	✗	✗	✓	✓	✓
Camera	✓	✓	✗	✓	✗
LiDAR	✓	✓	✓	✗	✗

Imaging Across the EM Spectrum



Visible Light:

- Good resolution (compared to RF)
- Optical contrast
- Non-ionizing radiation

Wavelengths:

- EM Visible $\sim \mu m$
- EM Radio $\sim cm$
- Ultrasound: $> cm$

Optical Contrast

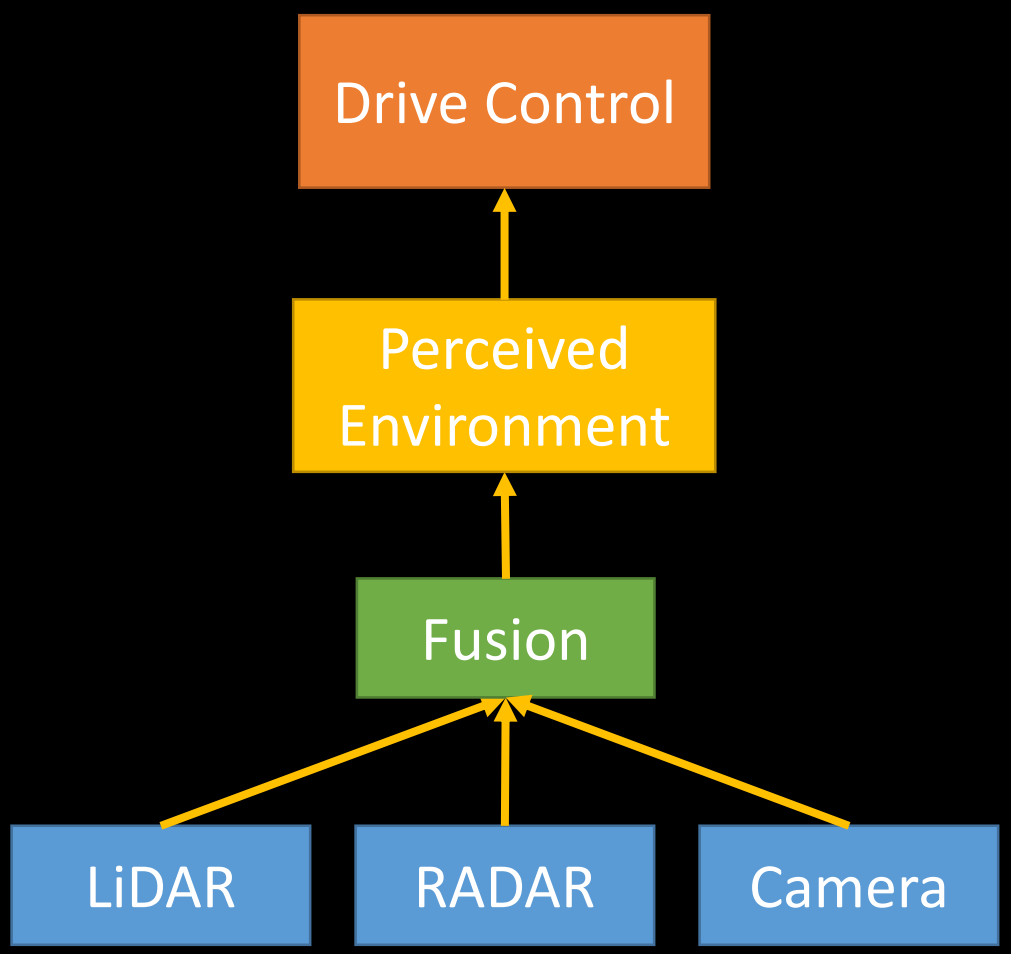
Wildlife Rehabilitation Center of Minnesota

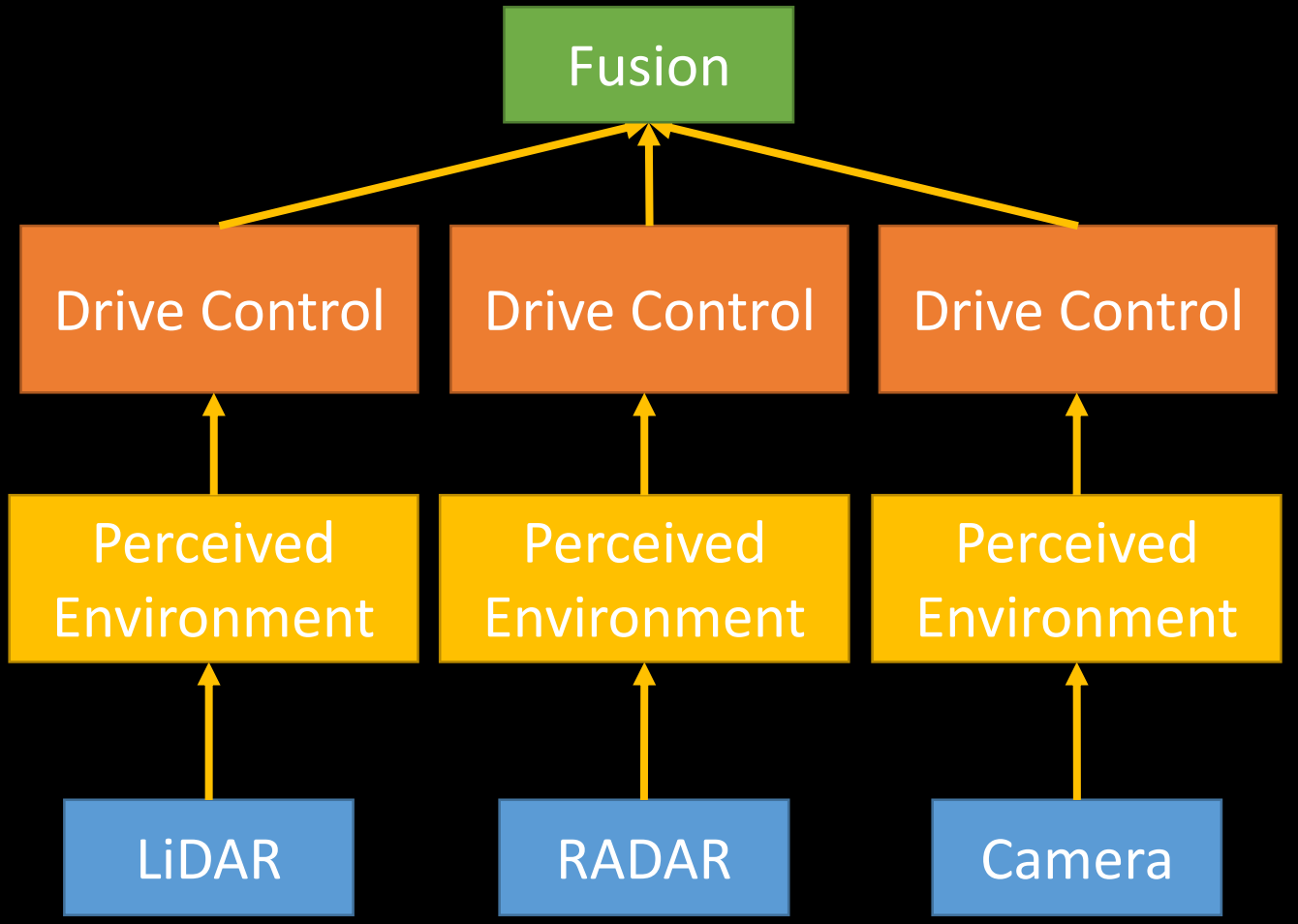
Other Sensors

- IR / Thermal cameras
- Time gating
- Stereo Cameras
- mmWave RADAR
- Event cameras

Image source: Wikipedia

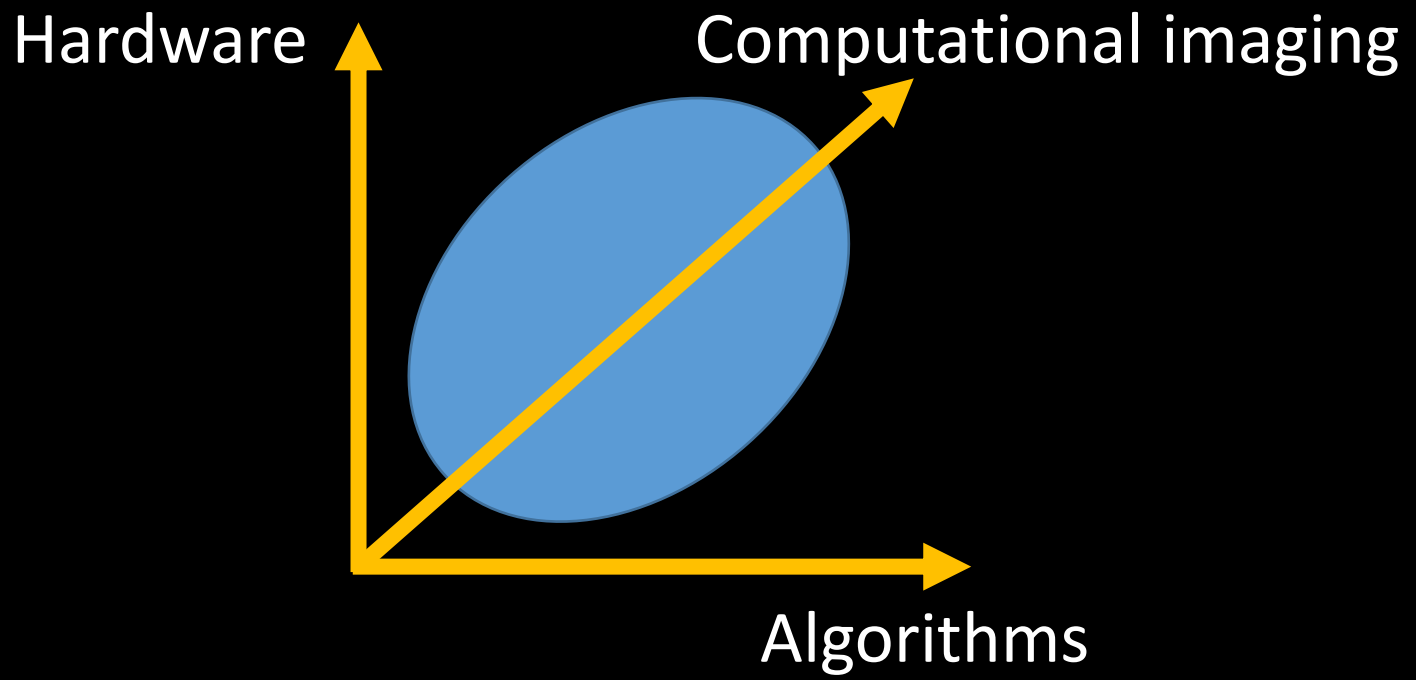
Sensor Fusion





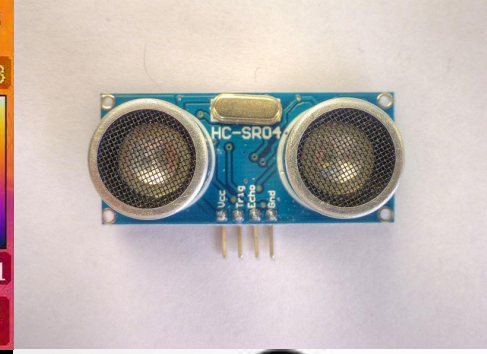
Learning to Sense

- What sensors do we really need?
- How does sensors spec affect end-to-end performance



Key Takeaways

- Different sensors for:
  - Complement limitations
  - Different applications
- Ultrasonic, RADAR, LIDAR, Camera
- Sensor Fusion



Images source: Wikipedia