3D Data Processing

3D Sensor

Department of Software Convergence
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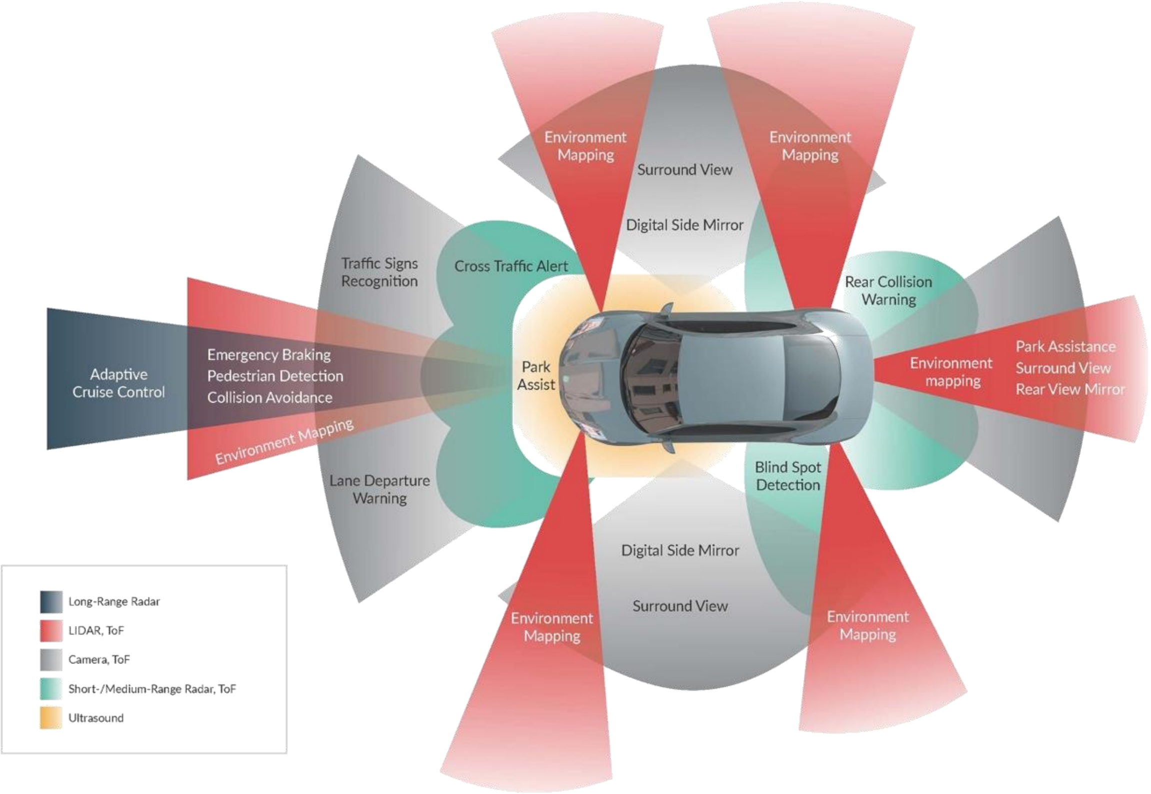
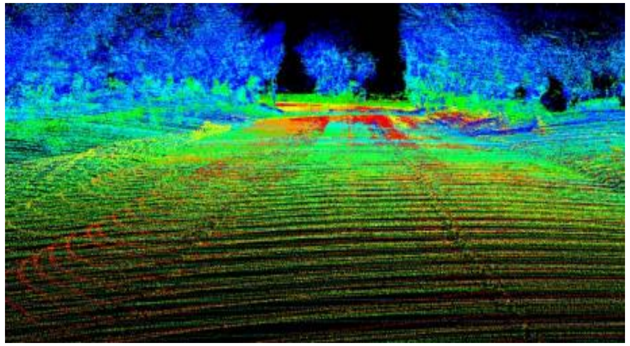
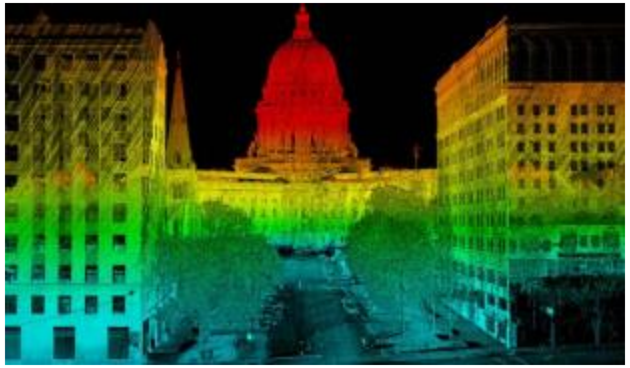
Range sensing and 3D technologies

- Complementary range sensing and 3D technologies used in a modern car







LiDAR

- LiDAR (Light Detection and Ranging)
  - Light pulses sent out, reflected off object and received for interpretation.
  - Produces high resolution, accurate, land-elevation information
  - The LASER system, employed for monitoring the nature of environment is called LIDAR.
  - In some cases, it is also called "Laser Imaging, Detection and Ranging”

- Principles
  - Laser generates an optical pulse
  - Pulse is transmitted, reflected and returned to the receiver
  - Return beam/pulse is collected and processed to obtain property of target.
  - Receiver accurately measures the travel time

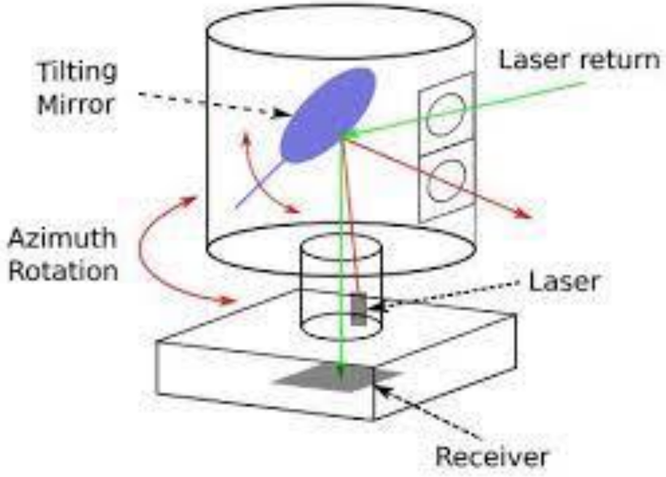
LiDAR

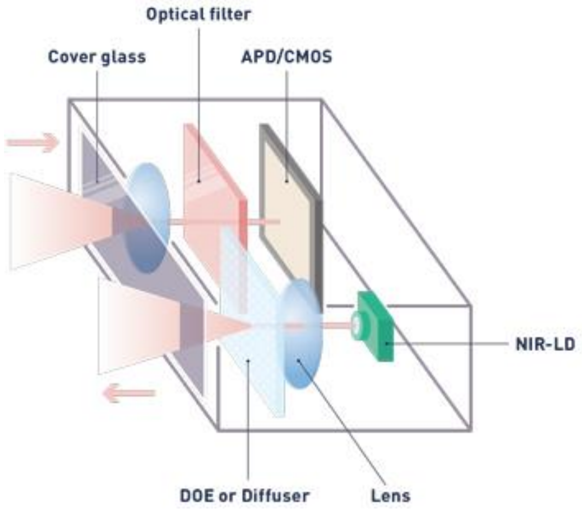
- Why LiDar?
  - LiDAR is most accurate perception sensor
  - 3D shape with width/height information
  - Distance with high accuracy

	LiDAR	Radar	Video
Range	+++	+++	-
Range Rate	++	+++	-
Field of View	+++	++	+
Width & Height	+++	-	+
3D Shape	+++	-	-
Object Rec @ Long Range	+++	-	-
Accuracy	+++	-	+
Rain, Snow, Dust	++	+++	-
Fog	+	+++	-
Night time	+++	+++	-
Read Signs & See Color	+	-	+++

LiDAR

- Components
  - Laser
    - 600-1000nm lasers used for non-scientific application
      - Inexpensive
      - Easily absorbed by eye
    - 1500nm lasers
      - less advanced, longer range , lower accuracy
      - Eye safe at much higher power level
      - Used in military application
  - Optics
    - They affect angular resolution and range
    - Hole mirror , Beam splitter
  - Photo detector and receiver electronic
    - photo detectors
    - Photodiodes
  - (optional) Mechanical system for dimension expansion

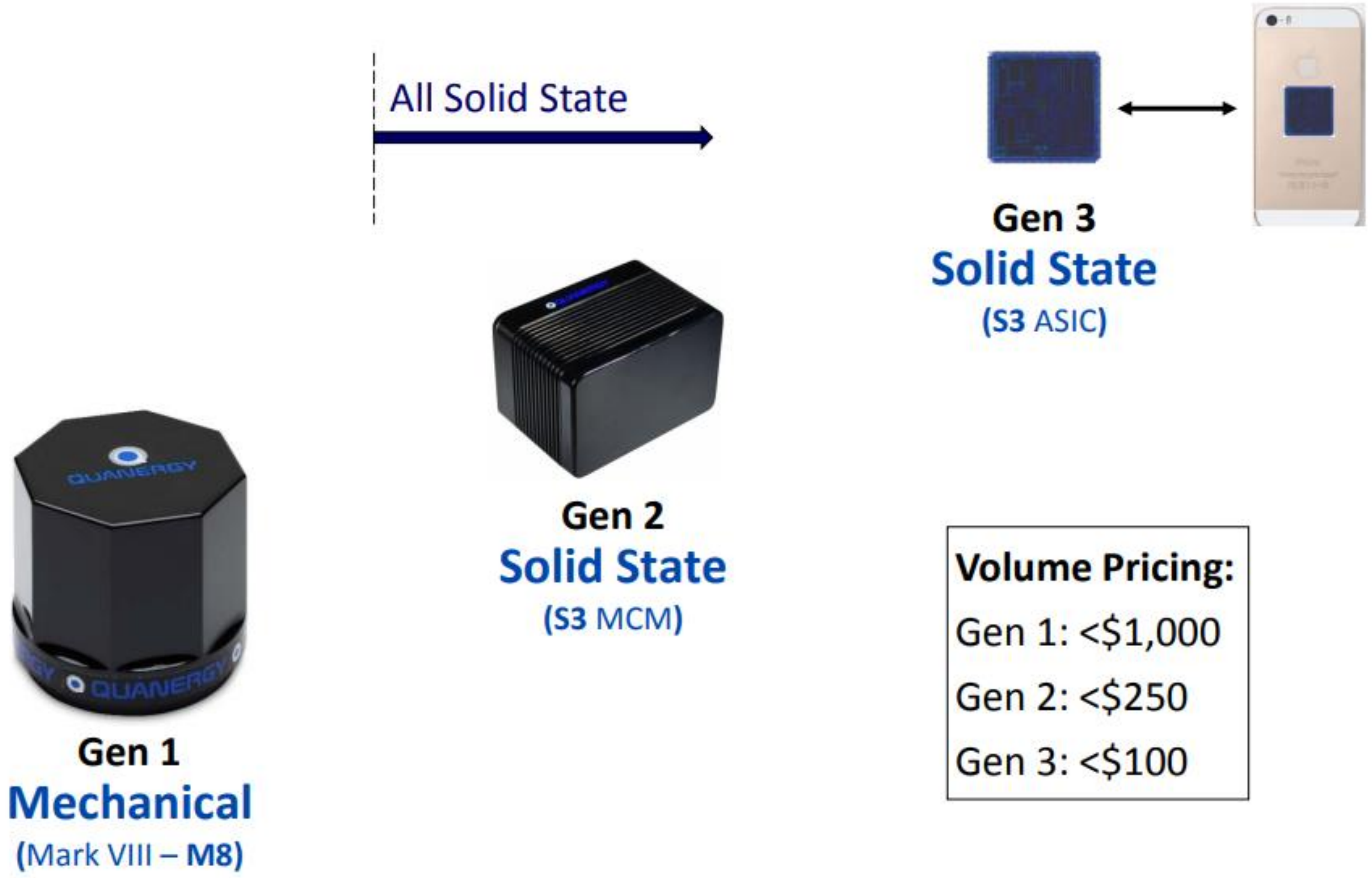




LiDAR classification

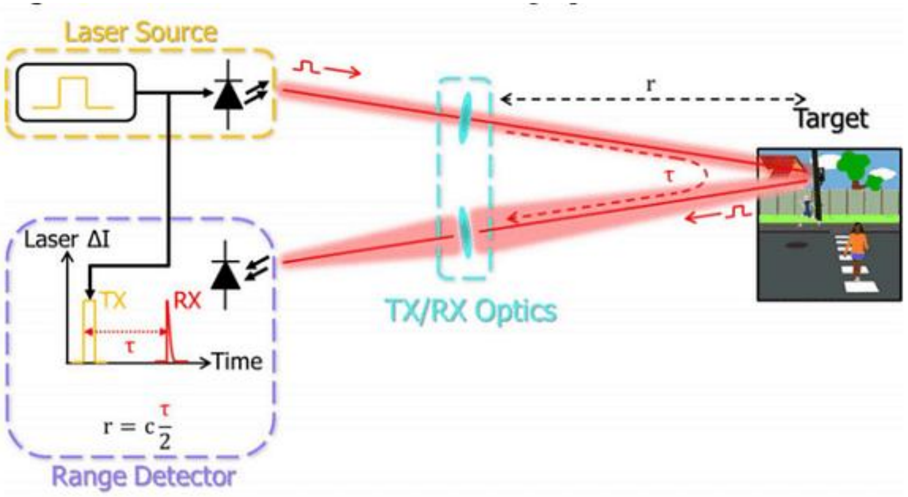
- How it measures
  - TOF (Pulse laser)
  - AMCW TOF
  - FMCW

- How it works
  - Mechanical LiDAR
  - Solid-state LiDAR



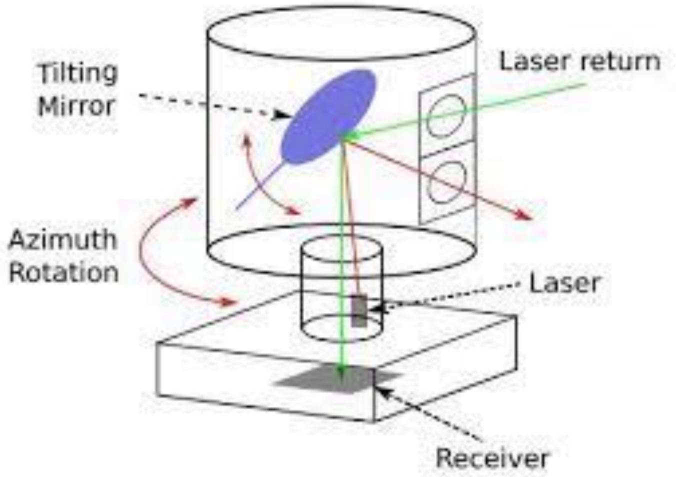
LiDAR

- Types of LiDAR
  - ToF (Time of Flight) - Pulsed Time-of-Flight (TOF) - dTOF
    - Resolve distance between the camera and the subject for each point of the image, by measuring the round trip time of an artificial light signal provided by a laser or an LED.
    - 6.7 ns per 1 m of distance!!



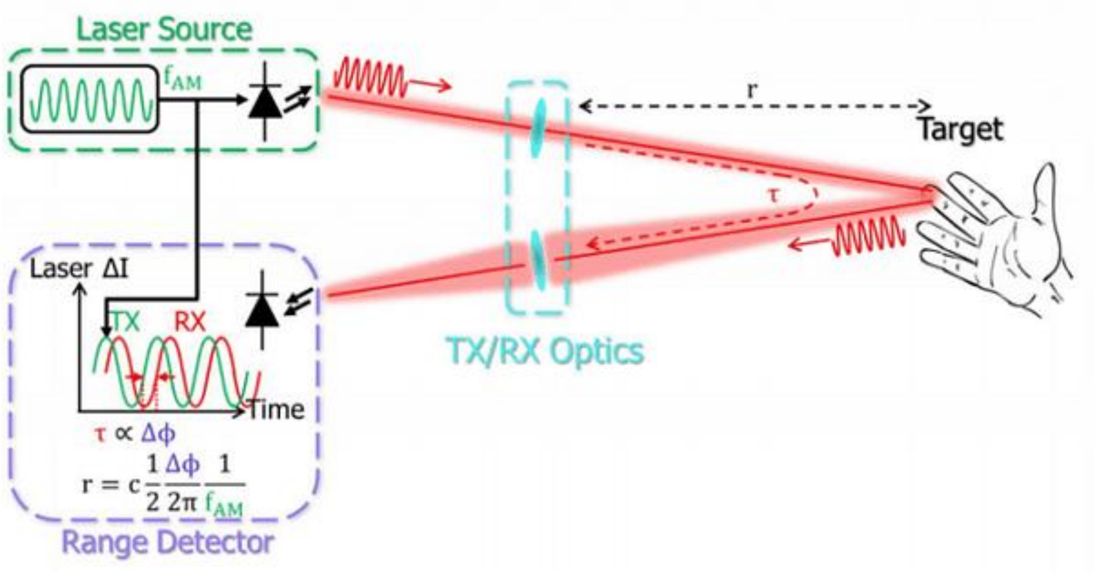
$$d = \frac{ct}{2}$$

d: $distance$
t: $time$
c: $light\ speed$



LiDAR

- Types of LiDAR
  - ToF (Time of Flight) - Amplitude Modulated Continuous Wave (AMCW) Lidar
    - Phase-shift method
    - By comparing the phase difference, the difference in radians of the peaks of the waves, the distance to the object can be found.

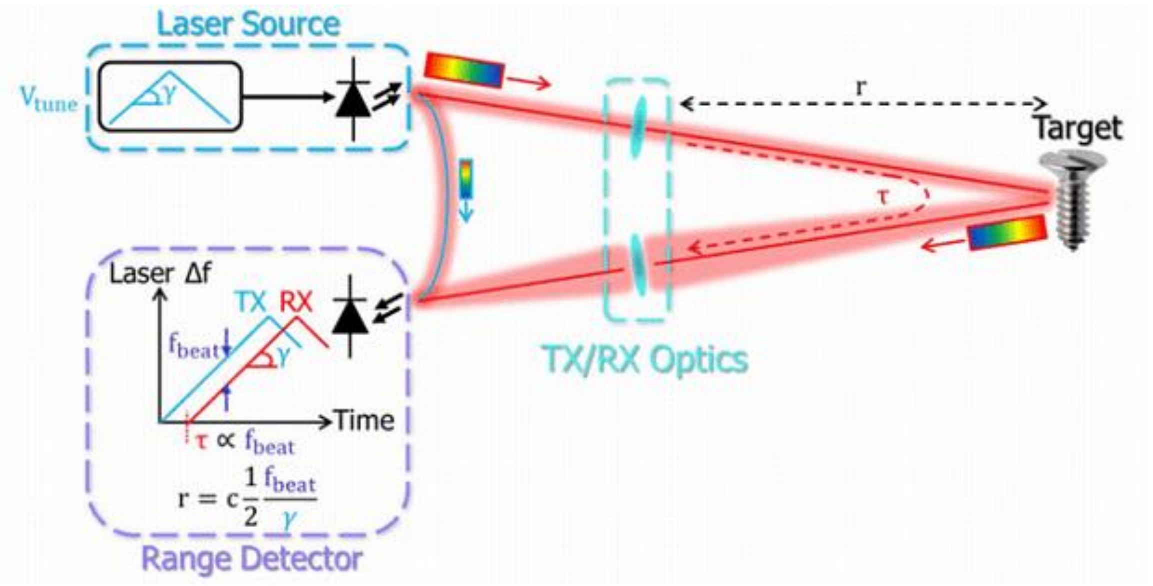


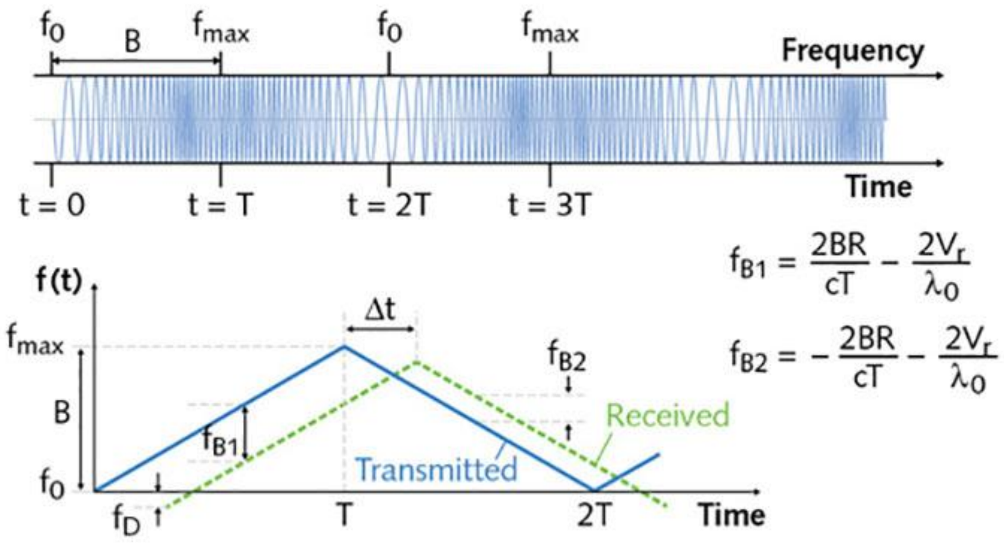
$$d = \frac{c\Delta\phi}{2\pi f}$$

d: $distance$
c: $light\ speed$
$\Delta\phi$: $phase\ shift$
f: $frequency$

LiDAR

- Types of LiDAR
  - FMCW: The Frequency Modulated Continuous Wave
    - FMCW radar can change its operating frequency during the measurement



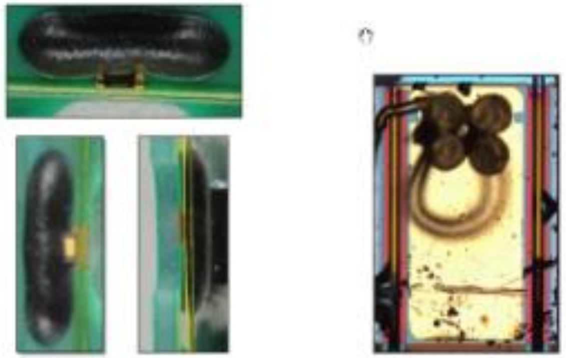


LiDAR classification

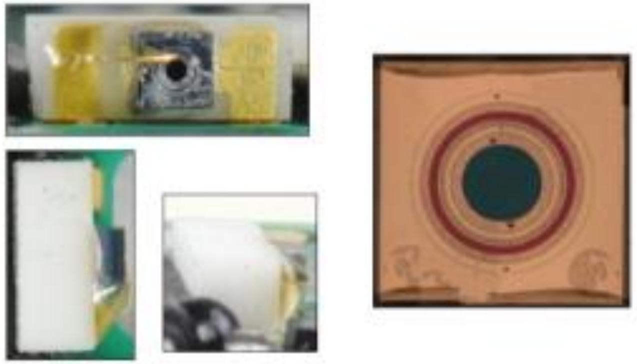
- Mechanical LiDAR
  - uses a motor to physically rotate the sensor to scan the environment.
  - Pros
    - Wide horizontal field of view (360 degrees)
    - Relatively good data accuracy.
  - Cons.
    - Cost
    - Poor durability
    - Pop-up
  - Product
    - Robosense, Velodyne

Velodyne Puck Processor

Velodyne Puck Motor



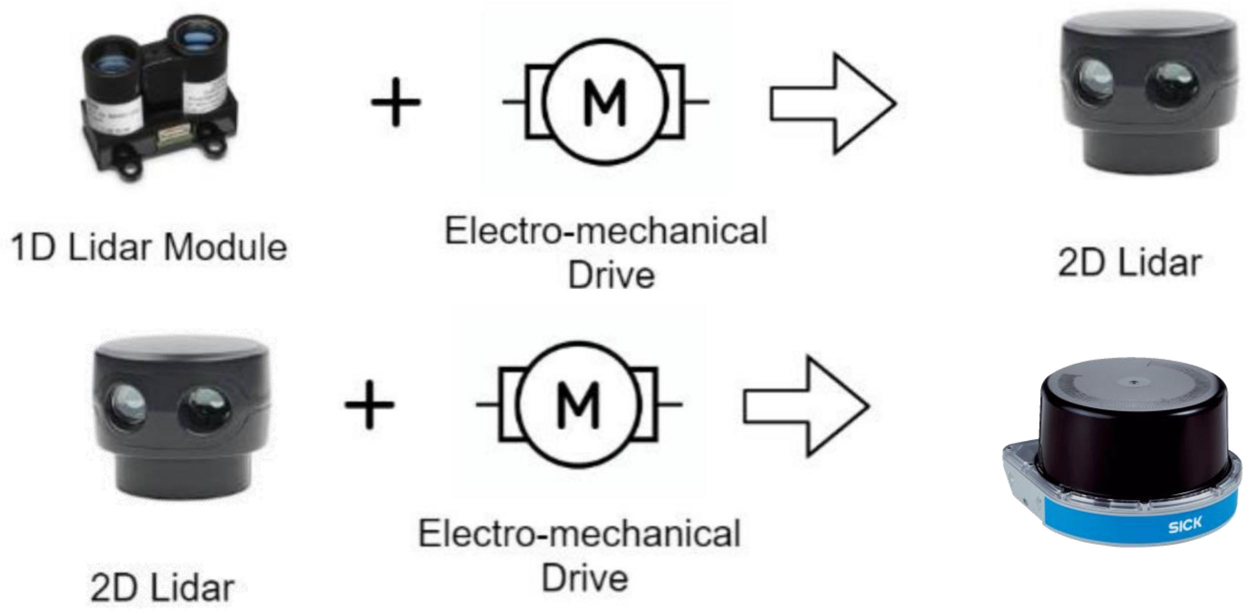
Velodyne Puck Laser Diode



Velodyne Puck Photodiode

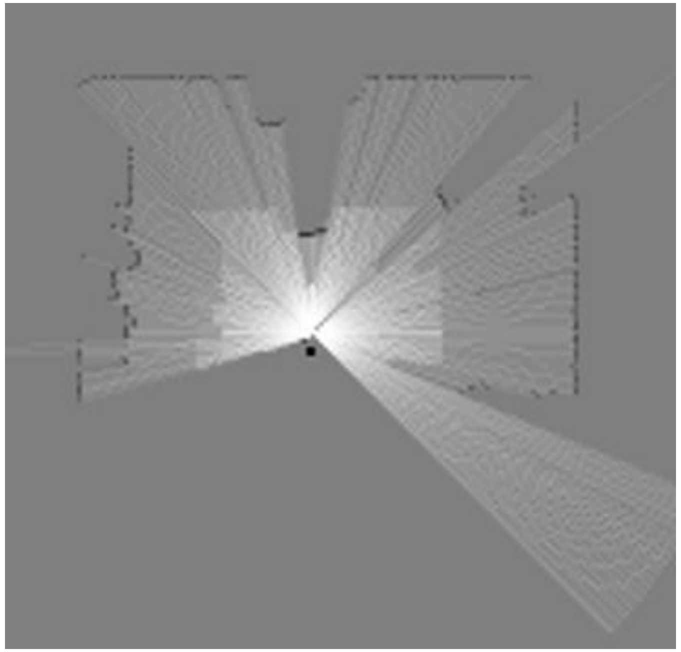
Mechanical LiDAR

- Dimension extension
  - Some Lidar can only measure distances in one dimension.
  - How can we extend the dimensions?
    - Continuously measurement following axis
    - Using 2D Array



Mechanical LiDAR

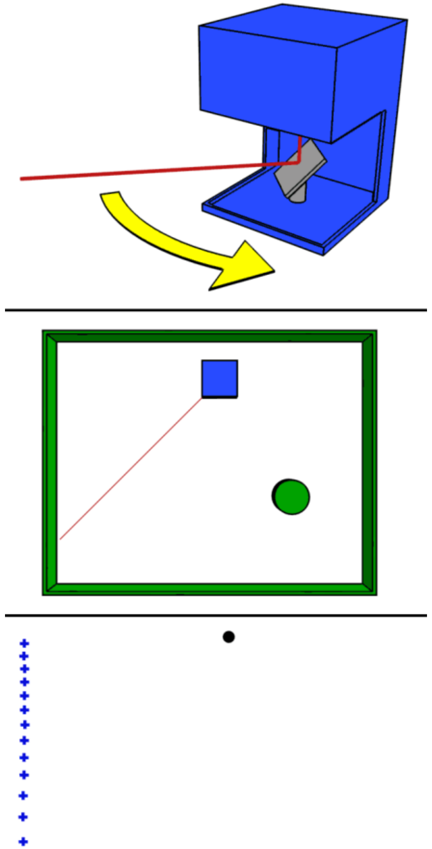
- 2D Lidar (LDS, Laser Distance Sensor)
  - In a short time, repeat distance measurements based on different angles.
  - Distance measurement in polar coordinate system based on the sensor.



LMS111

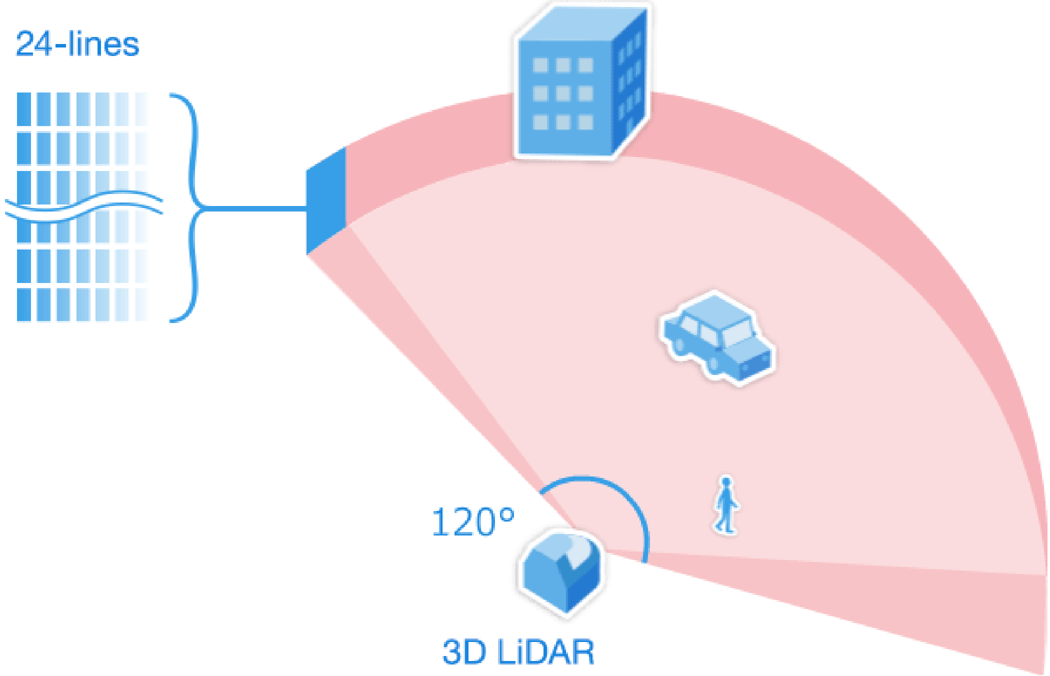
UST-20LX

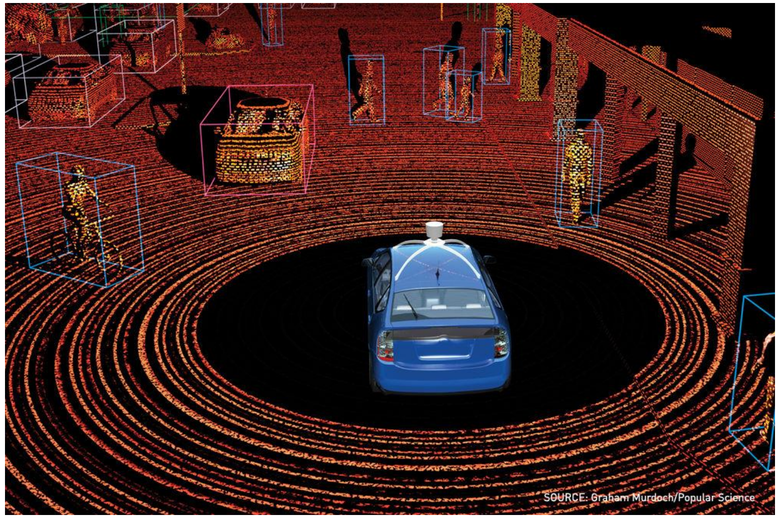
S3000

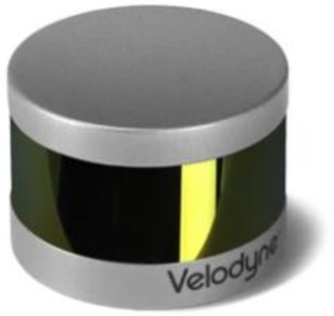


Mechanical LiDAR

- 3D Lidar
  - Rotate 2D (measured simultaneously) LiDAR along axis







Puck

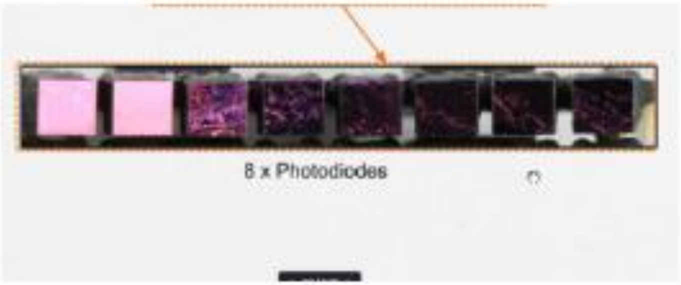
MRS1000 (Outdoor)

LiDAR classification

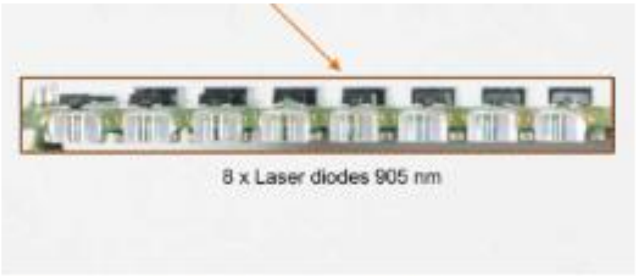
- Solid-State Lidar
  - Fixed, motor-less
  - Pros
    - High durability
    - Embedded type
    - High resolution
  - Cons.
    - Narrow FOV
    - Accuracy
  - Product
    - Livox, Cepton

Cepton Vista P60 Processor

Cepton Vista P60 Opto-Mechanical Unit



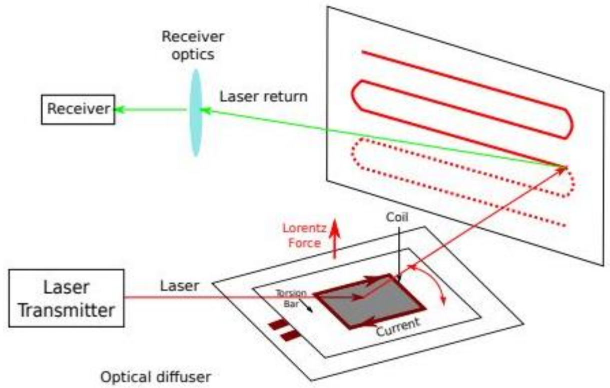
Cepton Vista P60 Photodiode



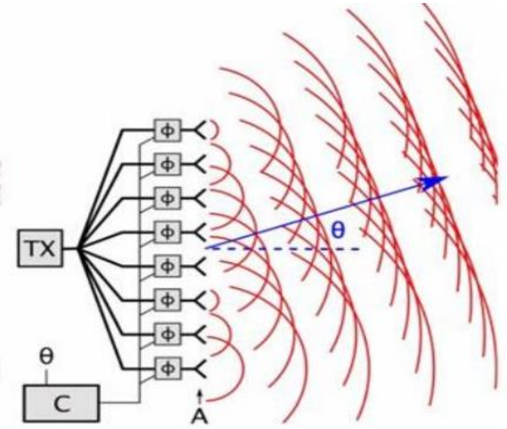
Cepton Vista P60 Laser Diode

LiDAR classification

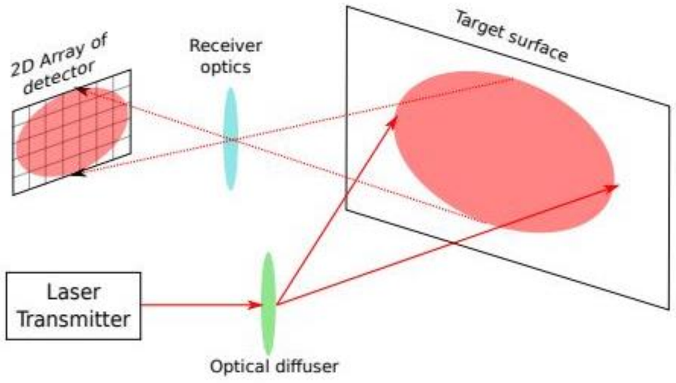
- Solid-State Lidar
  - Scanning Lidar (MEMS Lidar)
    - Mirror reflect the beam in the particular direction (piezzo)
  - Optical Phase Array(OPA)
    - Control direction using Optical Phase Array
  - Flash Lidar
    - a laser forward and capturing the scattered light reflected from a receiver



Scanning Lidar



OPA



Flash Lidar

LiDAR

- Comparison LiDAR by method

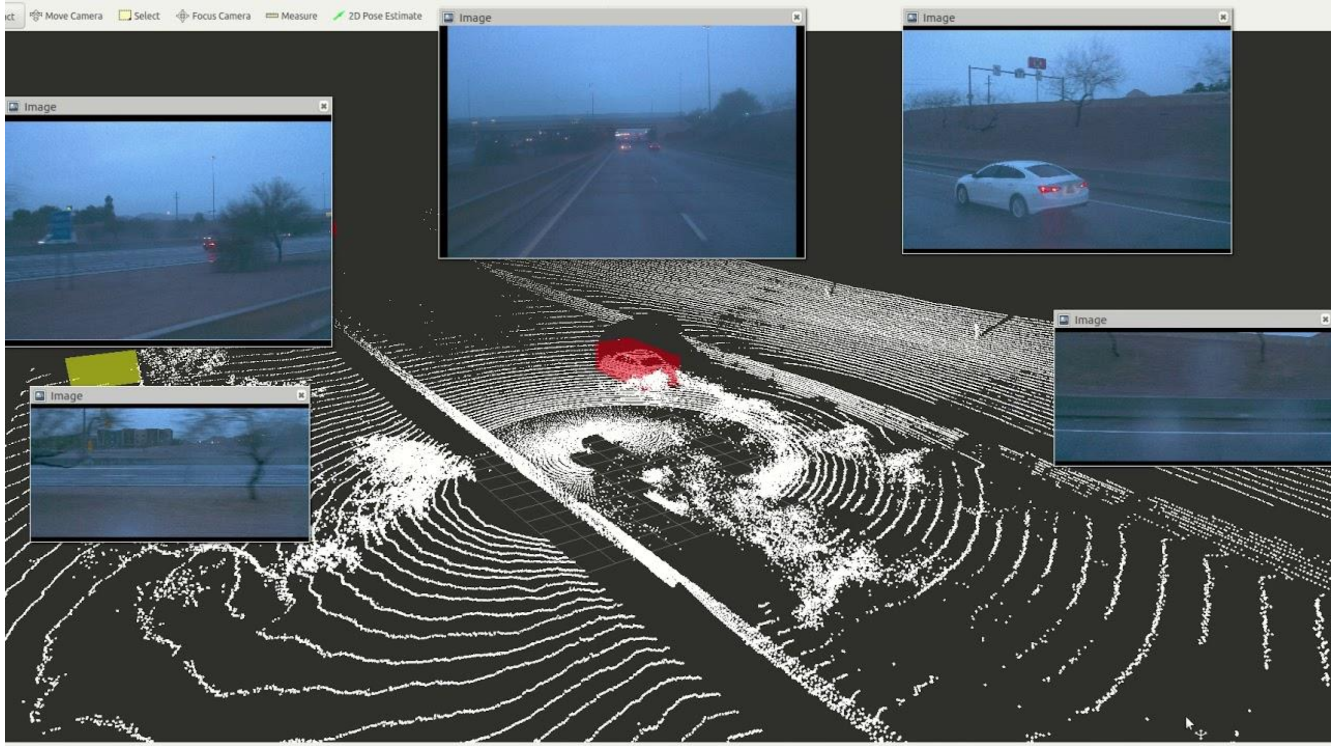
파라미터	TOF	FMCW	Phase shift
레이저 소스	Nd:YAG, CO2	반도체	반도체
파우어	1.5㎿	3㎽	10㎽
파장	1,064㎚	650㎚	1,100㎚
검출 소자	APD	APD	APD
측정 거리	300~20㎞	2~30m	2~400m
sampling rate	1~20㎑	4㎑	52㎑
최소 감지 파우어	12.7㎻	200㎻	23㎺
정밀도	5m	36㎜	21㎜
oscillator frequency	30㎒	4~60㎒	1㎒

LiDAR - Pros. And Cons.

- Advantages
  - Higher accuracy
  - Fast acquisition and processing
    - Acquisition of 1000 km2 in 12 hours.
    - DEM generation of 1000 km2 in 24 hours.
  - Minimum human dependence
    - As most of the processes are automatic unlike photogrammetric, GPS or land surveying.
  - Weather/Light independence
    - Data collection independent of sun inclination and at night and slightly bad weather.
  - Higher data density
    - Up to 167,000 pulses per second. More than 24 points per Square meter can be measured.
  - Multiple returns to collect data in 3D.

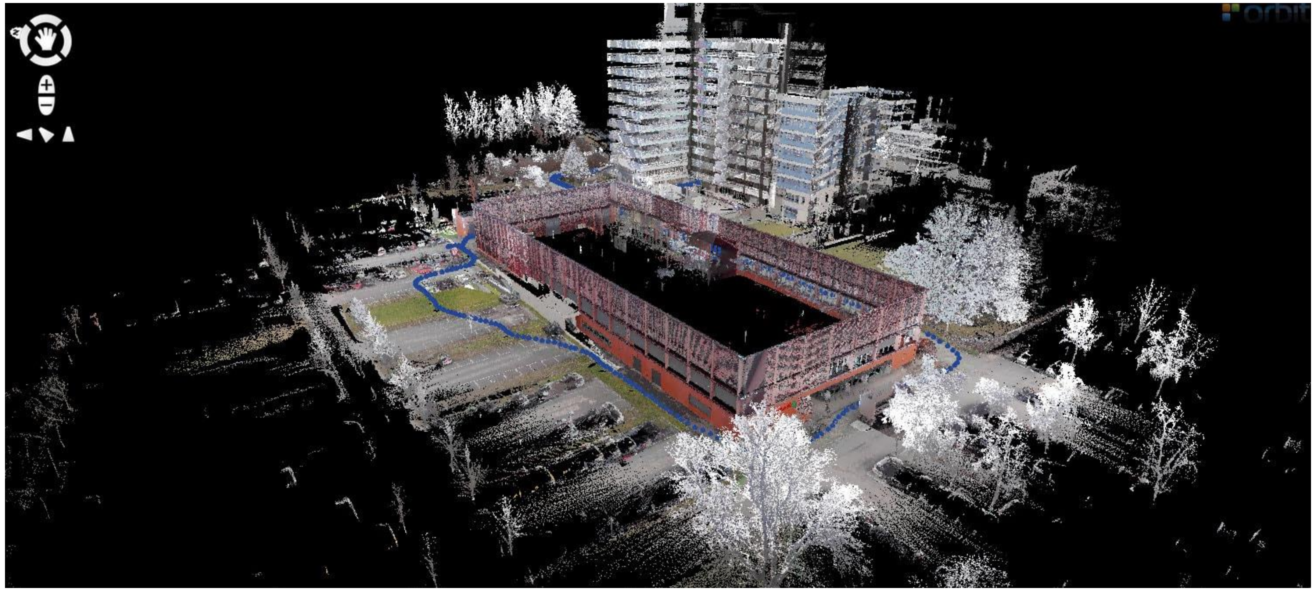
LiDAR - Pros. And Cons.

- Disadvantages
  - Ineffective during heavy rain and fog (snow).
  - High operational cost.
  - Indirect response
  - No texture



LiDAR

- Point cloud
  - Representation of measurement to 3D position (point)
  - is a group (set) of points
  - 2D or 3D representation is Point cloud acceptable, however, generally in 3D.



RGBD Camera

- RGBD sensor
  - Combination of two types of sensors
  - RGB camera + depth camera
    - In this case, depth camera is similar to LiDAR, but employs 2D array instead of sequential sensing
  - Microsoft Kinect and Intel RealSense are widely used.

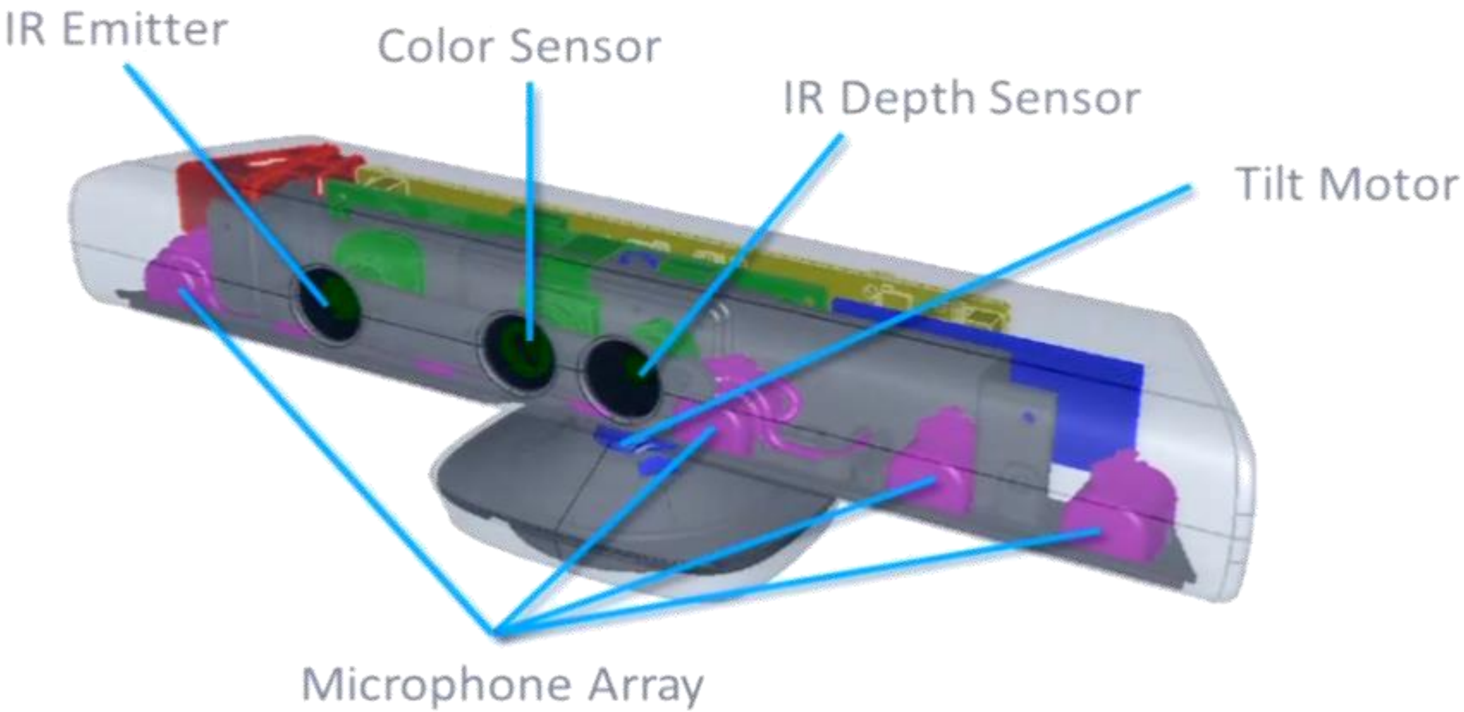
RGB depth

Azure Kinect

Realsense

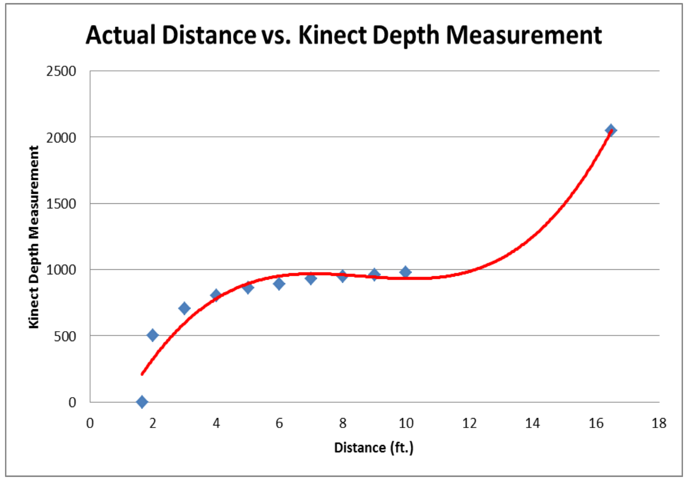
RGBD Camera

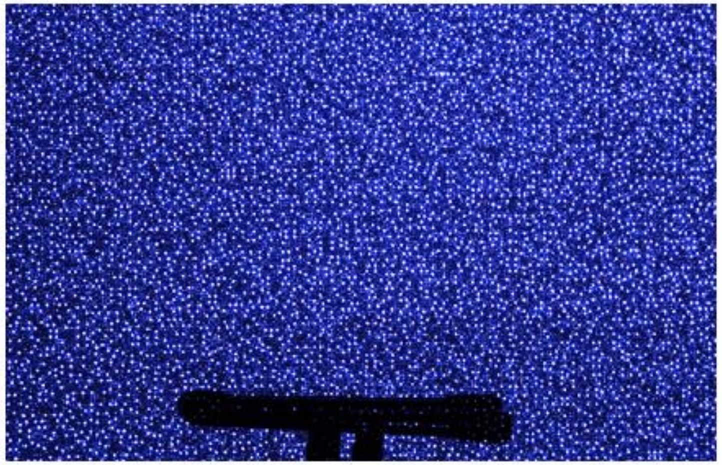
- Kinect
  - color camera (takes RGB values)
  - IR camera (takes depth data)
  - Microphone array (for speech recognition)

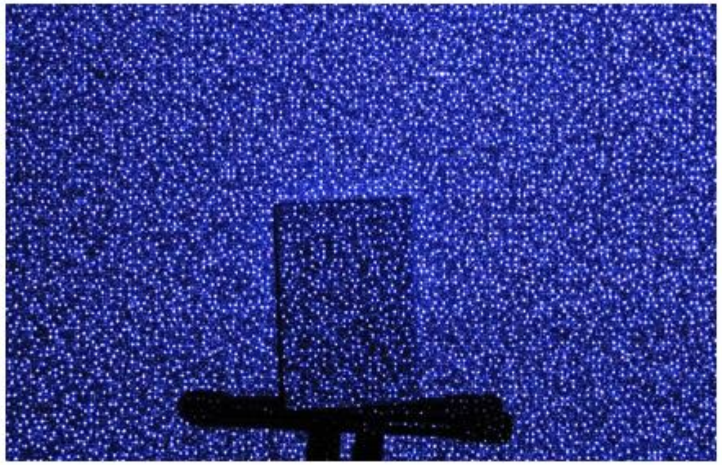


RGBD Camera

- Kinect-1
  - Depth sensor
    - IR projector emits predefined Dotted Pattern
    - Lateral shift between projector and sensor
    - Shift in dots determines Depth of Region
  - Distance accuracy

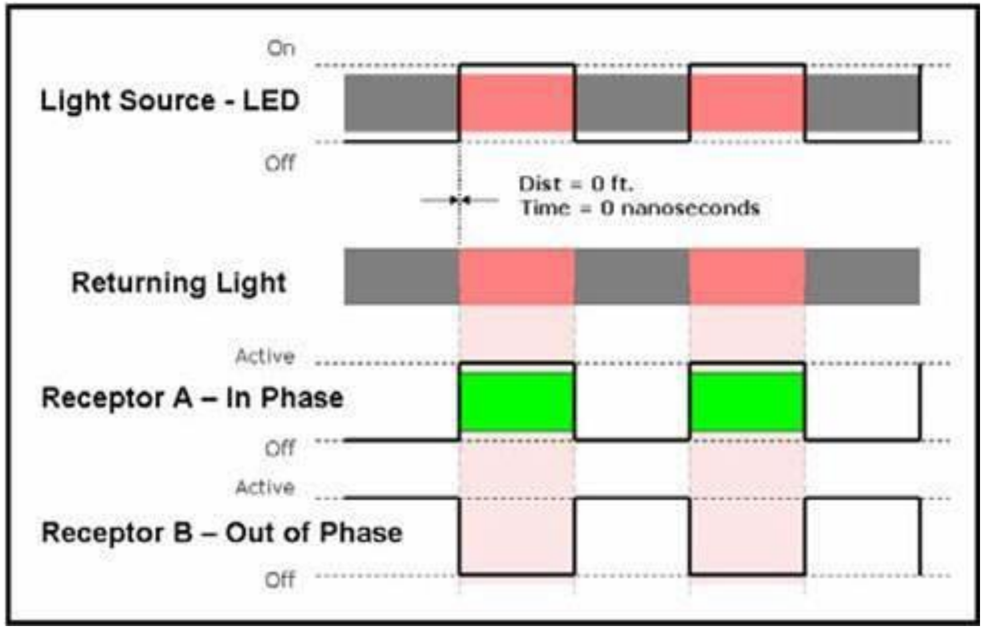


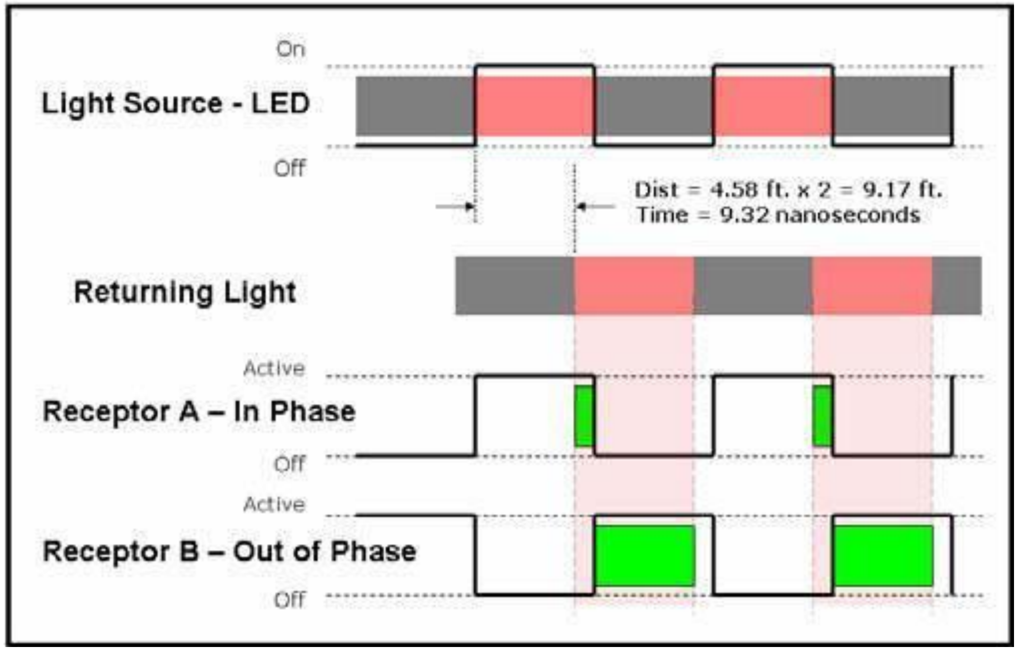




RGBD Camera

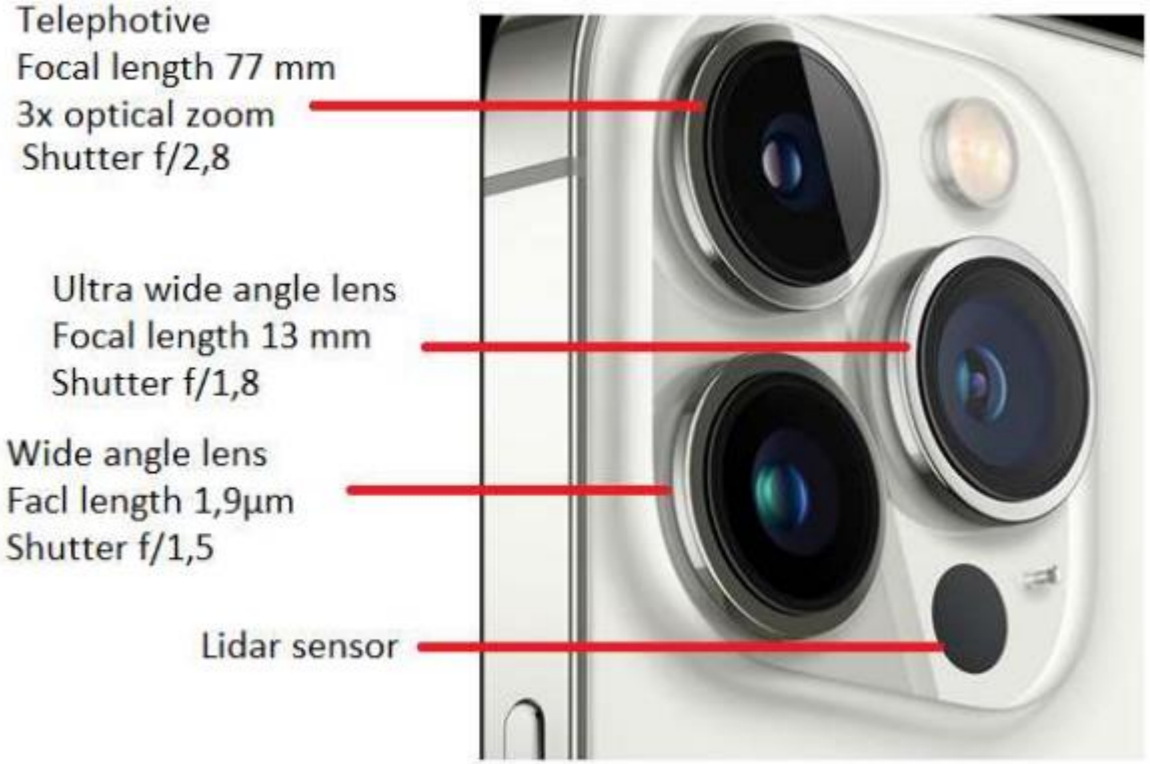
- Azure kinect
  - AMCW(Amplitude Modulated Continuous Wave) ToF(Time-of-Flight)

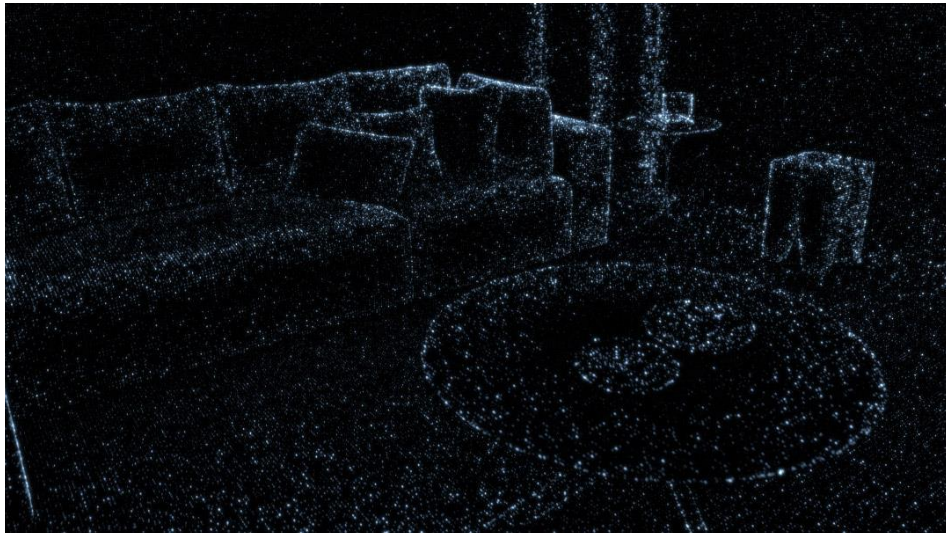




LiDAR

- I-Phone





End of the class

Q n A