Module specification	Explanation		
Teacher Name	--		
Training Topic	Robotics application in Virtual Laboratory		
Training Code	UNIOULU_02_sensors in robotis		
Module Name	Sensors in robotics		
Module duration	100 minutes		
Module objective	• Introduction to sensors in robotics • Distance and depth sensors • Getting (and presenting) data from sensor • Interacting with sensor • Data processing		
Mode of provision	Classroom		
Laboratory structure	Time (min)	Objective	Performed by?

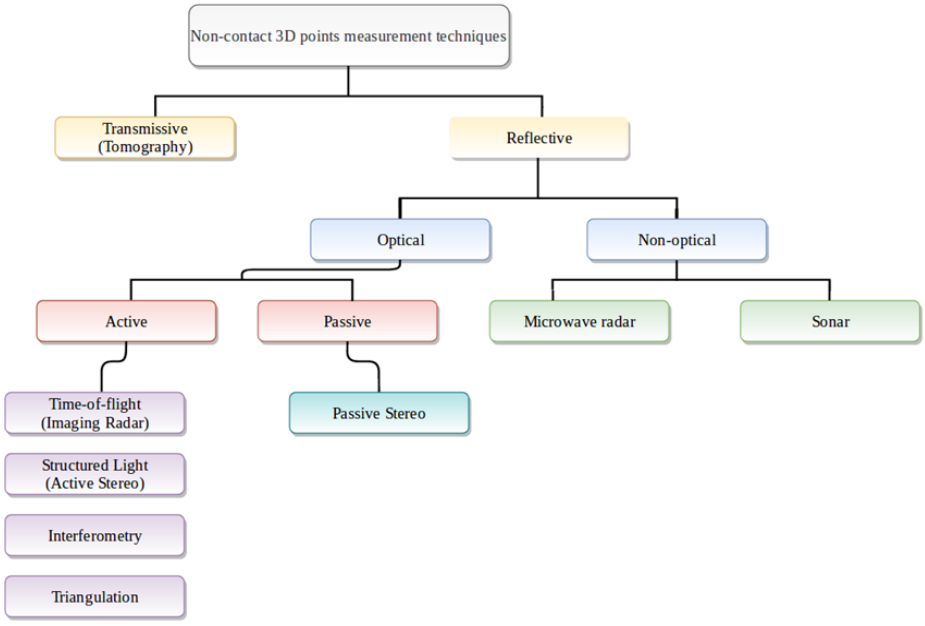


Figure 1. Remote Sensing Technique Taxonomy.

Since the release of Kinect v2 there has been many research works done in evaluation of the sensor, both systematic errors and non-systematic errors are analyzed. The systematic errors effect the accuracy of the vision algorithms, i.e., the closeness of results to the ground truth value. And random errors effect the precision, i.e., the variability in the results due to random noise in the image. In [2] [3] [4] both systematic and non-systematic errors of original Kinect and Kinect v2 was compared and concluded that Kinect v2 has better accuracy and precision than original Kinect. Some salient aspects was also analyzed such as preheating the device [2] [5] and modeling the non-systematic error [6]. In [6] the noise (*axial* and *lateral*) model is derived as a function of measured distance and the angle of the observed surface and the model was extended based on the incident angle of direct sunlight. The below *Figure 2* depicts the overview of teardown of Kinect v2, which senses depth by measuring the phase difference of light from infrared illuminator that hits the object and reflects to the infrared camera.

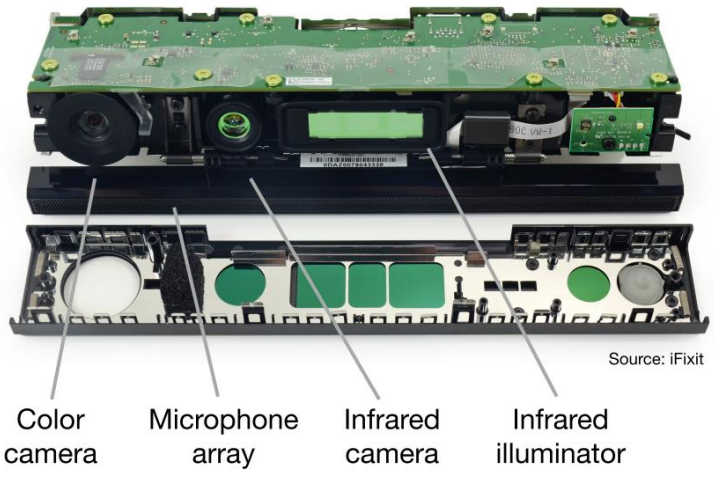
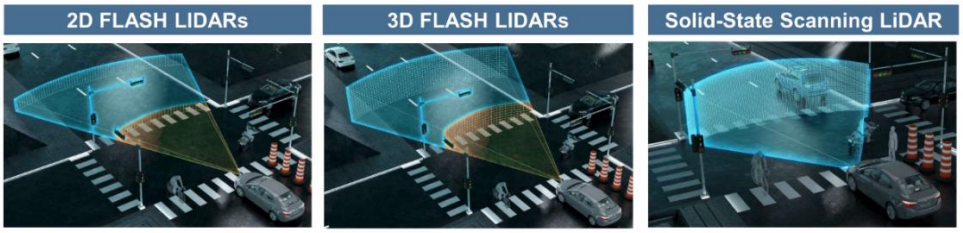


Figure 2. Overview of inside parts of ToF based Kinect V2 [6].

Light Detection and Ranging (LiDAR)

The performance of LiDAR supersedes the RGB-D in outdoor environment and especially under direct sunlight. However, the characterization of LiDAR should be analyzed in various surface, range measurement, errors due to target surface orientation, angular resolution, beam divergence and non-systematic errors during snowflakes, rainfall and foggy conditions. This type of analysis is very vital because inherent noise (due to systematic or non-systematic) of LiDAR can cause significant variations from ground truth value, which makes the sensor unreliable for autonomous systems. In [7], a detailed analysis of information characterization was performed for a medium range Hokuyo *UST-20LX* 2D LiDAR. In the analysis, it was found that dark target seems to consistently return a much shorter range than the actual and the error is minimal up to target range of 4.0 meters. The upcoming phase in LiDAR technology is 2D and 3D solid-state LiDAR and specially designed for automotive and autonomous systems. ***Figure 3*** shows the next generation of solid-state LiDAR by Leddar Tech.



Model	2DF-LR Model : 64 X 1 Range (vehicle): 300 m	3DF-LR Model: 64 X 16 Range (vehicle): 300 m	3DHD (Hybrid Flash / MEMS) Model: 256 X 64 Range (vehicle): >300 m
Emission type	Fixed, diffuse beam	Fixed, diffuse beam	Flash linear beam + 2D MEMS beam steering
Reception type	Linear receiver array	2D receiver array matrix	Linear receiver array

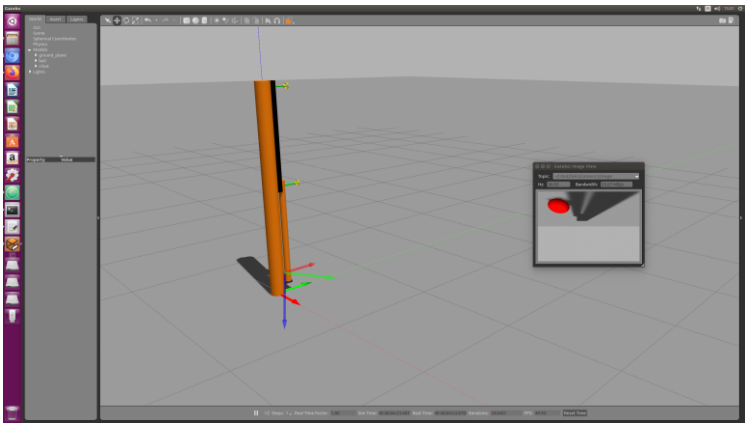
Figure 3. Next generation of Solid-state LiDAR[1].

A solid-state 3D LiDAR can be developed in three different approach, *Micro electro mechanical system* (MEMS) based, *Phased array* based and *Flash LiDAR*. In MEMS based, a tiny mirror (in millimeters) with low moment of inertia – steer a fixed laser beam in different directions. The mirror moves fast due to its low moment of inertia and trace out a scanning pattern. Three LiDAR companies are working in MEMS based LiDAR currently and those are Luminar, Innoviz and Infineon. One of the core advantage of MEMS approach is that a LiDAR sensor can dynamically adjust its scan pattern to focus on object of interest by directing finer grained laser pulses in the direction of a near or far distant object to identify more clearly. Evidently, this is not possible with conventional mechanical LiDAR.

Exercise:

Import RGBD sensor into gazebo and visualize the data in ros

[1] https://www.leddartech.com/



TO-DO

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