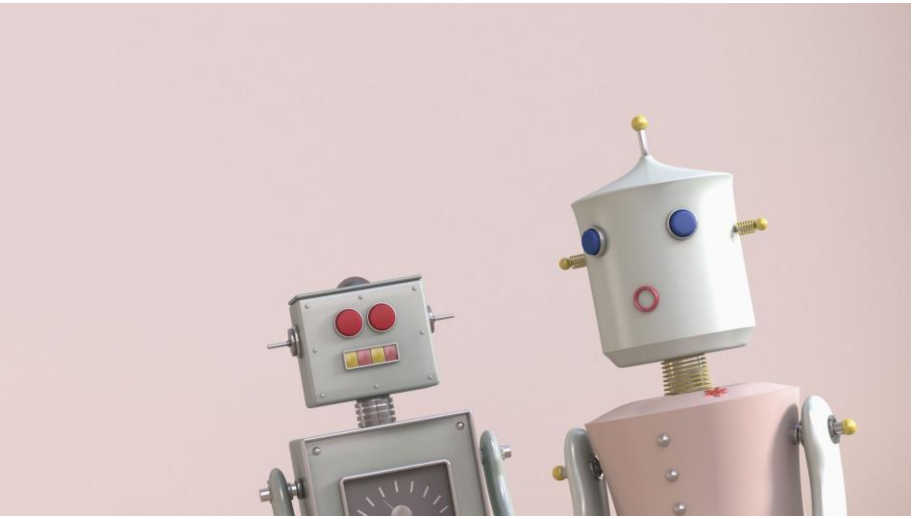
Seneca

Making a robot [Cont.]

Saeid Khosravani

Summer 2022



Sensors - IR

1 D Finders

Infrared linear distance sensor that can be used to make low-cost robots

- https://www.terabee.com/shop/lidar-tof-range-finders/ter

2 D Finders

Sensors that can measure the distance on 2D plane, and is mainly used for navigation

http://wiki.ros.org/hls_lfcd_lds_driver

Sensors - Camera

3 D Finders and Camera

Sensors used in 3D distance measurement such as Intel's RealSense, Microsoft's Kinect, ASUS's Xtion

http://wiki.ros.org/duo3d-driver

https://www.stereolabs.com/docs/ros/

- Camera driver used for object recognition, face recognition, character recognition, etc. and various application packages

Timeline of LiDAR Development

1960
First practical laser is created by Theodore Maiman

1969
U.S. Navy tests Pulsed Light Airbone Depth Sounder in aircraft

1971
Lidar used to map the surface of the moon

1984
Optec develops Larsen-500, the first commercial lidar...

1990s
Lidar becomes widely used for geographical mapping

2005
Lidar used in self-driving vehicles

2020
Apple introduces lidar sensors in iPhones for AR mapping

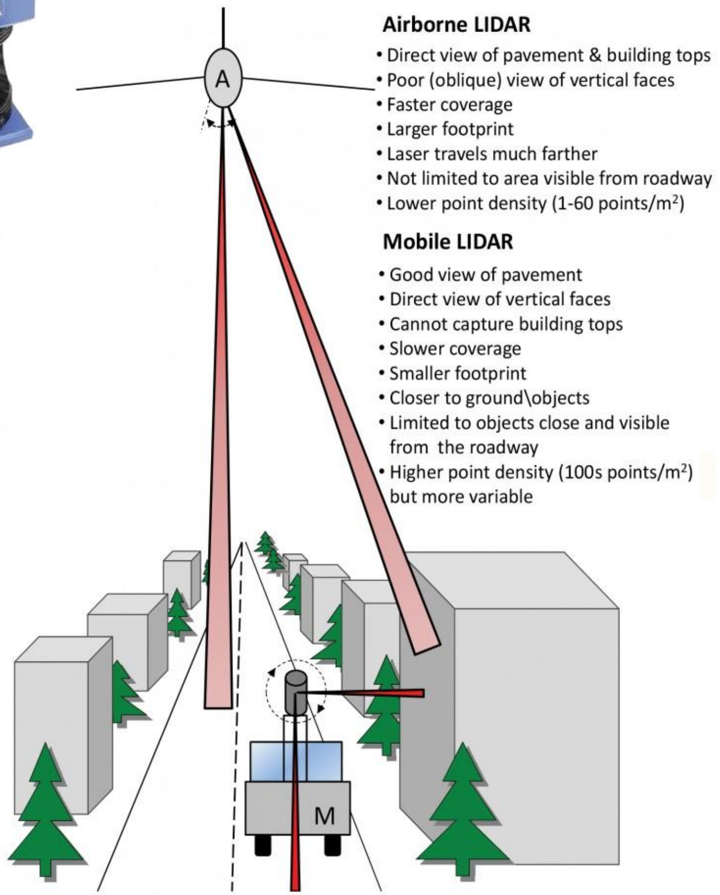
**Did not include every major development; these just represent events that I found interesting*

Sensors - LiDAR

What does LiDAR stand for?
LiDAR is an acronym of Light Detection and Ranging.

How does LiDAR work?
LiDAR works in a similar way to Radar and Sonar yet uses light waves from a laser, instead of radio or sound waves. A LiDAR system calculates how long it takes for the light to hit an object or surface and reflect back to the scanner. The distance is then calculated using the velocity of light*.
These are known as ‘Time of Flight’ measurements.

https://www.livoxtech.com/mid-40-and-mid-100

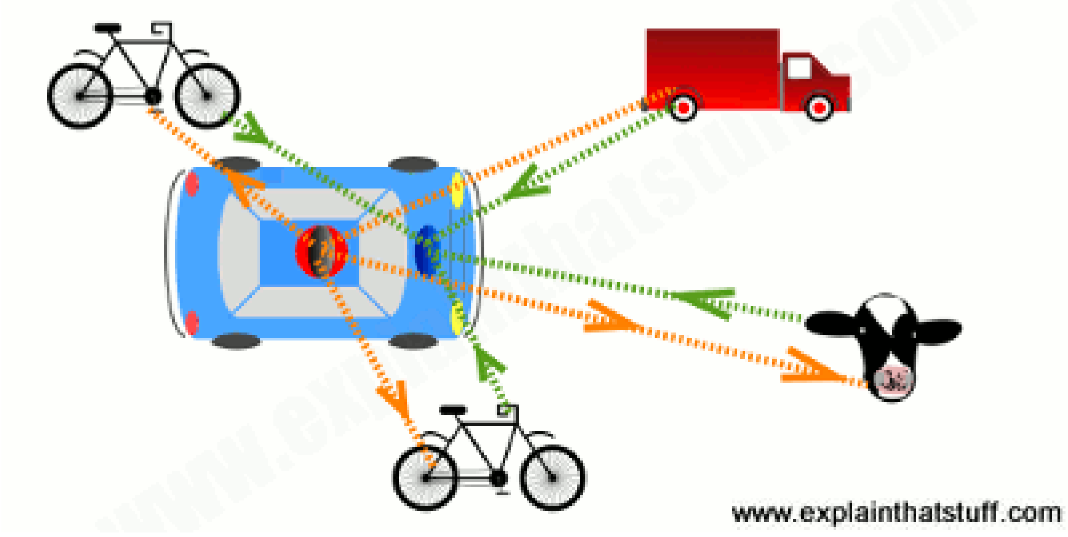


How do LiDARs Work?

- Emits pulses of light and detects the reflection of light pulse
- Calculates time of flight (time it takes for something to travel through a medium) of the light

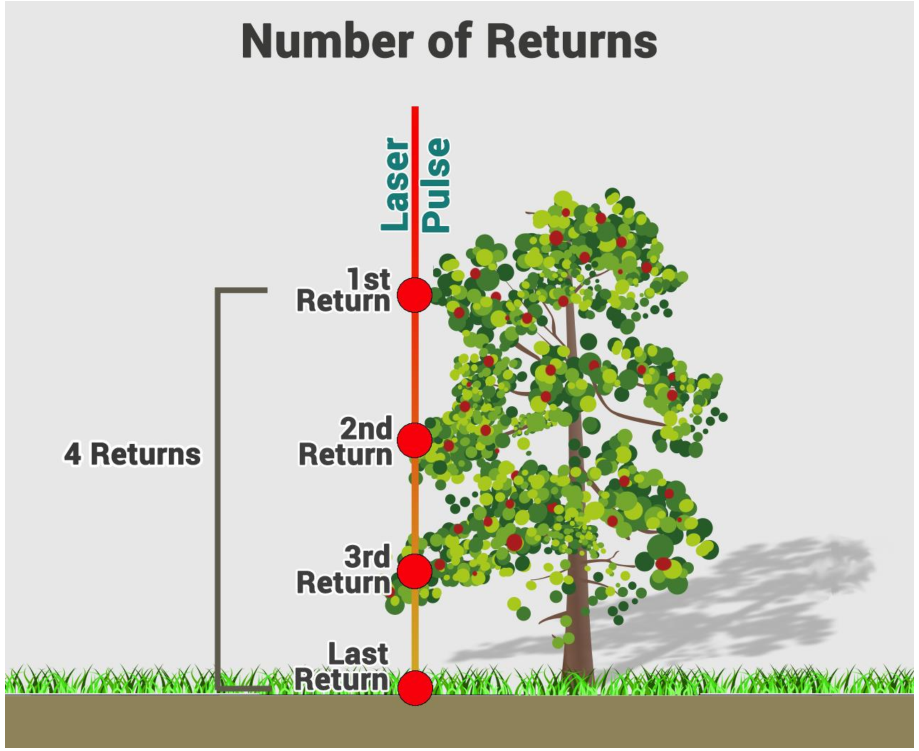
  Distance = (Speed of Light x Time of Flight) / 2

- With this information, it can calculate distance of an object



How do LiDARs Work?

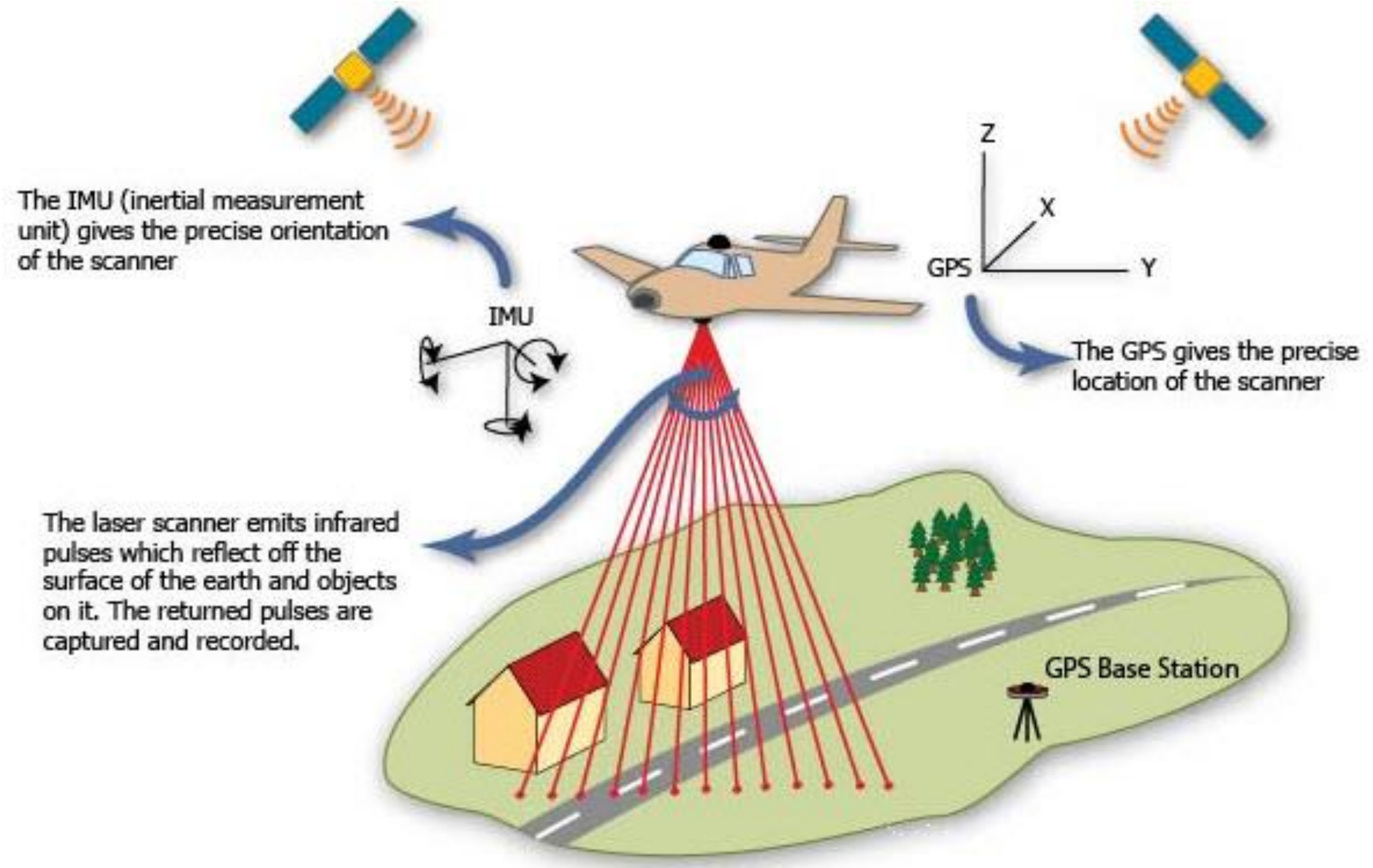
- LiDARs can also track the number of light pulse returns
- One pulse can have multiple returns if there are things in the way that reflect the light
- This can be used to map out topography and structure
- LiDAR drones map forest canopies in this way



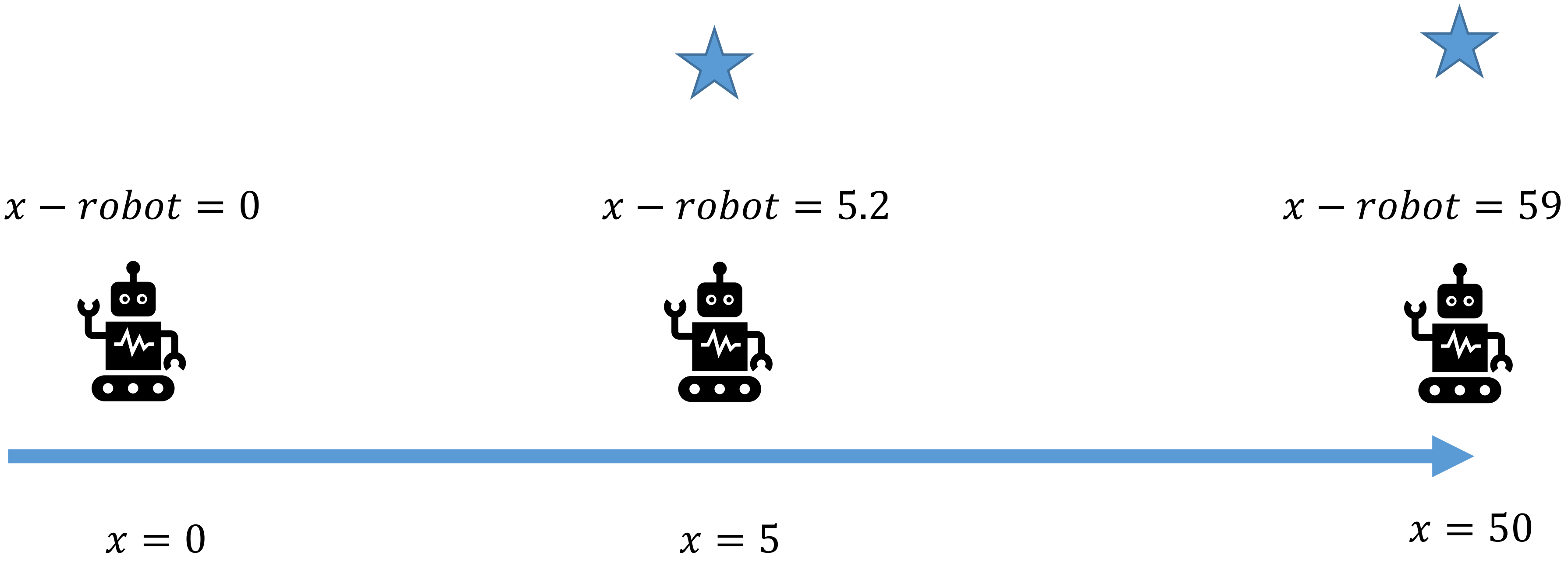
Sensors – LiDAR Components

- Laser
- Scanner and Optics
- Specialized GPS receiver
- Inertial Measurement Units (IMU)

Sensors - LiDAR



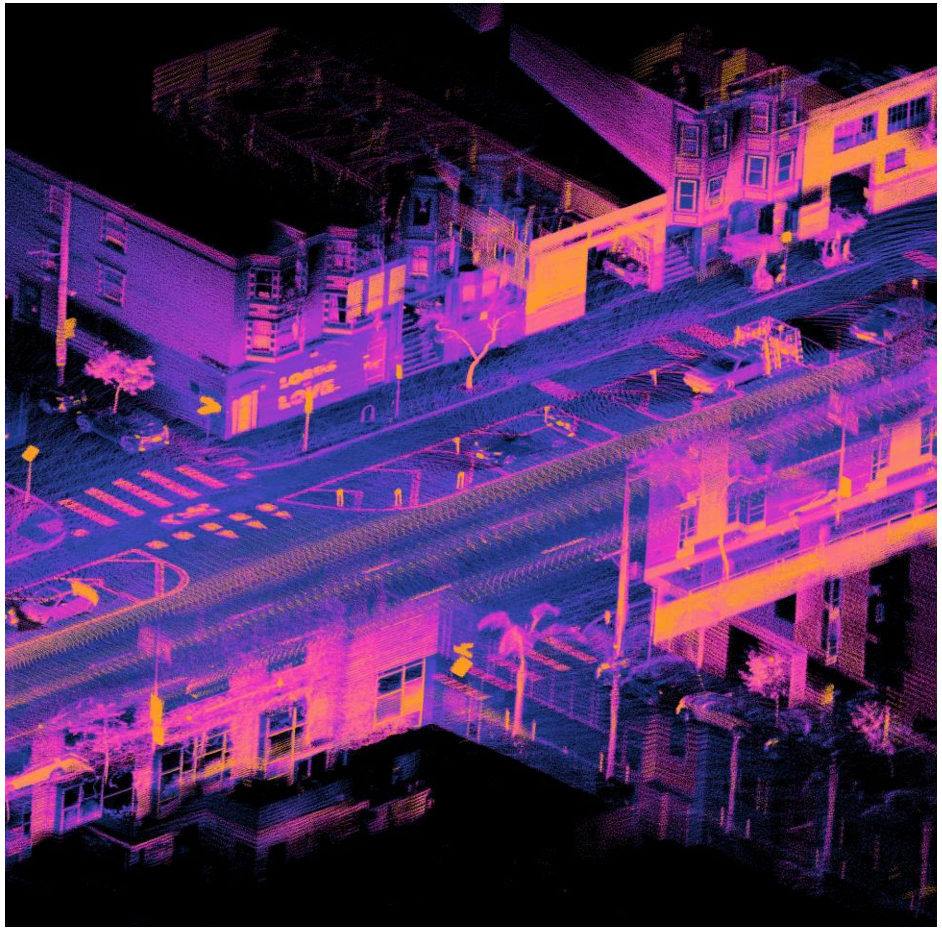
Sensors – LiDAR Components



Sensors - LiDAR

A "Point Cloud" is a simple map of data points in space. Each point therefore has an X, Y, and Z coordinate. This map can be used to represent the space around a given sensor.

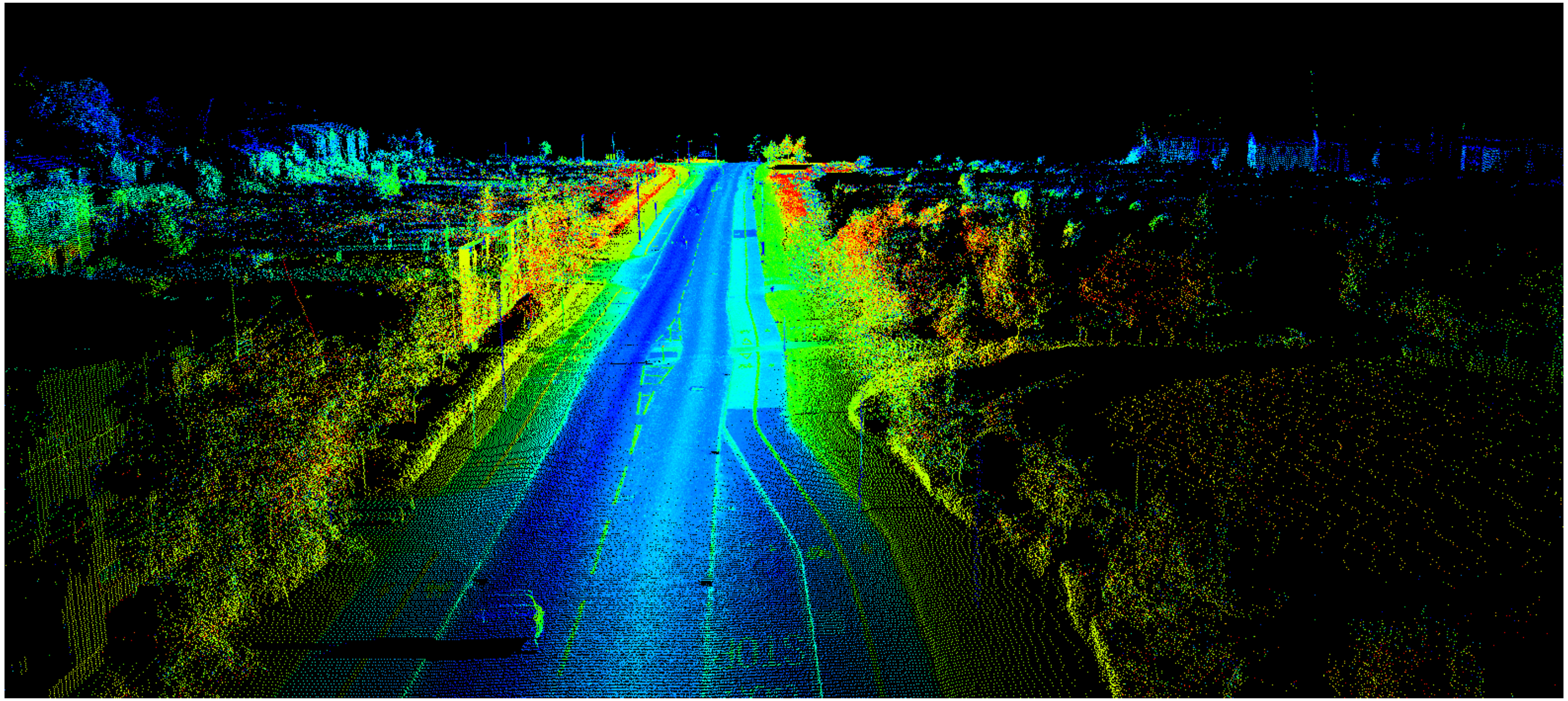
LiDAR generates a point cloud by firing tens of thousands of light pulses per second, and measuring the time of flight for each pulse. Each pulse becomes a single point in a point cloud.



A visual representation of a point cloud created with a LiDAR sensor on an autonomous vehicle
Daniel L. Lu, CC BY 4.0 <https://creativecommons.org/licenses/by/4.0>, via Wikimedia Commons

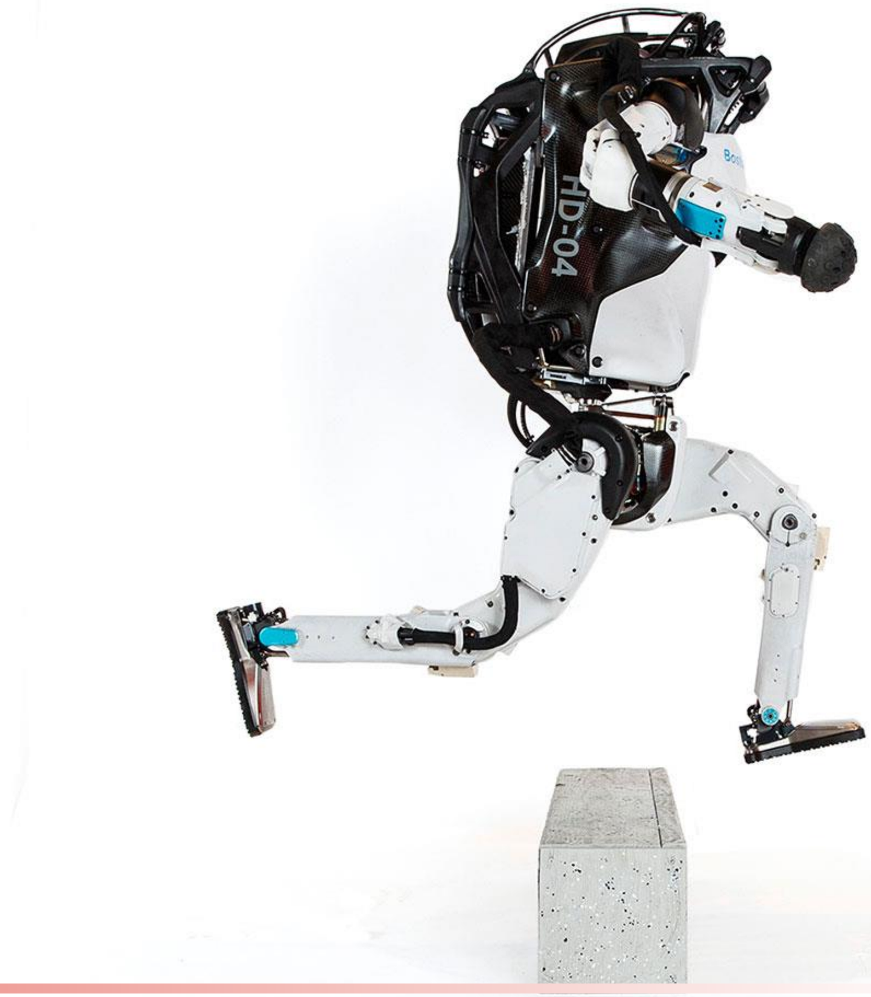
Sensors - LiDAR

An example of a point cloud generated via LiDAR. As you can see, it is capable of recognizing the road, lane separators, road markings, streetlamps, lanes, trees, and other obstacles.



Application of LIDAR systems

- Lidar systems have found their way into humanoid robots as well. As can be seen in this video from Boston Dynamics. The robot uses different sensors, like optical cameras to see the QR-like code in addition to the Lidar system in the robot's head (video is on the next slide).

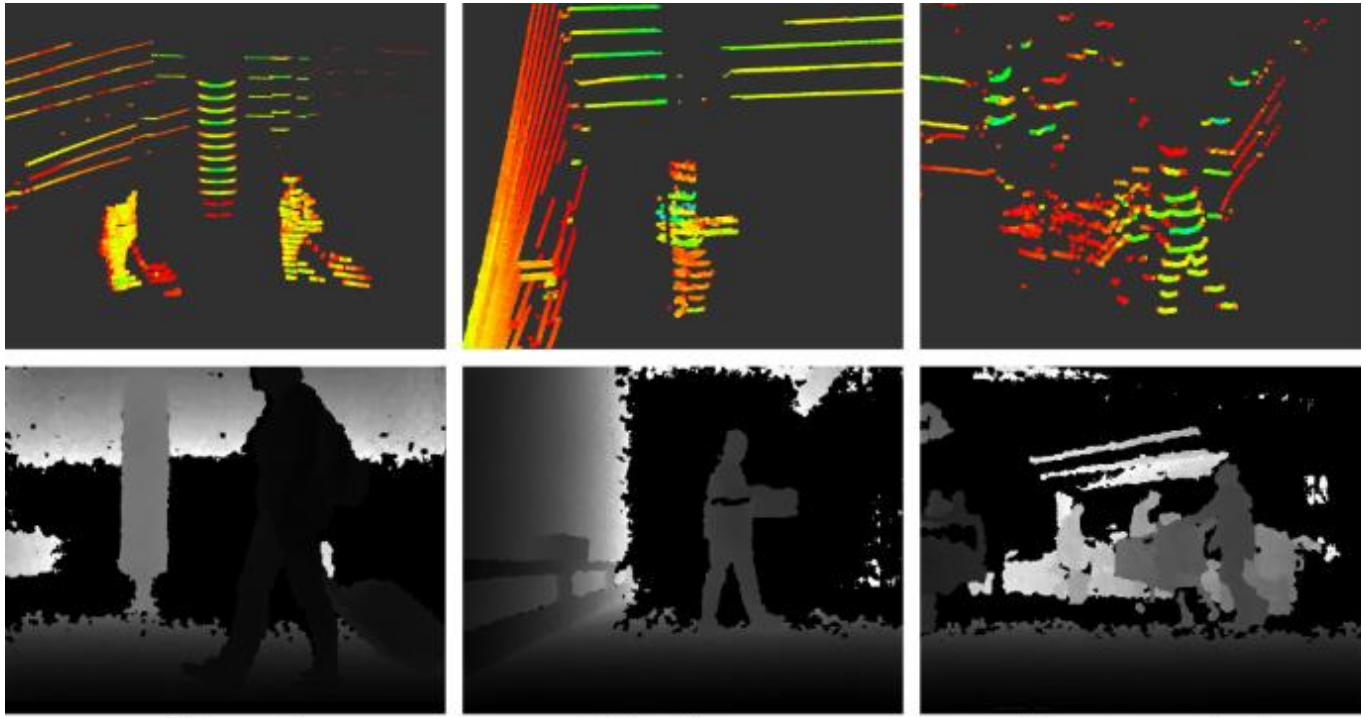


Application of LIDAR systems

Sensors – LiDAR in Robotics

Lidar enables the robot to not only identify the presence of an entity but also determine in real time if it is a human or object.

This allows the robot to assess appropriate risk behavior models, which is essential for managing safety in robot-human collaboration.



Airport Warehouse Supermarket

Sensors – LiDAR in Farming

LIDAR in robots

Mobile robots operating outside can rely on geolocation capabilities, such as GPS along with sensing technologies including lidar, to determine where they are located and where they are headed.

Sensors – LiDAR Application

Mobile robots operating indoors employ simultaneous localization and mapping (SLAM) technology that utilizes lidar’s data to build a map of the robot’s environment and locate the robot within that map.

The benefits provided by SLAM technology include easy navigation without reliance on external technologies and real-time formation of 3D maps with reduced cost and power requirements.

Sensors – LiDAR Application

- Distribution Centers, providing more efficient pick and palletization processes in warehouses.
- Food and Grocery Delivery, navigating sidewalks, pedestrians, and more while bringing hot or cold food to a customer.
- Retail, scanning aisles for product replenishment needs and answering questions for shoppers.

Sensors – LiDAR in Industrial Robotics

- Security, roaming corridors to identify security issues, such as unauthorized people, and open doors and windows.

- Industrial Automation, providing safety and efficiency in agriculture, construction, logging, maritime, mining, pipeline inspection, and railway.

Applications of LiDAR - Cars

- LiDAR is a major sensor used in autonomous cars
- LiDAR is also used in cars with more robust safety systems
- Used for automatic emergency braking, pedestrian detection, collision detection, etc.

LiDAR vs Radar

LiDAR	Radar
Used for ranging and detection	Used for ranging and detection
Sends out pulses of light	Sends out pulses of radio waves
More expensive	Cheaper
More accurate and generates clearer images	Higher range
Affected by weather (fog, snow, rain)	Not affected by weather

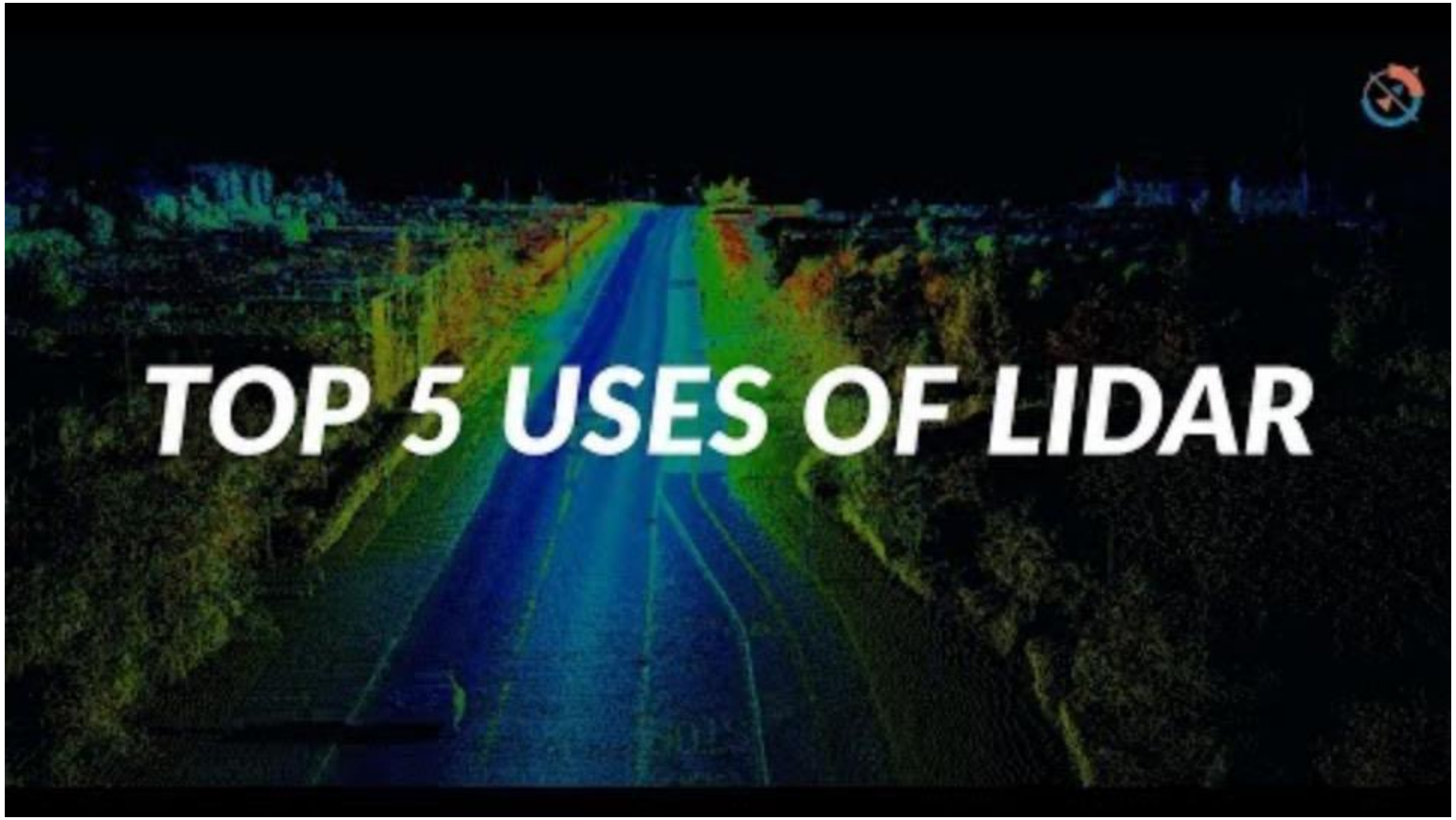
Sensors – LiDAR (Advantages)

- Data can be collected quickly and with high accuracy
- Capable of collecting elevation data in a dense forest
- Can be used day and night
- It has minimum human dependence
- It is not affected by extreme weather
- Can be used to map inaccessible and featureless areas

Sensors – LiDAR (Disadvantages)

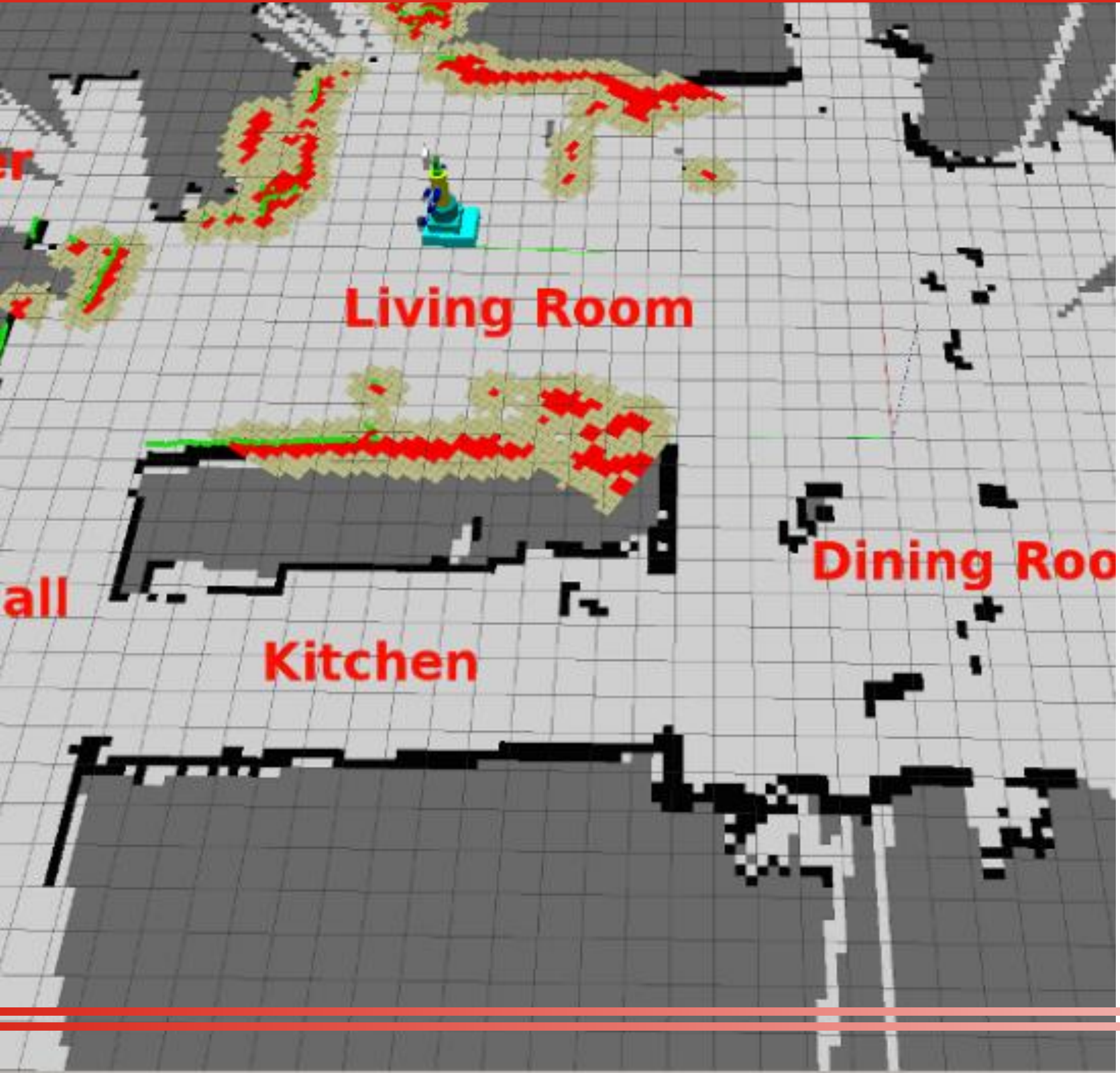
- High operating costs in some applications: Although LiDAR is cheap when used in huge applications, it can be expensive when applied in smaller areas when collecting data.
- Unreliable for water depth and turbulent breaking waves
- Very large datasets that are difficult to interpret
- No International protocols
- Elevation errors due to inability to penetrate very dense forests
- Requires skilled data analysis techniques

LiDAR Applications



- Method to measure distance to a target by illuminating the target with pulsed laser light and measuring the reflected pulses with a sensor.
- Differences in laser return times and wavelengths can then be used to make digital 3D representations of the target.

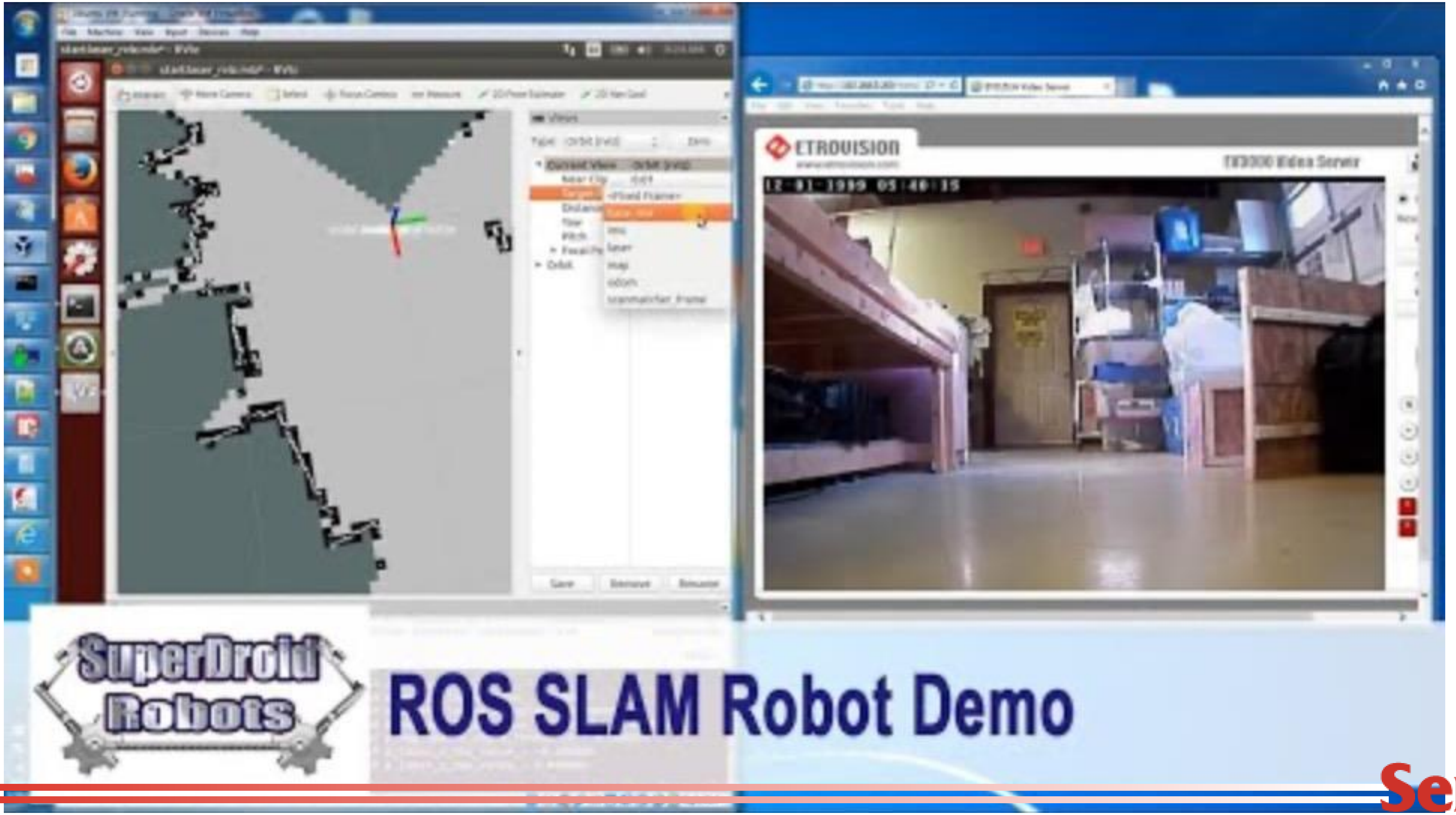
LiDAR Applications



Mapping

- A map is a model of the environment needed by the autonomous robot to navigate.
- Learning maps requires solutions to two tasks: mapping and localization.
  - Mapping is the problem of integrating the information gathered with the robot's sensors into a given representation.
  - Localization is the problem of estimating the pose of the robot relative to a map.
- Mapping and localization cannot be solved independently.
- Solving both problems jointly is often referred to as the Simultaneous Localization And Mapping (SLAM).

LiDAR Applications



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Sensor - Audio

Audio / Speech Recognition

https://www.hark.jp/

- https://www.youtube.com/watch?v=bi4ACLfaWy0&feature=emb_title&ab_channel=WillowGaragevideo

http://wiki.ros.org/pocketsphinx

Sensor - Environmental

- Weather
- Wind speed and direction data from the anemometer. [http://library.isr.ist.utl.pt/docs/roswiki/windsonic.html]

Force sensor:

http://wiki.ros.org/force_torque

https://wacoh-tech.com/en/products/dynpick/200n.html

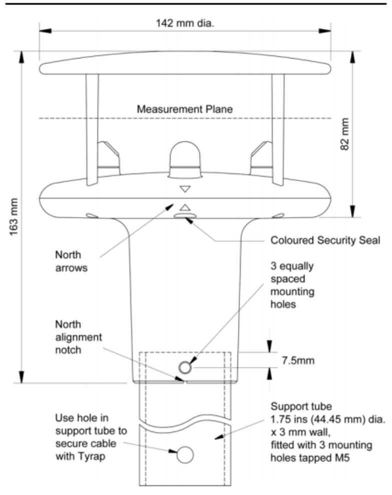
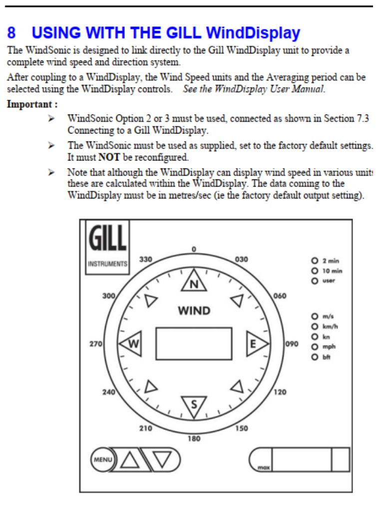


Figure 3 Alignment & Mounting details



8 USING WITH THE GILL WindDisplay

The WindSonic is designed to link directly to the Gill WindDisplay unit to provide a complete wind speed and direction system.

After coupling to a WindDisplay, the Wind Speed units and the Averaging period can be selected using the WindDisplay controls. *See the WindDisplay User Manual.*

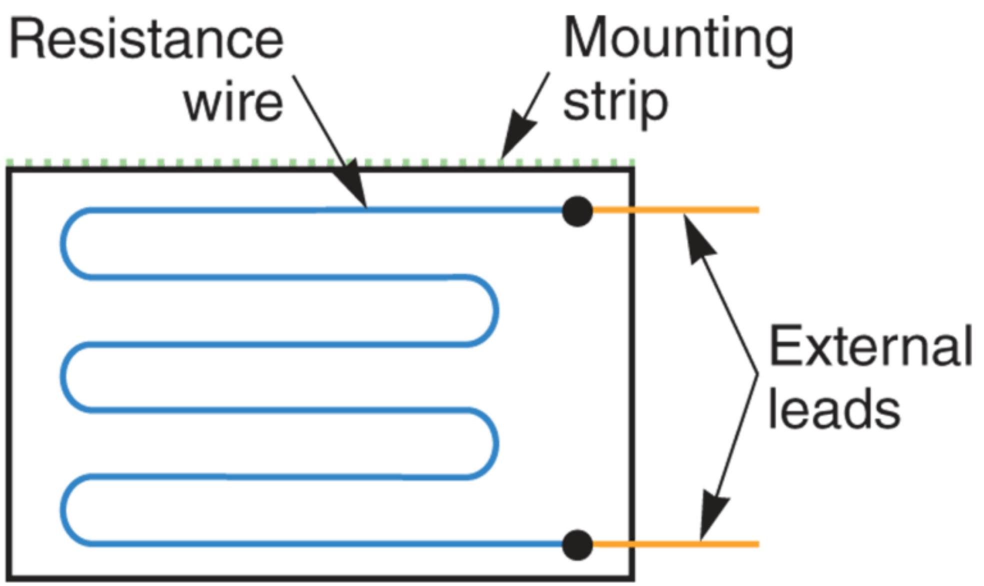
Important :

- WindSonic Option 2 or 3 must be used, connected as shown in Section 7.3 Connecting to a Gill WindDisplay.
- The WindSonic must be used as supplied, set to the factory default settings. It must **NOT** be reconfigured.
- Note that although the WindDisplay can display wind speed in various units these are calculated within the WindDisplay. The data coming to the WindDisplay must be in metres/sec (ie the factory default output setting).

Figure 4 WindDisplay

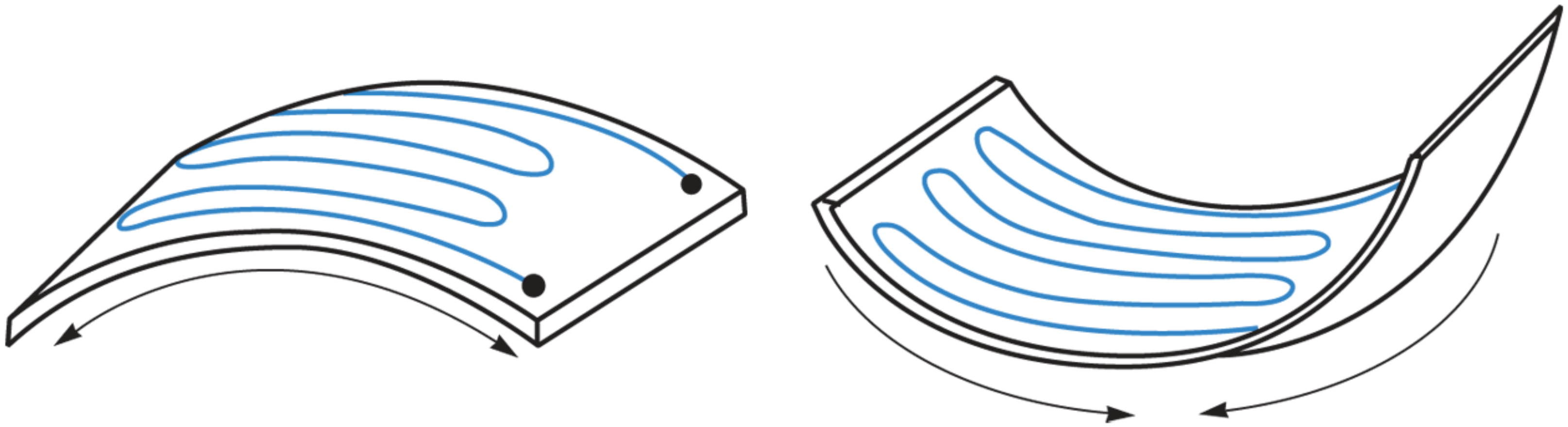
Sensor - Movement

- *Strain gauge is used to measure stress on the surface. In robotics, It can be used measure the force on the gripper to hold an object.*



Sensor - Movement

- Resistance increases under tension and decreases under compression



Sensor – Motion

Motion Capture

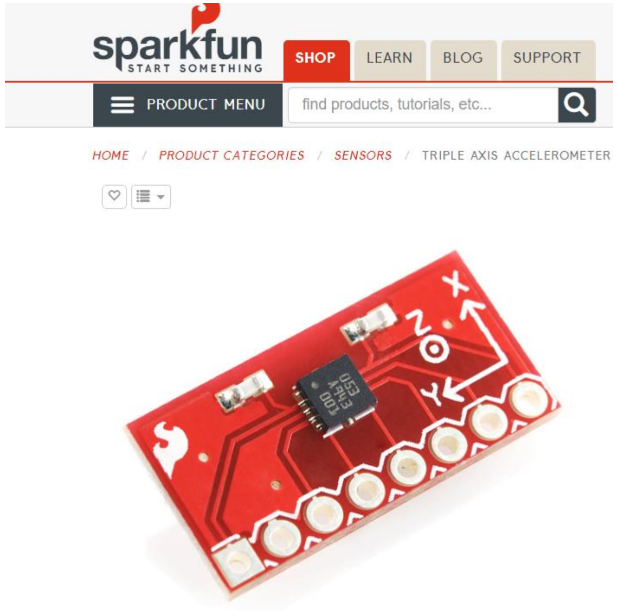
Leap Motion controller

https://www.youtube.com/watch?v=xzn-mLEjRZw&ab_channel=Engadget

Pose Estimation (GPS/IMU)

Ethernet interface to OxTS GPS receivers using the NCOM packet structure

https://bitbucket.org/DataspeedInc/oxford_gps_eth/src/master/



Sensor - Radar

RFID Scanner

https://www.jadaktech.com/products/thingmagic-rfid/flexpoint-hs-1-and-hs-2-handheld-barcode-and-rfid-scanner-series/

Radar-based Speed sensor

https://omnipresense.com/product/ops241-a-short-range-radar-sensor/

http://wiki.ros.org/radar_omnipresense

Programming Interfaces

Interfaces:

http://wiki.ros.org/ardusim → ROS and Arduino

http://wiki.ros.org/nxt_ros → LEGO NXT and ROS

Micro Controllers

Types of computer resources and ROS support

	8/16-bit MCU	32-bit MCU		ARM A-class	x86
		"small" 32-bit MCU	"big" 32-bit MCU		
Example Chip	Atmel AVR	ARM Cortex-M0	ARM Cortex-M7	Samsung Exynos	Intel Core i5
Example System	Arduino Leonardo	Arduino M0 Pro	SAM V71	ODROID	Intel NUC
MIPS	10's	100's	100's	1000's	10000's
RAM	1-32 KB	32 KB	384 KB	a few GB (off-chip)	2-16 GB (SODIMM)
Max power	10's of mW	100's of mW	100's of mW	1000's of mW	10000's of mW
Peripherals	UART, USB FS, ...	USB FS	Ethernet, USB HS	Gigabit Ethernet	USB SS, PCIe

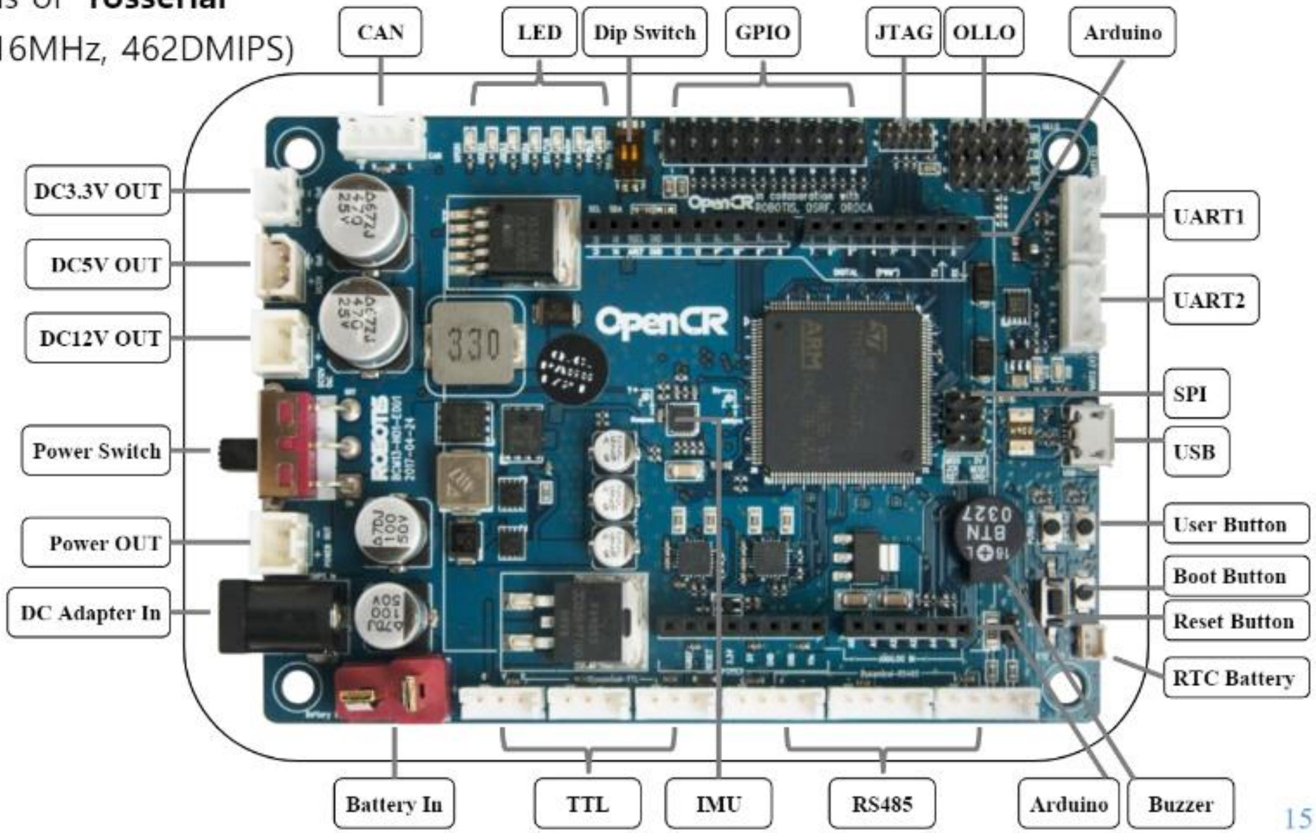
$\underbrace{\hspace{8em}}_{\textbf{ROS not installable}}$ (8/16-bit MCU, 32-bit MCU)

$\underbrace{\hspace{8em}}_{\textbf{ROS installable}}$ (ARM A-class, x86)

Morgan Quigley (OSRF) "ROS 2 on "small" embedded systems", ROSCon2015

Micro Controllers

- It is an embedded board that **supports ROS** and is used as the main controller in **TurtleBot3**
- **Open source H/W, S/W** : H/W information such as circuit, BOM, Gerber data, and all S/W of OpenCR as open source
- Configuration to overcome the limitations of **rosserial**
  - 32-bit ARM Cortex-M7 with FPU (216MHz, 462DMIPS)
  - 1MB flash memory
  - 320KB SRAM
  - Float64 support
  - Using USB packet transmission instead of UART
- **Power design** for use with SBC series computers and various sensors
  - 12V@1A, 5V@4A, 3.3V@800mA
- **Expansion port**
  - 32 pins(L 14, R 18) *Arduino connectivity
  - OLLO Sensor module x 4 pins
  - Extension connector x 18 pins



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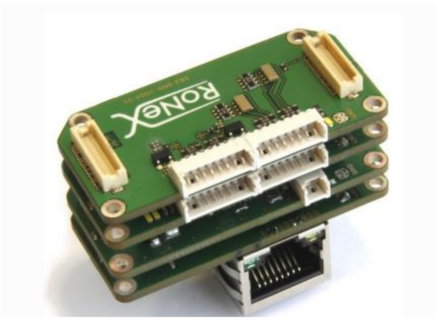
Make a Robot

What else do you need?

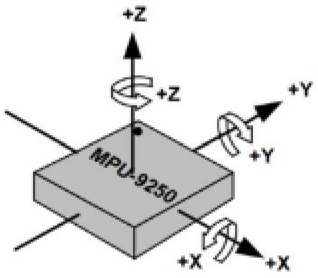
Enclosure
Power Supply
Wire
Protocol convertor
https://sr-ronex.readthedocs.io/en/latest/README.html
Learning on protocols?
ADC
Motor Drivers



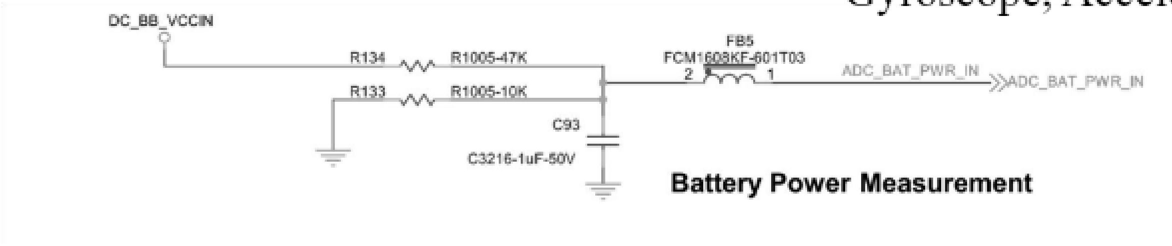
https://www.phidgets.com/?tier=1&catid=57&pcid=50

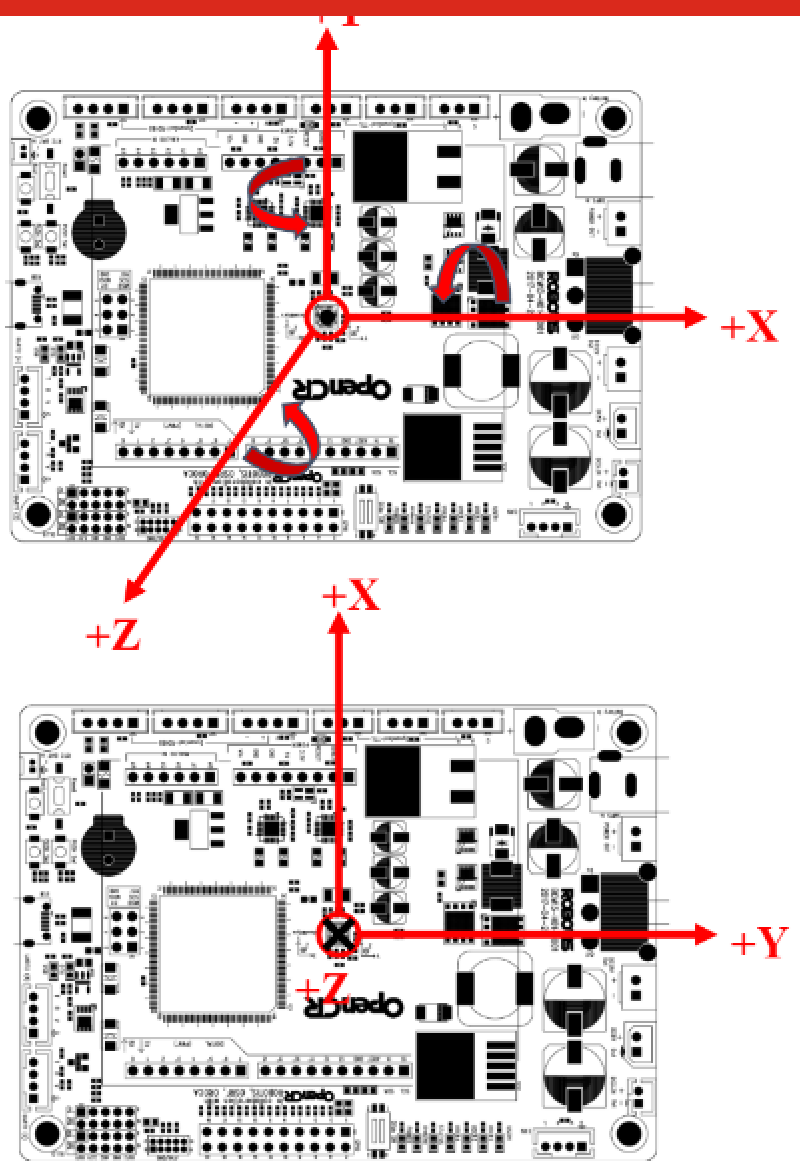
Micro Controllers

- Built-in Sensor
  - Gyroscope 3Axis
  - Accelerometer 3Axis
  - Magnetometer 3Axis
  - Voltage measuring circuit

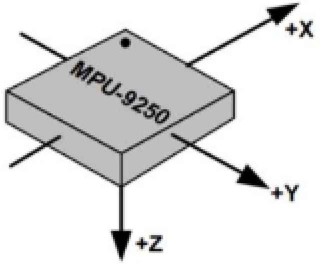


Gyroscope, Accelerometer





- Communication Support
  - USB, SPI, I2C
  - TTL, RS485, CAN



Magnetometer