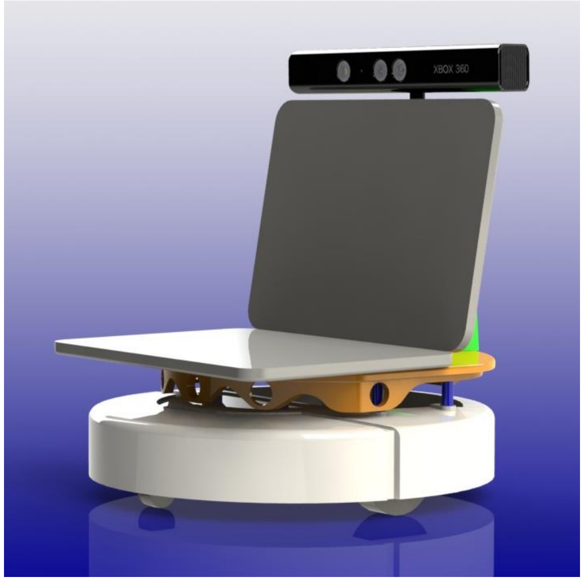
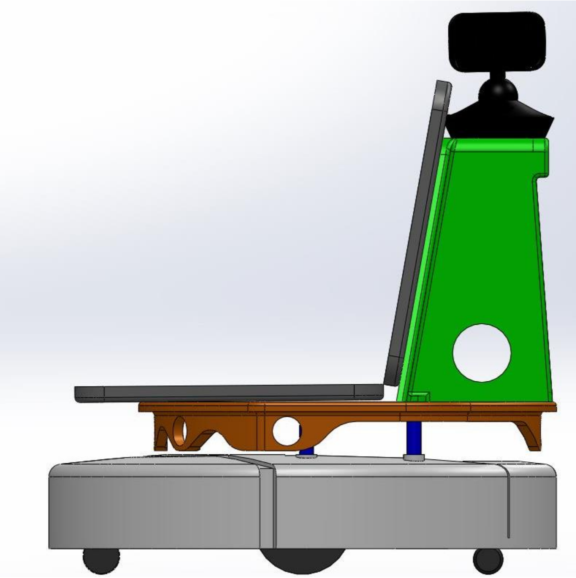
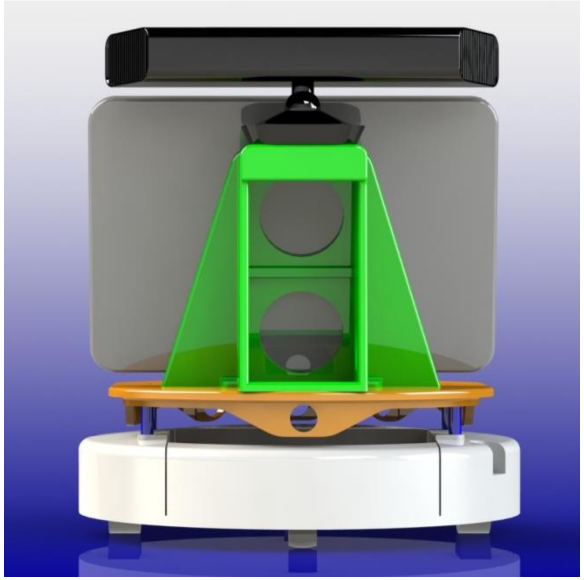
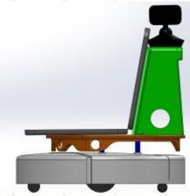
MAE 493G, CpE 493M, Mobile Robotics

4. Robot Sensors

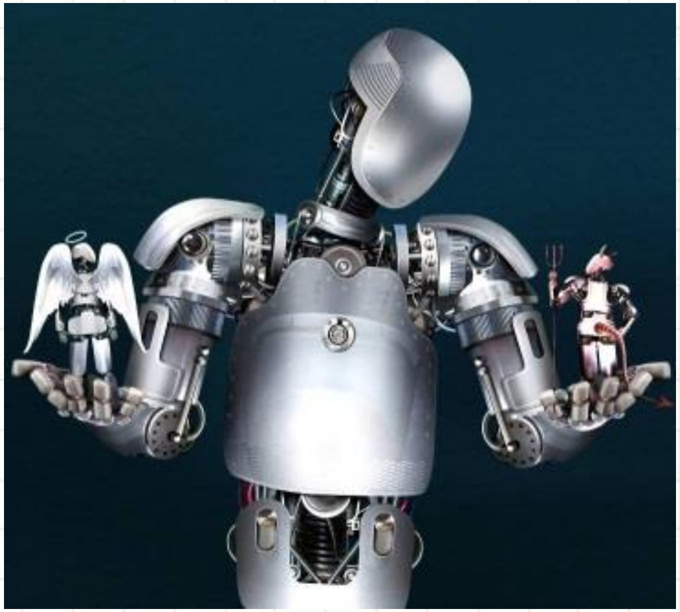




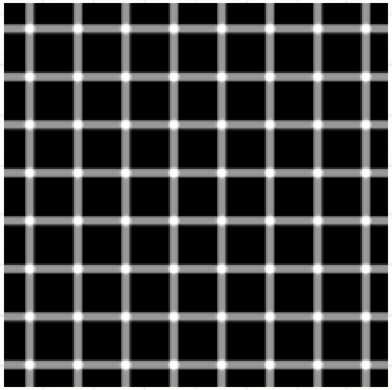
Robot Senses

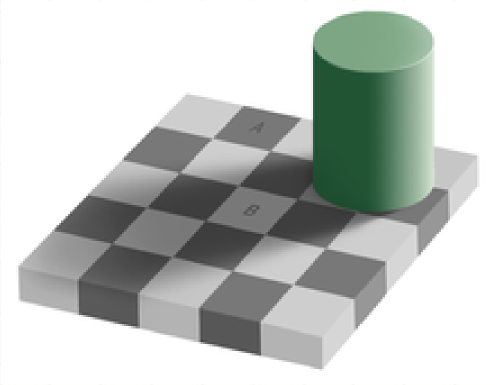
- One of the most important abilities of an intelligent creature is to acquire and process knowledge about itself and its environment;
- Humans have a multitude of senses. Sight, hearing, taste, smell, and touch are the five traditionally recognized. In addition, we can sense temperature, kinesthetic (proprioception), pain, balance, etc.;
- Some animals can sense electric and magnetic fields, ultrasound, local changes of air and water flow, polarized sky, etc.
- Ideally, we want robots to have all of our senses and beyond...

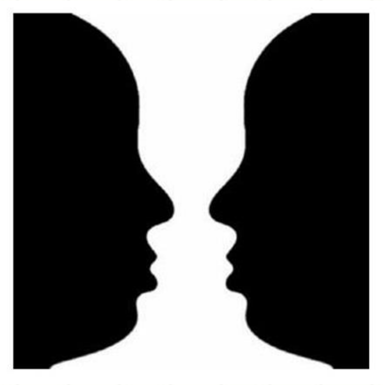


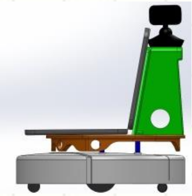
Sensing Vs. Perception

- Sensing is the lower-level process of performing measurements and collecting data; (Physical process)
- Perception is the organization, identification, and interpretation of sensory information in order to represent and understand the environment. (Mental process)





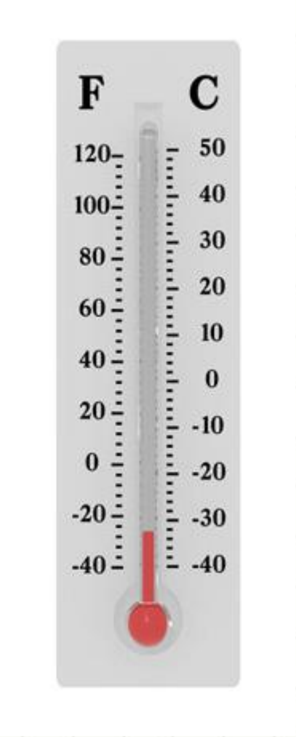




Sensor Fusion

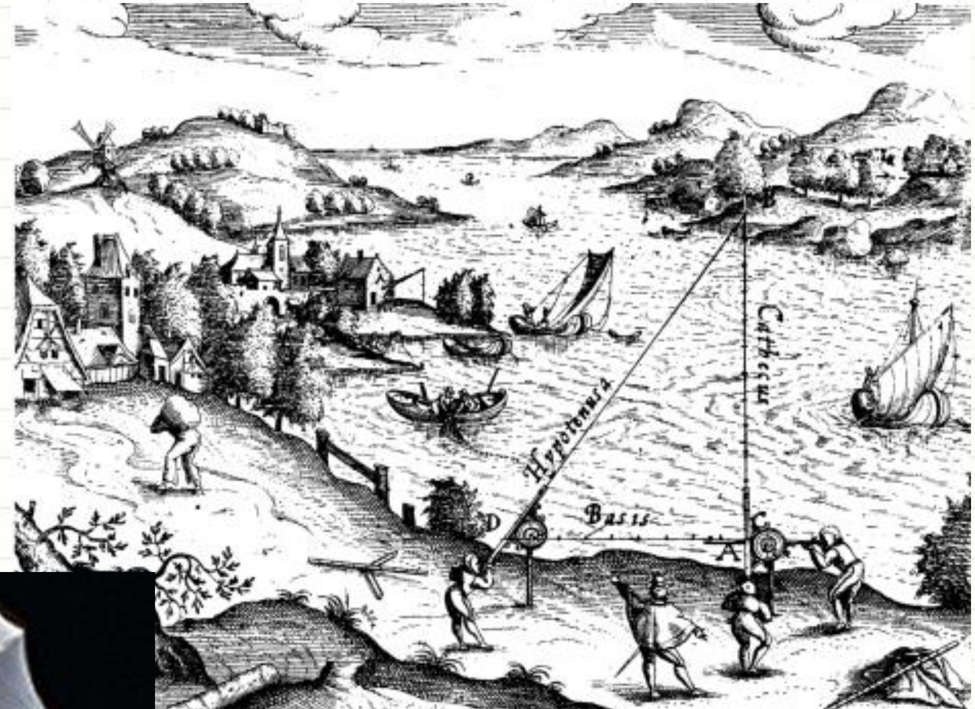
- Sensor fusion is the combining of sensory data or data derived from sensory data from disparate sources such that the resulting information is in some sense better than would be possible when these sources were used individually;
- The term better in this case can mean more accurate, more complete, or more dependable, or refer to the result of an emerging view, such as stereoscopic vision;
- E.g. how to measure the quality of a pizza?

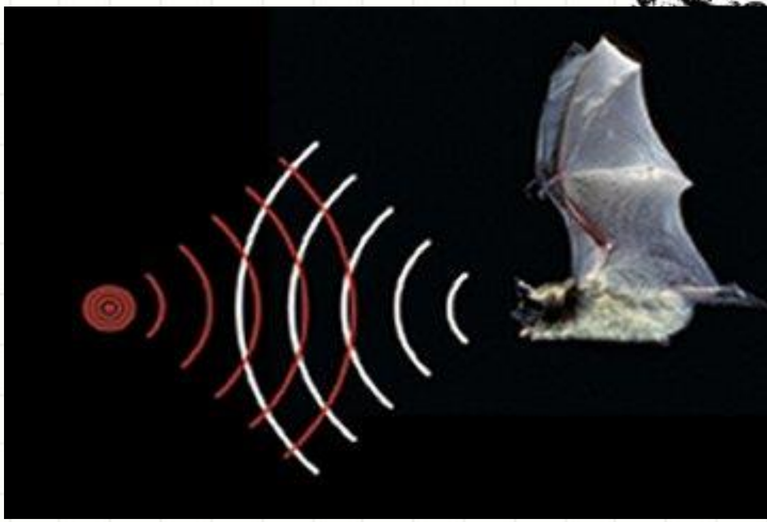
Distance Measurement Tools

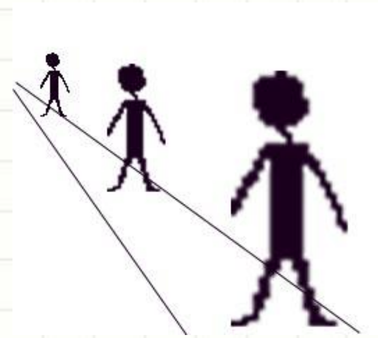


Distance Measurement Methods

- Template matching;
- Triangulation;
- Time of flight;
- Motion Integration;
- Gradient Sensing;
- More...





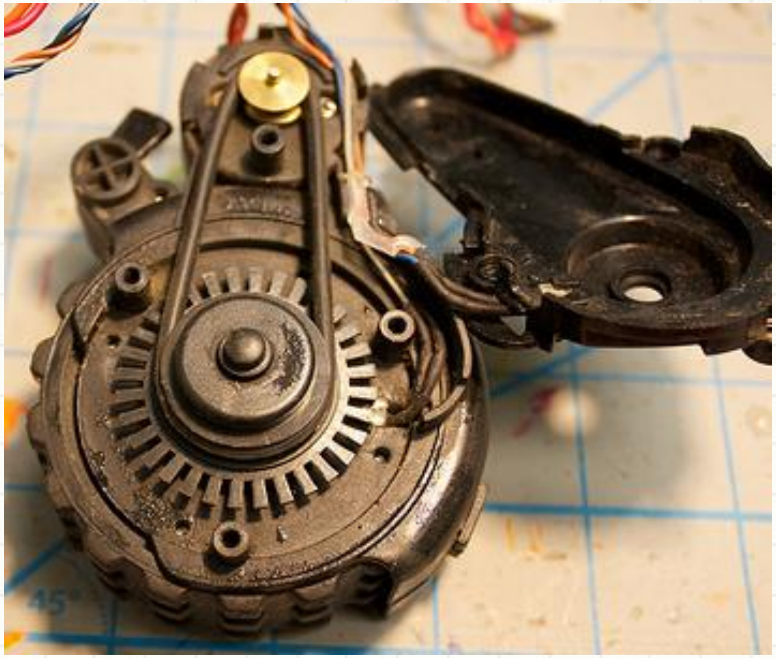


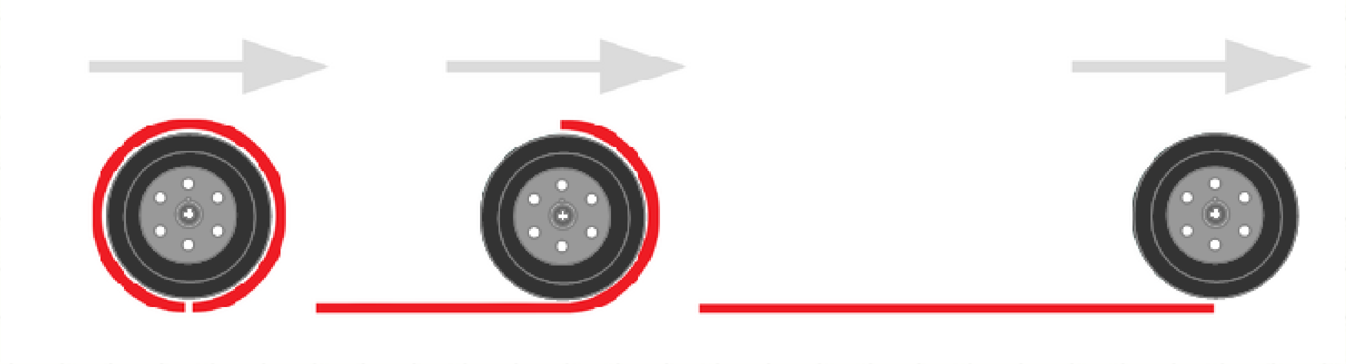
Sensors on SMART

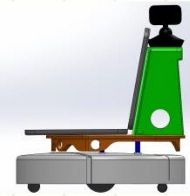
- Wheel Encoders;
- Ultrasonic range finders;
- Accelerometers;
- Gyroscopes;
- Magnetometers;
- Kinect;
- Optical switch;
- Mechanical switch;
- Clock;
- More...

Wheel Encoder

- Encoders can help to track how far each wheel of a robot has traveled.
- In a differential drive configuration, wheel encoders can help tracking a robot’s wheel velocity. The velocity measurements can then be used to estimate the robot relative position and heading angle.

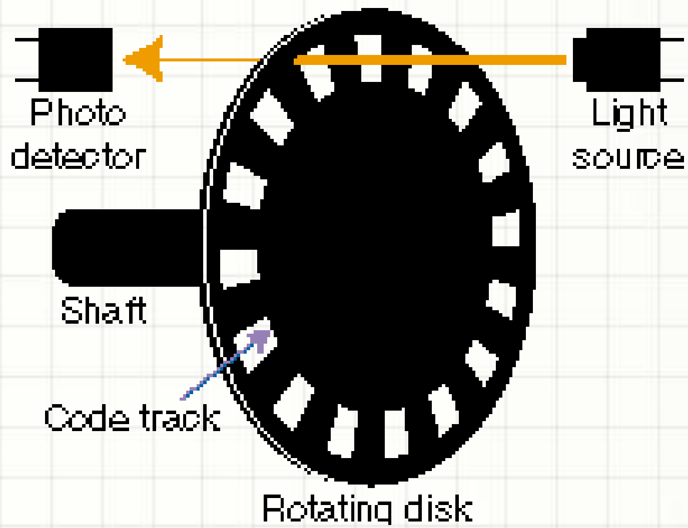






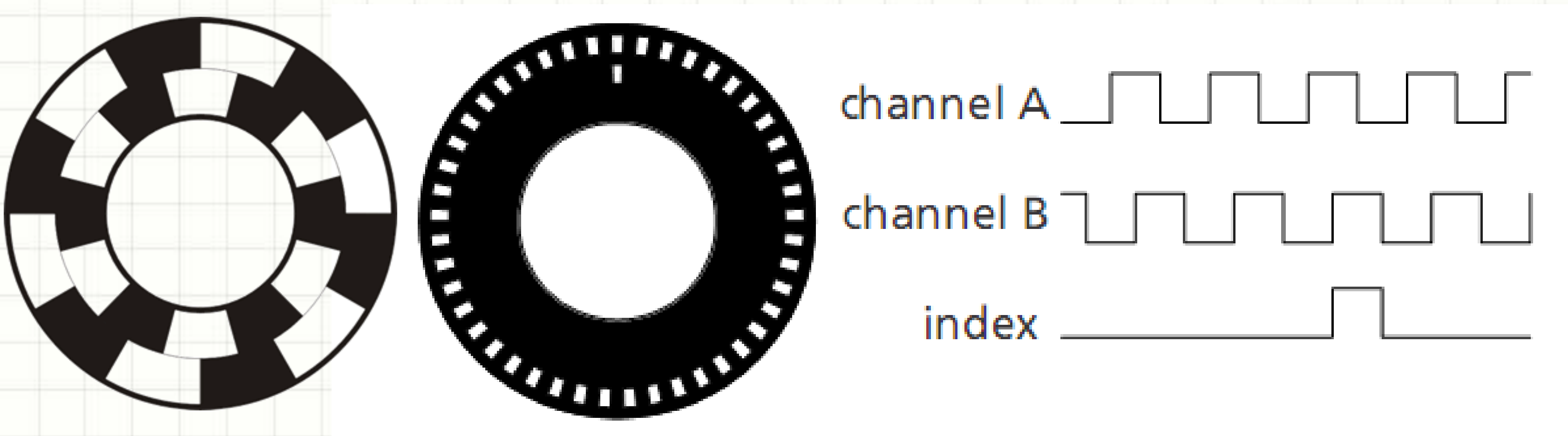
Incremental Rotary Encoder

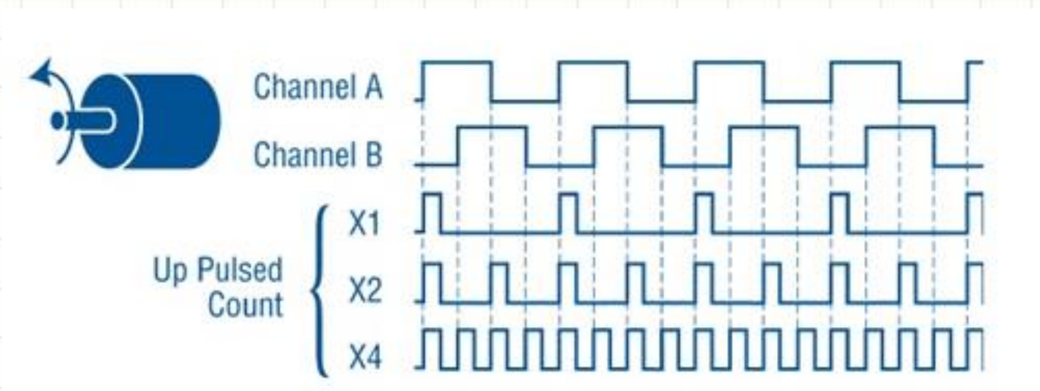
- Incremental encoders are relative position feedback devices in that the feedback signal is always referenced to a start or home position;
- The most common incremental encoders provide a digital pulse for each resolvable position to be counted and referenced to a home position. These digital pulses are then fed into a high-speed counter module located in a drive or controller interface;
- Incremental encoders are susceptible to missed counts and power interruptions. In the event of a power failure, a system using an incremental encoder must be reinitialized.
- If used as wheel encoder for distance estimation, slippage is often a big issue.

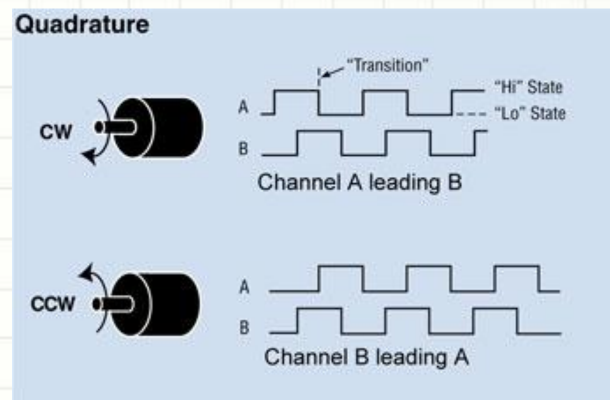


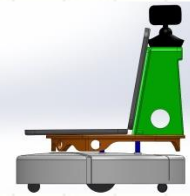
Quadrature Encoder

- Quadrature encoders have two outputs called A & B, which are called quadrature outputs, as they are 90 degrees out of phase.



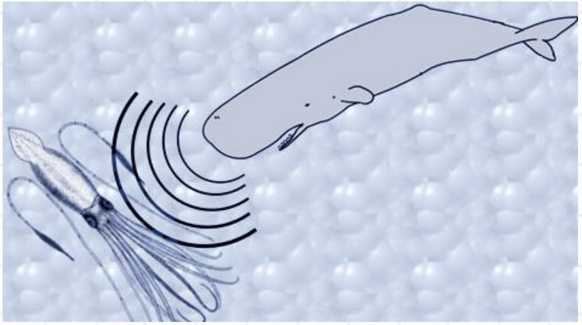


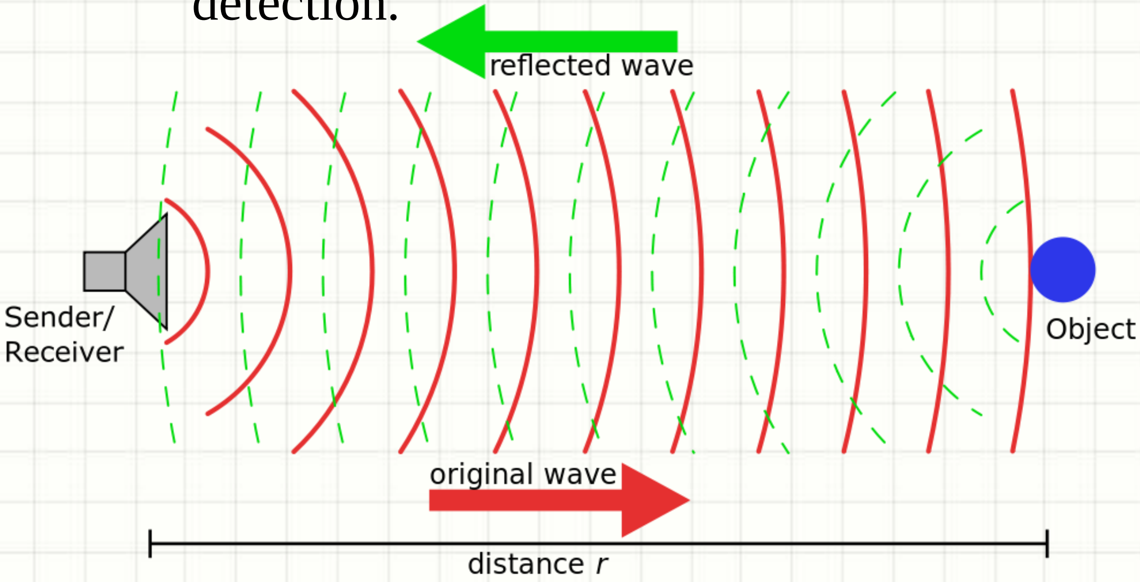


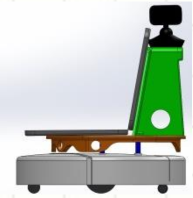


Ultrasound Ranging

- Ultrasound is an oscillating sound pressure wave with a frequency greater than the upper limit of the human hearing range (>20k Hz);
- A common use of ultrasound is in range finding; this use is also called Sonar;
- It measures the 'time of flight' for range detection.

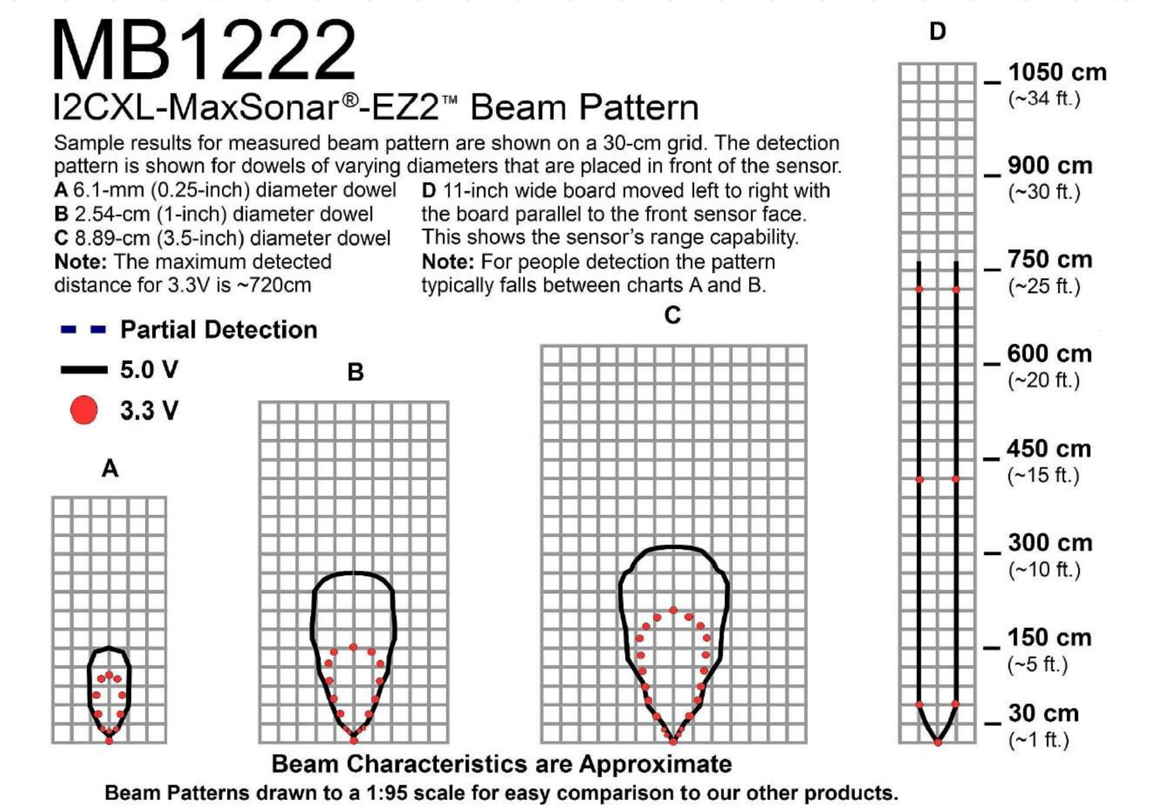


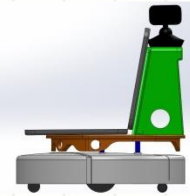




Maxbotix EX2 Range Finder

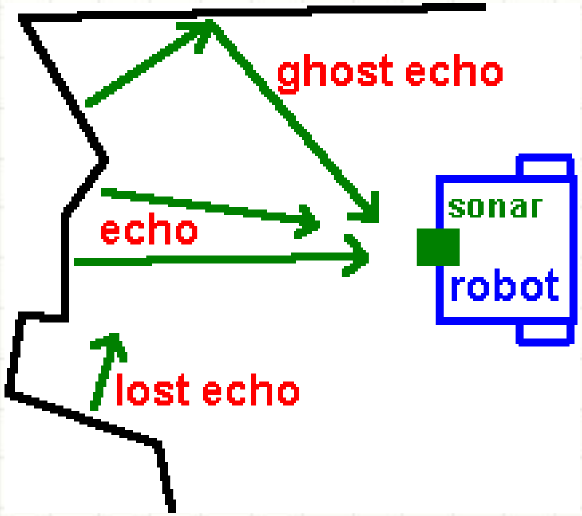
- Detection range: 0-254 inches (6.45 meter). 0-6 inch is reported as 6 inch;
- 2.5-5.5V operation (3.3V on SMART);
- Up to 20Hz update rate;
- 42KHz Ultrasound;
- Serial, Analog, and PWM interface;
- Data Sheet,
- Tutorials.

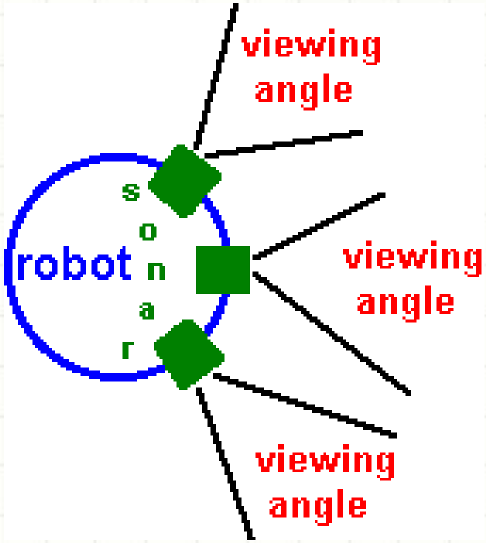


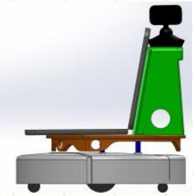


Issues with Sonars

- Minimum range. If the object is within 6 inches, the output will be fixed;
- Reflectance/Absorbance. Different surface material will have different sound reflection property, thus affecting the measurements;
- Multiple Echos. The transmitted sound can bounce around various walls before return to the sonar as a 'ghost echo';
- Multiple sonars may interfere with each other;
- A good discussion of sonar issues is here.
- An implementation guide for multiple sonars is here.





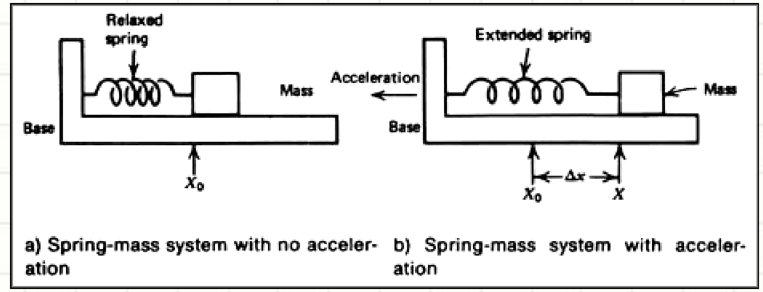


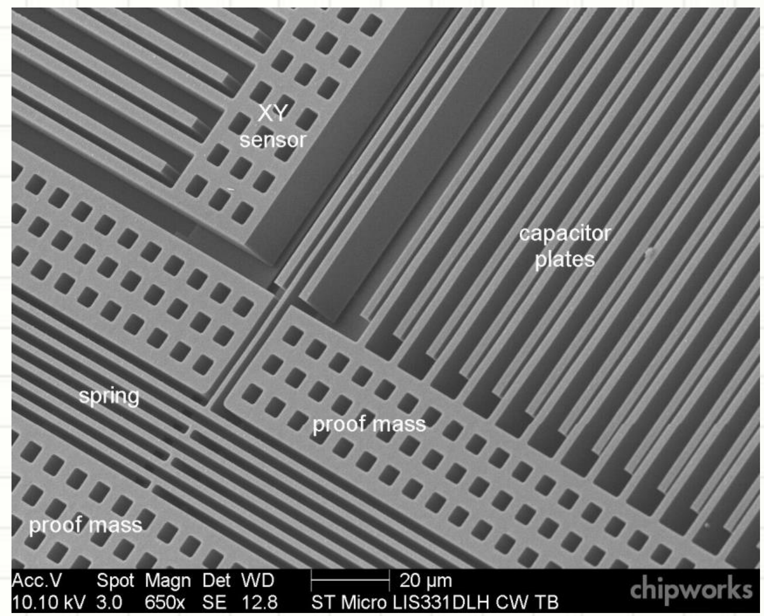
Accelerometer

- An accelerometer measures proper acceleration, which is the acceleration it experiences relative to free-fall and is the acceleration felt by people and objects;
- Accelerometers can be used to measure acceleration, vibration, shock, and gravity;
- The measurements can be used for position and tilt angle estimation;
- Accelerometers are widely used for autonomous vehicles, smart phones, video games, biology, earthquake monitoring, and industry applications.

Inside Accelerometer

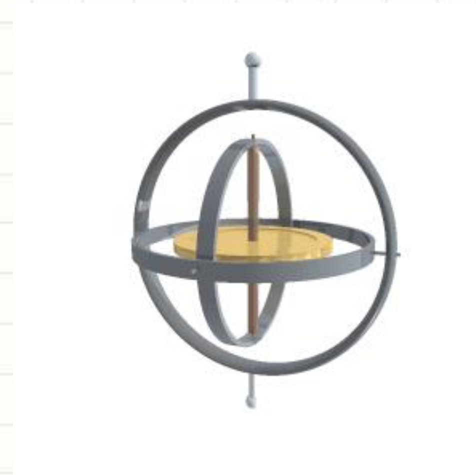
- Conceptually, an accelerometer behaves as a damped mass on a spring;
- The acceleration is first converted to displacement, then electrical signal using piezoelectric, piezoresistive, or capacitive components;
- Modern accelerometers are often small Micro Electro-Mechanical Systems (MEMS), consisting of a cantilever beam with a proof mass. Damping results from the residual gas sealed in the device.

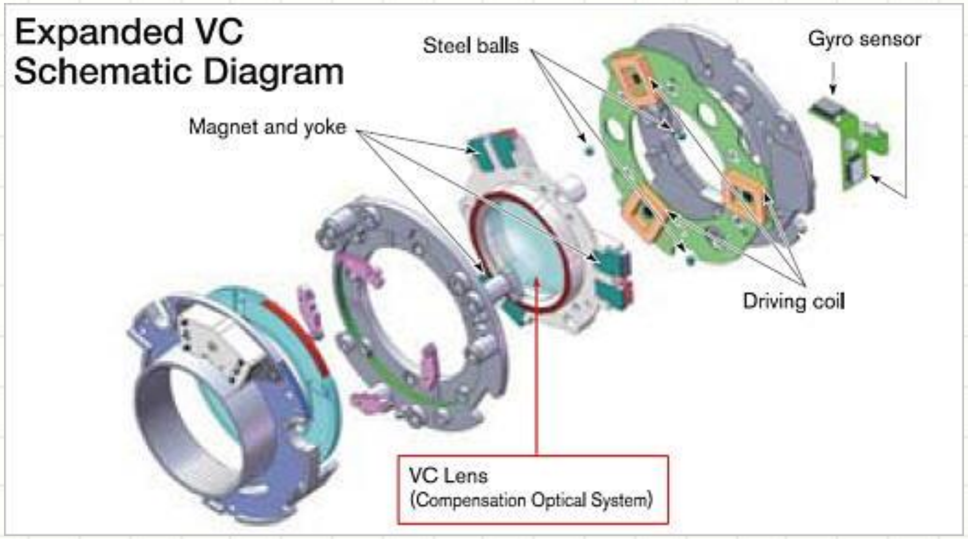




Gyroscope

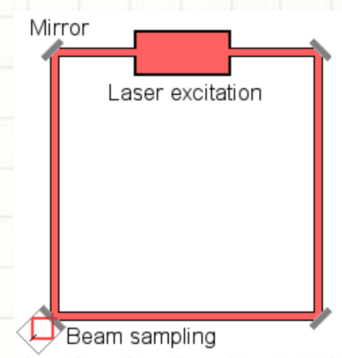
- A conventional gyroscope is a device for measuring or maintaining orientation, based on the principles of angular momentum;
- Modern gyroscopes are often based on different principles and can range from very small and low cost to highly expensive;
- Gyroscopes are commonly used for navigation, smart phones, video games, and industry applications.

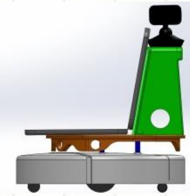




Modern Gyroscope Technology

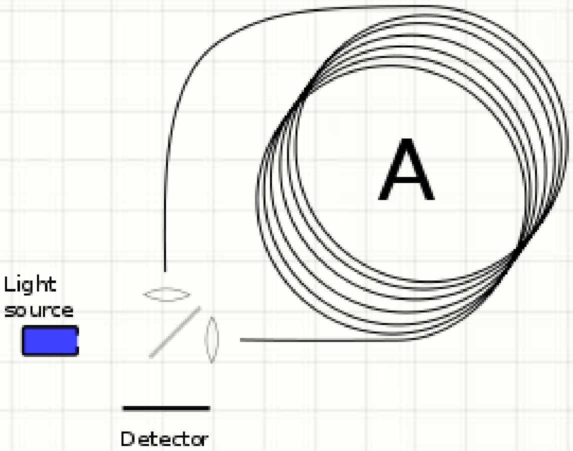
- The mechanical gyro in the Gravity Probe B has a drift rate less than one hundred-billionth of a degree per hour;
- A Ring Laser Gyroscope (RLG) consists of a ring laser having two counter-propagating modes over the same path in order to detect rotation;
- A certain rate of rotation induces a small difference between the time it takes light to traverse the ring in the two directions according to the Sagnac effect. This introduces a tiny separation between the frequencies of the counter-propagating beams.





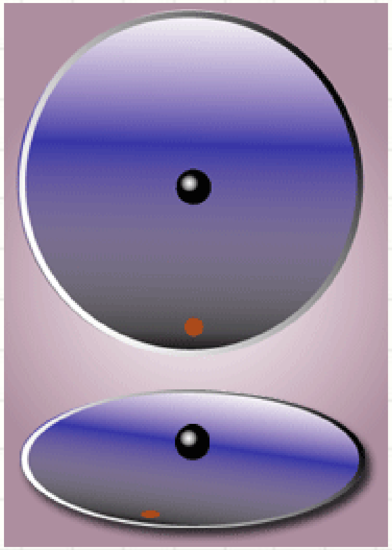
Fiber Optic Gyro

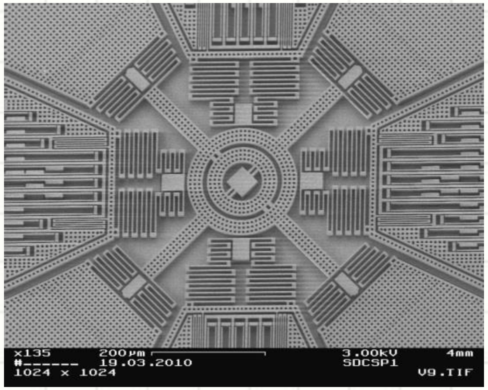
- A Fibre Optic Gyroscope (FOG) also operates on the basis of the Sagnac effect, but in which the ring is not a part of the laser;
- Two beams from a laser are injected into the same fiber but in opposite directions. Due to the Sagnac effect, the beam travelling against the rotation experiences a slightly shorter path delay than the other beam. The resulting differential phase shift is measured through interferometry;
- FOG is a lot easier to build than the RLG, but with generally lower performance.



MEMS Gyro

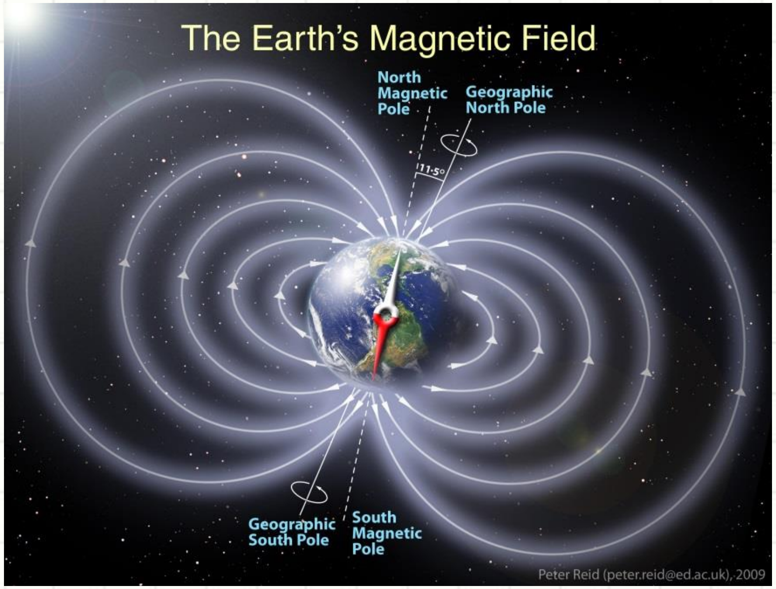
- Inspired by halteres of an insect.
- The underlying physical principle is that a vibrating object tends to continue vibrating in the same plane as its support rotates. In the engineering literature, this type of device is also known as a Coriolis vibratory gyro because as the plane of oscillation is rotated, the response detected by the transducer results from the Coriolis term in its equations of motion ("Coriolis force").
- MEMS gyros can be very low cost and their performance have been improving rapidly.





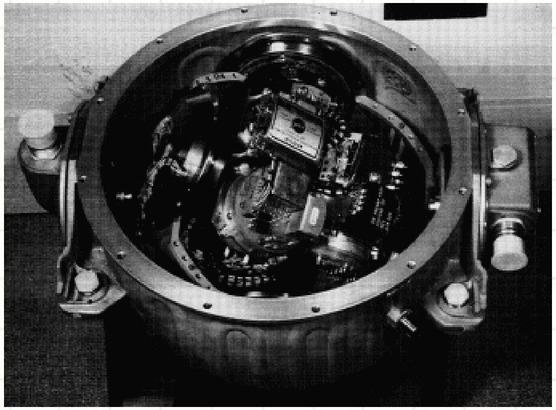
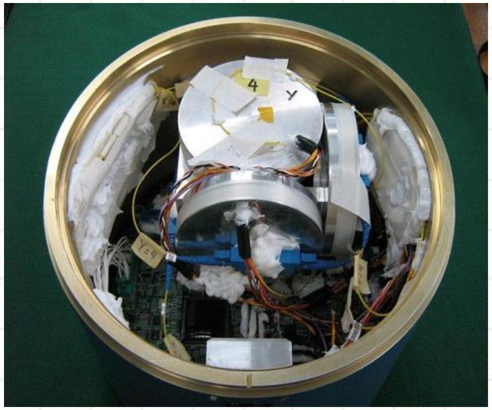
Magnetometer

- A magnetometer measures the strength and, in some cases, the direction of magnetic fields;
- Magnetometer can be used for heading estimation but can be easily interfered;
- Many animals can sense the magnetic field and use this information for navigation. (e.g. Pigeon, honeybee, turtle and shark);
- We will learn about how to calibrate a magnetometer later in this class.



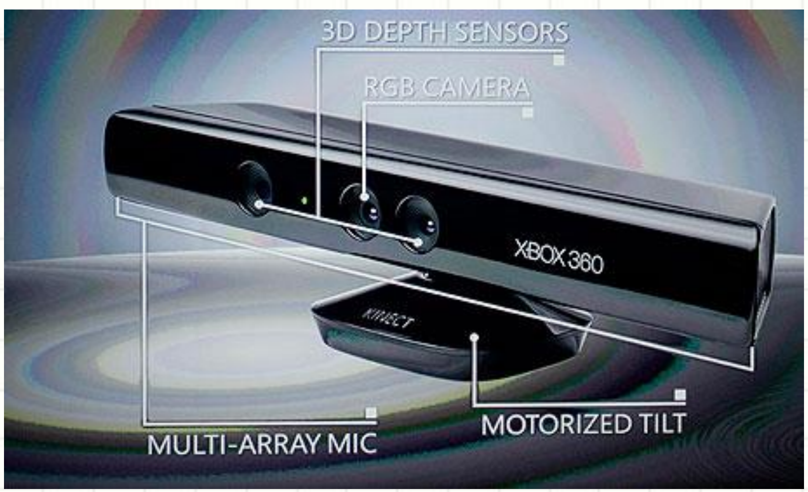
Inertial Measurement Unit

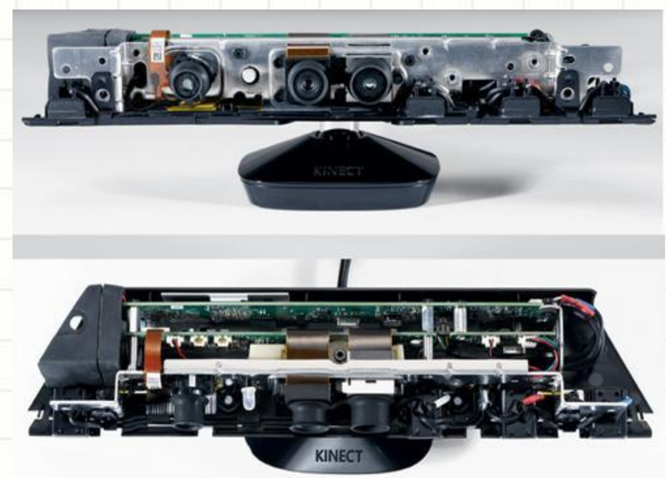
- An Inertial Measurement Unit (IMU), is an electronic device that include a combination of 3-axis accelerometers and gyroscopes, sometimes also magnetometers;
- IMU is the heart of an Inertial Navigation System (INS).

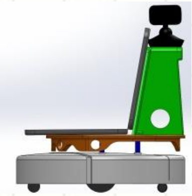




Kinect

- Kinect is a motion sensor made by Microsoft;
- It provides 640x480 RGB + depth data at 30Hz;
- The depth data has a 11-bit resolution, which has a range between ~0.8-4m;
- The sensor has an angular field of view of 57° horizontally and 43° vertically;
- There is also a array of four microphones on each Kinect.

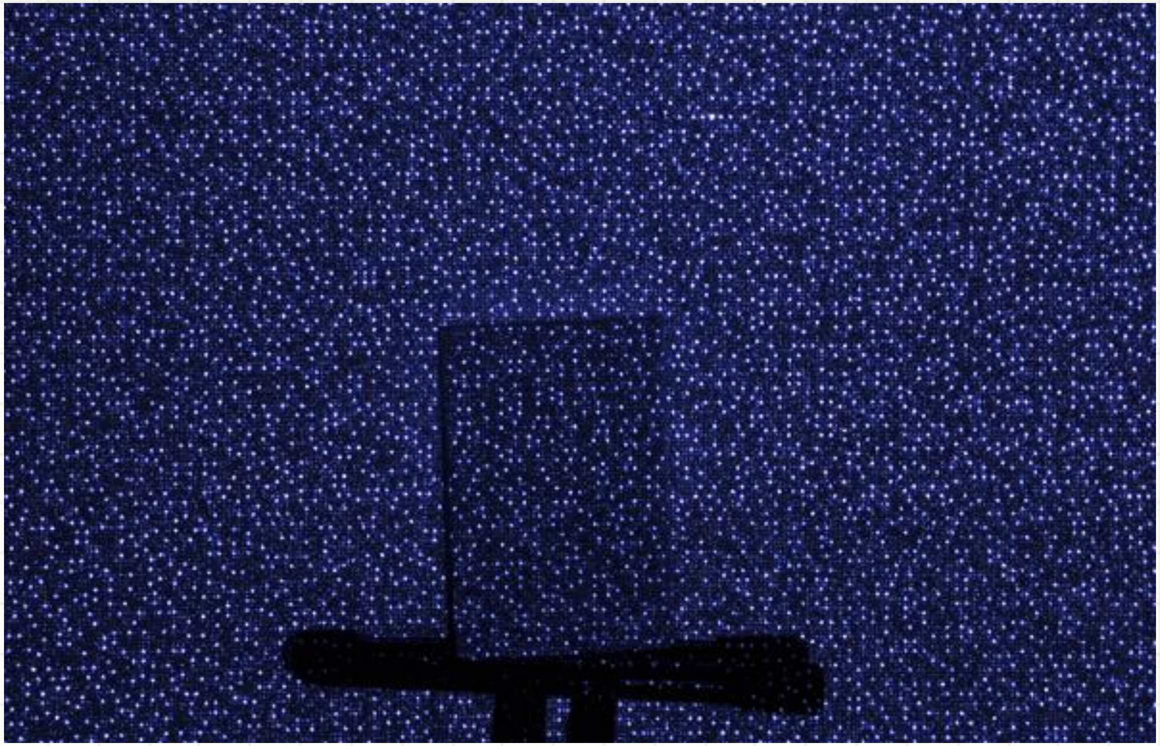


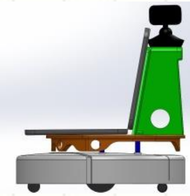




Kinect Depth Sensing

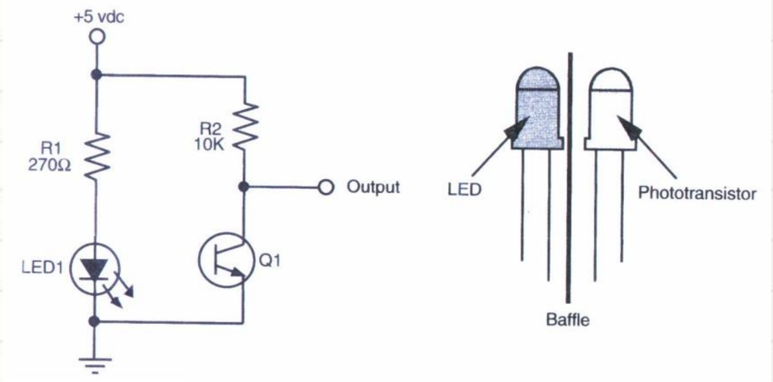
- How does it work? Link1
- Application: One, Two, and Three.





Optical/Mechanical Switches

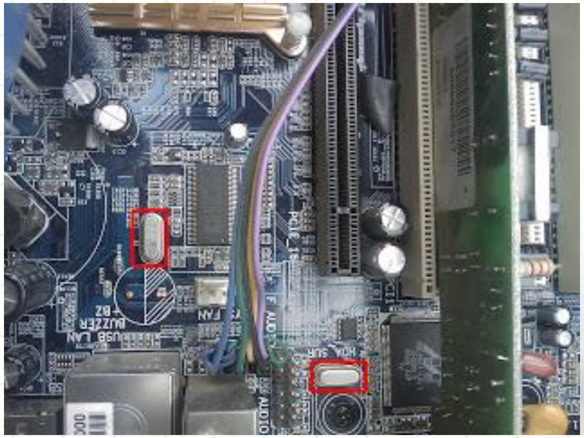
- Switches and proximity sensors are used for receiving user input, detect obstacle and cliffs, and detect collisions on the SMART robot;
- They are simple but very useful sensing devices;
- In fact, the primary navigation sensors for a Roomba are the switches behind its bumper.



The basic design of the infrared proximity sensor.

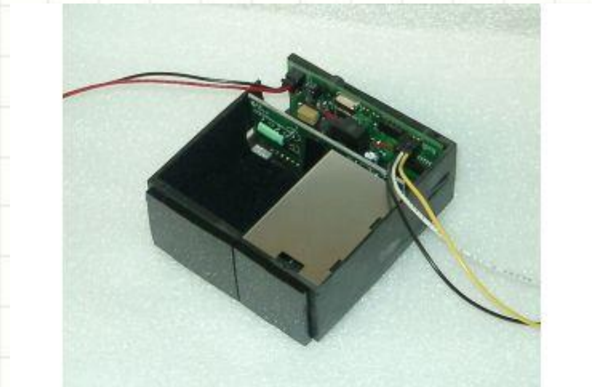
Time Measurement

- The importance of time measurement is often overlooked;
- Every event is a function of time;
- Multiple events are happening at the same time;
- It’s critical to accurately track and synchronize different events as they happen;
- Most computers use crystal oscillators to keep time;
- If you have access to the GPS signal, much more accurate time information can be acquired.



Other Common Sensors for Robots

GPS

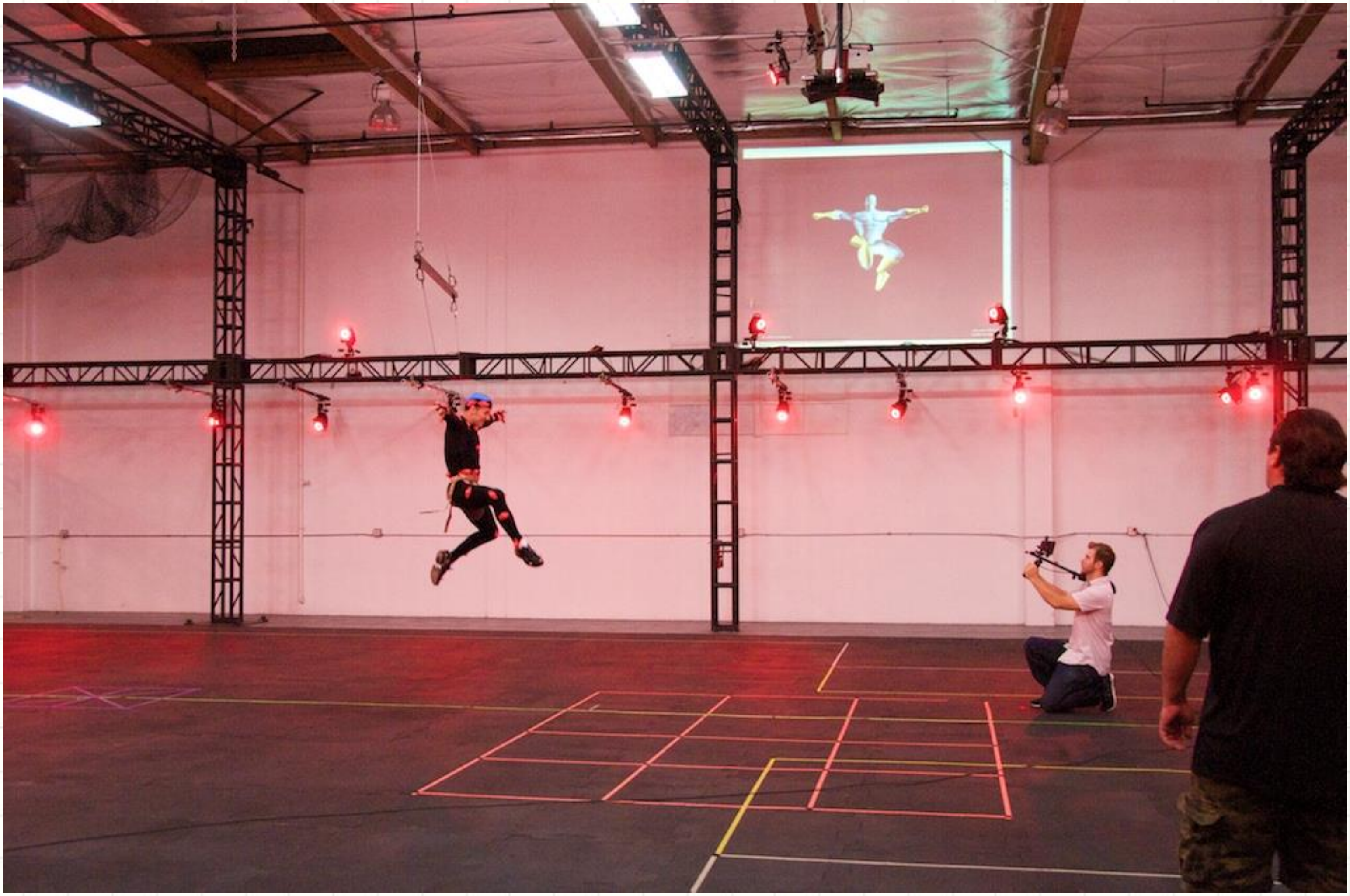


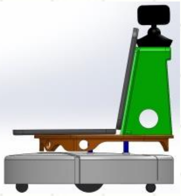
Laser Range Finder

Tactile Sensor

Laser Scanner

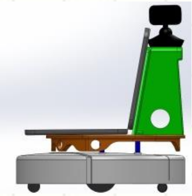
External Measurement Devices





Summary

- There are many different types of sensors available for mobile robots;
- They are often used to provide the kind of information natural creatures can acquire;
- Sensors are based on many different measurement principles;
- You can combine the output of multiple sensors to get better results;
- Modern sensors are quite good already, but how to make sense of the data (perception) is the much harder problem!



Further Reading

- Search for sensing, perception, and different types of sensors on Wikipedia;
- MaxBotix tutorials for ultrasonic range finders: http://www.maxbotix.com/tutorials.htm