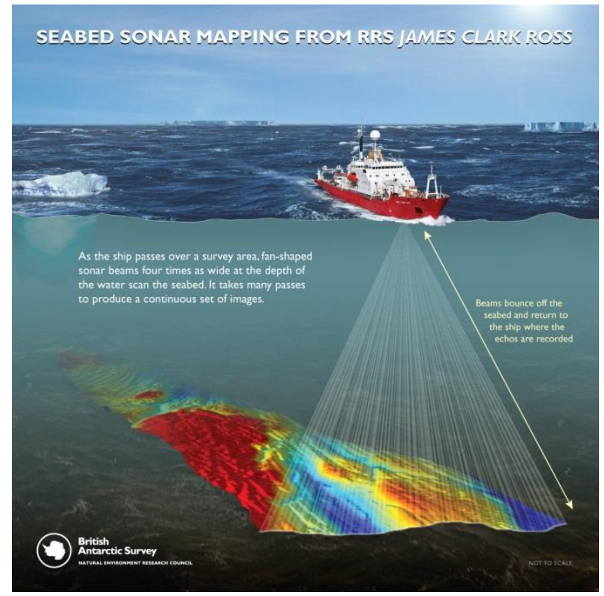
Sensors and Control for Mechatronic Systems

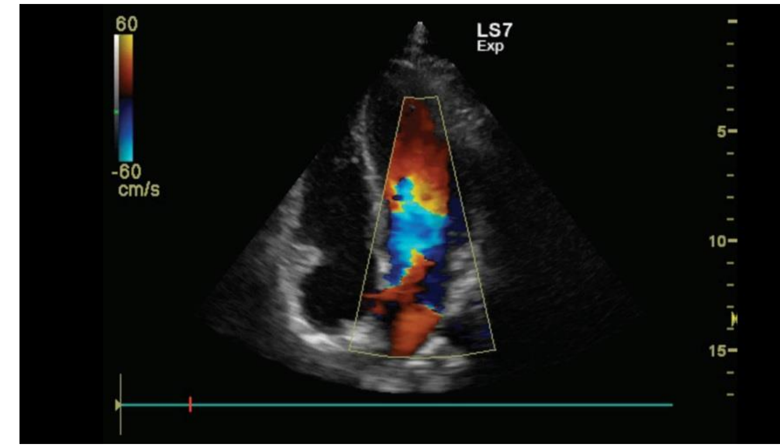
Dr Liang Zhao

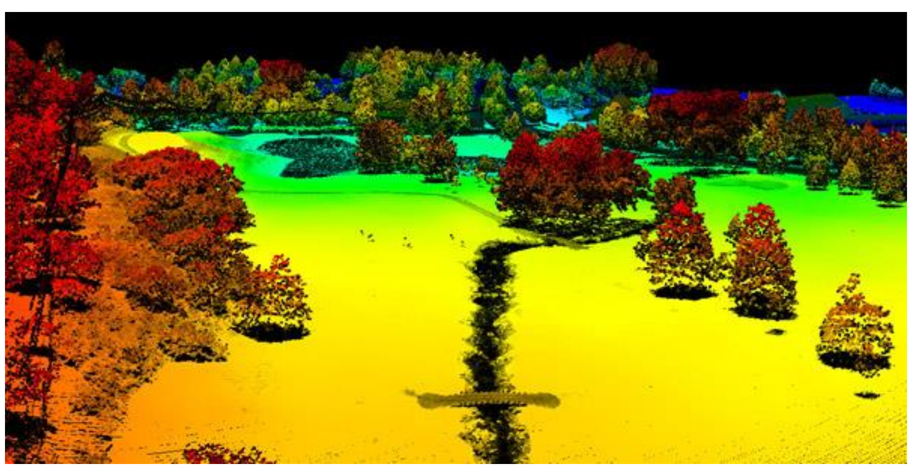
Faculty of Engineering and Information Technology,
University of Technology, Sydney

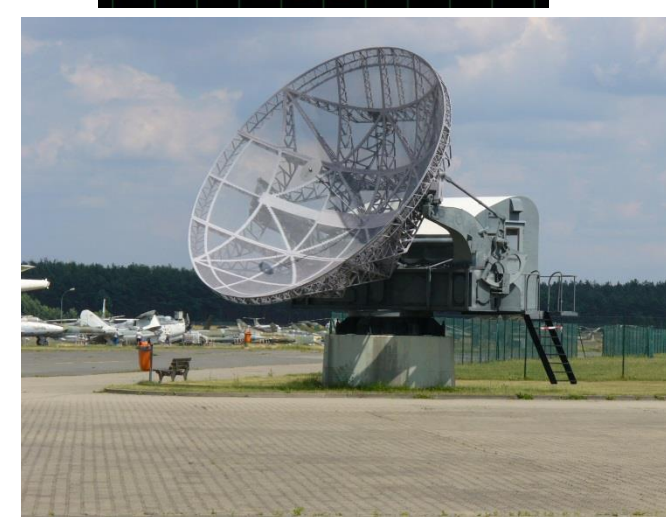
Time of Flight Sensors

- Sonar sensors
- Ultrasound sensors
- Lidar sensors
- Radar sensors







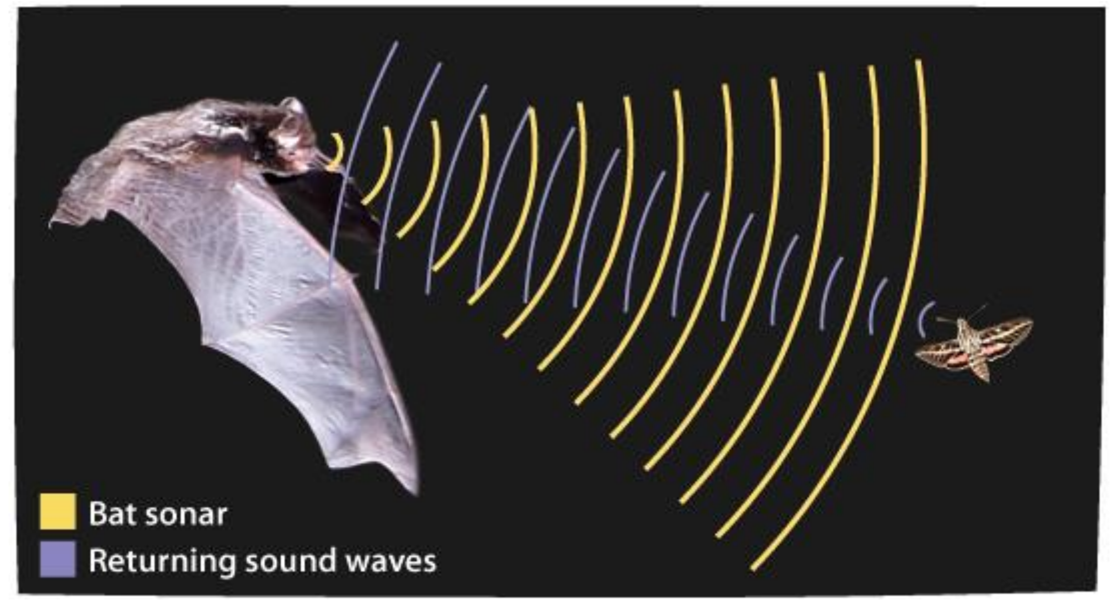


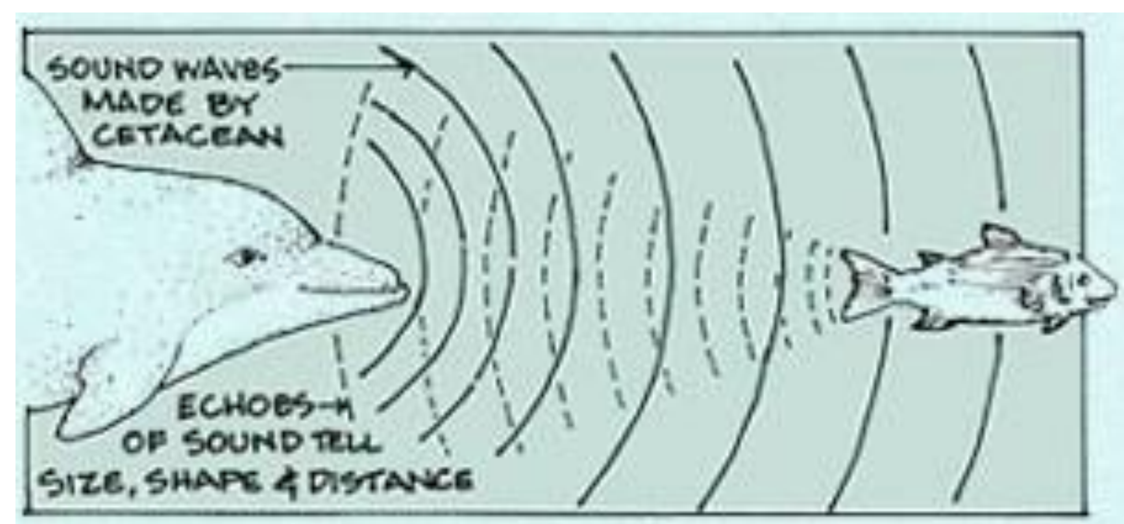
Sonars

- Sonar: Sound navigation and ranging
- It uses the reflected sound waves to detect, locate and determine the speed of objects.
- A system using transmitted and reflected underwater sound waves to detect and locate submerged objects
- The acoustic frequencies used in sonar systems vary from very low (infrasonic) to extremely high (ultrasonic).
- https://www.youtube.com/watch?v=-fAAxEIFeLU

Sonars - History

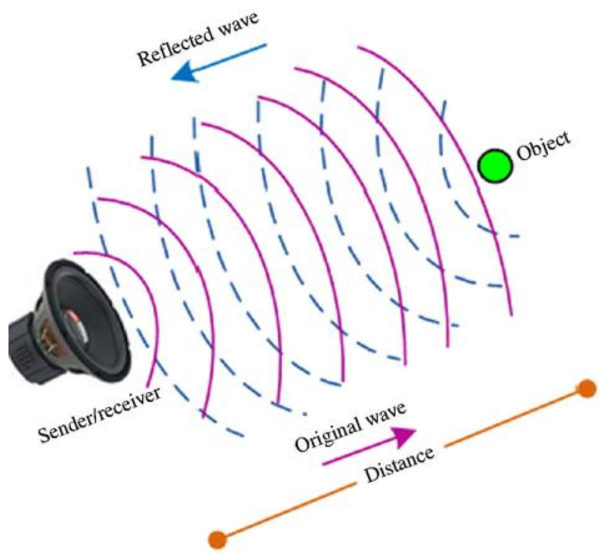
- Some animals like bats and dolphins use sound waves to detect objects
- Use of the sound by humans in the water is initially recorded by Leonardo da Vinci in 1490: a tube inserted into the water was said to be used to detect vessels by placing an ear to the tube
- Sonar was first patented by Lewis Richardson and German physicist Alexander Behm in 1913.

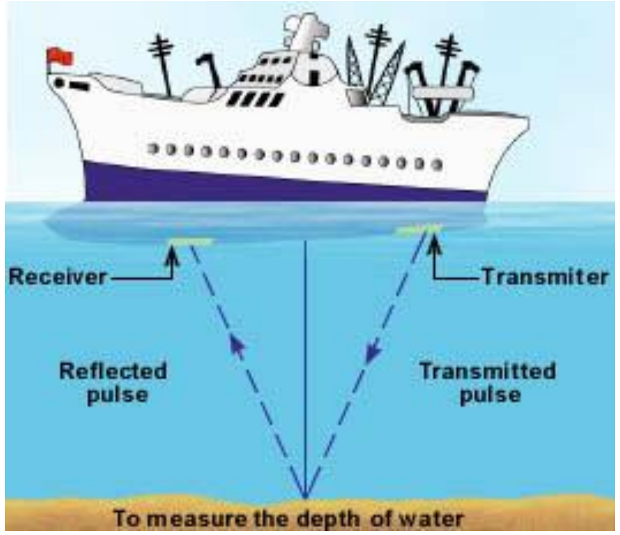




Sonars - Types

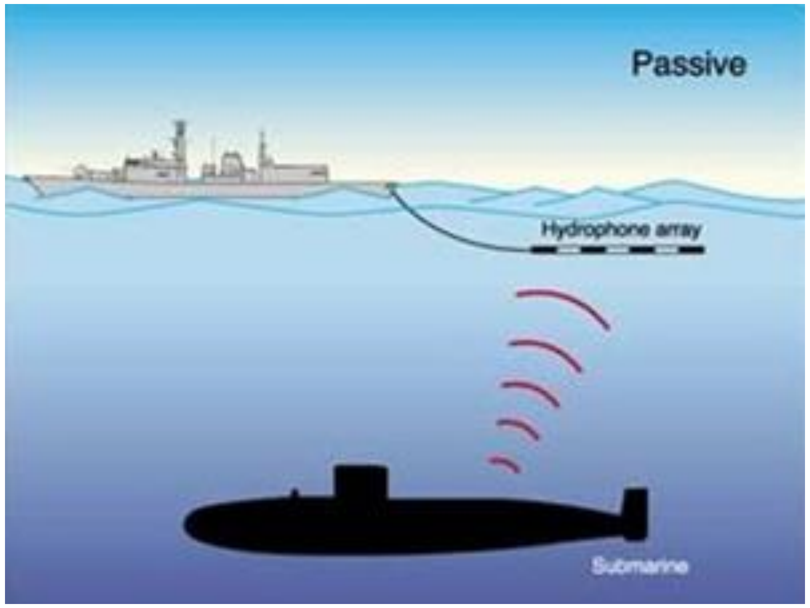
- Active sonar
  - Monostatic mode : when the transmitter and receiver are at the same place.
  - Bistatic mode : when the transmitter and receiver are separated by some distance.
  - Multistatic mode : When more transmitters (or more receivers) are used, again spatially separated.





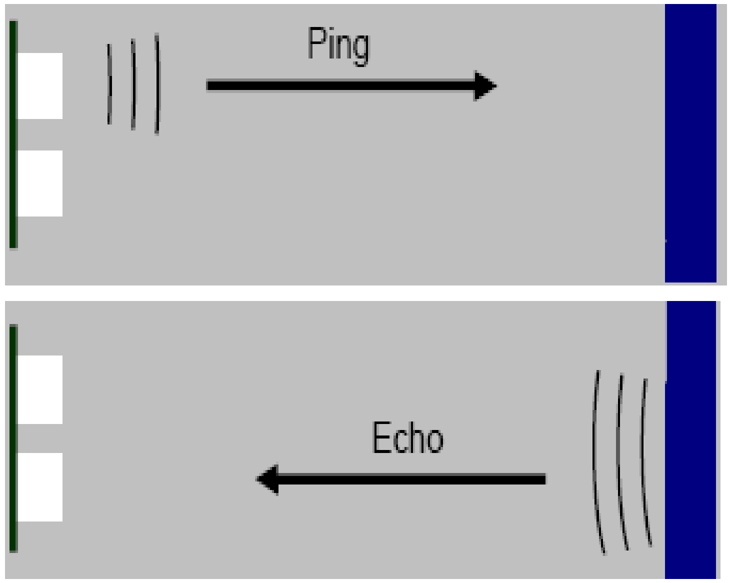
Sonars - Types

- Passive sonar
  - Passive sonar listens without transmitting.
  - Passive sonar has a wide variety of techniques for identifying the source of a detected sound.
  - Passive sonar system have large sonic database but sonar operator classify signals by use of computer and use these databases to identify classes of ships and action.



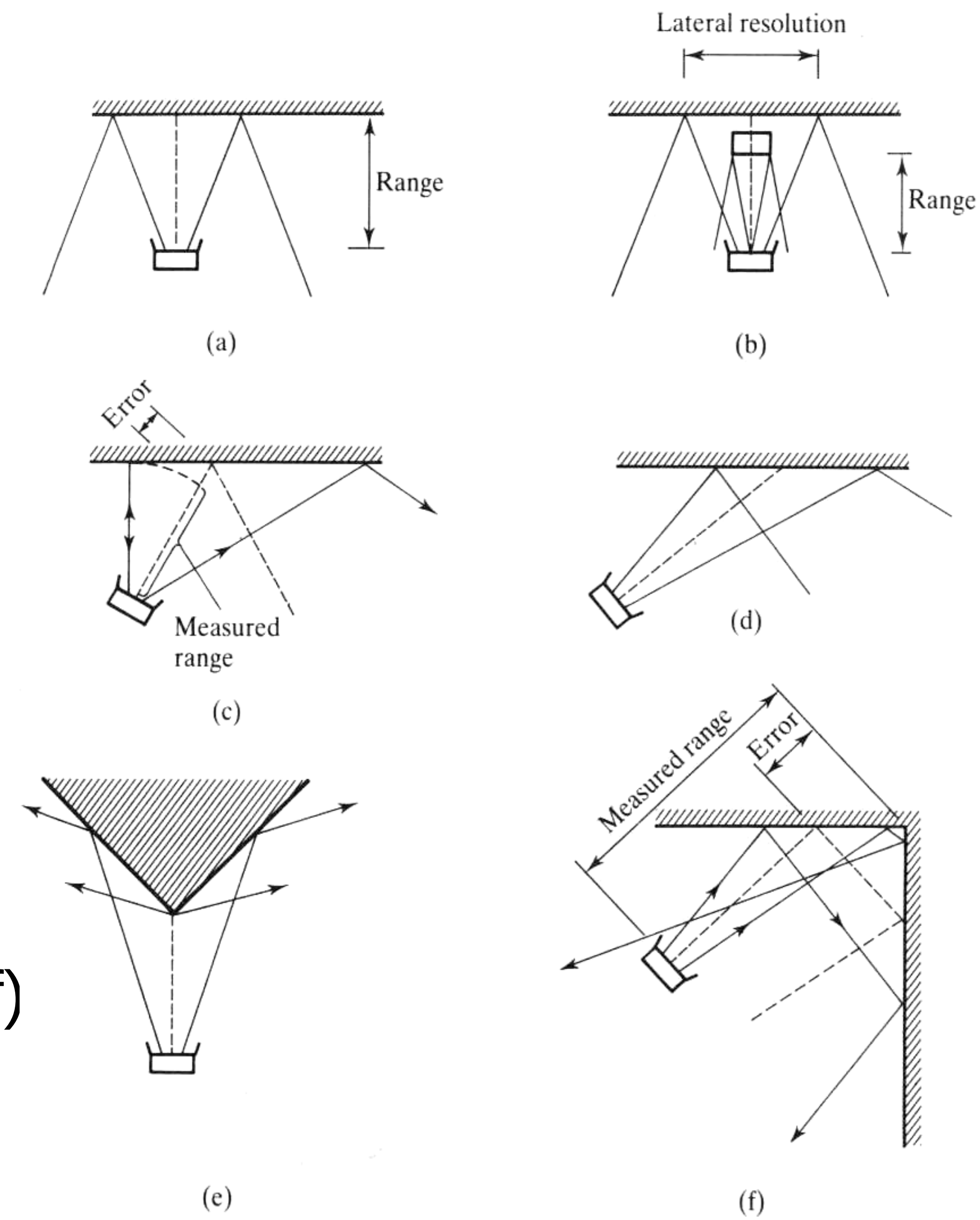
Sonars – Operating Principal

- Generating a short burst of sound (a ping)
- Listening for the echo
- Distance is calculated based on the elapsed time



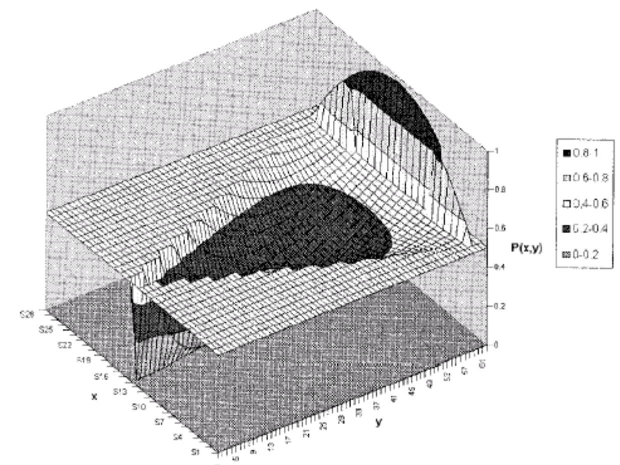
Sonar – Usage

- Sonar providing an accurate range measurement (a)
- Angular resolution is not very precise; the closest object in the beam's cone provides the response (b-c)
- Specular reflections cause walls to disappear (d)
- Open corners produce a weak spherical wave front (e)
- Closed corners measure to the corner itself because of multiple reflections --> sonar ray tracing (f)

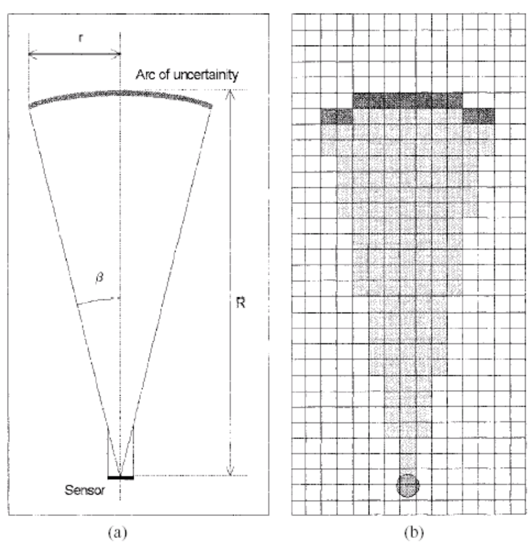


Sonar - Sensor Model

- Sonar provides
  - Accurate range information
  - Inaccurate angular measurement

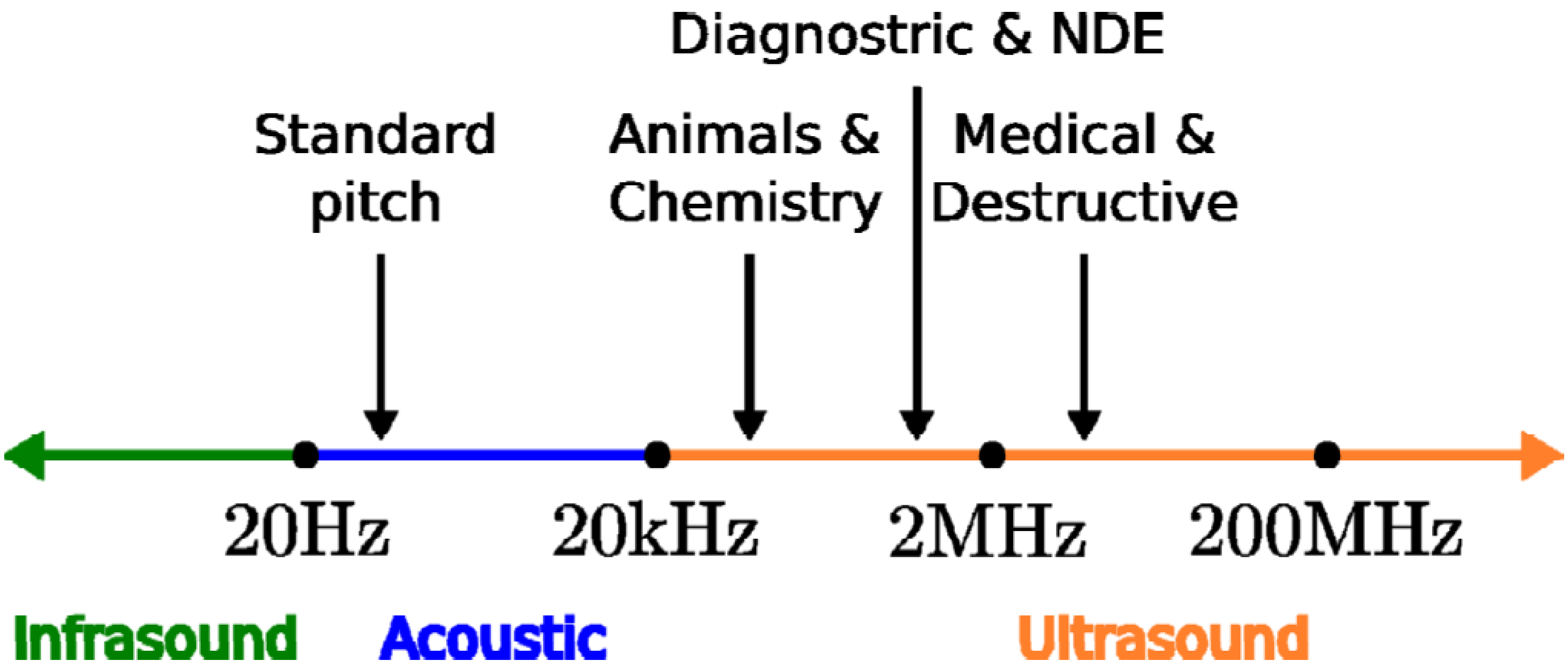


Probabilistic representation



Occupancy Grid representation

Ultrasound



Diagnostric & NDE
Standard pitch
Animals & Chemistry
Medical & Destructive
20Hz
20kHz
2MHz
200MHz
Infrasound
Acoustic
Ultrasound

Ultrasound - History

- Sonar: First practical application, 1912 unsuccessful search for Titanic
- Sonar: WW II brought massive military research

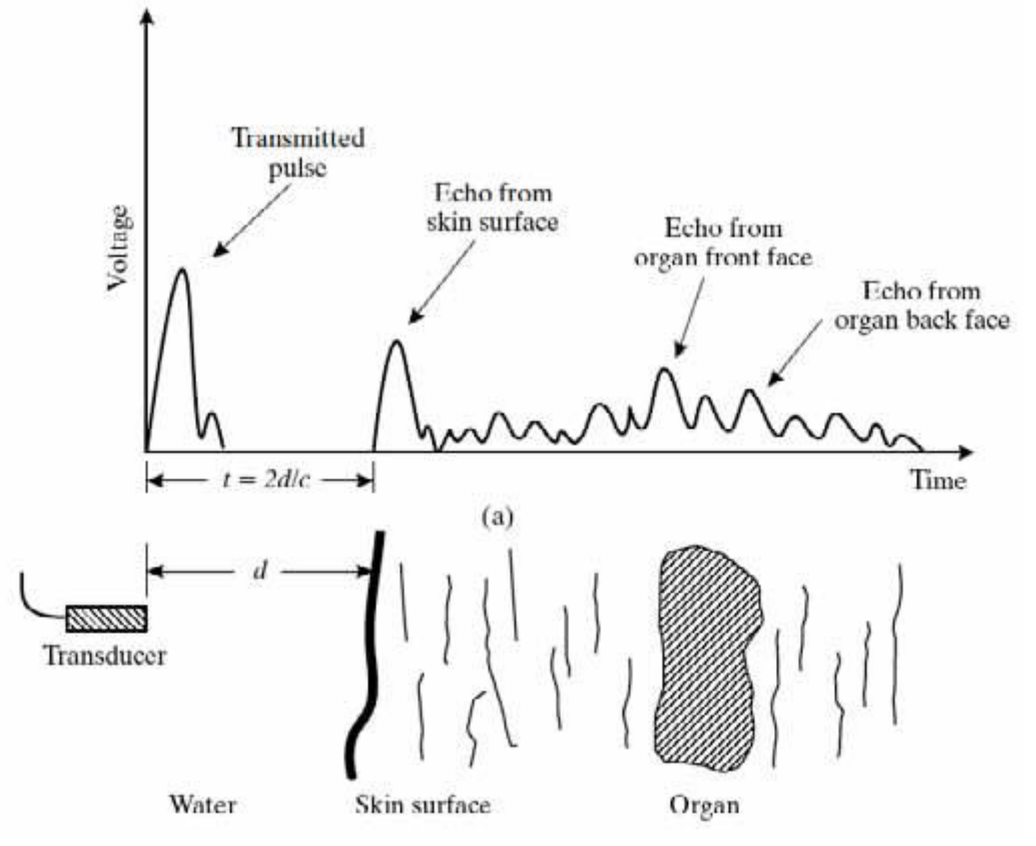
- 1914: Langevin - First Ultrasound generator using piezoelectric effect
- 1928: Solokov - Ultrasound for material testing
- First used as diagnostic tool in 1942 for localizing brain tumours
- 1950's 2D gray scale images
- 1965 or so real-time imaging

The water-bag B-mode scanning system, the SSD-1, from Aloka in 1960

Ultrasound - Operation

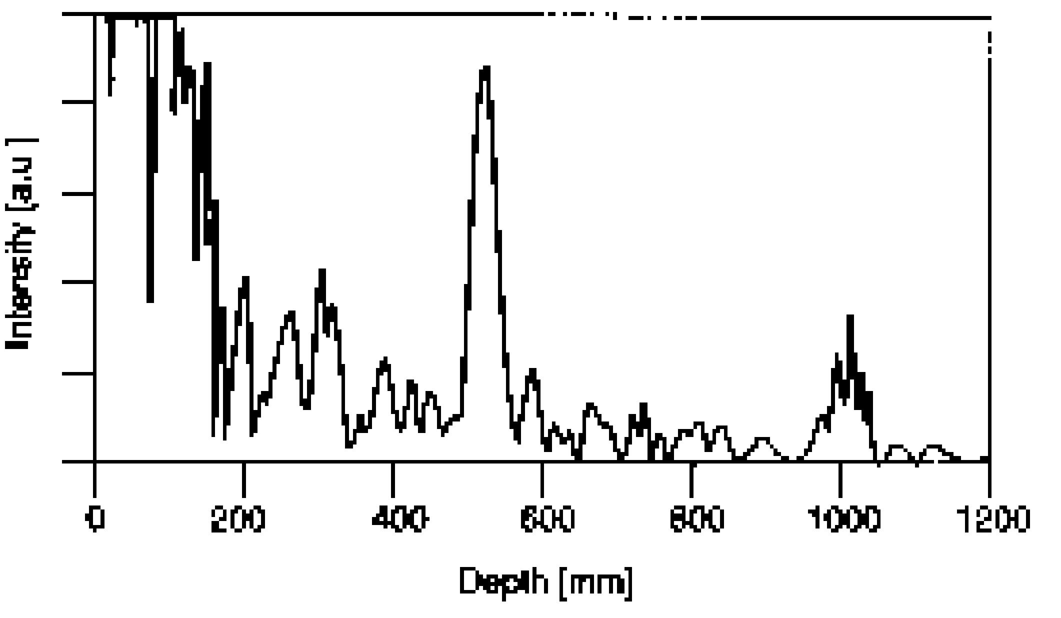
- Human sensitivity: 20 - 20,000Hz
- Ultrasound: > 20 KHz
- Diagnostic Ultrasound: 2.5 - 14 MHz

- An ultrasound wave is generated
- Listen for the return signal
- Figure shows the transmit signal and the reflected signal.



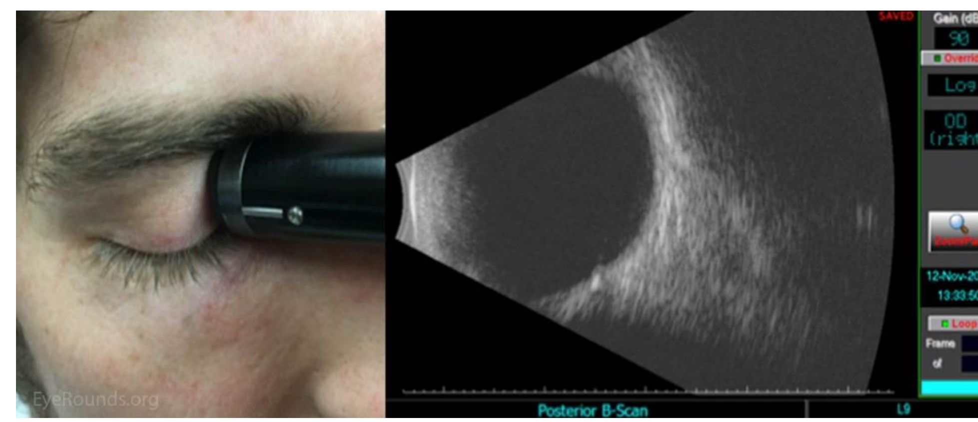
Ultrasound - Operation

- **A-Scan**
- The A-scan presentation displays the amount of received ultrasonic energy as a function of time.
- The relative amount of received energy is plotted along the vertical axis and the elapsed time (which may be related to the sound energy travel time within the material) is displayed along the horizontal axis



Ultrasound - Operation

- **B-Scan**
- The B-scan presentation is a profile (cross-sectional) view of the test specimen.
- In the B-scan, the time-of-flight (travel time) of the sound energy of multiple scans are displayed in the same plot.



Lidar

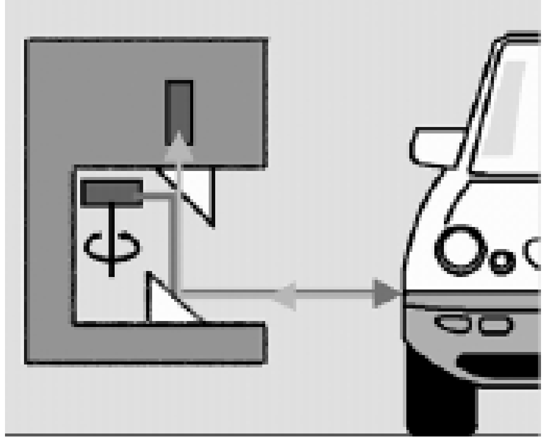
- Light Detection And Ranging
- A LIDAR transmits & receives electro-magnetic radiation and operate in the ultraviolet, visible and infrared region of the electromagnetic spectrum. The LIDAR is also popularly known as LASER RADAR.
- A LIDAR basically consists of a transmitter, receiver & detector

2D Lidar

- Operating principal
  - Measuring the time of flight of laser light pulses
  - The pulsed laser beam is deflected by an internal rotating mirror
  - The measurement data is available in real time via serial interface

LMS 291

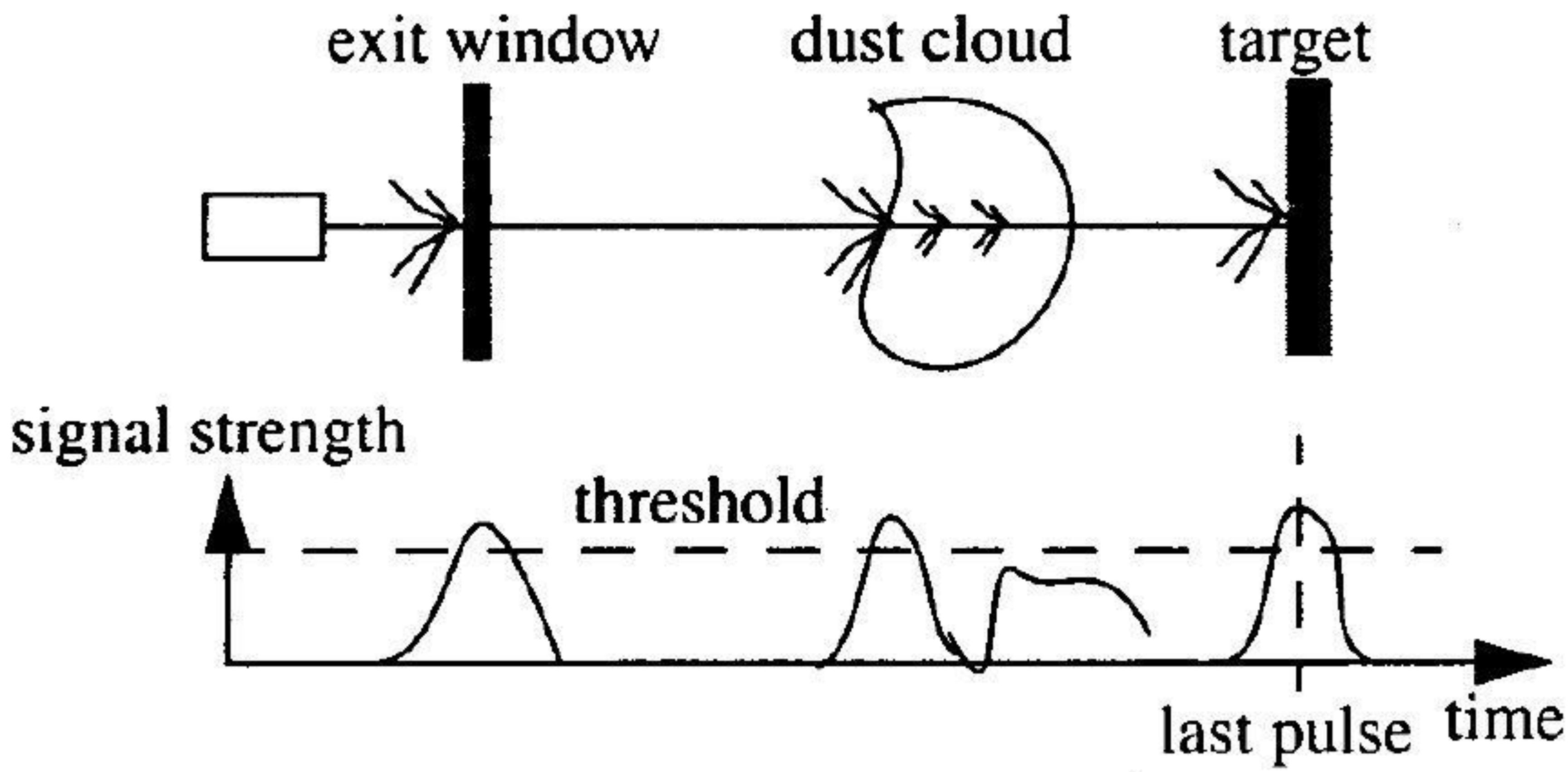
LMS 220



Measuring system

Lidar: Laser Measurement Systems

- Last pulse measuring technique



Types of laser measurement systems

2D SICK laser

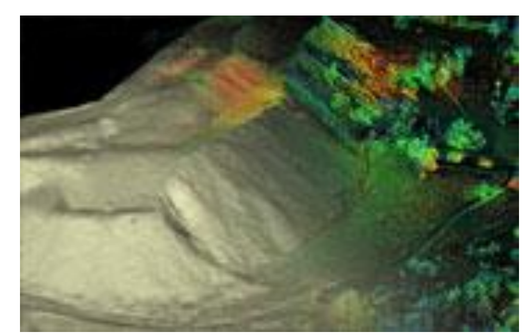
- Measures range (80 m) and bearing (180 deg) to objects in 2D

360^0 SICK laser

- Measures range (80 m) and bearing (360 deg) to objects in 2D

3D Riegl laser with a camera

- Measures range (350 m) and bearing (horizontally 360 deg and vertically 80 deg) to objects in 3D

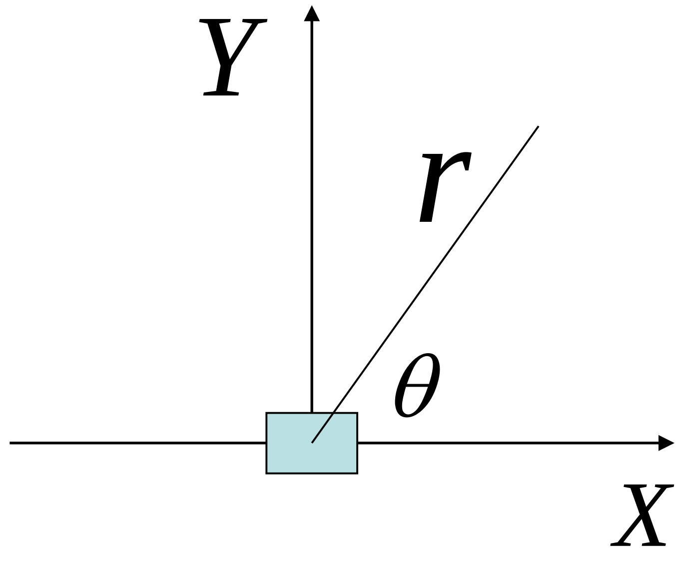


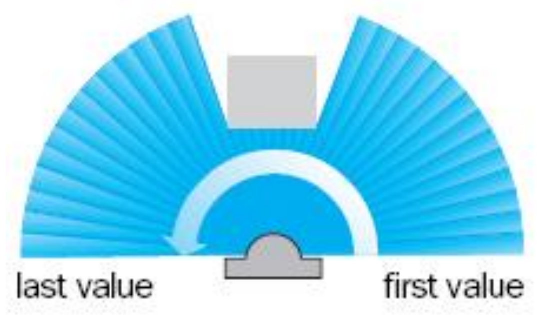
2D Laser sensor model

- 2D laser sensor provides range and bearing to an object
  - Accurate range
  - Accurate bearing

$$x = r\cos\theta$$

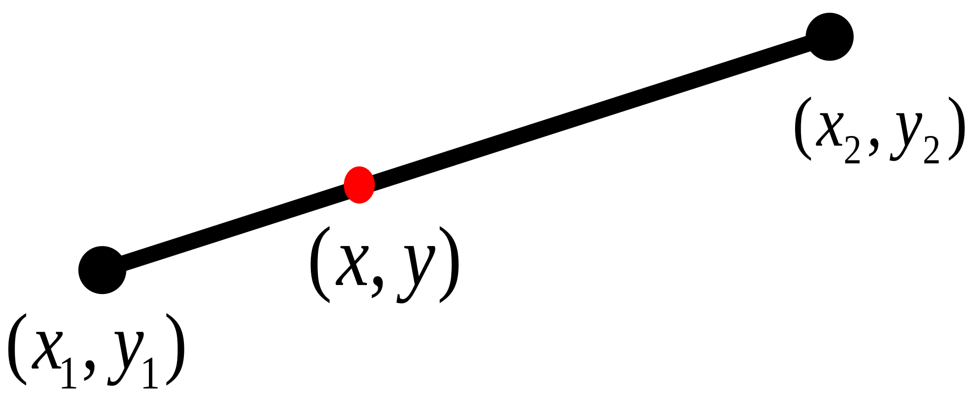
$$y = r\sin\theta$$





Line extraction

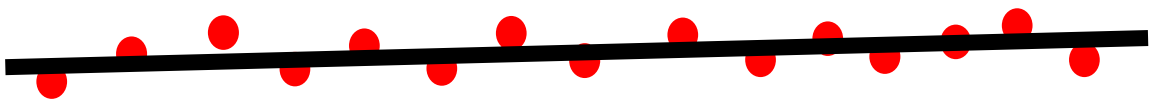
- Equation of a line



$$\frac{y - y_1}{x - x_1} = \frac{y_2 - y_1}{x_2 - x_1}$$

$$y = mx + c$$

- Least squares solution



  - Line equation

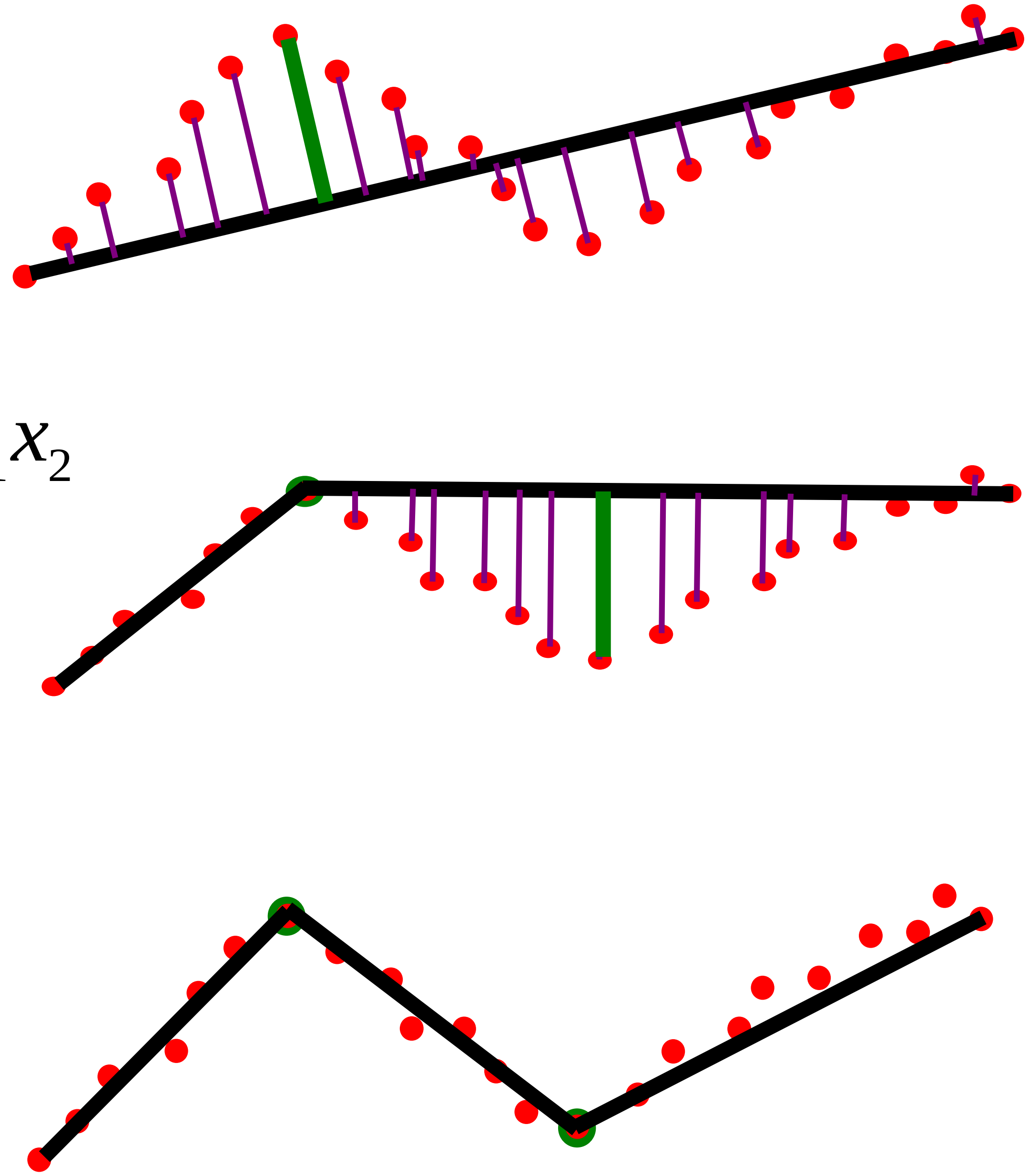
$$y - mx - c = 0$$

  - Error fit

$$\sum_i (y_i - mx_i - c)^2$$

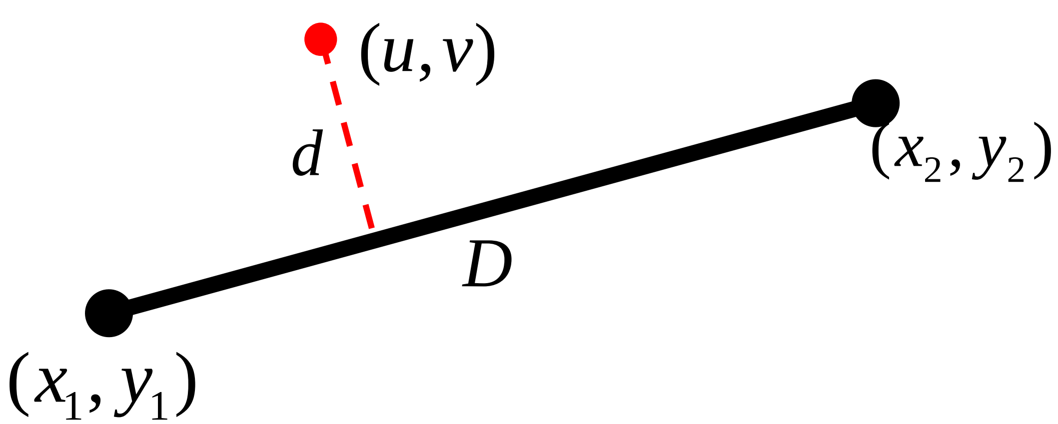
Line splitting

- Perpendicular distance to a line



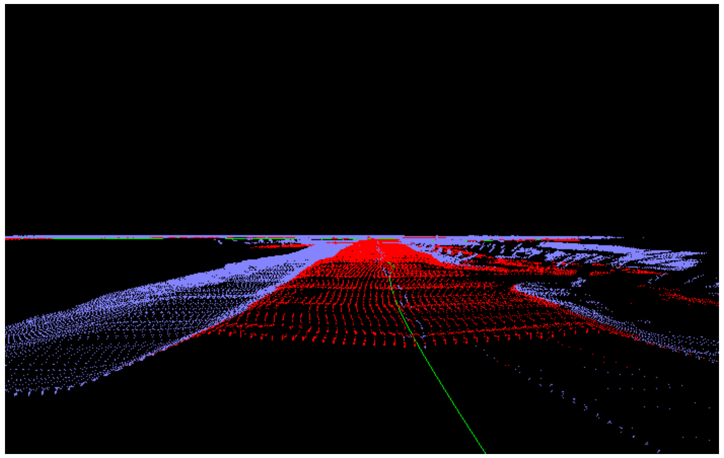
$$r = u(y_1 - y_2) + v(x_2 - x_1) + y_2 x_1 - y_1 x_2$$

$$d = \frac{r}{D}$$



Applications

- –Mapping
- –Area monitoring
- –Surveying
- –Localization
- –Dynamic Object tracking



https://www.youtube.com/watch?v=nXlqv_k4P8Q