Autonomous Systems
Sensors summary

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Artificial Intelligence &
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Autonomous Systems Sensors

- Autonomous Systems sensors allow for mapping, localization in the 3D space, and perception of surrounding obstacles.

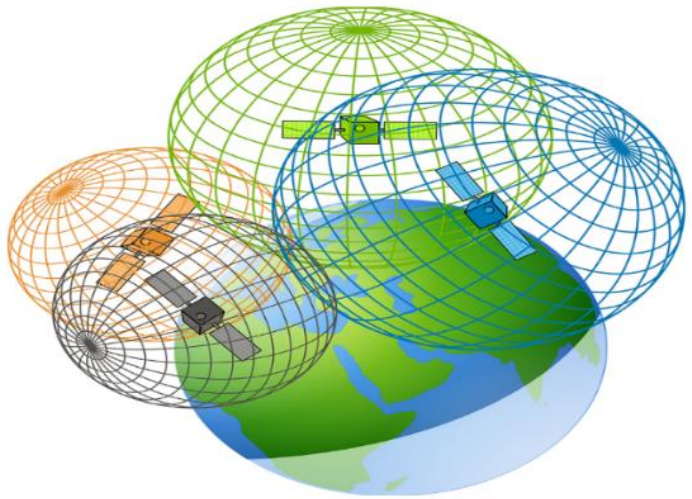
- This lecture describes the most commonly used sensors, their working principles and their common applications.

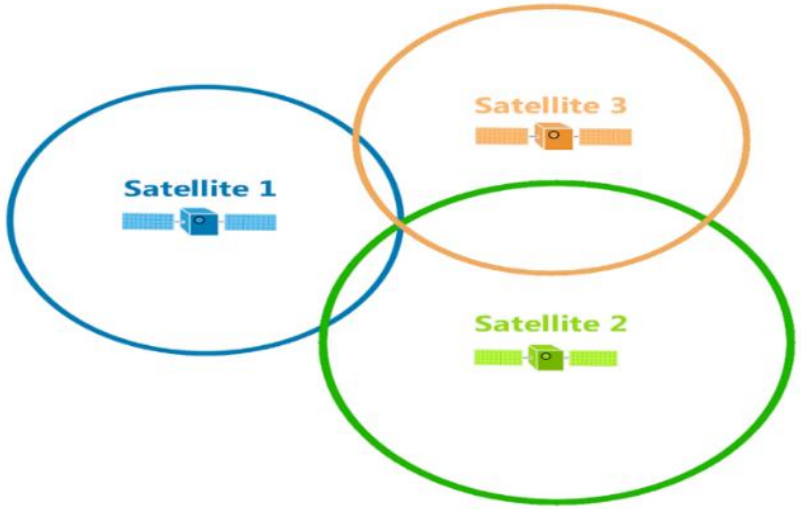
GPS

- The ***Global Positioning System*** (***GPS***) is a constellation of 27 Earth-orbiting satellites (24 in operation and three extras, in case one fails).
- GPS receivers receive position information from ***GPS satellites*** and then calculate the device geographical position (difference from Satellite position).
- ***GPS Coordinate system***:
  - ***Longitute*** varies from 0^0 (Greenwich) to 180^0 East and West.
  - ***Latitude*** varies from 0^0 (Equator) to 90^0 North or South.
  - ***Elevation*** (from a reference ellipsoid that maps sea level).

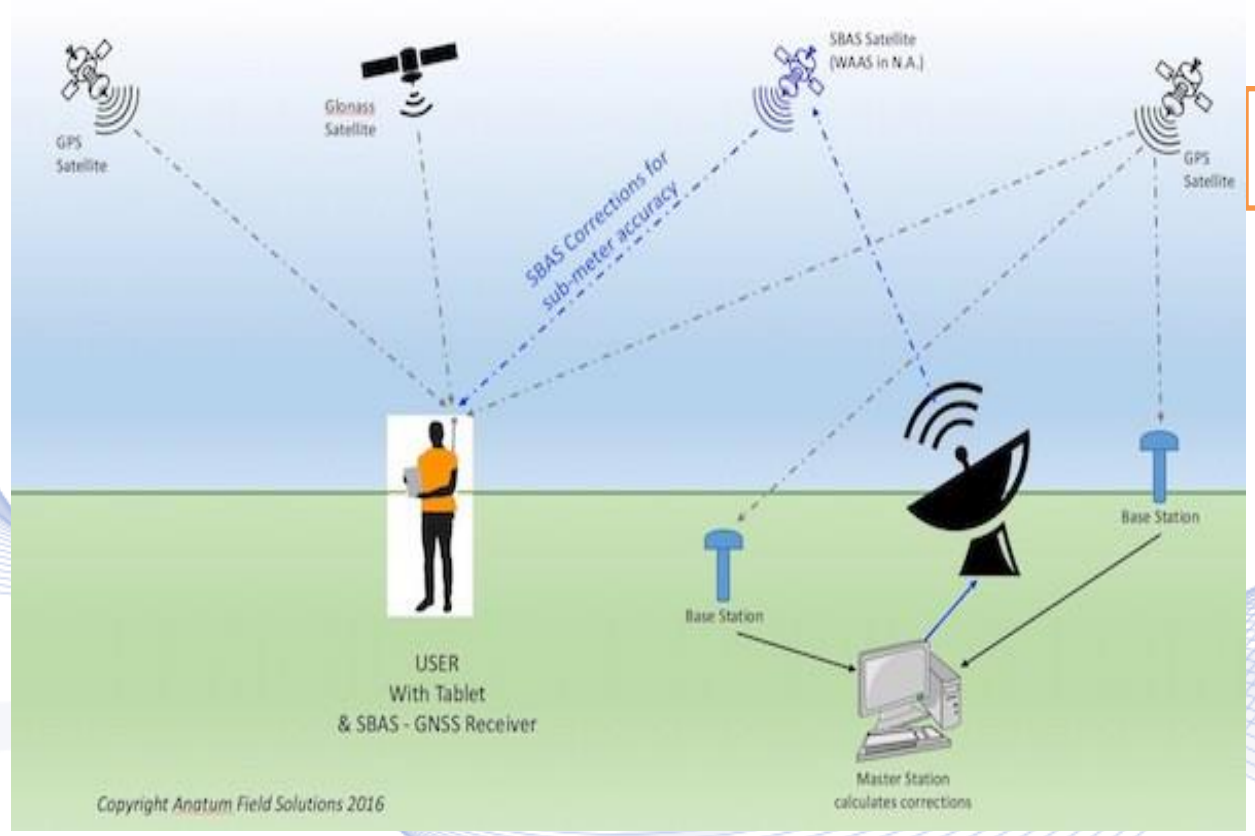
GPS

- ***Trilateration*** is a simple method for finding the position (Latitude, Longitude, Elevation) of GPS receiver.
- 4 GPS satellites must be received for localizing a GPS receiver.





RTK GPS

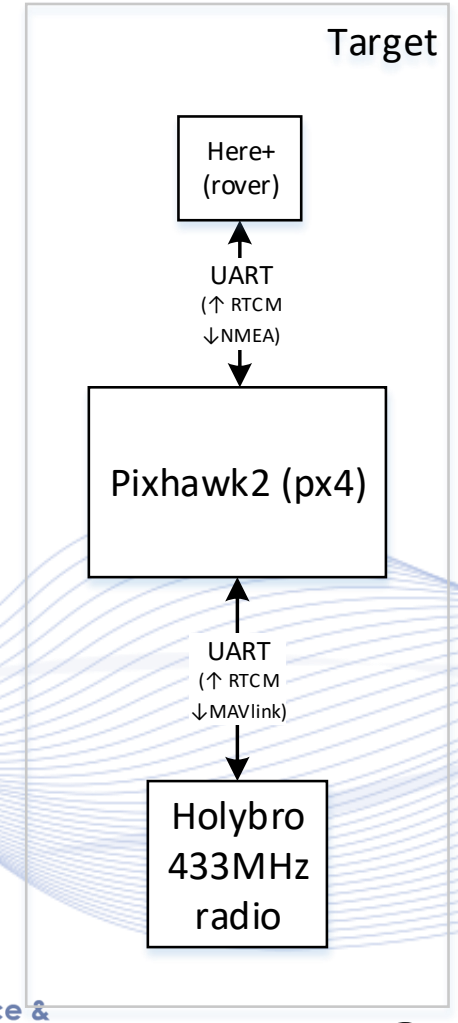


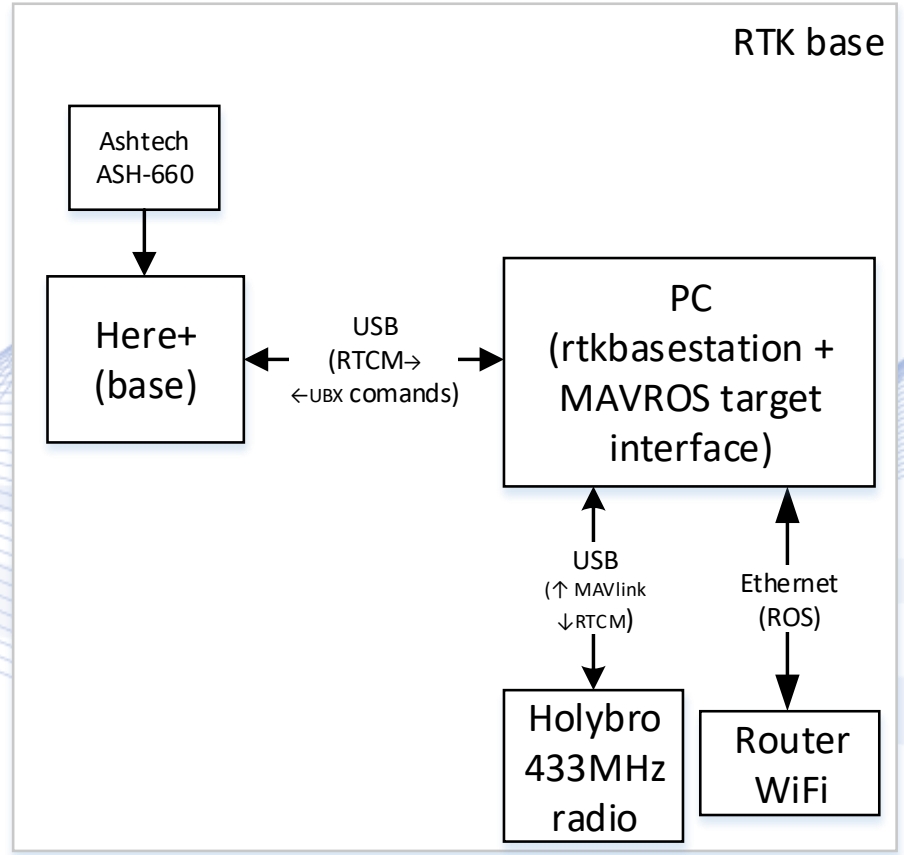
Base Station

Rover

RTK-GPS receiver.

RTK GPS





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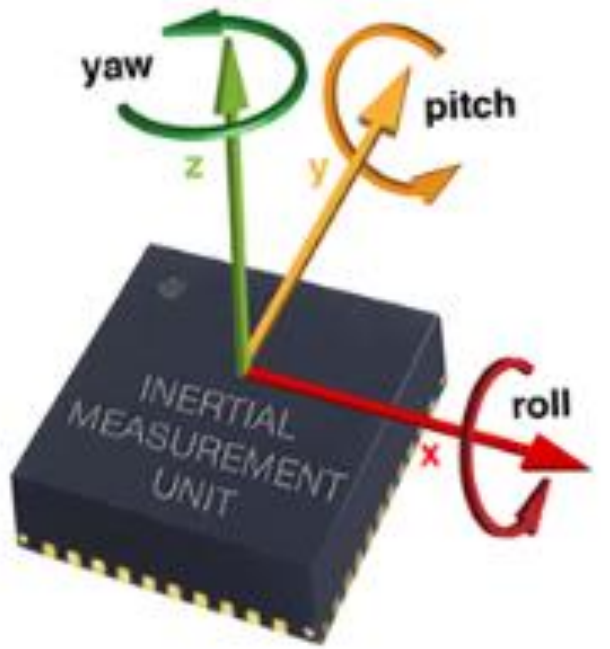
On-target RTK-GPS receiver.

IMU

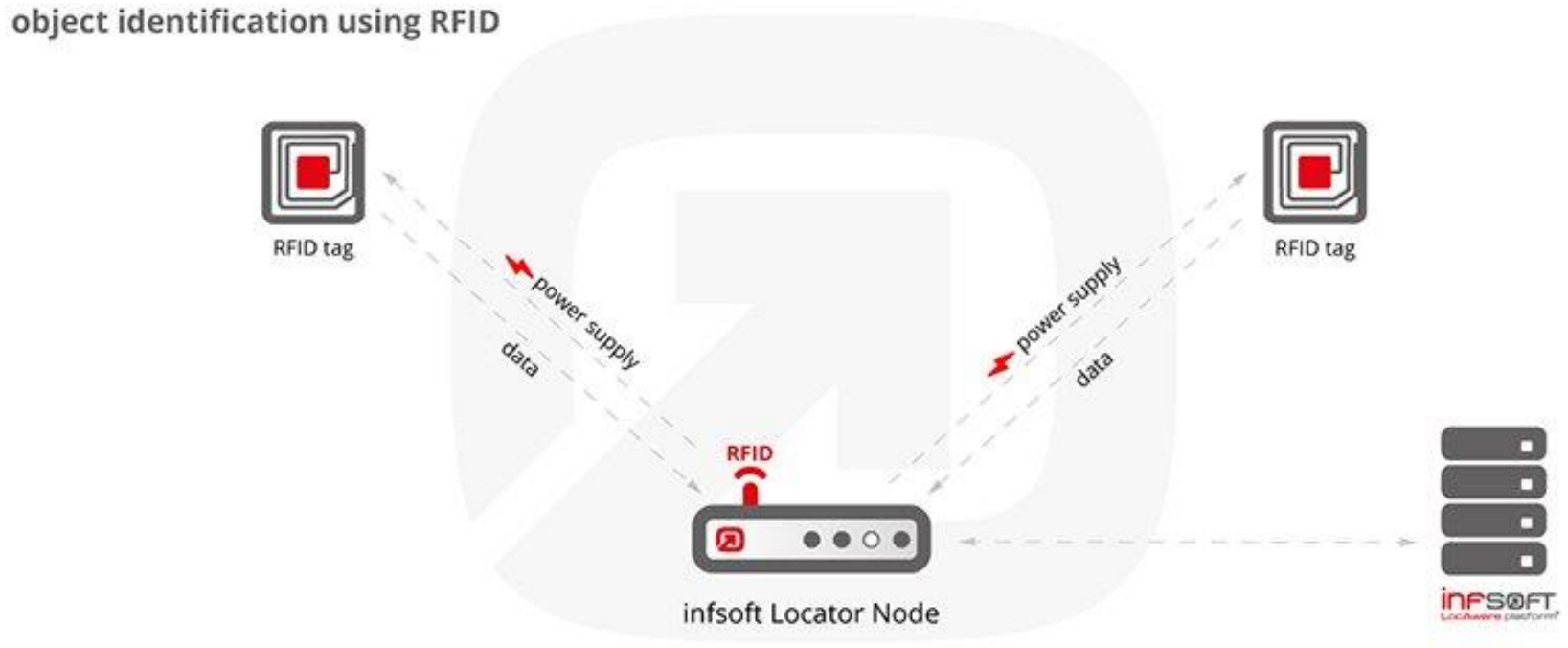
Inertial Measurement Unit (***IMU***):

- It measures and reports a body's specific force, angular motion rate and, sometimes, the magnetic field surrounding the body.



- It uses a combination of accelerometers, gyroscopes and, sometimes, also magnetometers.

RFID Sensors



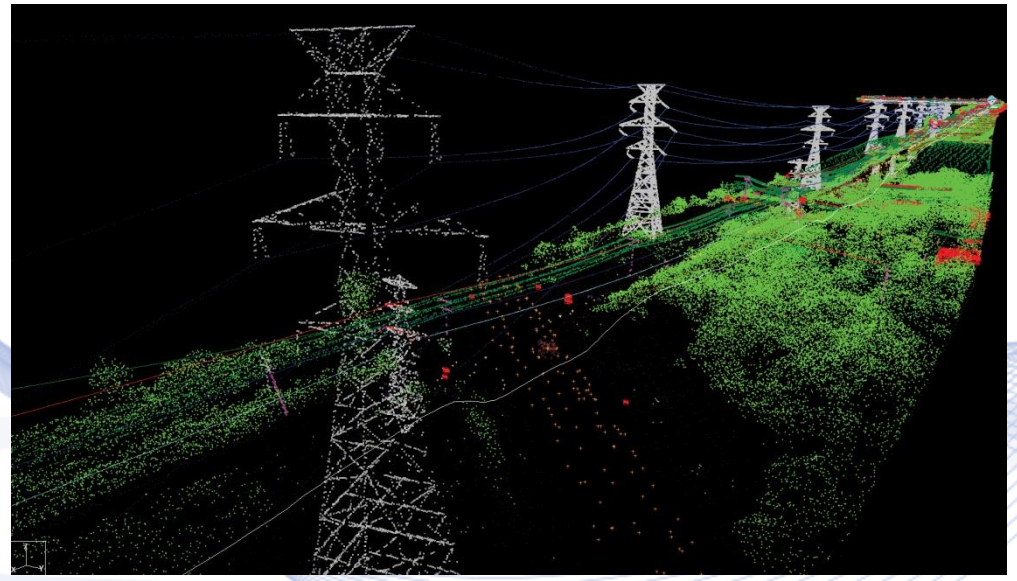
Radio-Frequency Identification (RFID) [INFS].

Other localisation sensors

- ***Wi-Fi***, ***Bluetooth beacons*** employ a ***Received Signal Strength Indicator*** (***RSSI***).
  - Wi-Fi localization accuracy: $5 - 15\ m$.
  - Bluetooth: up to $1m$.
- ***Ultra-wideband localization*** measures Time Of Flight:
  - short-range radio technology, that employs transit time methodology (Time of Flight, ToF). Exact localization requires 3 receivers (trilateration). Each tracked object is equipped with a battery powered tag. Accuracy $10 - 30\ cm$.

Mapping and localization sensors

LIDAR sensors



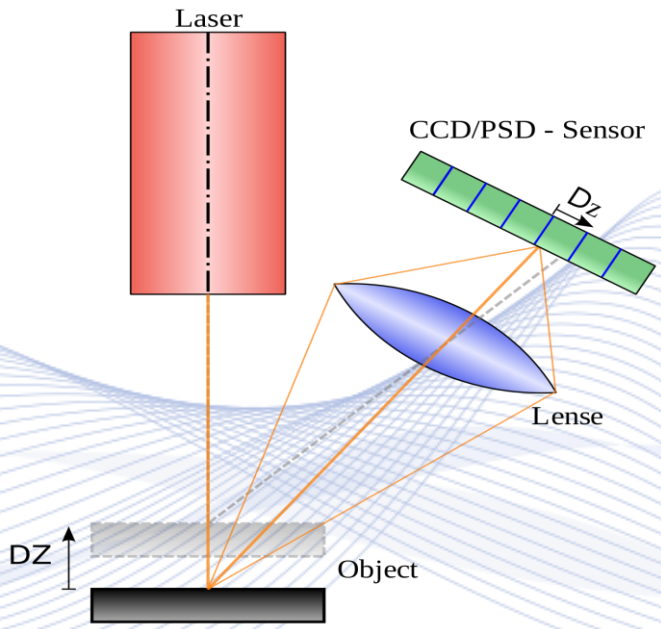
http://eijournal.com/print/articles/understanding-the-benefits-of-lidar-data?doing_wp_cron=1517767340.6914100646972656250000

Monocular or stereo

https://www.youtube.com/watch?v=8LWZSGNjuF0

Laser scanning

A ***3D laser scanner*** uses a technique that employs reflected laser pulses to create accurate digital models of existing objects.



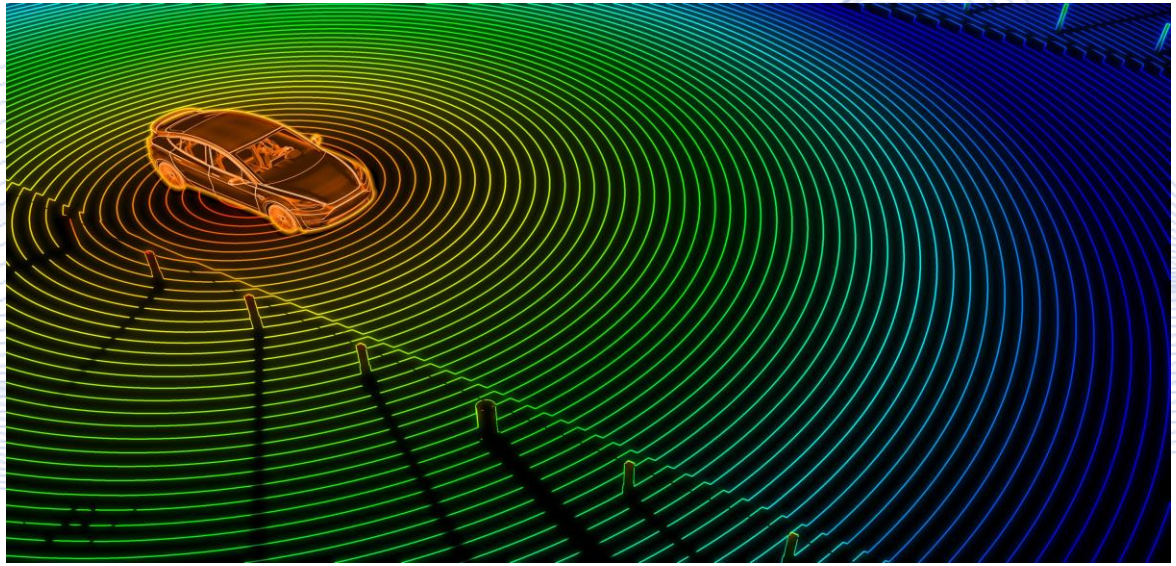
Laser scanning.

Lidars

- Lidars are active sensors.
- Lidar illuminates a target with pulsed laser light and measures the source distance to the target, by analyzing the reflected pulses.
- It uses instant ***Time-of-Flight*** (***ToF***) measurement methods:
  - ***Frequency modulation continuous wave*** (***FMCW***) or
  - ***Amplitude modulation continuous wave*** (***AMCW***).

Lidars

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

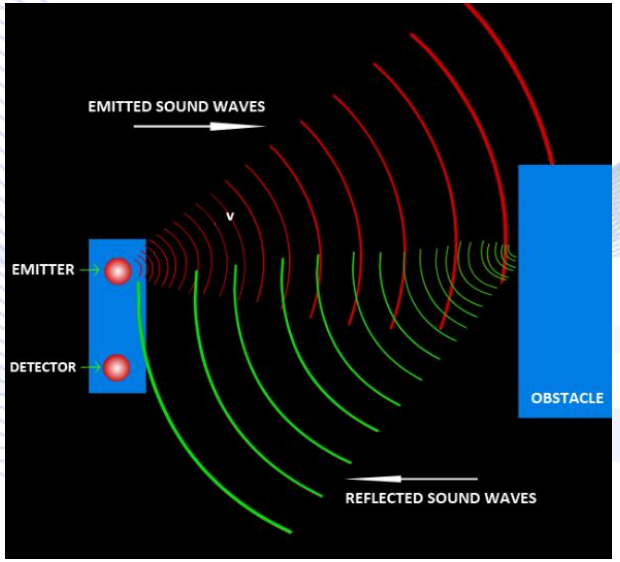


Laser altimeter

- It measures the altitude (height) above a fixed ground level.
- It emits laser pulses which travel to the ground surface, where they are reflected.
- Part of the reflected radiation returns to the laser altimeter, is detected, and stops a time counter started when the pulse was sent out.
- The distance is then easily calculated by taking the speed of light into consideration.

Ultrasonic sensor

- Ultrasonic sensor measures the distance of a target object by emitting ultrasonic waves.
- An ultrasonic sensor has two components:
  1. Transmitter
  2. Receiver.



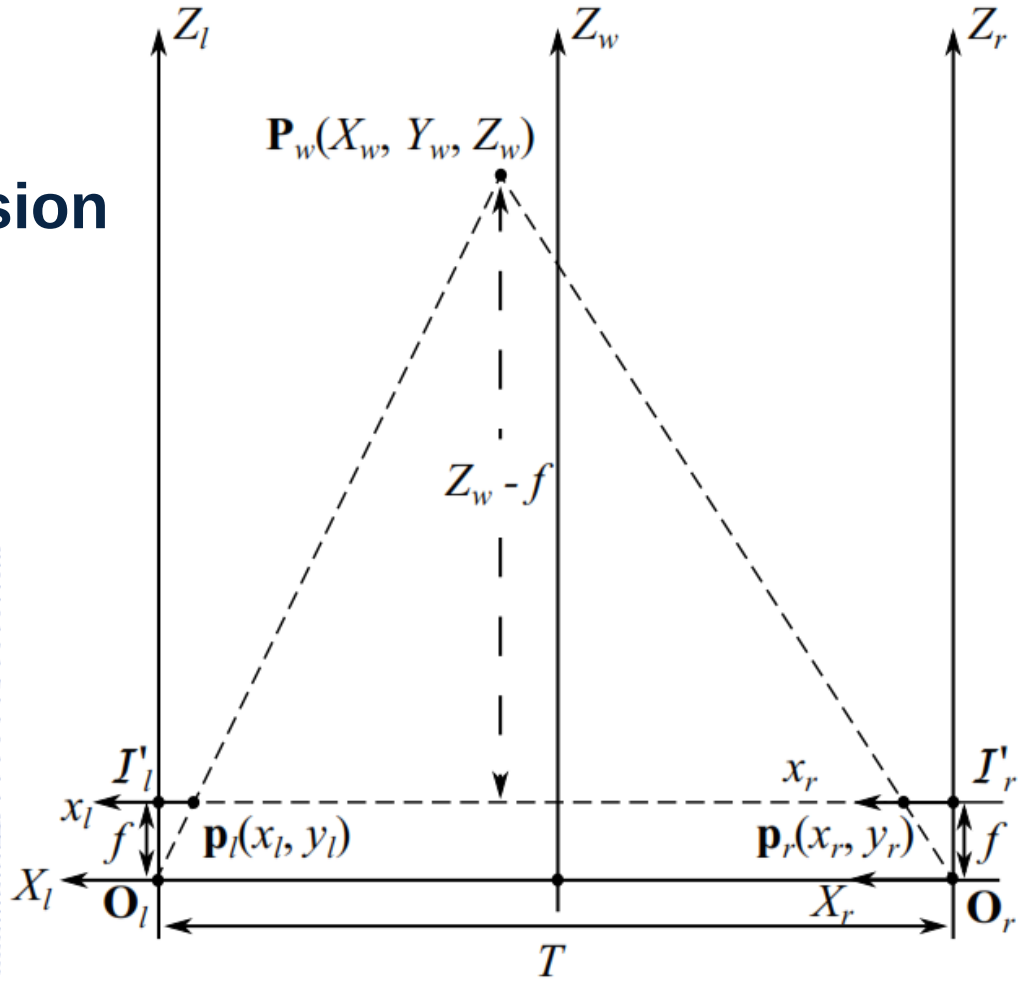
Monocular images

- A single monocular image does not convey depth information.
- But it can detect points at any range.

Basics of Stereopsis

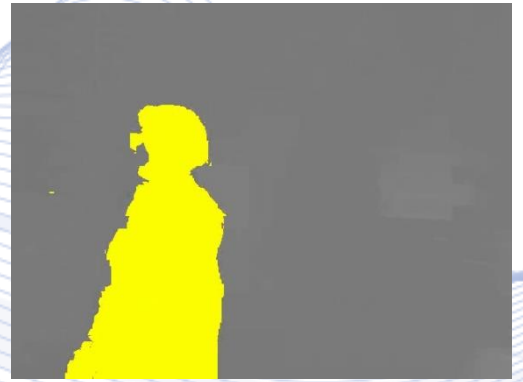
Parallel Stereo vision Geometry

T: baseline
f: focal length



Stereo imaging

- Two cameras in known locations.
- Calibrated cameras.
- Stereo images can create a disparity (depth) map.

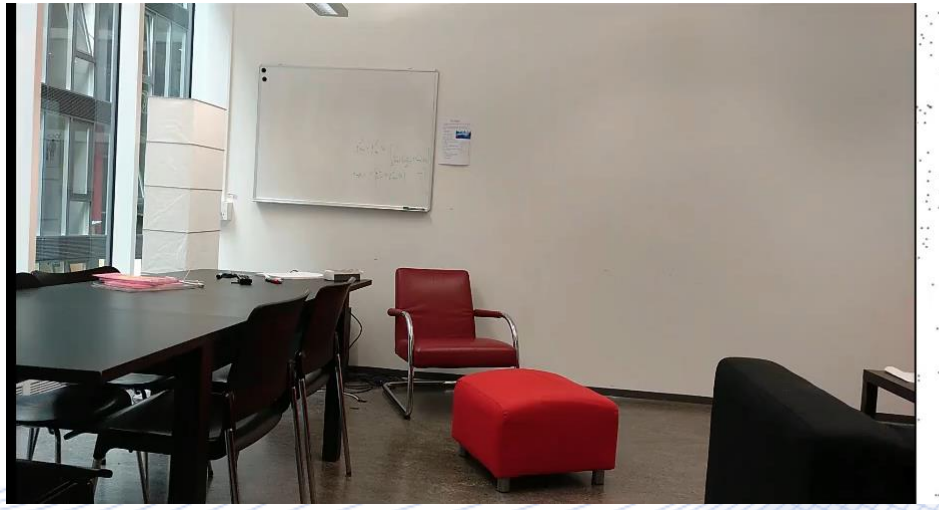


Event cameras

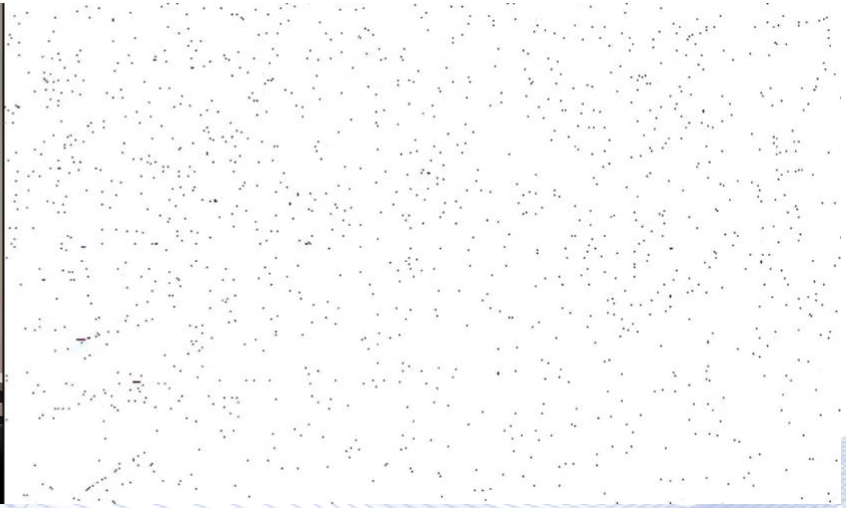
- Novel sensor that measures only ***scene motion***.
- Low-latency (~ 1 μs).
- No motion blur.
- High dynamic range (140 dB instead of 60 dB).
- Ultra-low power (1mW vs 1W).
- Traditional vision algorithms do not work!

Event cameras

Standard Camera



Event Camera (**ON**, **OFF** events)



Δt = 40 ms.

Proximity sensors

Proximity sensor types:

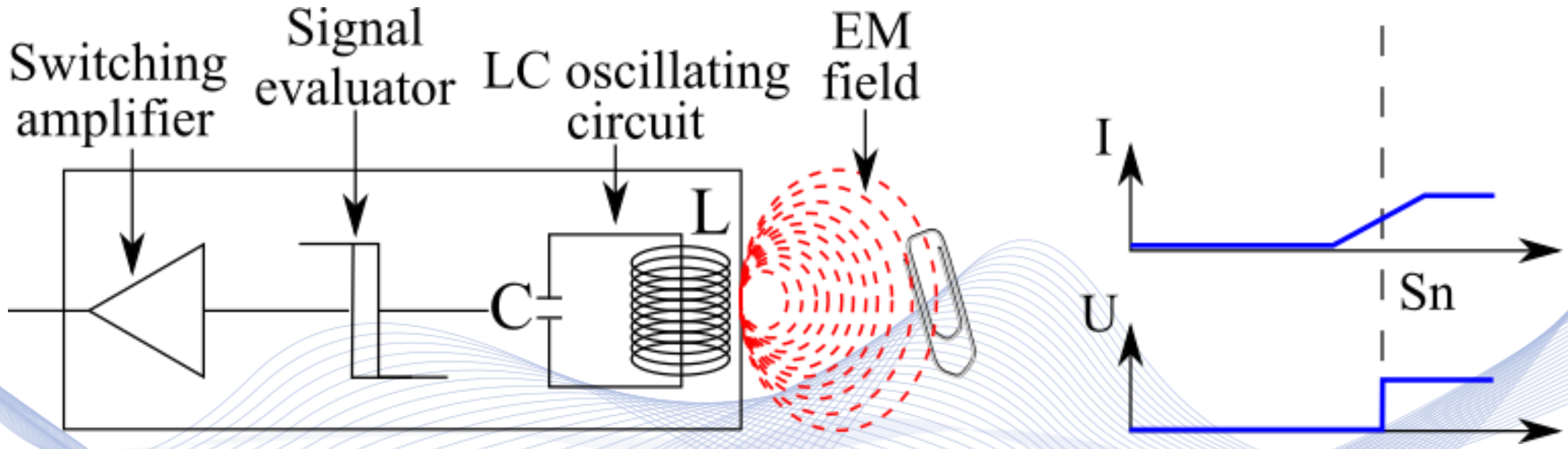
- Inductive Proximity Sensors
- Capacitive Proximity Sensors
- Ultrasonic Proximity Sensors
- IR Proximity Sensors
- Photoelectric Proximity Sensors(use high-end photoelectric technology)
- Magnetic Proximity Sensors(detect magnetic objects)

Inductive sensors

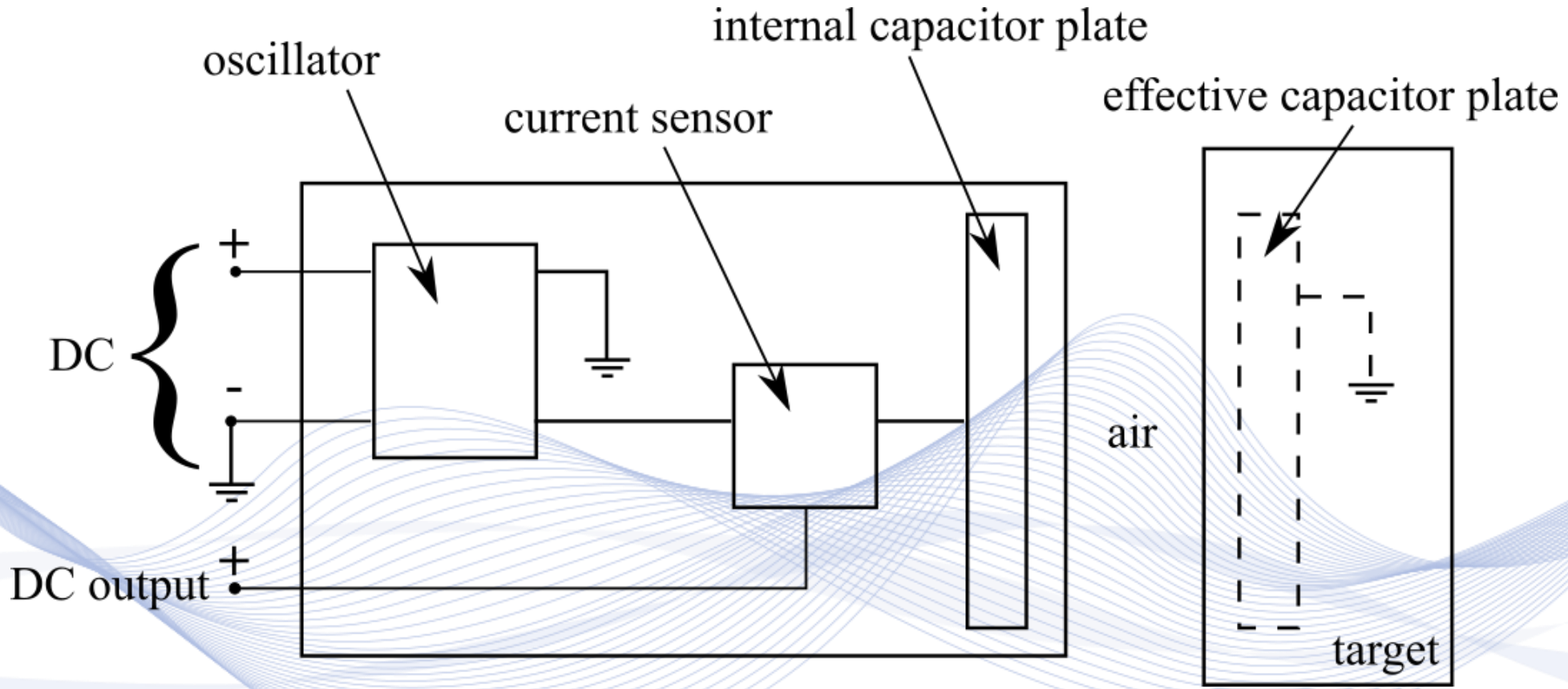
Inductive sensors detect the presence of metallic objects.

- It consists of:
  - A ***coil***;
  - ***High frequency oscillator***.
- The presence of a metal changes ***oscillation amplitude***.

Inductive sensors



Capacitive sensors - WP



Q & A

Thank you very much for your attention!

More material in
http://icarus.csd.auth.gr/cvml-web-lecture-series/

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