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# SENSORS USED IN AUTONOMOUS VEHICLES

There are broadly two categories of sensors used in autonomous vehicles:

- **Active sensors**: These send out energy in the form of a wave and look for objects based upon the information that comes back.

Examples: LiDAR, RADAR, Ultrasound

- **Passive sensors:**Passive sensor technologies gather target data through the detection of vibrations, light, radiation, heat or other phenomena occurring in the subject's environment.They do not include transmitters that send out signals.

Examples: Cameras

**1. LiDAR**

LiDAR works by emitting laser pulses that are reflected by an object and picked up again by a photodetector. LiDAR sensors emit up to one million laser pulses per second and summarize the results in a high-resolution 3D map of the environment. It's used in self-driving cars.

ADVANTAGES:

- LiDAR is highly reliable as it isn't dependent on environmental factors. Things like an overcast sky or pouring rain doesn't hinder the functioning of a LiDAR detector.
- Can give a 3D map of the surroundings
- High Resolution imaging
- Can work over long ranges

DISADVANTAGES:

- Expensive(as it is relatively new technology)
- Information is monochromatic, hence no color vision
- Isn't well established commercially

**2.RADAR**

RADAR works on a similar principle as LiDAR, it emits short pulses in the form of electromagnetic waves, and as soon as these pulses hit an object they bounce back and are collected by sensors. Information is received from the time interval between the emission of a pulse and the collection of the reflected pulse.

ADVANTAGES:

- RADAR technology is used in adaptive cruise control and collision avoidance.

- Independent of environmental factors
- Compact size
- Cost-effective
- Established technology, hence easy to implement
- Long ranged

DISADVANTAGES:

- Low resolution data, hence objects can only be detected but not classified
- No color vision

**3.ULTRASOUND**

Ultrasound works by emitting high frequency sounds. It is based on the time-of-flight principle. It works great in close ranges and is used in parking aids in cars.

ADVANTAGES:

- High accuracy in close range
- Independent of environmental factors
- Established technology
- Cost effective
- Compact size
- Reliable and robust

DISADVANTAGES:

- Does not work for long ranges
- No color vision
- Low resolution, hence cannot be used to identify objects

**4.CAMERA**

Cameras give color vision and are already an integral part of vehicles. They are used to make maneuvering and parking easier by giving the driver a field of view behind the car. Beyond visible light cameras, there are also infrared cameras, which offer superior performance in darkness and additional sensing capabilities.

ADVANTAGES:

- High resolution
- Color vision
- Established technology
- Long ranged sensing

- Cost effective

DISADVANTAGES:

- Depends on environmental factors, cameras may not be reliables in a snowstorm or an overcast sky
- Does not give 3D information directly

## SENSOR FUSION

Using LiDAR, cameras, RADAR, Ultrasound and even satellite sensors like GPS, in combination by playing into their strengths we can design a sensing system where individual parts assist each other and ensure topmost safety and efficiency in autonomous vehicles.
While ultrasound can be used in close range sensing, LiDAR can be used in long range, hence they balance each other's weaknesses and play into their strengths.