SWAYAM NPTEL COURSE ON

MINE AUTOMATION AND DATA ANALYTICS

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Module 03:
Proximity Sensors

Lecture 08 A:
Proximity Sensors

CONCEPTS COVERED

- Introduction on proximity sensor
- Sensor Working Principle
- Applications
- Challenges
- Advantages
- Type of Sensors
- Proximity sensor comparison

Introduction

Proximity sensors are a type of electronic device used to detect the presence or absence of an object within a specified range without any physical contact.

Proximity sensors are an essential component in various industrial, automotive, and consumer applications, providing a non-contact method for detecting the proximity, position, or movement of objects.

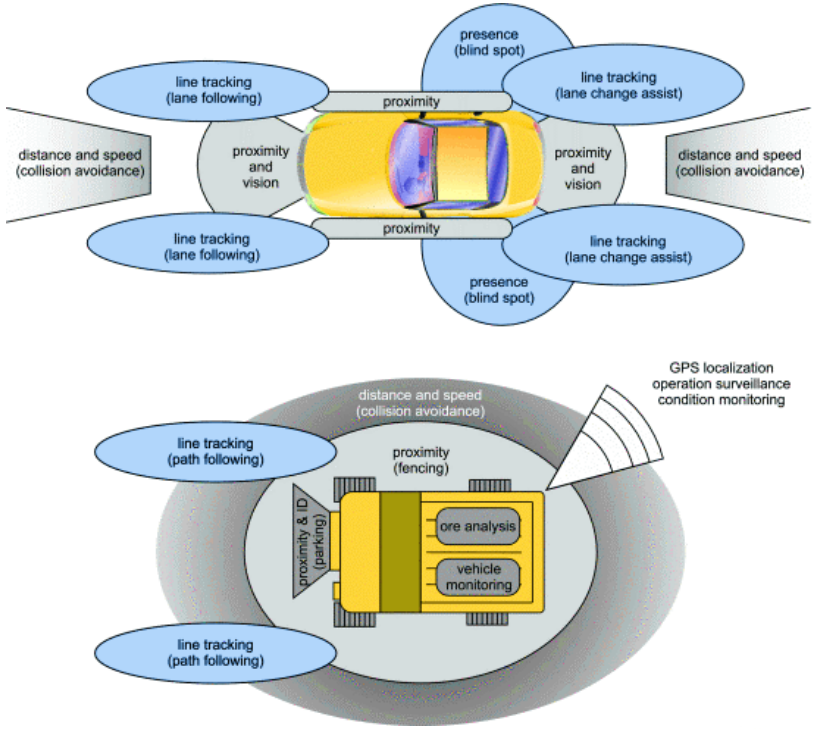


Figure 1. Schematic description of driving sensors used in passenger vehicles (top) and mining haul trucks (bottom).

Sensor Working Principle

Proximity sensors work on various principles, such as:

Ultrasonic sensor:

Ultrasonic sensors use high-frequency (30–500 kHz) sound waves and measure the time it takes for the sound waves to bounce back after hitting an object. They are versatile and can detect a wide range of materials.

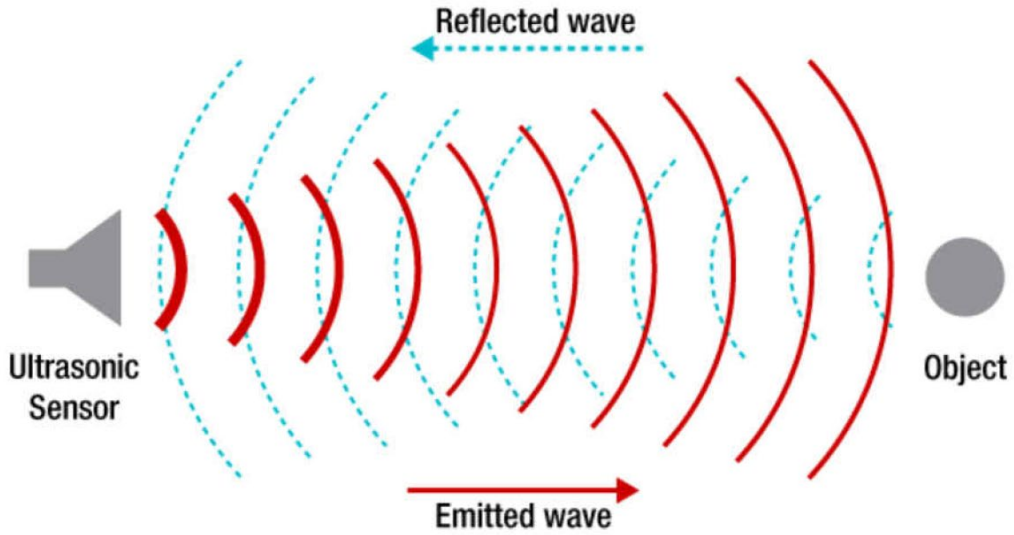


Figure 2. Ultrasonic Time-of-Flight Measurement

Infrared (IR) sensor:

IR sensors emit and receive infrared light to measure the distance of an object. IR sensors are commonly used in applications like object detection and object counting.

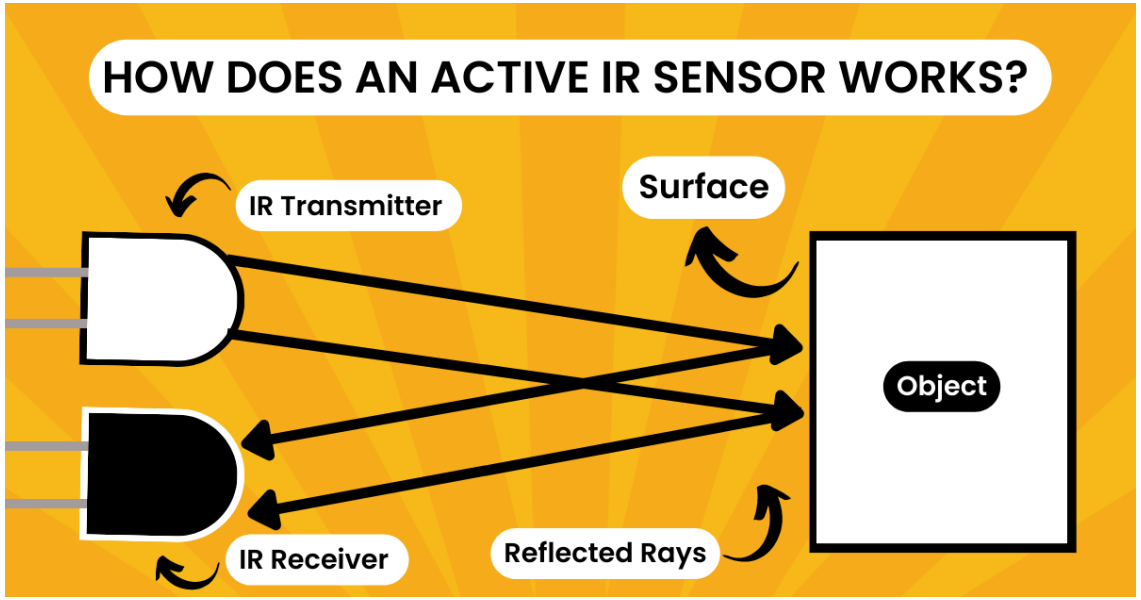


Figure 3. Active IR sensor working

Inductive sensor:

These sensors generate an electromagnetic field and detect changes in the field when a metallic object enters their detection range. They are commonly used for metal detection.

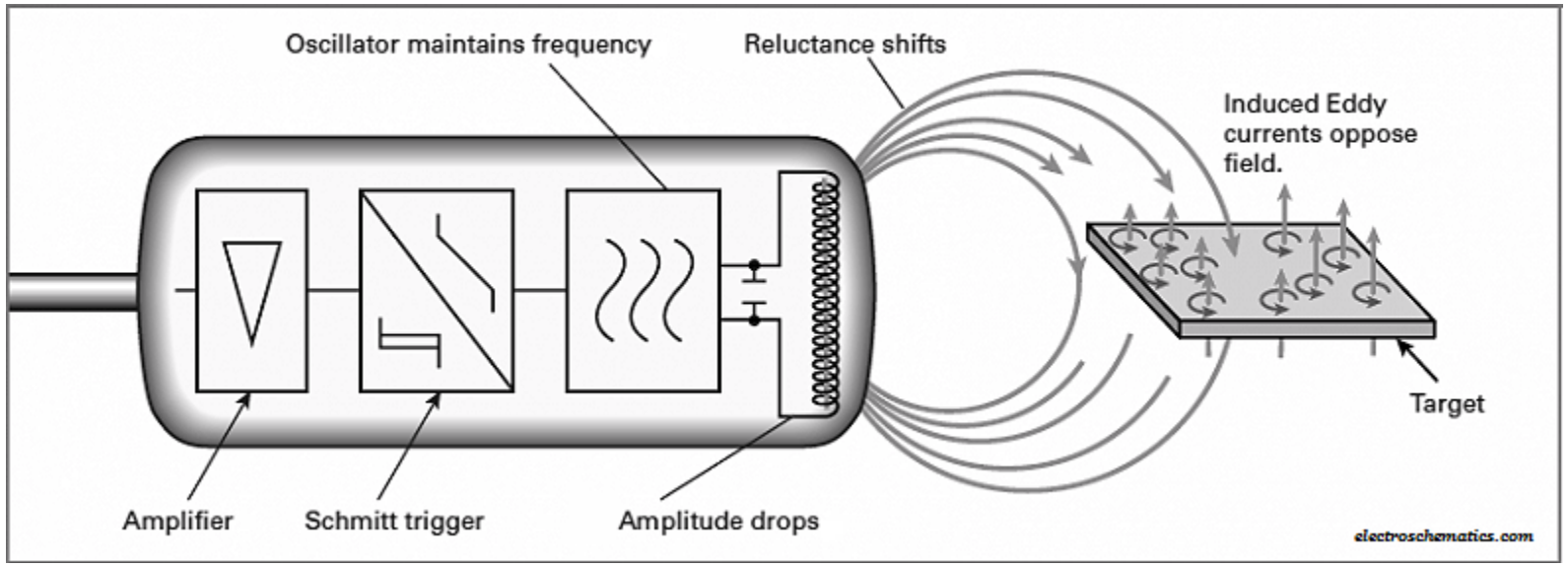


Figure 4. Inductive sensor working principle

Capacitive sensor:

Capacitive sensors detect changes in capacitance when an object enters their range. They are suitable for detecting both metal and non-metal objects.

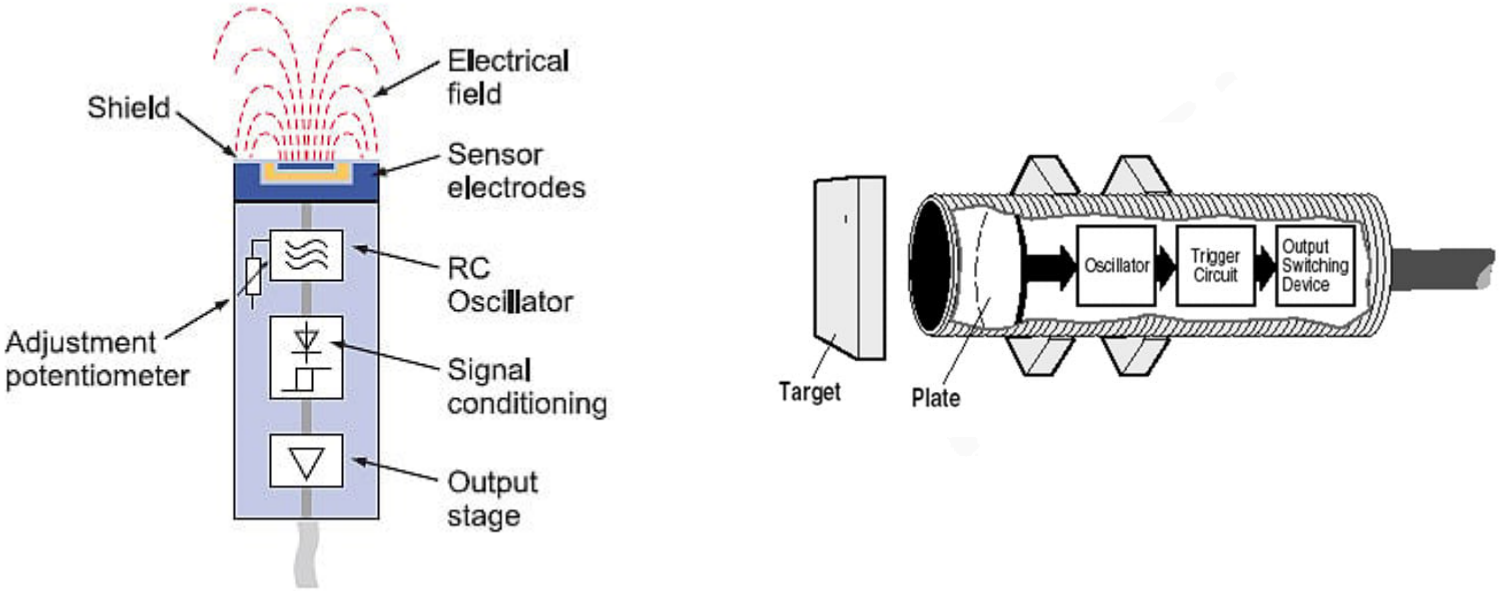


Figure 5. Working Principle of Capacitive Proximity Sensor

Applications

Proximity sensors have a wide range of applications, including:

Object Detection:

They can be used to detect the presence of objects on an assembly line, in elevators, or in automated machinery.

Obstacle Avoidance:

Proximity sensors are crucial for obstacle detection in autonomous vehicles and robots.

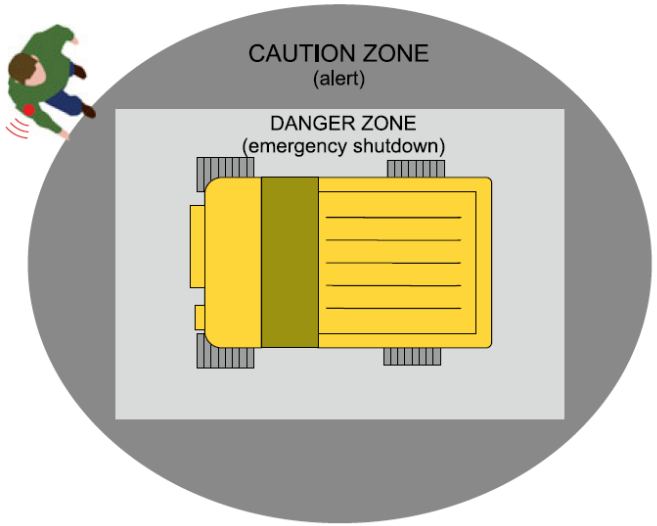


Figure 6. Description of fencing hazardous areas by proximity sensing.

Gesture Recognition:

Proximity sensors are utilized in consumer electronics for gesture-based control, such as in smartphones and gaming consoles.

Position Sensing:

They are employed in applications like level sensing in tanks and proximity-based switches in keyboards.

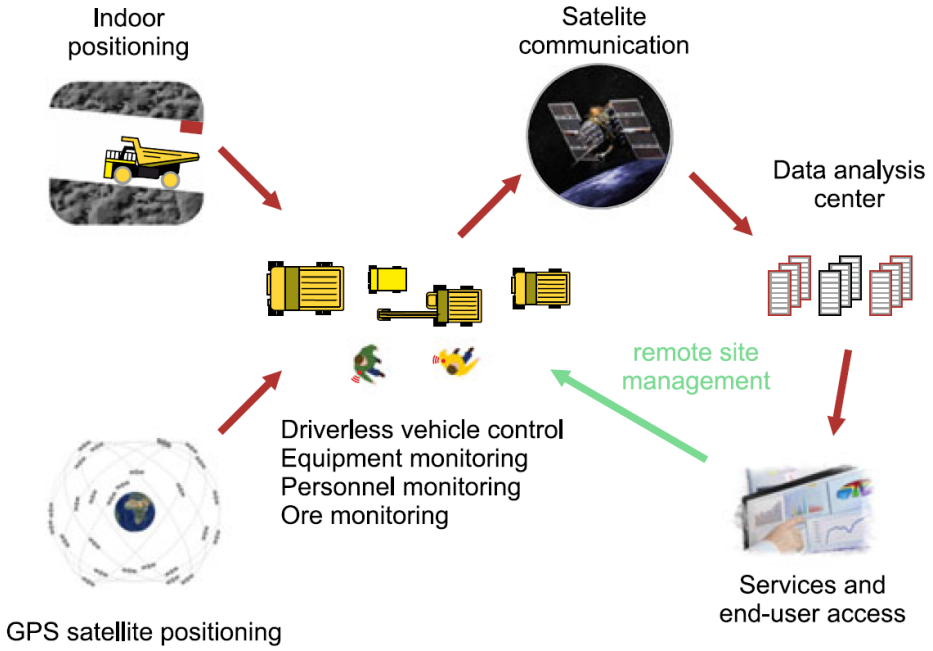


Figure 7. Data flow of positioning and monitoring in mining sites.

Advantages

Non-contact:

Proximity sensors do not physically touch the objects they detect, reducing wear and tear.

Speed and Accuracy:

They can provide fast and precise detection in various conditions.

Reliability:

These sensors are known for their long lifespan and minimal maintenance requirements.

Challenges

Limited Range:

The detection range of proximity sensors is typically limited, and it can vary based on the sensor type and technology used.

Material Sensitivity:

Some sensors may be affected by the material and surface properties of the objects they detect.

Environment Sensitivity:

Sensors may be affected due to humidity, presence of dust particles and temperature in the surrounding area.

Type of Sensors

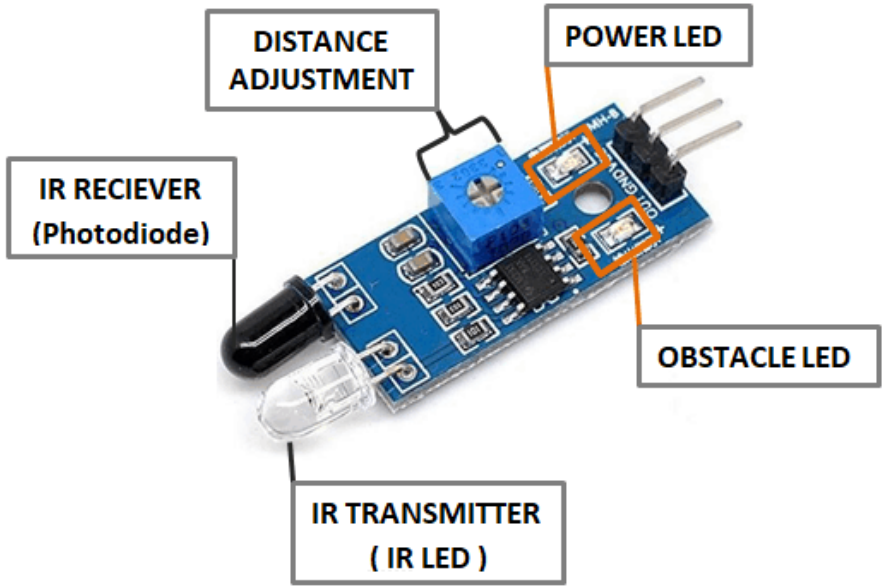
Various types of sensors used in Mining machinery, including:

- **Infrared (IR) Sensors (300 GHz to 400 THz)**
- **Ultrasonic Sensors (30–500 kHz)**
- **Lidar Sensors (Scanning LiDAR typically spin and measure distance in an angular range up to 360° circle based on spinning frequency between 1Hz and 100Hz)**
- **Cameras**
- **Wheel Encoders**
- **Gyroscopes**
- **Accelerometer**
- **Touch Sensors**

Types of sensors

Infrared (IR) Sensors

IR sensors applications in obstacle detection and avoidance.

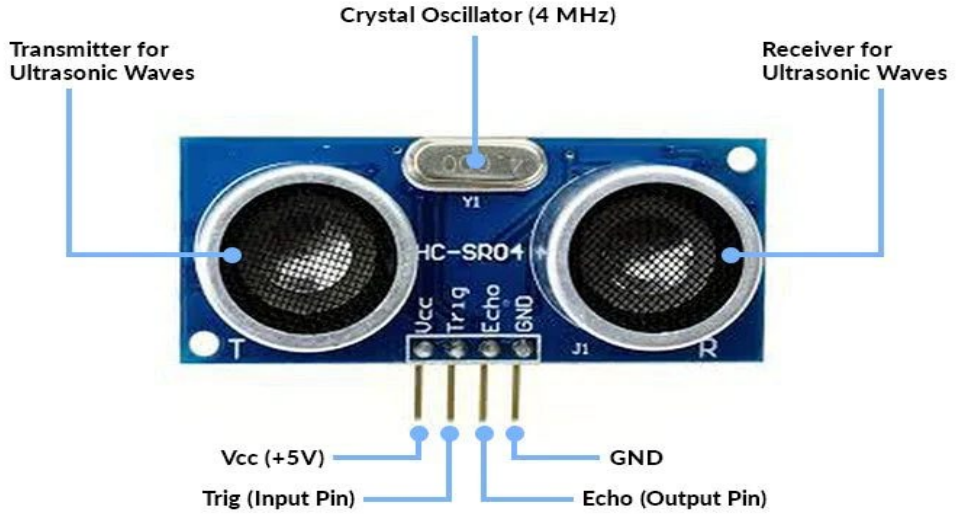


Main Chip	LM393
Operating Voltage (VDC)	3.6 ~ 5
Average Current Consumption (mA)	0.06
Detection Angle	35 Â°
Distance Measuring Range (CM)	2 ~ 30
Dimensions (mm) LxWxH	48 x 14 x 8
Weight (gm)	5
Shipping Weight	0.01 kg
Shipping Dimensions	5 × 4 × 1 cm

Figure 8. Infrared based proximity sensor and Specification

Ultrasonic Sensors

Ultrasonic sensors use in distance measurement and object detection.



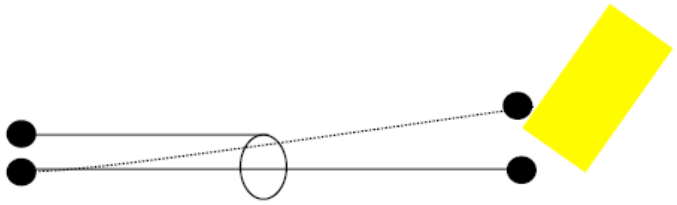
Specification
Supply voltage +5 V;
Consumption in silent mode 2mA;
Consumption at working of 15 mA;
Measurement range – 2 to 400 cm;
Effective measuring angle 15 Degree;
The dimensions are 45×20×15 mm.

Figure 9. Ultrasonic based proximity sensor and specification

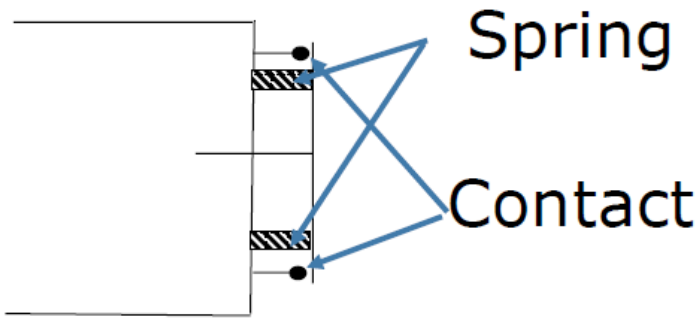
Example:

Tactile Sensors

Measure contact with objects



Touch sensor



Bumper sensor

Example:

Time of Flight Sensors

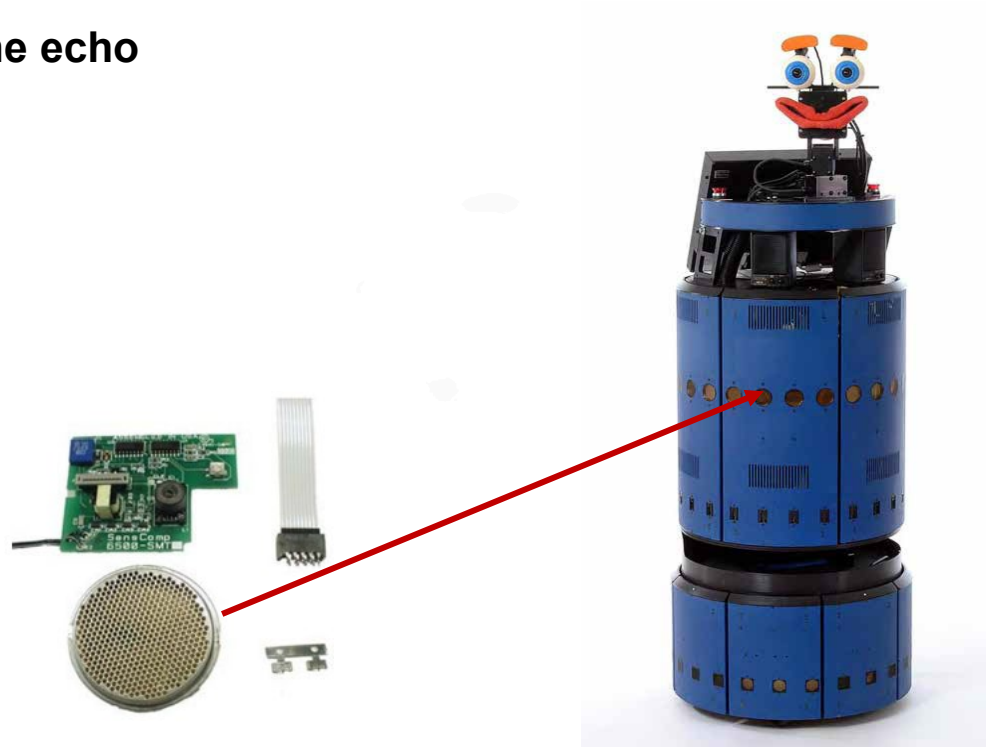
$$d = v \times t/2$$

Where
d: Distance
v: speed of the signal
t: time elapsed between broadcast of signal and reception of the echo

Example:

Polaroid ultrasonic sensor used for obstacle avoidance

- Emit an ultrasonic signal
- This sonar operates at its resonance frequency of 50 kHz.
- Wait until they receive the echo
- Time of flight sensor



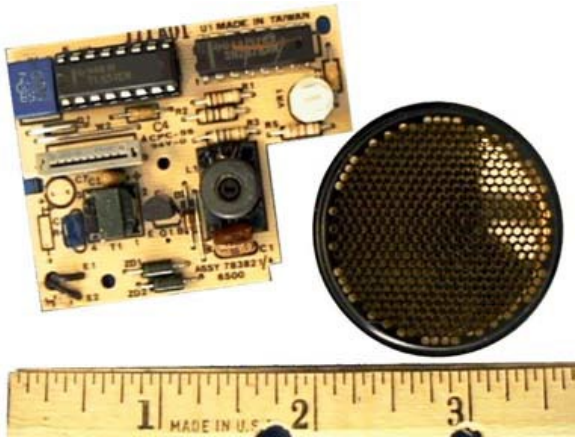
Polaroyd 6500

Example:

The Polaroid 6500 Series (see Figure 10), which is commonly used on mobile robots for obstacle avoidance.

This sonar operates at its resonance frequency of 50 kHz.

The propagation pattern for the Polaroid 6500 sensor is shown in Figure 10.



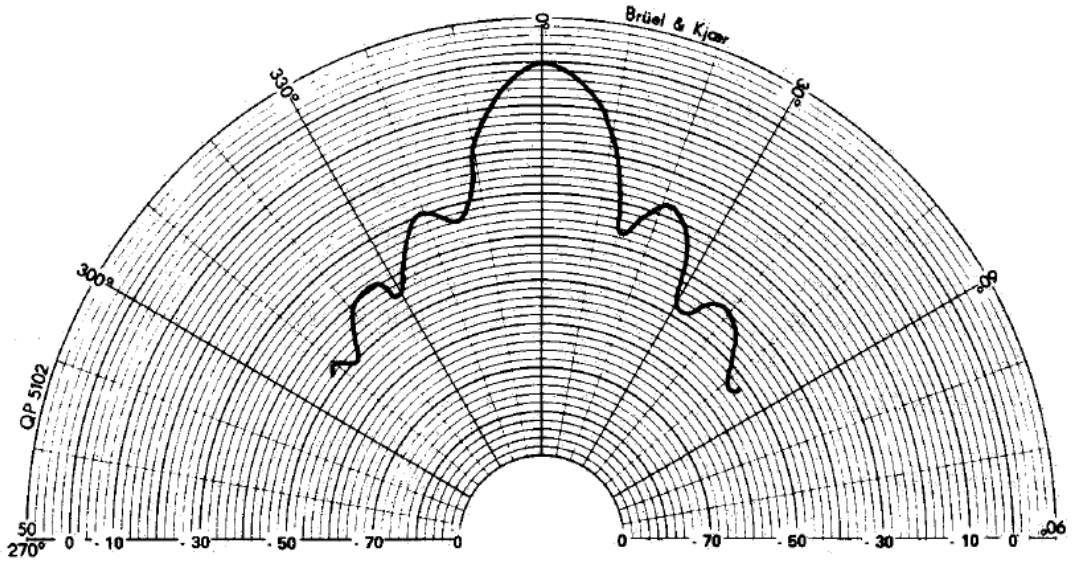
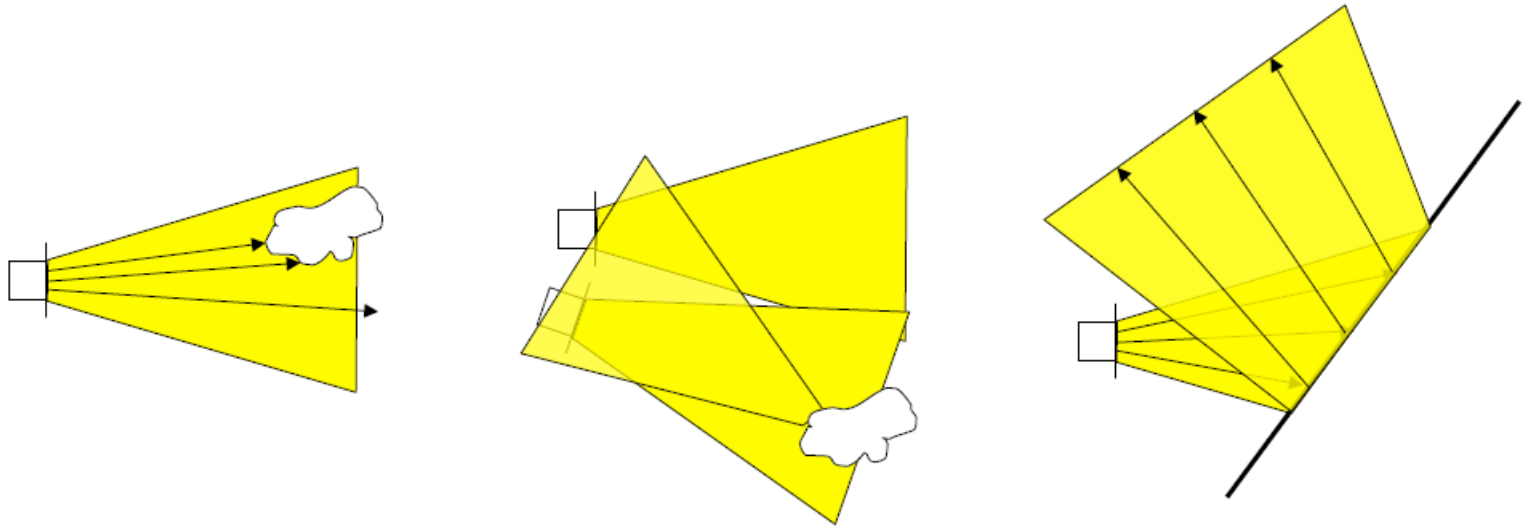


Figure 10. The Polaroid 6500 Series ultrasonic Sensor and Typical propagation pattern for the Polaroid 6500 Series ultrasonic sensor.

Example:

Sources of Error

- Opening angle
- Crosstalk
- Specular reflection



Lidar Sensors

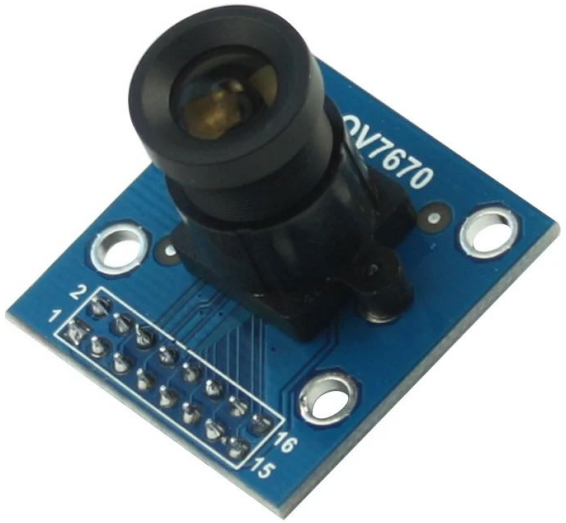
Highlight their role in creating detailed 2D or 3D maps of the environment.

Specification
Operating Range 0.3 - 12m;
Average Power Consumption 0.12W;
Resolution 1cm;
Operating Voltage 4.5 - 6V DC;
Acceptance Angle 2.3°;
Frequency Range 100Hz;
Wavelength 850nm;
Dimensions 3 x 2 x 1cm;
Weight 15gm;

Figure 11. Lidar based proximity sensor

Cameras

Mention applications like object recognition, navigation, and image processing.



Specifications (MODEL: OV7670 640X480 VGA CMOS CAMERA)
Pixel Coverage: 3.6um x 3.6um;
Duck Current: 12 mV/s at 6'C
Support VGA, CIF and from CIF to 40 x 30 format;
Vario Pixel method for sub-sampling; Auto Image Control: AEC, AGC, AWB, ABF, ABLC;
Image Quality Control: Color saturation, hue, gamma, sharpness, and anti-blooming;
ISP includes noise reduction and defect correction; Support image scaling; Lens shading correction;
Flicker 50/60Hz auto-detection;
Color saturation level auto adjust;
Edge enhancement level auto adjust;
High sensitivity for low light applications
Low voltage suitable for embedded applications
Standard sccb interface, compatible with i2c interface

Figure 12. OV7670 640×480 VGA CMOS Camera Image Sensor Module and specification

Wheel Encoders

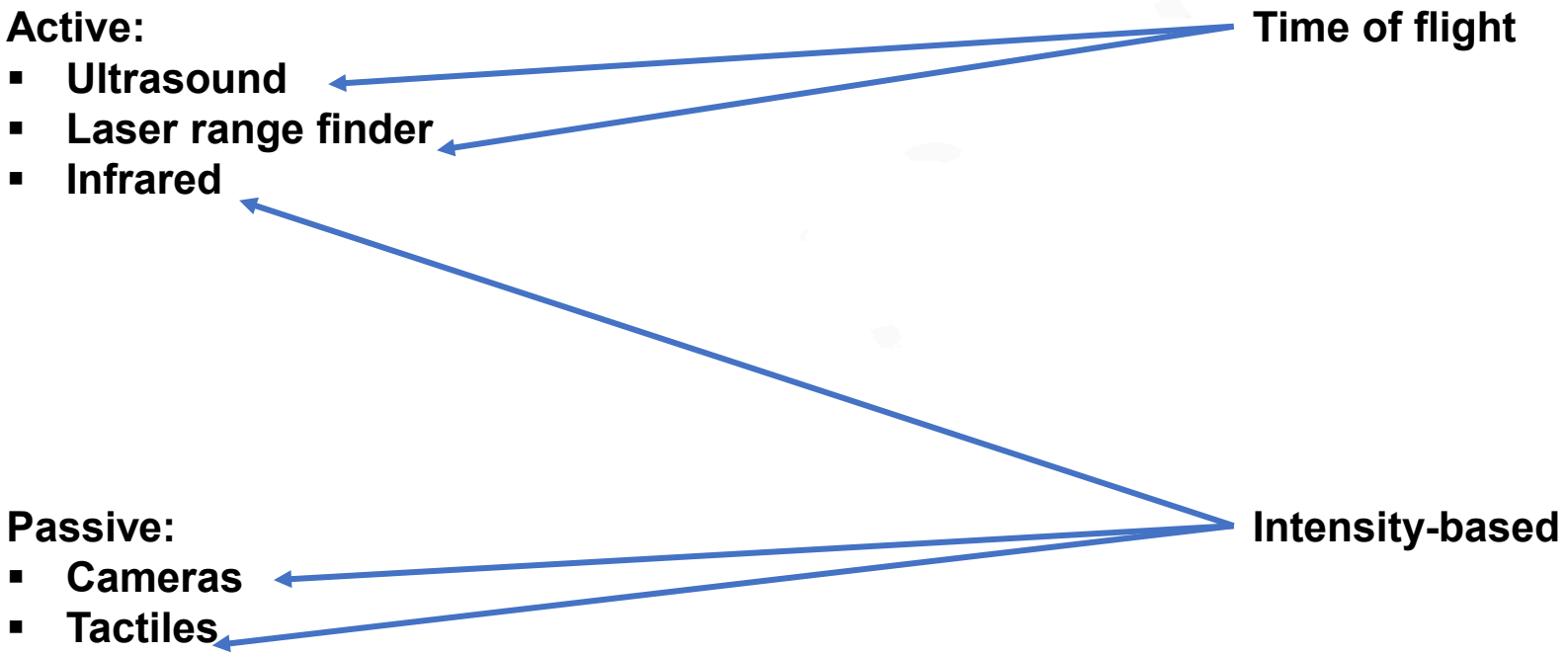
Their importance in odometry and tracking the robot's position.

Figure 13. Wheel based proximity sensor

Example:

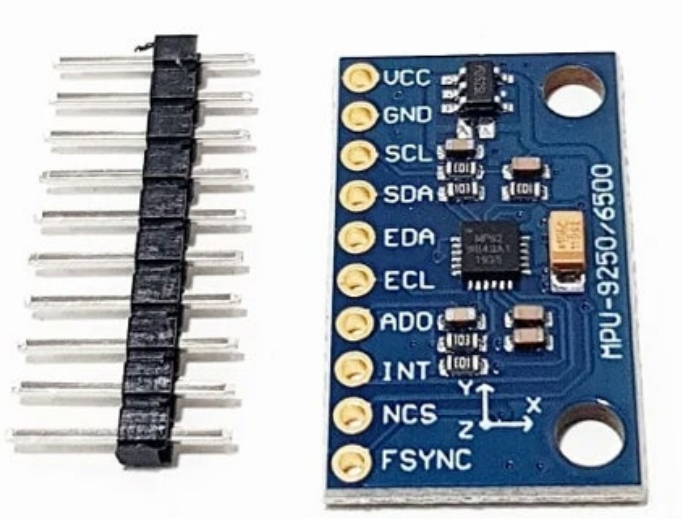
Sensors of Wheeled Robots

Perception of the environment



Gyroscope and Accelerometer

Analyze the movement of machine. They can be used in stabilizing and controlling the robot.



Power Supply	4.4 to 6.5 V or 3.3V (if you solder the jumper near the on-board voltage regulator)
Gyro range	± 250 500 1000 2000 ° / s
Acceleration range	± 2 ± 4 ± 8 ± 16g
Degree of Freedom (DOF)	6
Interface	I2C
Shipping Weight	0.01 kg
Shipping Dimensions	4 × 2 × 1 cm

Figure 14. MPU6500 Gyroscope/Accelerometer/Digital Motion Processor (DMP) 6-axis Motion Sensor with I2C/SPI Interface and specification

Touch Sensor

It has applications such as detecting physical interactions, heavy machinery control (Rugged touch screen), telemetry system (machine health and performance), ergonomic workstation (comfortable machinery control), digital communication and collisions.

Operating Voltage (VDC)	2 ~ 5.5
Output high VOH	0.8VCC V
Output low VOL	0.3VCC V
Response time (touch mode)	60 mS
Response time (low power mode)	220 mS
Length (mm):	24
Width (mm)	24
Height (mm)	2
Weight (gm)	0.6
Shipping Weight	0.085 kg
Shipping Dimensions	3 × 3 × 1 cm

Figure 15. Digital Sensor TTP223B Module Capacitive Touch Switch and specification

Sensor Fusion

Combining data from multiple sensors can enhance a robot's perception.

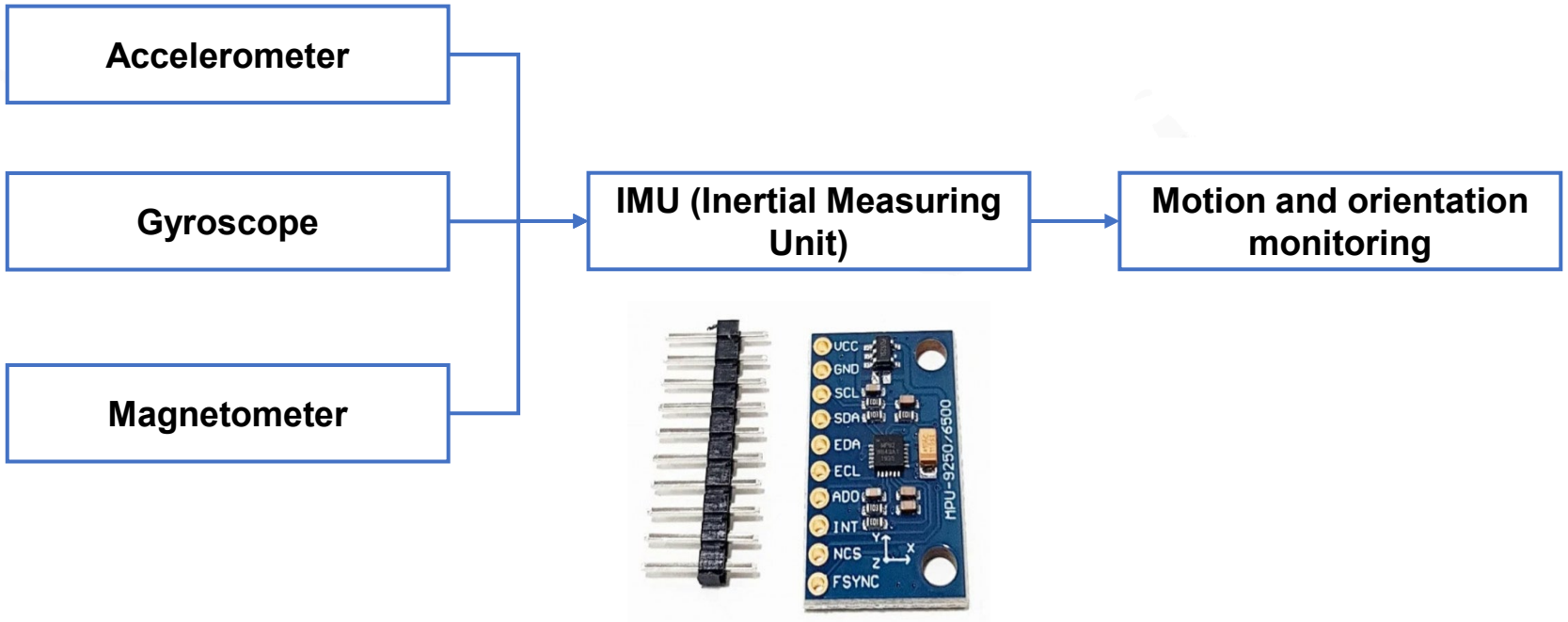


Figure 16. Fusion based sensor

Sensor Fusion application in Opencast mine

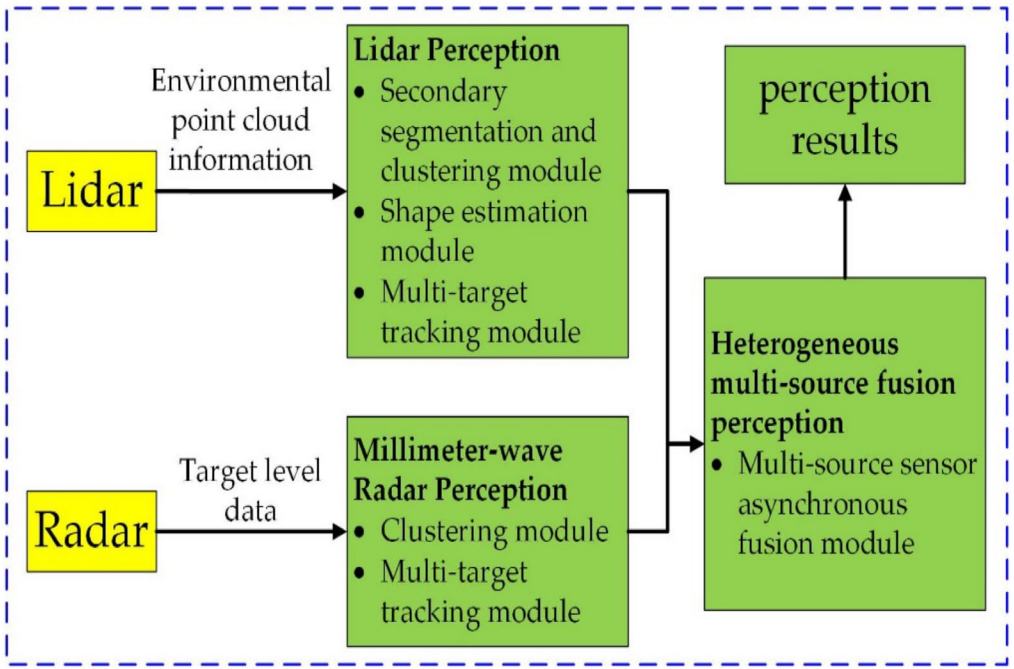
- There exist many difficulties in environmental perception in transportation at open-pit mines, such as unpaved roads, dusty environments, and high requirements for the detection and tracking stability of small irregular obstacles.

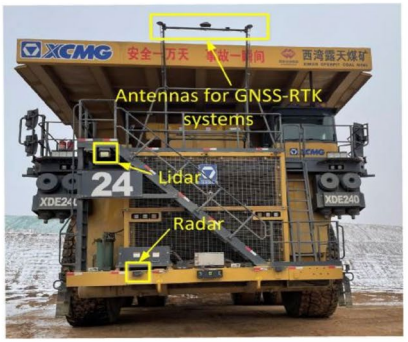
- In order to solve the above problems, a new multi-target detection and tracking method is proposed based on the fusion of sensors (Lidar and millimeter-wave radar).

- It advances a secondary segmentation algorithm suitable for open-pit mine production scenarios to improve the detection distance and accuracy of small irregular obstacles on unpaved roads.

- An adaptive heterogeneous multi-source fusion strategy of filtering dust, which can significantly improve the detection and tracking ability of the perception system for various targets in the dust environment by adaptively adjusting the confidence of the output target.

Sensor Fusion application in Opencast mine





(a) main sensors of a mining truck

(b) main road

(c) rough road

(d) dust scene

Figure 16. The framework of the multi-target detection and tracking method diagram (a) The photo of the mine truck with Lidar and millimeter-wave radar; (b) The main road littered with stones; (c) The rough road in the loading area; (d) The dust scene in the unloading area.

Proximity sensor comparison

Sensor Type	Operating Principle	Sensing Range	Output Type	Target Material	Power Supply	Application Example
Inductive	Eddy Currents	0.8mm - 80mm	NPN/PNP, Analog	Metal (usually ferrous)	10-30V DC	Metal detection, automation
Capacitive	Change in Capacity	1mm - 30mm	NPN/PNP, Analog	Non-metallic materials	10-30V DC	Liquid level sensing, touch
Ultrasonic	Sound Waves	2cm - 10m	Digital, Analog	Almost any material	5-24V DC	Object detection, distance
Photoelectric	Light Beam	1mm - 100m	NPN/PNP, Analog	Various materials	10-30V DC	Object detection, counting
Magnetic	Magnetic Field	1mm - 15mm	NPN/PNP, Analog	Ferrous materials	5-24V DC	Position sensing, security
Hall Effect	Hall Effect	0.1mm - 10mm	Analog	Ferrous and magnetic	5-24V DC	Position sensing, rotation
Infrared (IR)	Infrared Light	2cm - 150cm	Digital, Analog	Various materials	5-24V DC	Proximity detection, gesture

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CONCLUSION

- **Proximity sensors are devices that detect the presence or absence of objects within a certain range without direct contact.**
- **Utilizing technologies like infrared, ultrasonic, capacitive, inductive, or magnetic sensing, these sensors are crucial in various industries such as manufacturing, automotive, and consumer electronics.**
- **They offer non-contact operation, reliability, and quick response times, enhancing efficiency and safety in applications ranging from automation in factories to proximity detection in smartphones.**


THANK YOU