Mine Automation and Data Analytics

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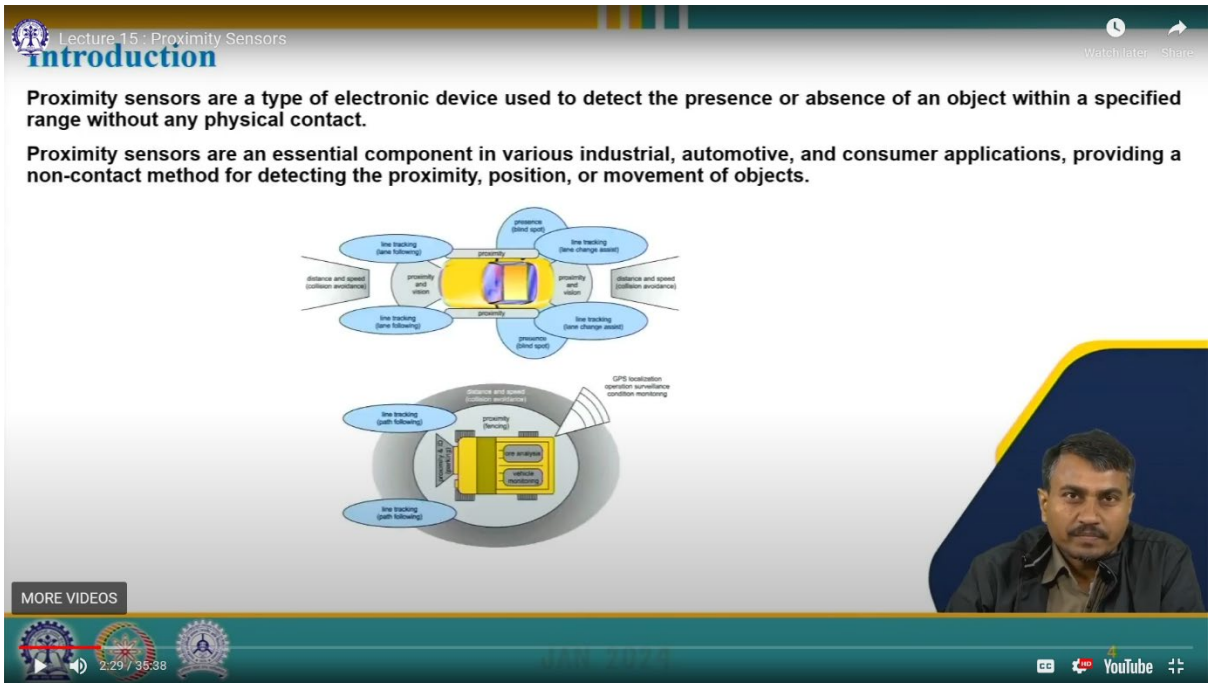
Week-3

Lecture-15

Proximity Sensors

Welcome back to my course, Mine Automation and Data Analytics. In this lecture, we are going to discuss on Proximity Sensors and Sensing System used in Mining Automation System. So in this lecture, we are going to cover the following. We will introduce what is proximity sensor and sensing system. We will discuss the sensor working principle, its application, the challenges in using these sensing systems in mines, the advantages of these sensing systems, the types of sensors used in proximity sensing systems, and lastly the proximity sensor comparison. So proximity sensors is a type of electronic device that is used for a detection of a presence or a non-presence of an object within a specified range without any physical contact.

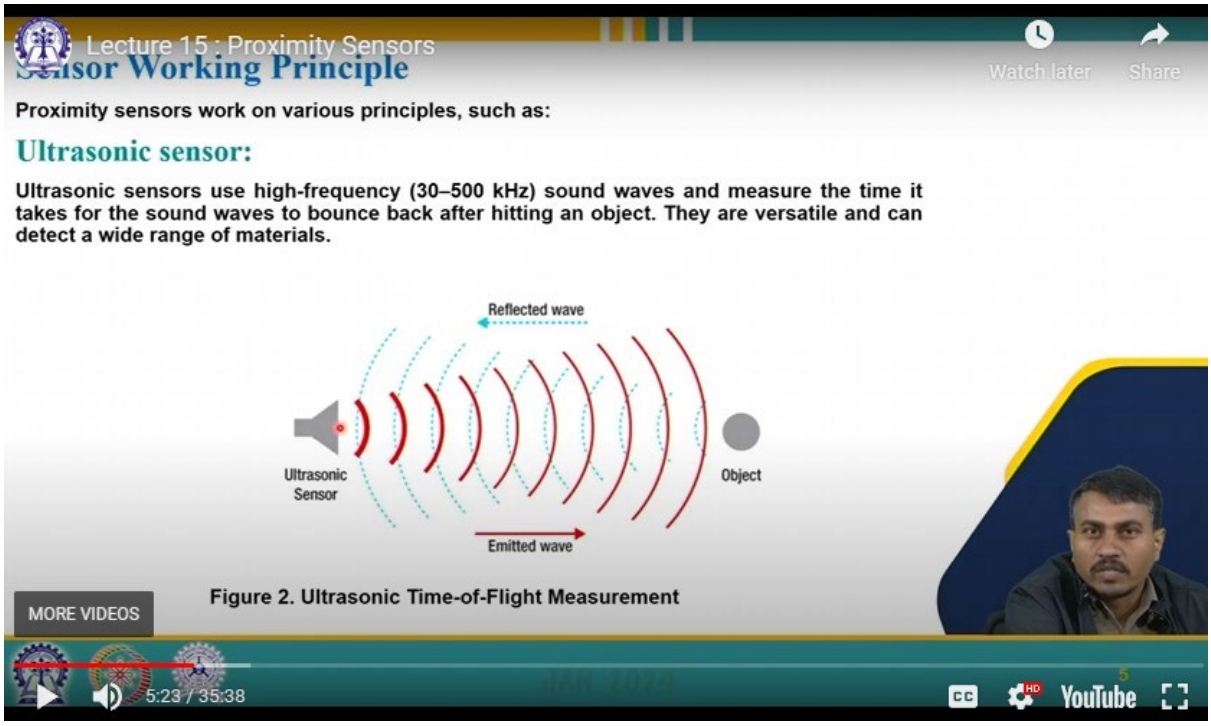
So the proximity sensors are an essential component in various industrial, automotive, and consumer applications providing a non-contact method for detecting the proximity, position, or movement of objects. So this is a typical example. Here, this is a vehicle. So this vehicle is fitted with the proximity sensing system.



So there is a front zone, there is a back zone, as well as side zone. So within this particular zone, this particular sensing system detects any object presence. So based on the object

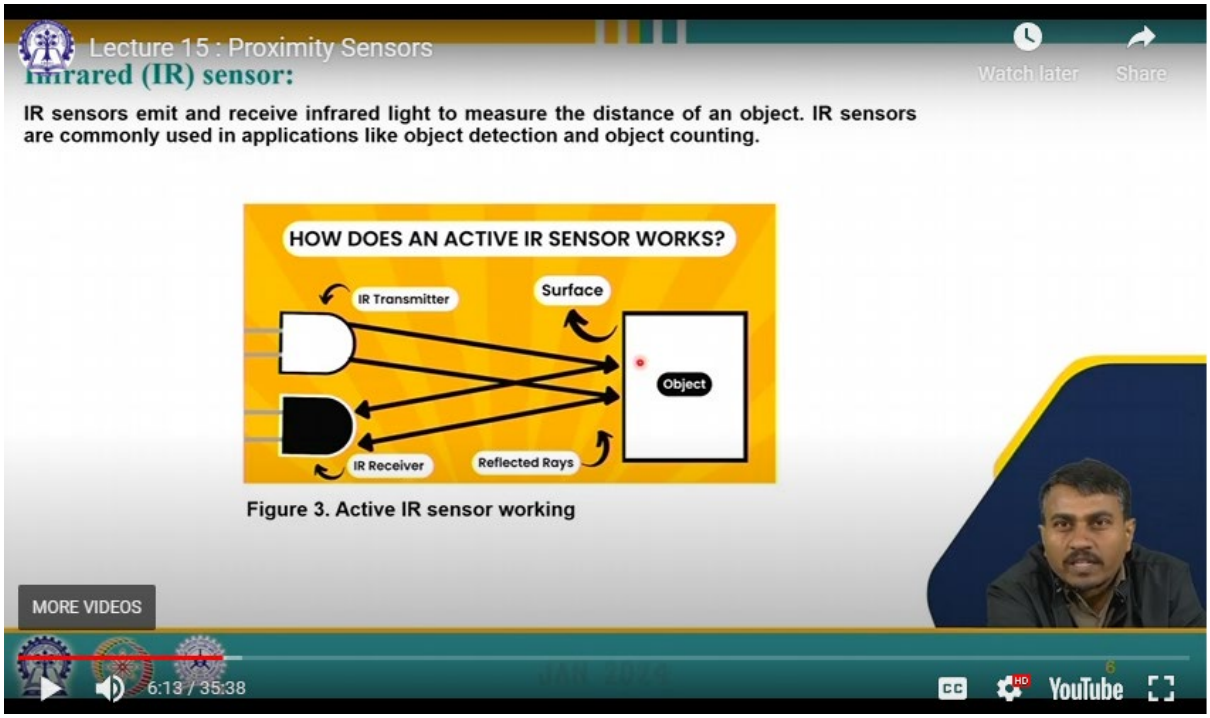
presence, it basically sounds the beacon that something is there nearby so that the vehicle can move safely and the driver may be alerted time to time as in when something is coming into this particular zone. Similar to this dump truck, haul truck used in mines for conveying the materials, conveying the overburdened materials to the dumping station, so here also it creates a virtual zone and within that zone if something comes into, it basically emits the beacon signal that there is something in the zone. So it helps to operate this kind of vehicle, this is a heavy vehicle, heavy earth-moving machinery with safety in the mine roads without any hazard.

So this is basically helping autonomously to detect any object within this virtual surrounding of this particular machine. So thereby it helps to detect any object presence in that particular zone. So there are various kinds of proximity sensing systems that are used in the mines. So one is the ultrasonic sensing system. So ultrasonic sensors use high frequency sound wave and measures the time it takes for the sound waves to bounce back after hitting an object.



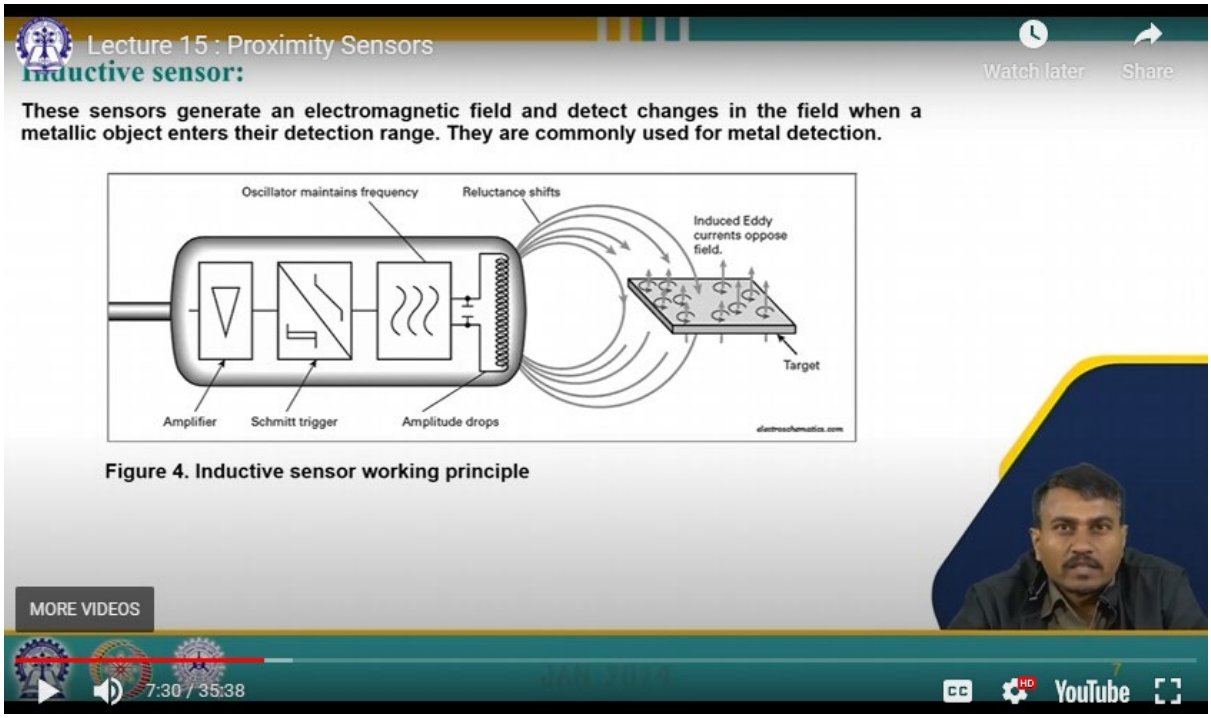
So they are versatile and can detect a wide range of materials. So this is a typical functioning how the ultrasonic sensors are working. So it emits ultrasonic wave of 30 to 500 kHz sound waves. So these waves heat the object and that wave return back. So there is a receiver as well on this particular sensing system.

So it emits the wave as well as it receives the wave. So based on the time taken by this wave, it basically calculates the distance. So this is a very robust kind of proximity sensing system for detecting the object in front of the machine. Infrared sensing system. IR sensors emit and receive infrared light to measure the distance of an object.

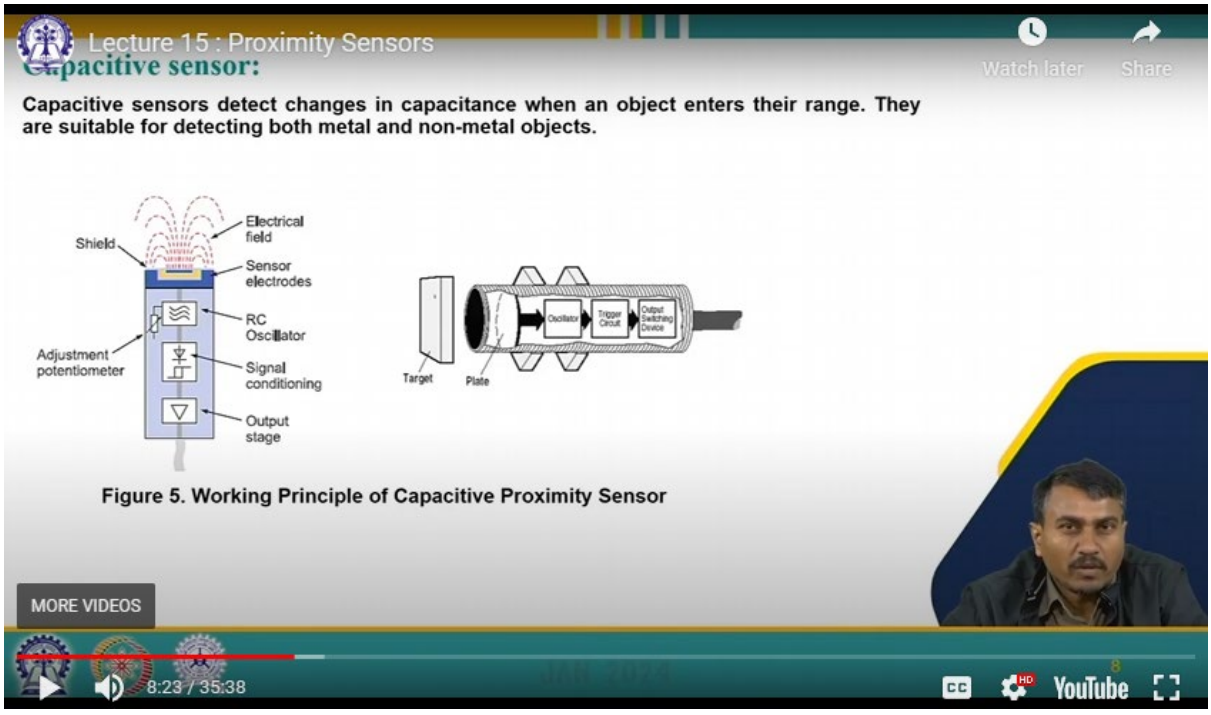


IR sensors are commonly used in applications like object detection and object counting. So this is an IR sensor transmitter. So this transmits IR wave that heats the object and the return wave, the reflected wave, again received by the sensor system by the IR receiver. And based on that it basically detects the object. Other than that, these IR sensing systems are used for the mapping purpose as well as well as the temperature zoning of that particular vicinity of that area.

Inductive sensor. So these inductive sensors are, generates electromagnetic field and that detect the change as well in the electromagnetic field when something comes into. Something means here a metallic object. So when the metallic object comes into that particular field, so we know that when a metal object comes into the electromagnetic field, it will generate the eddy current and that eddy current opposes the electromagnetic field. So when a metal object comes in proximity with a particular machine, so this sensing system will detect the change in electromagnetic field.



So by that comparison, the change in electromagnetic field, this particular sensing system recognizes and detects the distance of that metallic object from the machine. So this is basically comprises of the amplifier, trigger and the oscillator maintaining frequency system and that basically always maintains the electromagnetic field. And whenever the metallic object comes into the change, that it detects and that gives the output that the object may be few centimeter away from that particular machine. Capacitive sensors. So capacitive sensors detect change in capacitance when an object enters into their range.

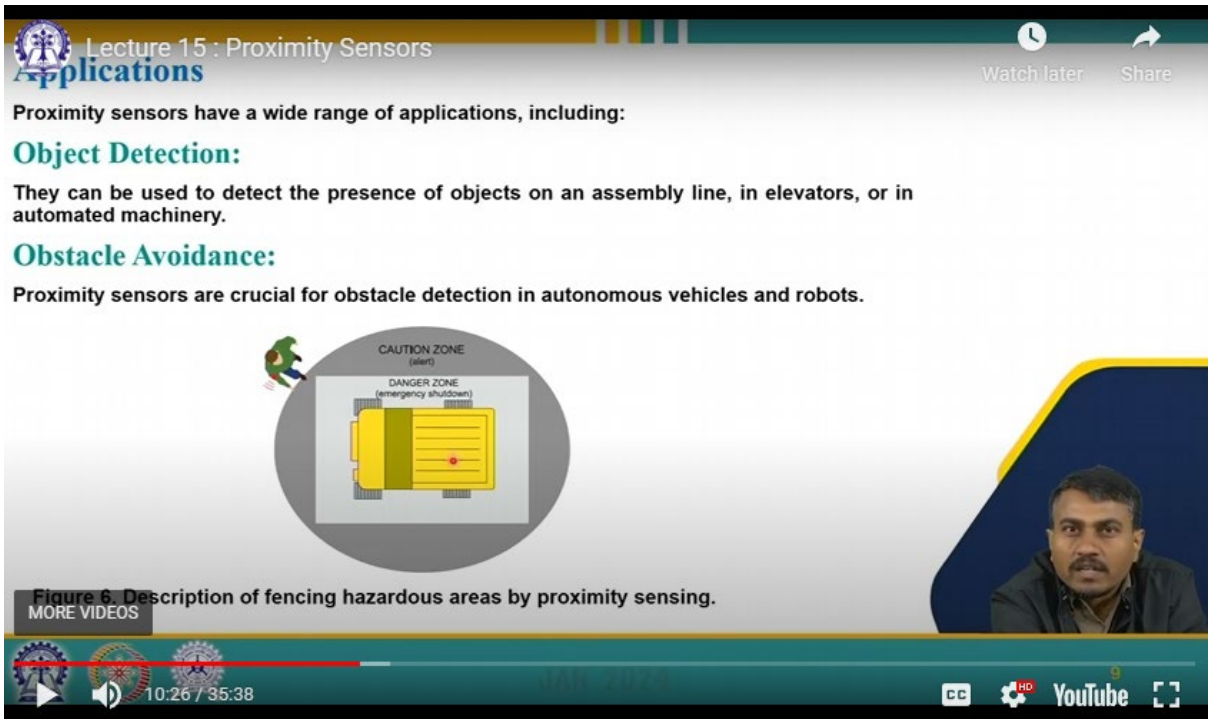


So they are suitable for detecting both metal as well as non-metal objects. So here in the inductive sensing system, we have seen the change in electromagnetic field. Here we are

sensing the change in capacitance, okay, and that is irrespective of metal as well as non-metal. So this is basically the sensing system. It basically emits the electrical signal and it basically sends the object and whenever some object comes into this particular electrical field, so there is a change in capacitance.

So that change in capacitance by that it basically measures the distance of that particular object. Applications. Proximity sensors can be used for object detection. So they can be used for detecting something in front of that particular machine or in line in an autonomous area where different machines are operates, different vehicles are operates. So this is a very suitable system for detecting something in front of that particular machine.

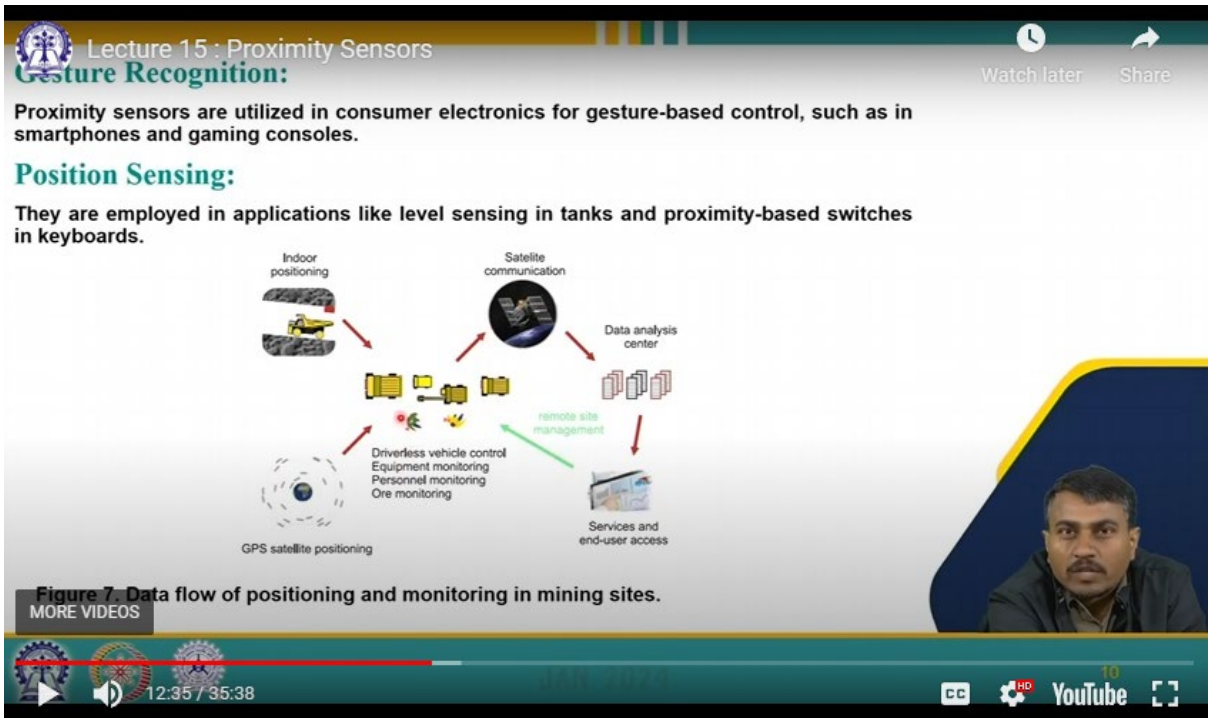
Obstacle avoidance. So for a smooth movement of any machine in the particularly in the mine hall road or any in the factory line or in the vicinity of the mine location, so whenever we operate with autonomous system, in that autonomous system there should be some obstacle avoidance system as well. So using the proximity sensing system, we can basically use it for obstacle avoidance system as well. So this is a particularly a good example of that obstacle avoidance system. Here a mine hall dumper is operated in the hall road.



So using the proximity sensing system it basically creates a virtual zone. Two zones, virtually one danger zone and a caution zone. So whenever some miner enters into that particular zone, so there would be a beacon sound is blinking. So that basically notifying that miner that you are entering into a zone that might be dangerous. So by that we are alerting the miner not to enter in that particular area.

So this is a good example that in a mine site when this kind of heavy earth moving machinery operates and with this proximity kind of sensing system, we can avoid accidents and we can operate the mines safely without any accident. Gesture recognition, proximity sensors are utilized in consumer electronics for gesture based control such as smartphone and gaming console. Positioning sensing system, so they are employed in application like level sensing in tank, proximity based switch in keyboards. So this is a particular example again of the mine

site that this is fitted with the proximity sensing system along with the GPS system in these heavy earth moving machinery. So these heavy earth moving machinery operates in a mine hall road and that mine hall roads are also used for other purpose as well.



Other vehicles are also operating on this particular route and also sometimes miners are also used this particular route. So in this particular situation, these particular dump trucks are fitted with the GPS system and they are in communication with the central control room. So whenever some miners enter into that particular vicinity of that hall road, so they will alert, give the alert that yes you are entering into the hazard zone. Similarly for the vehicle that, vehicle will be alerted that someone is entering into that particular vicinity. So by that effectively, by this centralized kind of system, we can avoid accidents, we can use this system for accurate positioning of the vehicles as well as this will help for achieving the target or the particular target of these using these dumpers for the material convenience smoothly and seamlessly.

Advantages, non-contact, so proximity sensor does not physically touch the object they detect and by that it reduces wear and tear because proximity sensor does not touch the object so there is no question of any wear and tear of that particular object. Speed and accuracy, they can provide fast, precise detection in various conditions and that basically helps the mining system very well, particularly entry exit system of these in the mines. So if these proximity sensing systems are being used and they have a particular ID, those are the vehicles to be given entrance of that particular area. So they can be detected automatically and automatically the gate will be open. So by that, machine can apply on that particular area without any help of any physical person to allow and detect and everything.

So everything can be done automatically in the control system by installing the proximity sensing system. Reliability, so these sensors are known for a long lifespan and minimal maintenance requirements so it is very much reliable. Challenges, the main challenge of this

proximity sensing is the limited range. It can detect, it can operate in a very short range. So typically based on different sensing system, it has different distance as well.

So more particularly, it can operate on a smaller range only. That is basically one of the challenges. Material sensitivity, some sensor may be affected by the material and surface properties of the object they detect and some may not. So this is basically some of the sensors are sensitive to some materials. Environmental sensitivity, sensor may be affected due to the humidity, presence of dust particles and temperature in the surrounding area.

And more particularly the dust and humidity sometimes basically affect the efficiency of these proximity sensing systems.

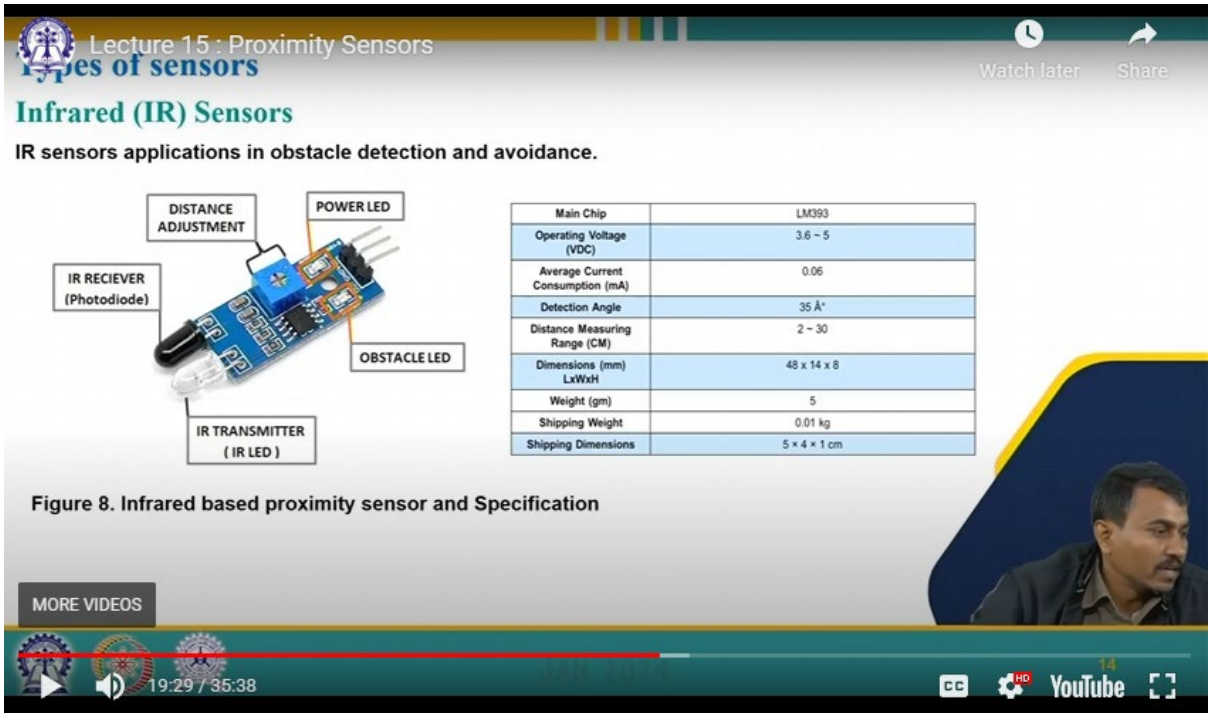
Types of sensors, there are various sensors used in mining machinery for the proximity sensors. First is the infrared sensor. Basically the frequency of the sensor in system is 300 GHz to 400 MHz. As I said in the starting of this particular lecture that IR sensors are used for object detection as well as this IR sensor can also be used for mapping the temperature in the vicinity of that particular machine as well.

And for other movement detection can also be used for using this infrared sensing system. Ultrasonic sensor, it is basically used the sound wave from the range of 30 to 500 kHz. It is a very robust sensing system used in the mining machinery and little bit costly but it is very much reliable compared to other sensing system. Lidar sensors is a very good sensor. These leader sensors are basically used for mapping purposes mostly for basically three dimensional objects or 3D point clouds are basically created in the vicinity of that particular machine that operates

So by that it basically can help effectively to develop an obstacle avoidance system in the machine. So typically the Lidar sensing are basically have some spinning facility that rotates in angular range from 0 to 360 degree with a spanning frequency of 1 Hz to 100 Hz. So this is a very suitable sensing system for mapping the surrounding objects near the machines and that is also used as a proximity sensing system. Cameras, visual cameras are also used for vision object detecting the image and mapping the line of sight as well. Wheel encoder, basically used in the robots, mine robots for the movement of the wheels.

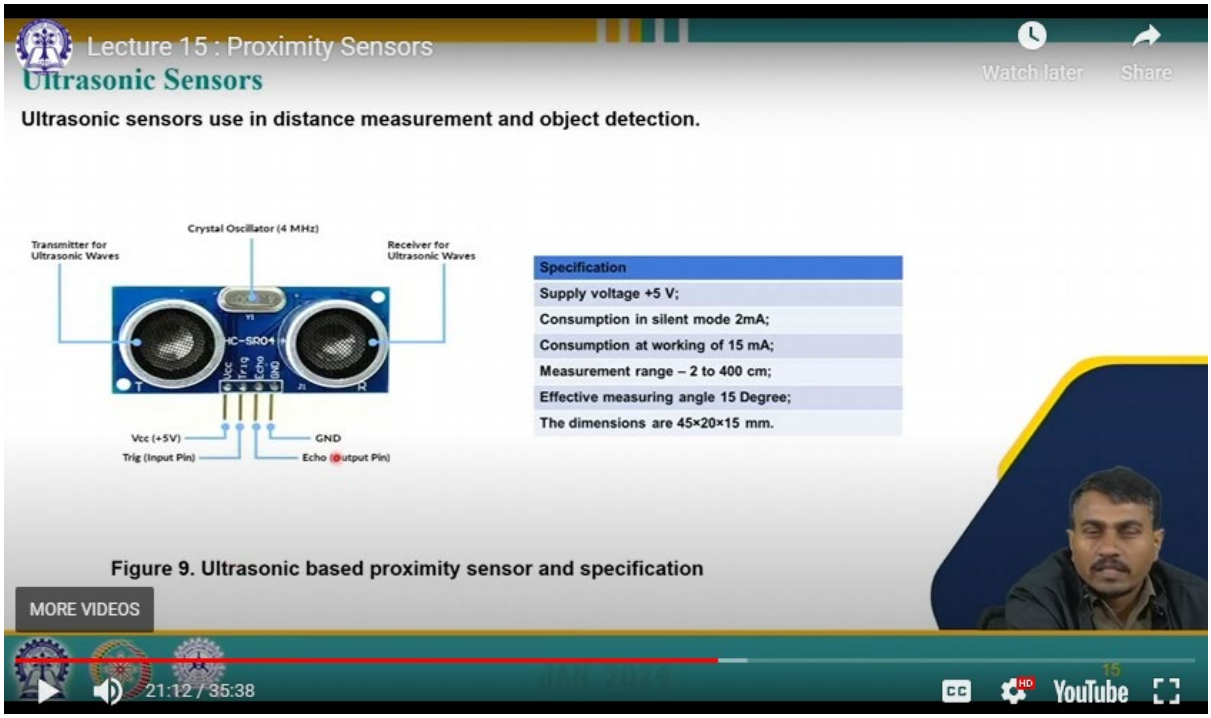
Gyroscope, it is basically a sensor used for measuring the angular change more particularly because for example when we are using basically the cursor, mouse. So mouse change its location and it is basically reflected on the screen. So mouse also use the gyroscope. So it is a kind of system that basically try to maintain the angular momentum. So whenever there is an external change that basically change and that measure basically measure the angular velocity as well.

Accelerometer, it basically measures the acceleration in the system. Touch sensor, this is a kind of touch switch as well based on the capacitive sensing system. Type of sensors, IR sensors, so IR sensors application in obstacle detection and avoidance. So this is a typical example of IR sensing system. So this is the IR transmitter, IR wave transmitter and also here we have the IR receiver.



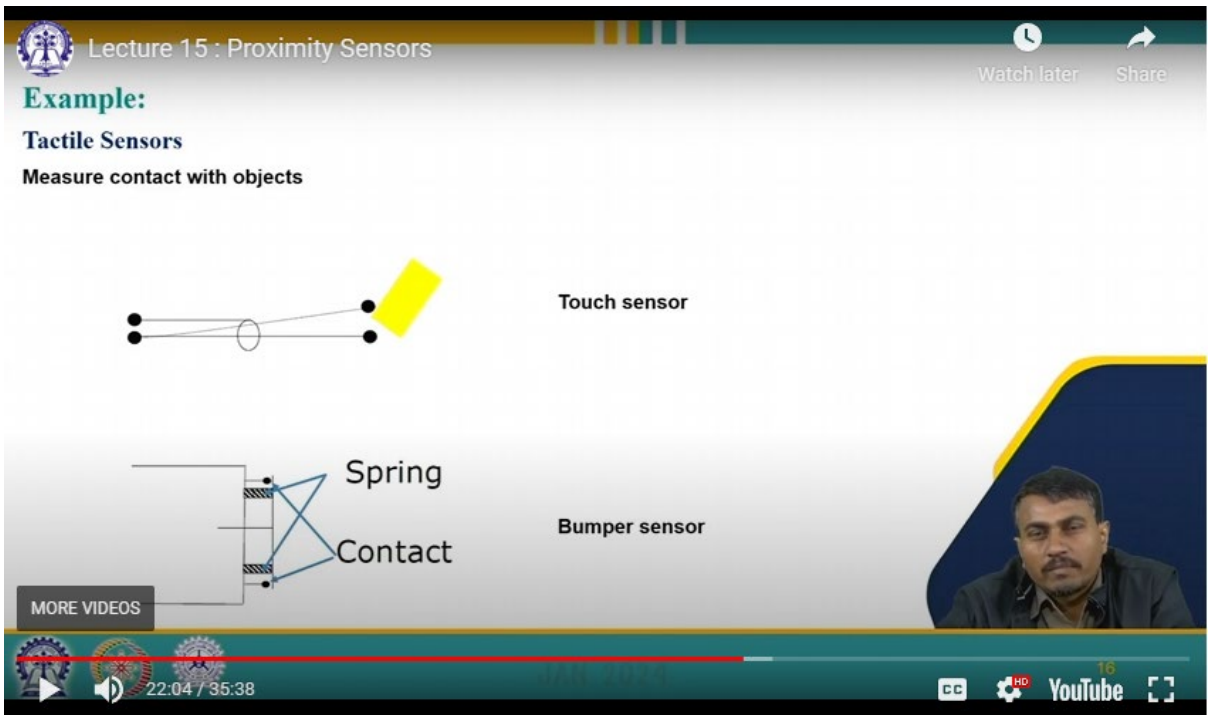
So all IR sensing system have the transmitter as well as the receiver. So that basically powered by the batteries and electrical power, TC power basically. So that basically comprises of the circuits and these circuits have the generator of IR wave. So in this circuit IR wave is generated and that maintains the particular frequency. And it basically operates on particularly here this particular sensing system and operates on 3.6 to 5 voltage. So this is a smaller IR chip. So this basically used for sensing the object in front of it.

Ultrasonic sensor. So ultrasonic sensor are used for measuring the distance and object as well. So here also in the ultrasonic sensing there are transmitter and there are receiver. So sound wave is emitted from this end and reflected sound wave comes back and received by the receiver and based on the time gap and we know the velocity of the sound wave and based on that it basically detects the object distance.



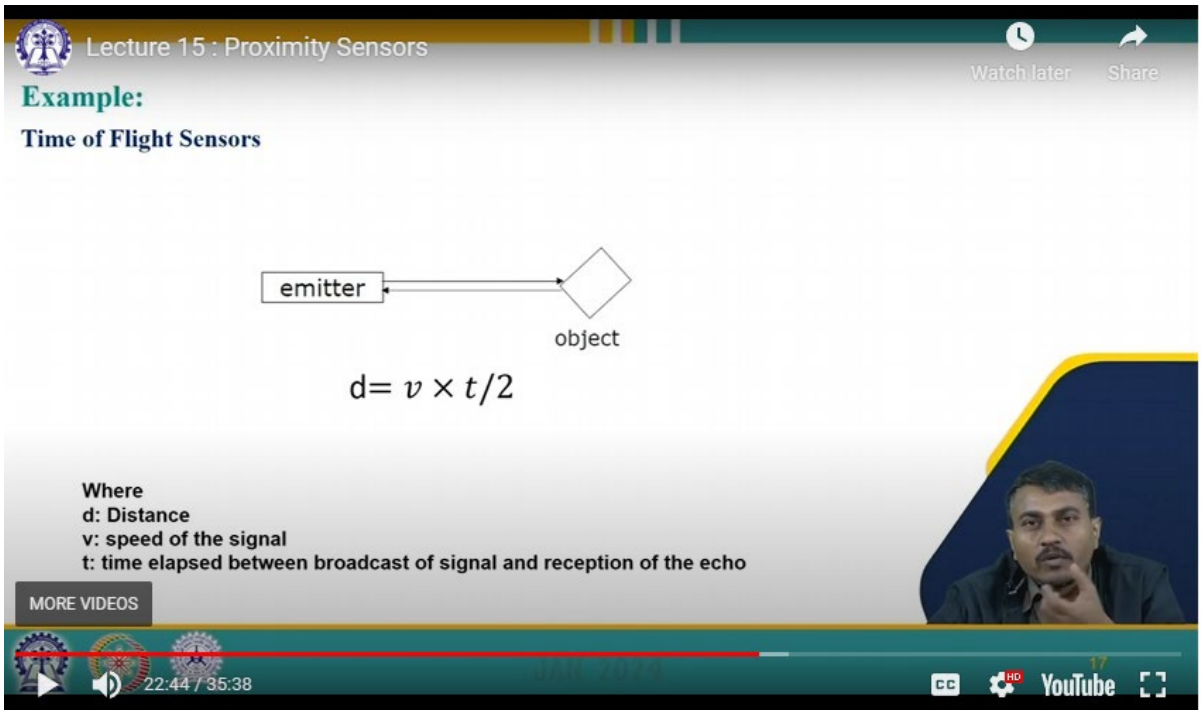
So this particular machine, this particular sensor operates on 5 voltage and in silent mode it consumes the power of 2 milliampere and in working time it consumes 15 milliampere current. And measuring range particularly it is around 2 to 400 centimeter. So effectively it can also measure some 15 degree angle alignment as well in the vicinity in the front.

Tactile sensor. So this is a touch kind of sensing system that by the touch it basically sense the object.



So there are two kind of system touch sensing and the bumper sensor both are working on the touch sensing basis. Basically in the virtual reality we will mostly use this kind of tactile sensor as well as for robotic application we use the tactile sensing system.

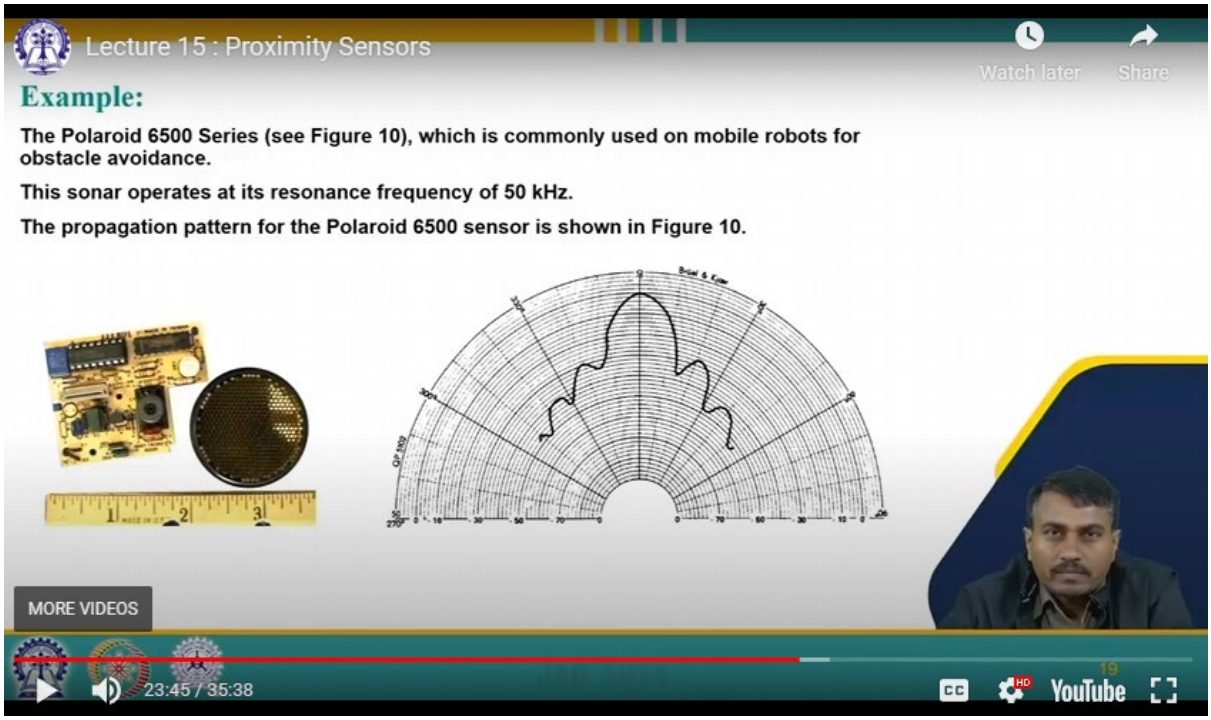
Time of flight sensor. So here the emitter emits the wave and object return back the wave. Based on the time difference we basically calculate the distance.



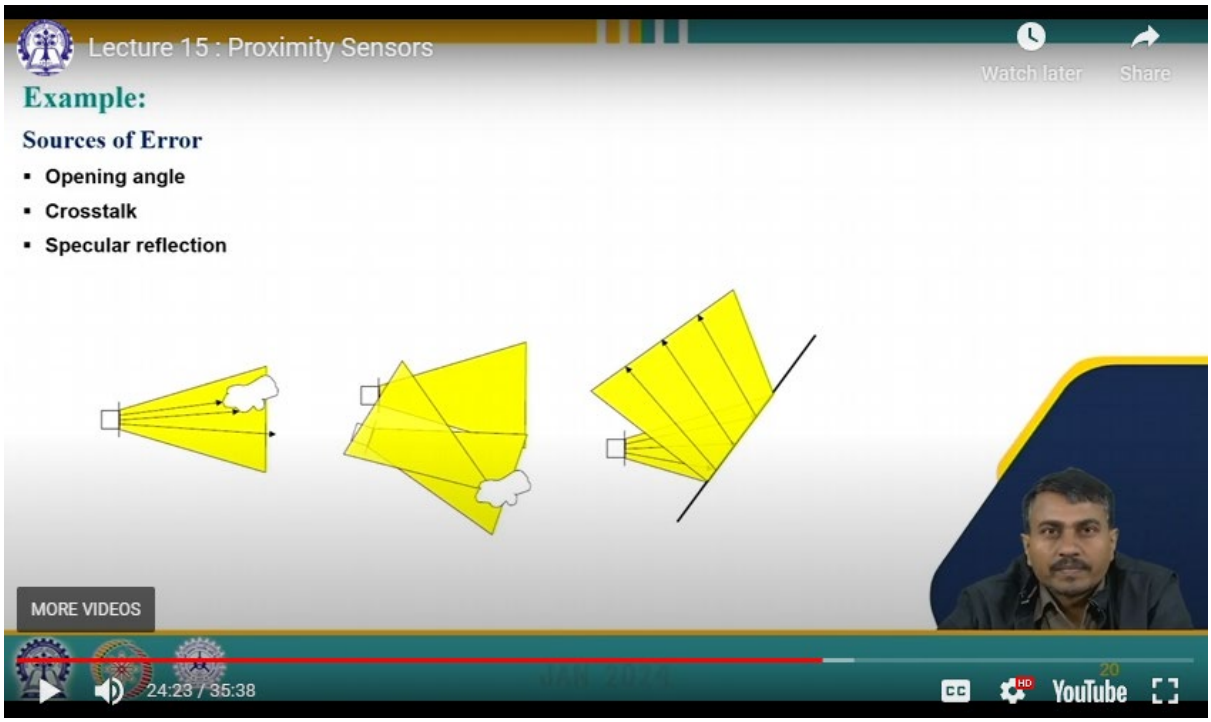
So here the V is the speed of the signal. For the electromagnetic wave we know the V, for the sound wave we know the V. So based on that we can easily calculate the D and T is basically calculated, basically measured in the sensing system.

Polaroid ultrasonic sensor used for obstacle avoidance. It emits the ultrasonic signal. It operates on a resonance frequency of 50 kilohertz.

It waits until they receive the echo and based on the time of flight sensor it basically detects the obstacle in front of it. So this is a particular example of the Polaroid 6500. And we also have some kind of graph this machine basically captures. So this is a typical kind of graph that we created using these sensing system in the mobile robots.

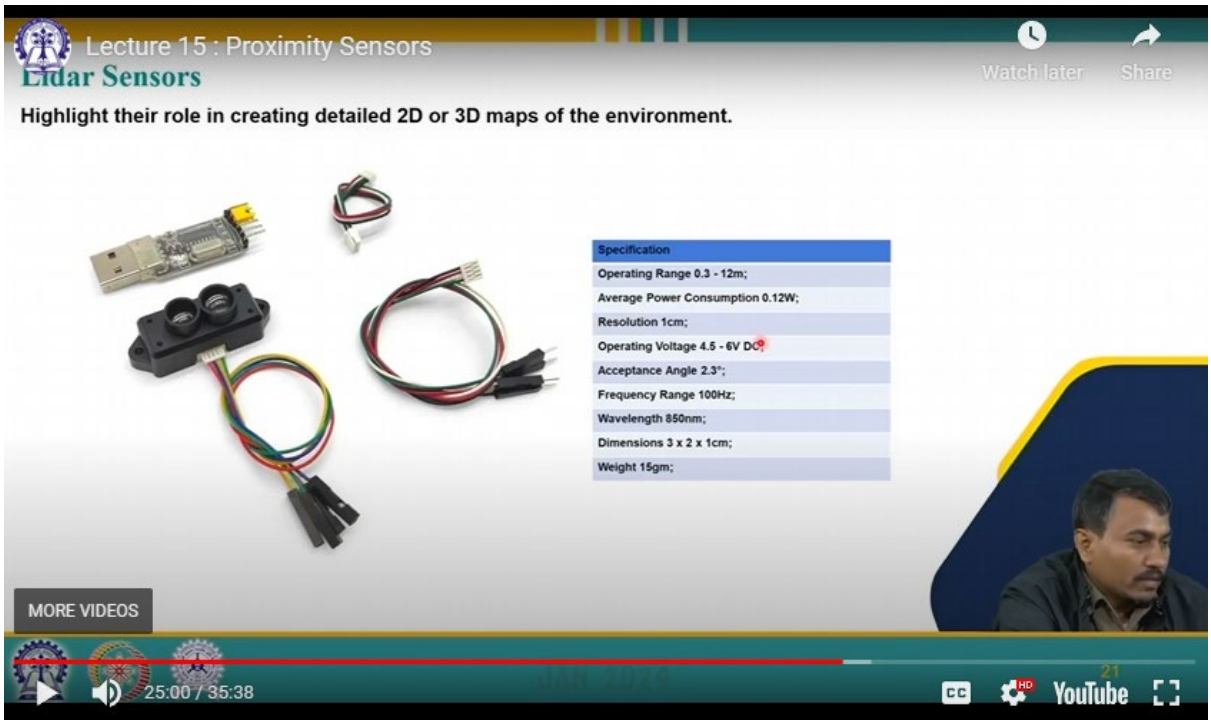


Sources of error. In this kind of sensing system there are some problems and there are some errors incurred during the measurement. One is the opening angle error, cross talk error and the spectacular reflection error. So these are basically depending on the object, object presence and object orientation and the surface. These are the type of errors that may occur for the measurement of the sensing system.



Lidar sensor. This is used for the 3D reconstruction or the 3D mapping of that particular object and 3D point cloud is generated using this leader. So this is the Lidar and it is basically supplied by the DC source battery and this is a very small range leader. It operates only from 0.3 to 12 meter and average here wattage consumption is 0.

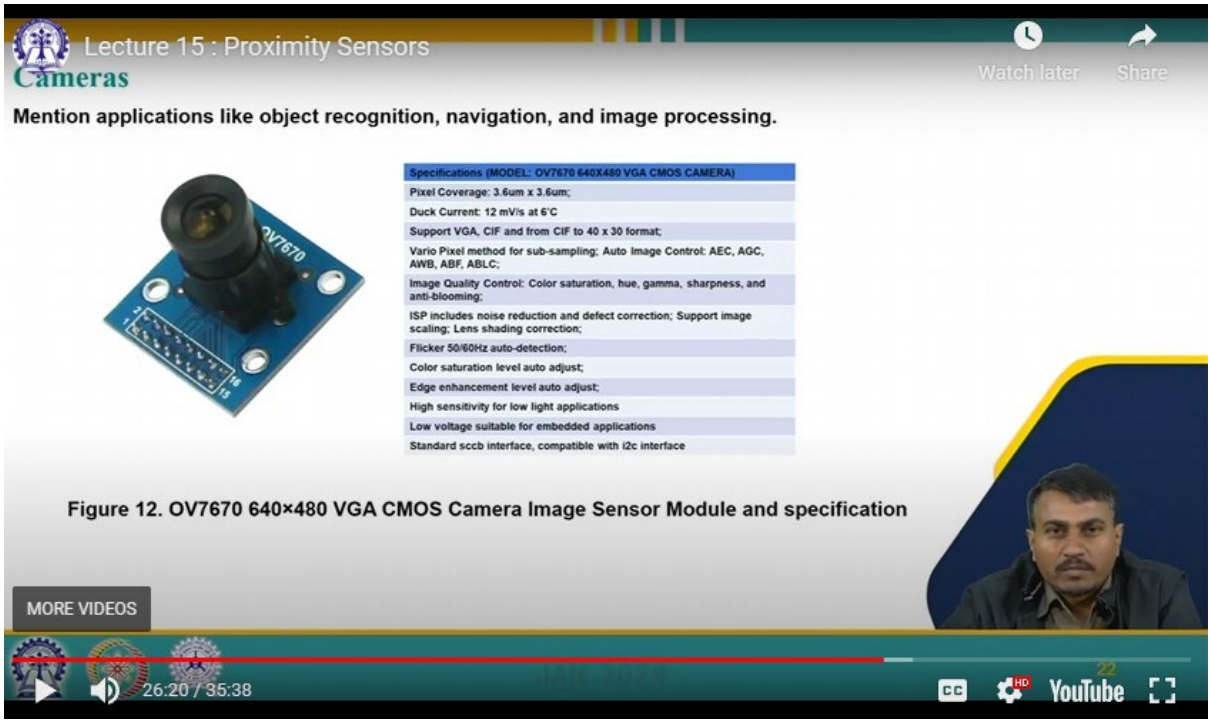
12 watt and the resolution is 1 centimeter. So 1 centimeter at 1 centimeter each 1 centimeter the average distance between the point is 1 centimeter. So that basically creates the point cloud. So by that the object can be understood that what kind of object it is in front of the machine. So these leader sensors are used primarily for that for object detection and the obstacle avoidance in autonomous vehicles. And its frequency range is around 100 Hertz and as I said that it can operate on a rotational basis as well.



So it can measure the position of the object in 360 degree angle.

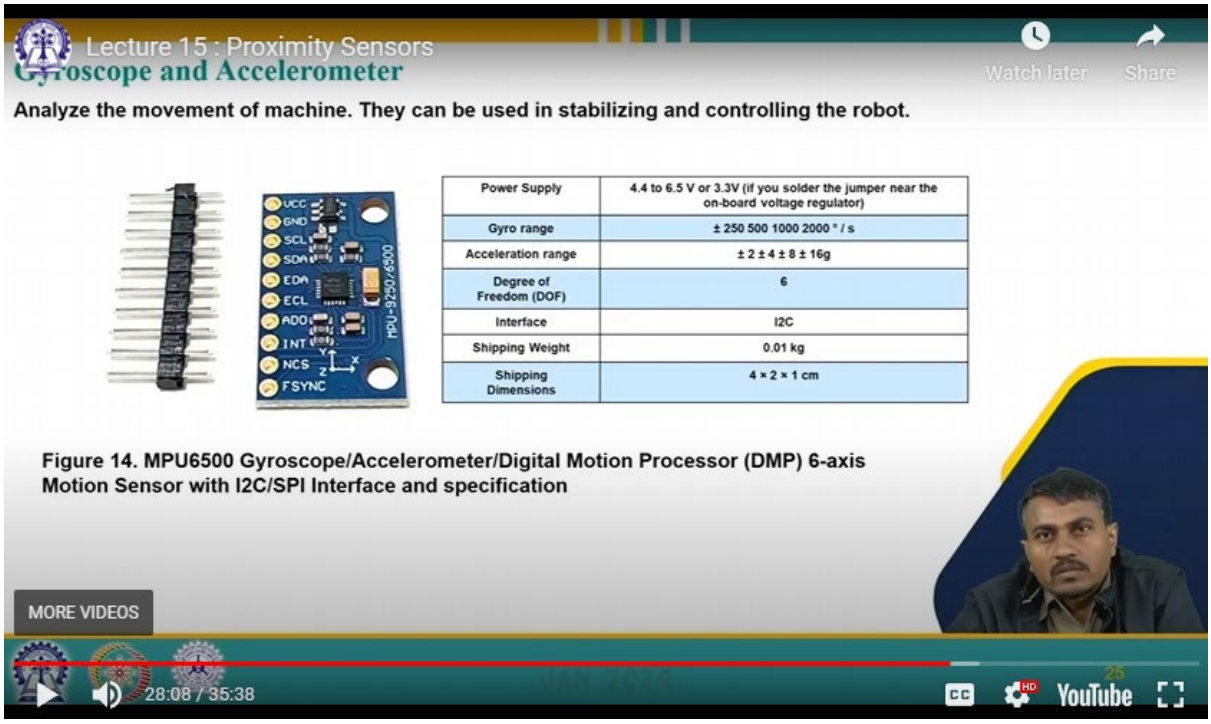
Cameras. So this is a typical camera, C-OMS sensor system. So this camera basically detects the object in three colors, red, green and red.

So RGB. This is a camera sensor. This is used for capturing the image of the vicinity. So this is very much used and using the image processing technique there could be multipurpose use of this kind of data for obstacle detection, obstacle avoidance system as well. And most of the autonomous vehicle that operates on the mine site are fitted with the camera sensing system as well. Not only that, these camera sensors are also used in the factory process plant for monitoring the progress of the task as well as in sometimes in the conveyor belt, top of the conveyor belt for detecting the quality of the material flow over the conveyor belt. And there are multifarious applications of this particular sensor system.



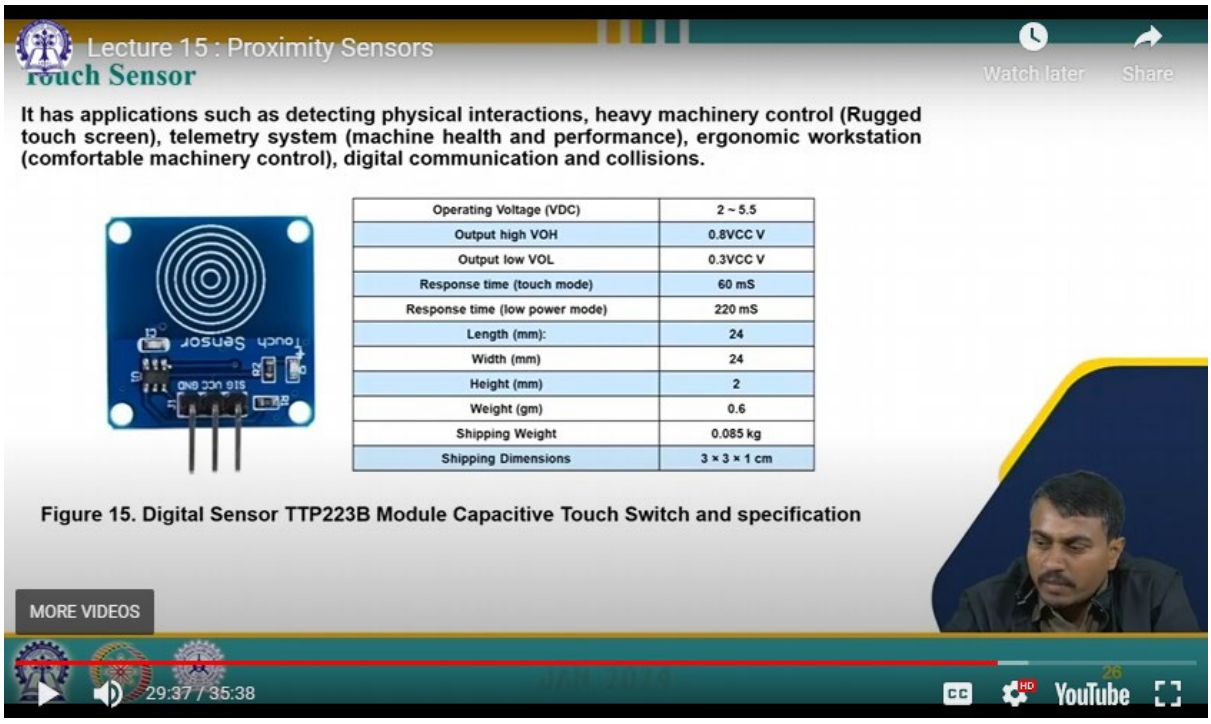
Wheel encoder. This is typically used in odometry and tracking the robot position. So this is basically two types of sensing systems are used in wheel robots. One is active, that is ultrasound, laser lens finder and infrared. And passive one is basically the camera and tactile sensor. So ultrasonic and laser finder are based on the time of flight and infrared cameras and tactile based on the intensity of that particular way.

Gyroscope and accelerometer. So gyroscope and accelerator is used for measuring the acceleration as well as the angular change of position of that particular machine and object. So this is a typical example of MPU 6500 gyroscope. This is a 6 degree of freedom accelerometer. Inherently it has some damping system as well as correction system. So this is also used for digital motion processor and this operates on DC voltage and this is available in digital format as well.



And this is very much versatile. It is used for measuring the acceleration as well as the angular change of that particular vehicle.

Touch sensor. So it has an application that whenever you touch the switch particularly in a rugged machine or a telemetry system or some ergonomics workstations, this can be used as a couple switch as well. Touch sensor couple switch. So this is a very handy use of the proximity sensing system and it basically safeguard the machine's safety as well as the worker's safety.



So this is based on capacitive sensing system. So in the switch there are two layers, there are two capacitors and in between there is an insulator. So whenever I press that bill it is switched

on. So there are basically work on the touch and that touch may be on the basis of the pressure and so on and so forth.

Sensor fusion. So here we are going to elaborate you one example that how the few sensors can be used together for achieving some target.

For example, here we are fusioning the accelerometer, gyroscope and magnetometer for measuring the IMU, inertial measurement unit. It is used as a IMU sensing system for detecting and measuring the motion and orientation for a vehicle or for a particular moving object. So this is typically used in robots when the robots are flying on the autonomous area. So their motion, their orientation, their acceleration can be easily tracked using the fusion of these combination of these three sensor system. So based on the user understanding, user can also fuse some more sensor in the system and for getting better data, for getting better control over the system.

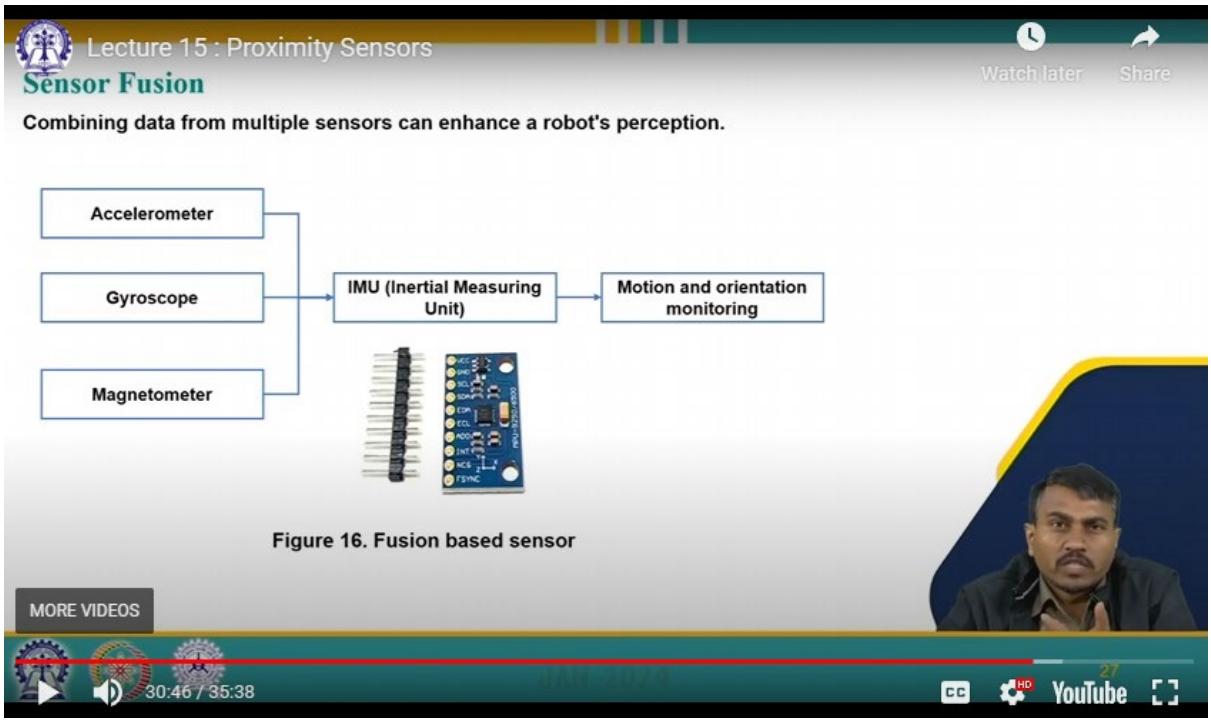
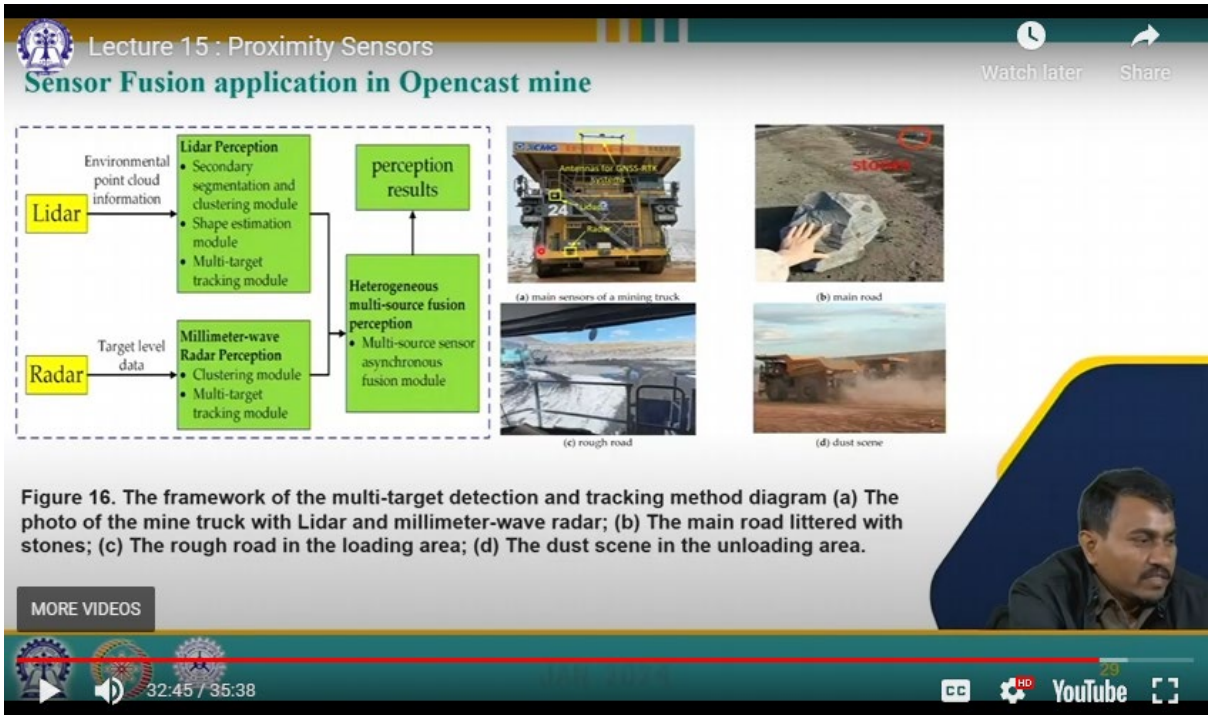


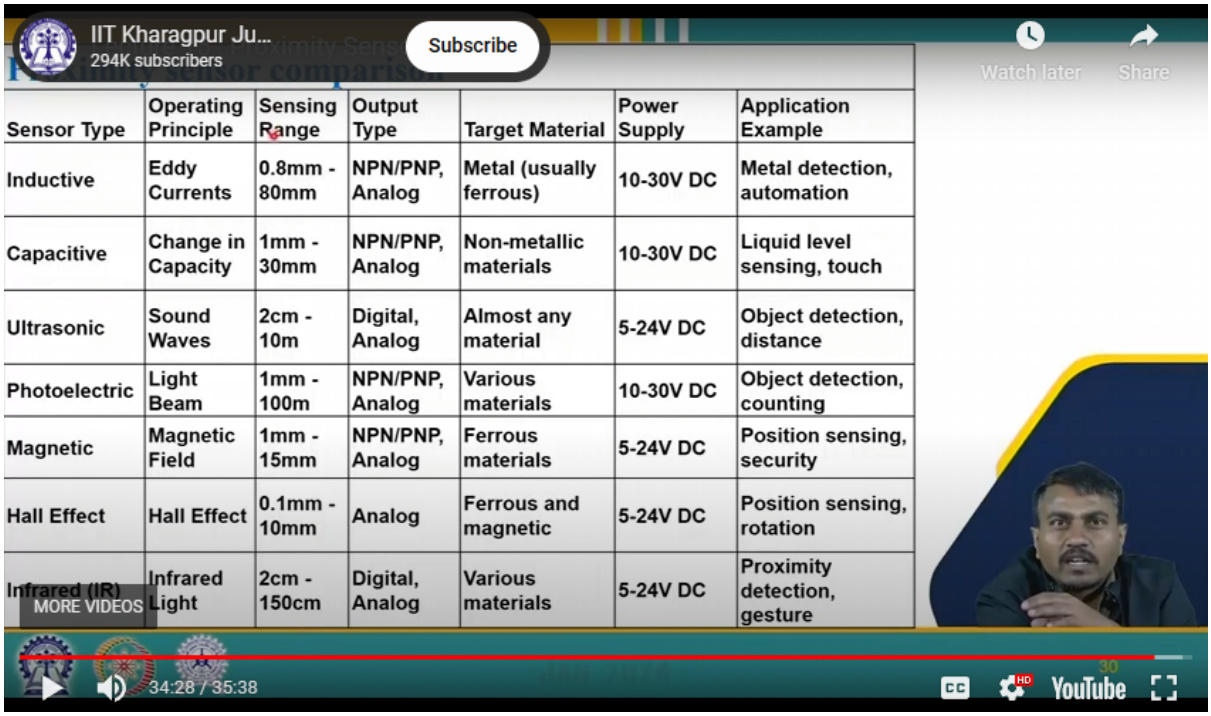
Figure 16. Fusion based sensor

So the sensor fusion application in open pit mine have a numerous application, particularly the mines are having very difficult situation for perception of the environment, particularly the unfaved roads and the dusty environment, high requirement for the detection of the front and tracking stability of that particular vehicle in that particular situation. So in those kind of situation, rather than relying on a single sensor, a multiple sensor to be fused together and to be used for better efficiency and better control over the system. And in a new target detection as well as object detection and the obstacle detection, LIDAR and millimeter wave sensor are used in combination. And it advance for a secondary segmentation algorithm suitable for open pit mine production scenarios to improve the detection distance and accuracy of small irregular obstacle on unpaved roads. And 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.

So this is a typical example that the LIDAR sensor system and the radar sensing system are fused together, used both for getting a better perception about the environment in front of the vehicle. And it is used on a very heavy arc moving machinery, the mining dampers. So mining dampers fitted with LIDAR and radar, it can easily detect the object in front of it as well as the object distance in real time. So combination of the LIDAR and radar data, it has a better operating control in the system. So it can detect the blocky rocks in the terrain, it can operate on a dust terrain and it can also operate on a dusty scene as well.



So this is basically giving a better safety and better control environment and better system run of this kind of system using the fusion technology. Here we summarize the different kinds of sensors can be used for proximity sensing system. So most of these sensors that we have summarized here are operated on a DC source. And inductive sensors are particularly useful for metallic object detection.



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

Capacitive sensors are used for liquid and other sensors and objects. Ultrasonic are used for object detection and object distance detection. Photoelectric is used for object detection. Magnetic is used for positioning sensor and security. Hall effect sensor is used for positioning sensing.

And the infrared is used for proximity detection and gesture. So these are the sensors that can be used as a proximity sensor. And the distance range we have summarized. So these are mostly operated on a very small range from millimeter to centimeter to maximum a few meters.

So these are the references.

So let us summarize what we have covered in this lecture. So we have introduced the proximity sensing system and their usage on the mining terrain. And basically it detects the object without physically touching the object in a particular range. And using this technology there are different sensing systems that evolve. For example infrared, ultrasonic, capacitive type, inductive type, magnetic sensing type are used for various purposes. And it is very much reliable and one of the major advantages is it is a non-turn current contact operation. So it can be very seamlessly operated and it has very high reliability in operation. Thank you.