Mine Automation and Data Analytics

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Week-4

Lecture-20

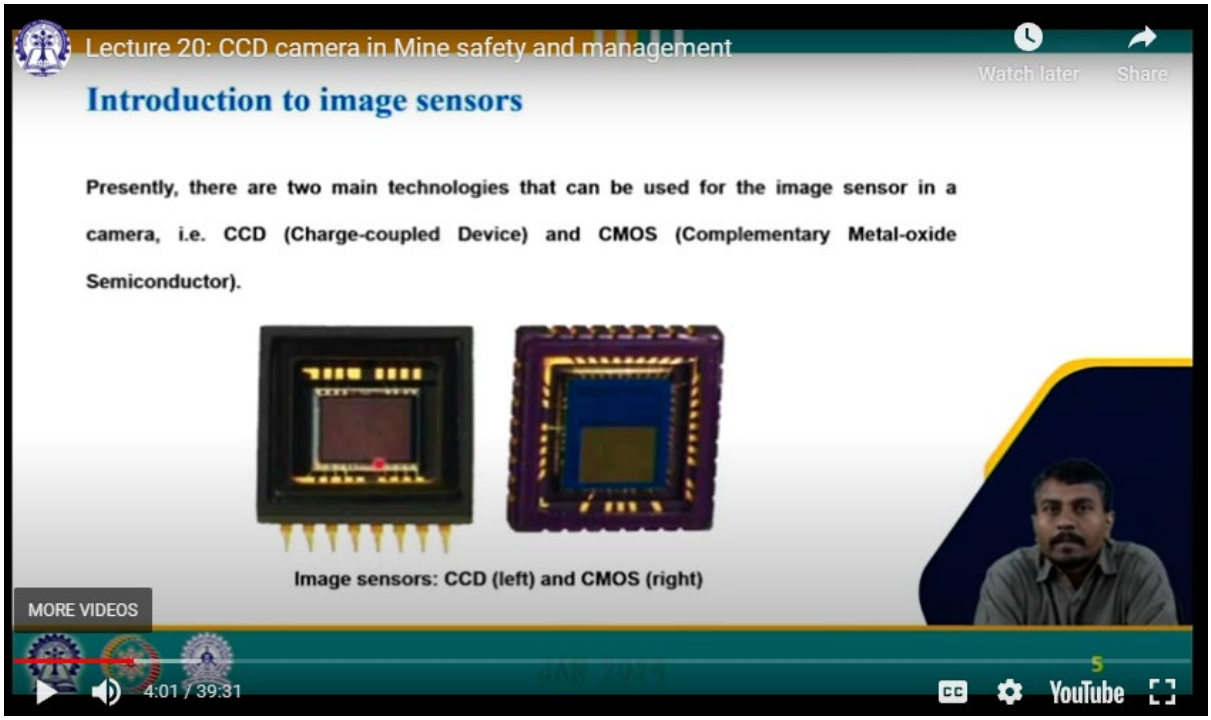
CCD camera in Mine safety and management

Welcome to my course, Mine Automation and Data Analytics. Today in this lesson we will discuss on CCD technology that to be used for mine safety and management in an overall objective of attaining a very smooth mine automation in the mines.

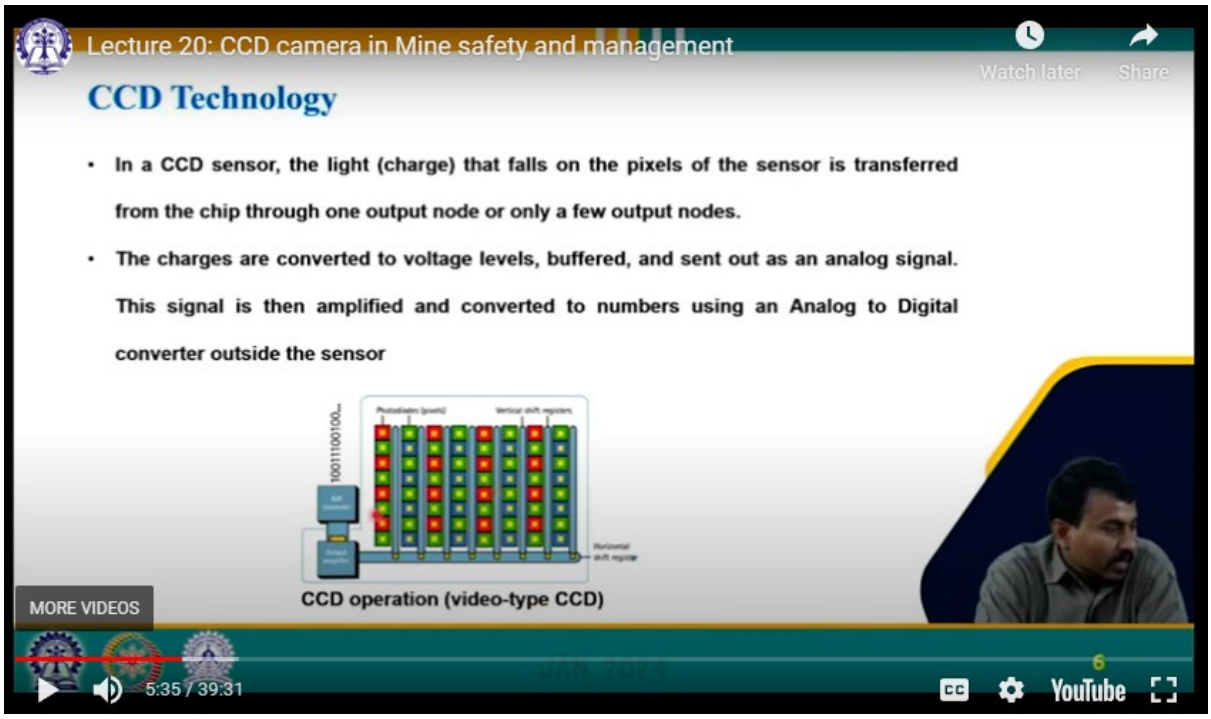
So in this lesson, we will cover the following: The introduction to different image sensors we will basically discuss today on CCD and COMS sensors. The CCD technology, the basic operation in CCD technology, the COMS technology, the difference between the CCD and the COMS technology and the data collection methods. Different CCD camera used in different usage in the mining industry and some of the examples of CCD cameras in mines.

So what is image sensor? Image sensor is a sensor when an image is being captured by a network camera, light passes through the lens and falls on the image sensor. These image sensors may be capacitors. The image sensor consists of picture elements also called pixels that register the amount of light that falls on them and they convert the received amount of light into a corresponding number of electrons.

The stronger the light, the more electrons are generated and the electrons are converted into voltage and then transferred into numbers by means of an analog to digital converters. The signal constituted by the numbers is processed by electronic circuits inside the camera. Presently there are two main technologies that is now used in the image-sensing process, particularly in the camera range image I am talking about. The CCD, charge coupled device and the CMOS, complementary metal oxide semiconductor. These are the image of the CCD, the left side. This is the CCD and this is the CMOS sensor used in the camera and circuits.



So, CCD technology in a CCD sensor, the light that is charged that falls on the pixel of the sensor is transferred from chip through one output node or only a few output nodes. The charges are converted to voltage level, buffered and sent out as an analog signal and this signal is then amplified and converted to numbers using an analog to digital converters outside the sensor, means circuit is outside. So this is a typical picture and here in this CCD type you can see the photodiodes and the horizontal shift resistor and the vertical shift resistor. So, these pixels are represented by the P-doped metal oxide semiconductor capacitor that is MOS capacitor basically and these MOS capacitor is the basic building block of these CCD technology.



And in 2009 and Boyle and Smith was awarded the physics Nobel Prize for the invention of the imaging semiconductor circuit that is the CCD sensor for these invention they were awarded the Nobel Prize.

So this CCD operates at a network of an analog shift registers, you can see these are the registers, these are the horizontal shift registers and the vertical shift registers and the horizontal shift register basically that is the moves charges packets from one line of sensors to the output. And when that line is basically complete then the vertical shift register moves the charge packet from the next line into the horizontal shift register and which then basically performs the read out in this way this basically functions.

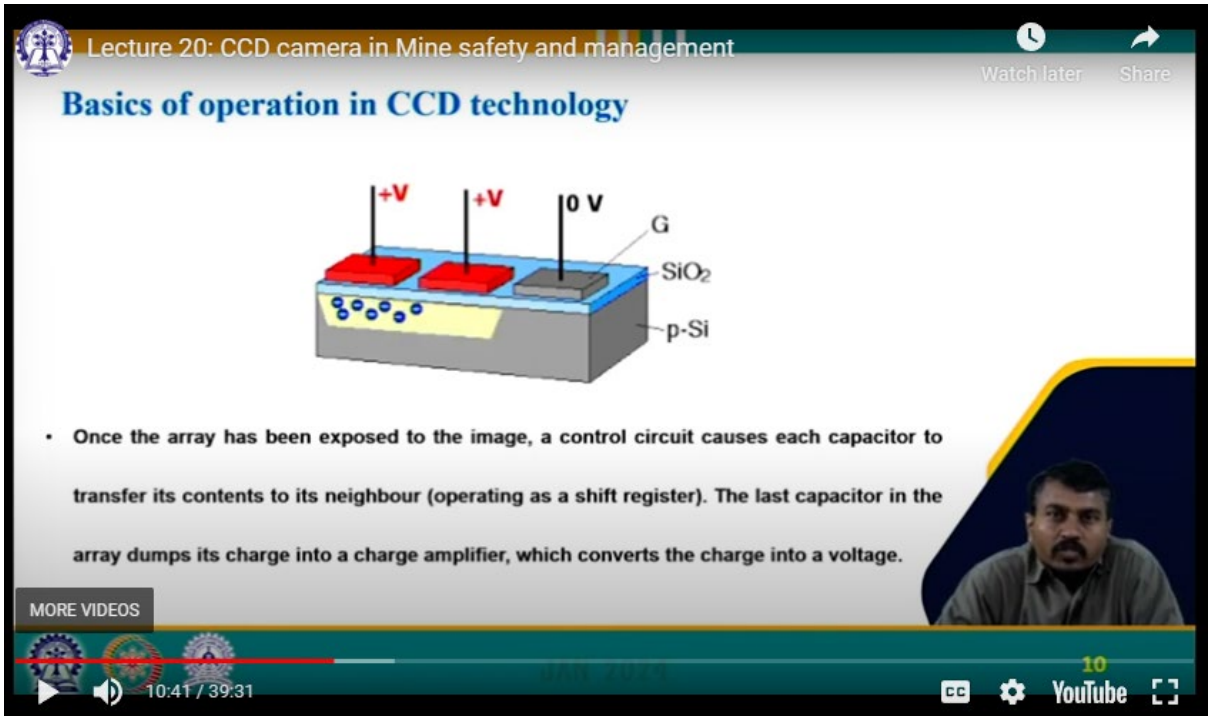
So, the CCD technology is developed specifically to be used in cameras and CCD sensor has been used for more than 30 years this is basically developed in the Bell laboratory in America. Traditionally CCD sensors have had some advantage compared to the CMOS sensors such as better light sensitivity and less noise.

The disadvantage of CCD sensors are that they are analog component that requires more electronic circuitry outside the sensor and they are more expensive to produce and can consume up to more than 100 times power than the CMOS sensors. So, the increased power consumption can lead to heat issue in the camera and which is not only impact the image quality negatively but also increase the cost and environmental impact of the product. And the CCD sensors are also required a higher data rate since everything has to go through just one output amplifier and a few output amplifiers. So, this is basically CCD sensors are mounted on the printed circuit board here.

The basic operation in CCD technology. In a CCD for capturing images there is a photo active regions okay a layer of silicon and a transmission region made out of a shift register that is we have already explained the few slides back with the horizontal shift register and the vertical

shift registers. An image is projected through a lens onto the capacitor array and the photo active regions so causing each capacitor to accumulate an electric charge proportion to the light intensity at that location. So, a one-dimension array is used in line scan camera and capture a single slice of the image whereas a two-dimensional array use a video used in video and still cameras captures a two-dimensional pictures corresponding to the same to the scene projected onto the focal plane of the sensor.

So here in this particular animation you can see that it is shifted from one sensor to the another that is never basically. So once the array has been exposed to the image a control circuit cause each capacitor to transfer its contents to the never operating as a shift register horizontal shift register for example here.

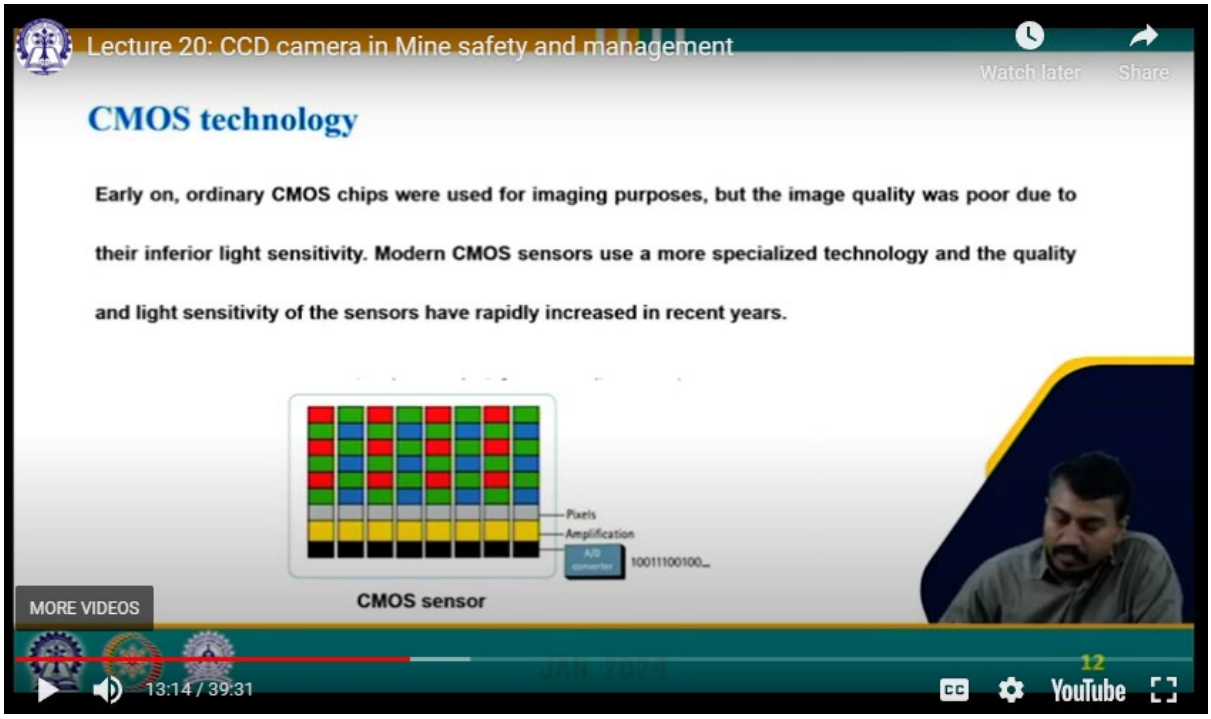


The last capacitor is basically the array dumps its charge into charge amplifier and which converts the charge into a voltage. By repeating this process the controlling circuit converts the entire content of the array in the semiconductor to a sequence of voltage. So in a digital device these voltage are then sampled digitized and usually stored in a memory in an analog device such an analog video camera and they are processed into a continuous analog signal that is by feeding the output of the charge amplifier into a low pass filter which is then processed and fed out to other circuits for transmission, recording and other processing.

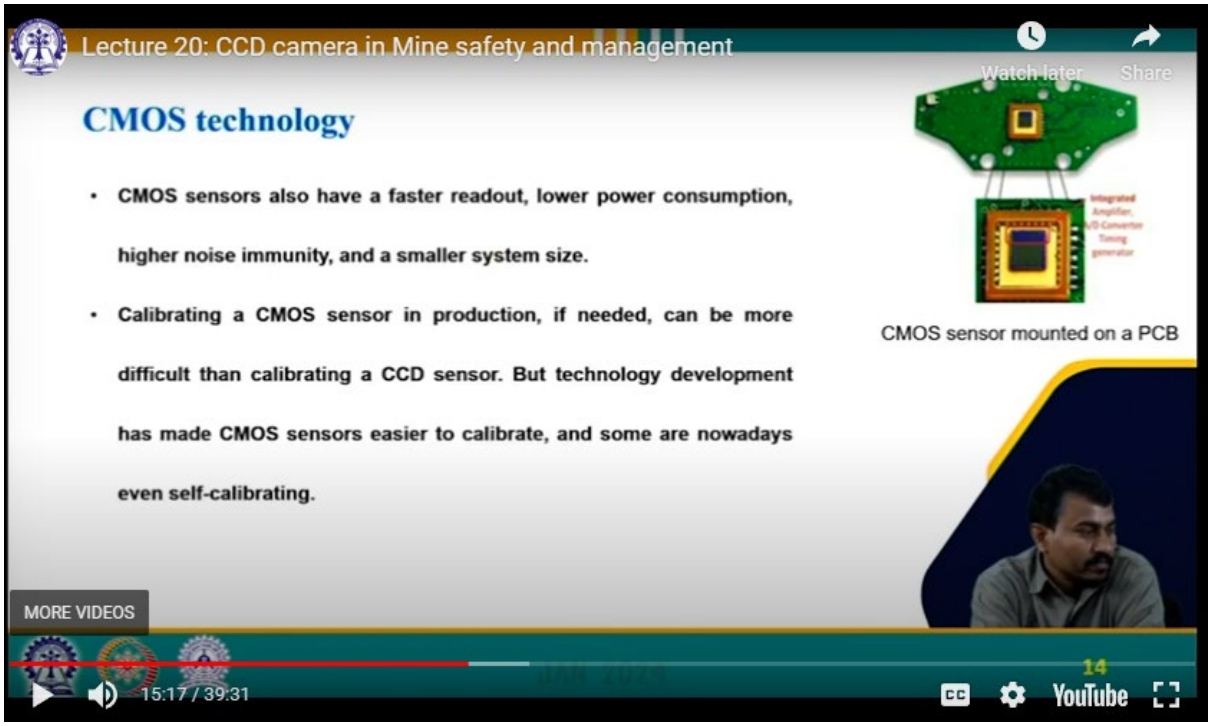
CMS technology, Basically, the CMS technology is developed in the early 80s in Japan and later in the Jetpapansar laboratory in 1993 it was further developed and CMS technology is used since then and early on ordinary CMS chip were used for imaging purposes but the image quality was poor due to their inferior light sensitivity.

The modern CMS sensor use a more specialized technology and the quality and light sensitivity of the sensors have rapidly increased in recent years. So, the complementary metal oxide semiconductor that is CMS is a type of metal oxide semiconductor field effect transistor that is MOSFET fabrication process that uses complementary and symmetrical pairs of P-type and N-type MOSFETs for the logic function. So we have seen in the CCD that is the MOS capacitor

is the building block. Here is the MOSFET is basically the building block of the CMS technology. And here you can see in these circuits particularly in the pixel and their amplifications and it is inbuilt with the analog to digital converters. And this is basically the beauty of the CMS technology, this amplification process and this is very smooth compared to the CCD technology.



So CMS chip have several advantage unlike the CCD sensor the CMS chip incorporates amplifier analog to digital converter which lowers the cost for cameras since it contains all the logics needed to produce an image. Compared to the CCD sensor CMS sensor have better integration possibilities basically in the chip design the CMS sensor is very much suited IC design and it is more functional and moreover these addition of circuitry inside the chip can lead to a risk of more structured noise such as strips and other patterns as well that we have to take care. The CMS sensor have a faster readout, lower power consumption and higher noise immunity and a smaller system size. Calibrating a CMS sensor in production if needed can be more difficult than calibrating a CCD sensor. But technology development has made CMS sensor easier to calibrate and some are nowadays even self-calibrating. So here on the printed circuit board CMS sensors are mounted.



The few differences of these two technologies CCD and the CMS. A CMS sensor incorporates amplifier analog to digital converters and often circuitry for additional processing whereas in a camera with a CCD sensor many signal processing functions are performed outside the sensors. The CMS sensor have a lower power consumption than the CCD image sensors which means the temperature inside the camera can be kept at low. The heat issue with the CCD sensor can increase interference but on the other hand CMS sensor can suffer more from the structured noise.

A CMS sensor allow windowing and multi-view streaming which cannot be performed in a CCD sensor. A CCD sensor generally has one charge to voltage converter power sensor and whereas a CMS sensor has one per pixel. The faster readout from a sensor CMS sensor make it easier to use in multi-megapixel cameras.

How do CMS sensor differ from the CCD sensor in terms of power consumption? (A) CMS sensor consume more power. (B) CMS sensor have lower power consumption. (C) both sensor consume the same amount of power. (D) CMS sensor have no power consumption and (E) none of these.

The right answer is (B) CMS sensors have lower power consumption.

Enhancing mine safety and management with the CCD cameras. Cameras are employed in a variety of industries to allow the driver to navigate in a blind spot region in real-time through a display in the driver's cab. This is a kind of CCD camera typically available in the market.

RGB camera. An RGB that is red green blue camera can be employed for multiple purposes including surveying, mapping, stockpiling, volume calculation, traffic, security surveillance, inspection and many more. To provide depth assessment at a large number of pixel RGB camera employ either active stereo or time of flight sensing technology.

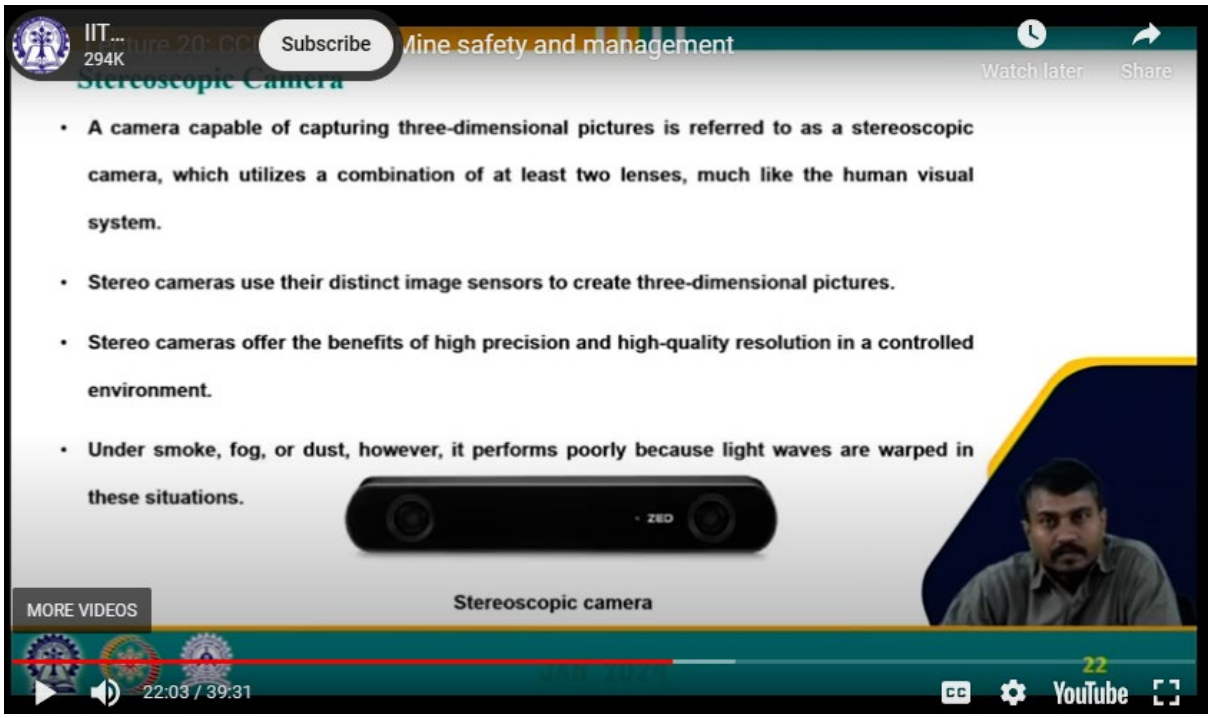
The camera must be carefully chosen taking into account the drone powers consumption. For a fixed wing drone a tiny camera is preferred because bulky gadget cannot be carried. So this is a lightweight camera is often preferred for the drone related applications. Infrared camera. A thermal camera is a type of camera that uses heat sensing technology to detect and display temperature of object in the area of vision.

The thermal camera work by detecting the infrared radiation emitted by the objects and converting that information into an image and that can be displayed on a screen. So this basically use the spectrum between the visible and the radio wave. Infrared camera. This also allow thermal cameras to see through darkness, fog and other forms of visual obstruction. As well as detect hot and cold spots that may not be visible to the naked eye.

So, this can be used in the overburden spontaneous heating because in the overburden sometimes we observe that cool and mixed and due to the spontaneous heating heat is emitted. So, because of that also some pressure is generated and crack also developed in the overburden. So, this can be easily observed and monitored using the infrared camera technology. There are several applications for thermal cameras including security, search and rescue, military industrial maintenance and building energy efficiency management.

Stereoscopic camera. A camera capable of capturing three dimensional picture is referred to as a stereoscopic camera which utilizes a combination of at least two lenses much like human visual system, our visual systems. We always see and we can get a 3D structure around us by the stereoscopic camera system inbuilt in our system. The stereo camera use their distinct image sensors to create three-dimensional pictures. Stereo cameras offer the benefit of high precision and high-quality resolution in a controlled environment. Under smoke, fog or dust however it

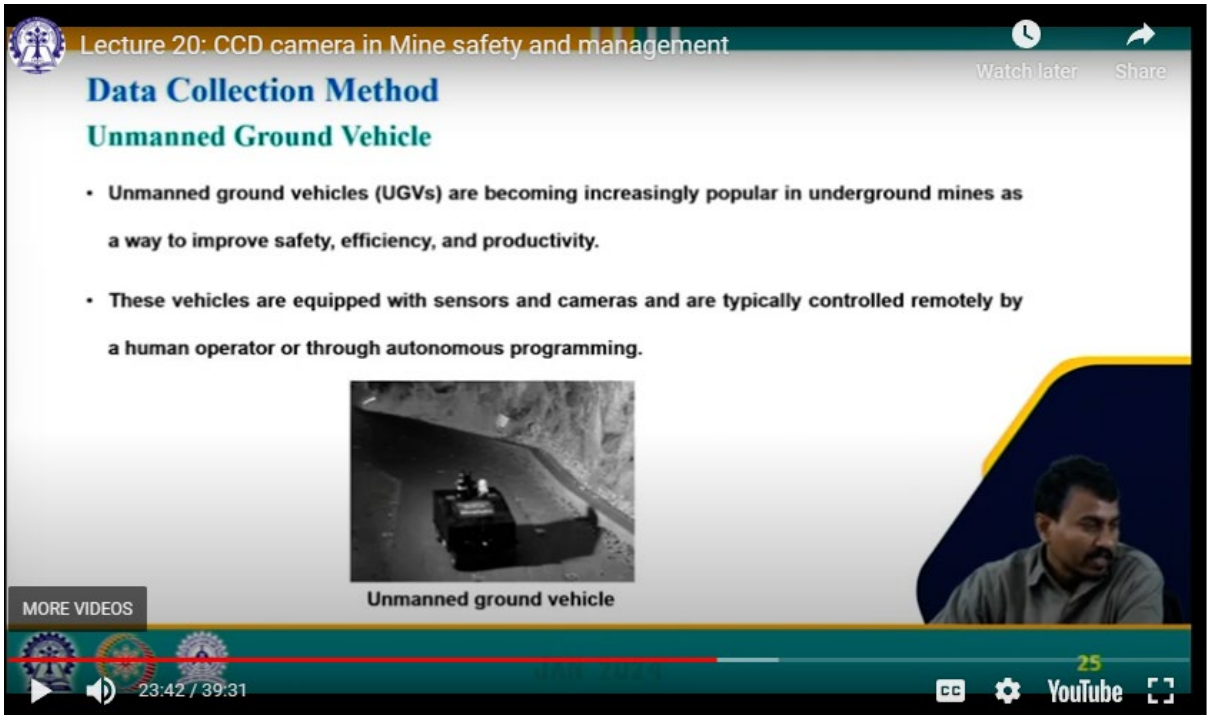
performs poorly because light waves are wrapped in these situations. So this is an image of stereoscopic camera.



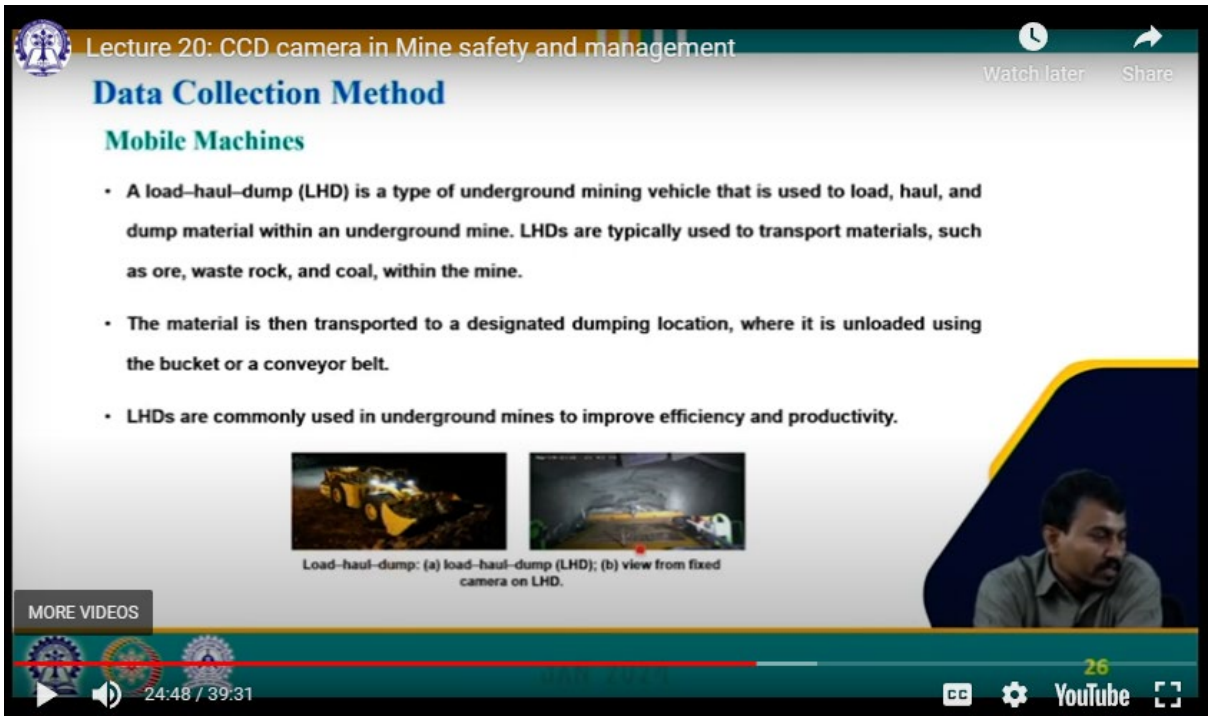
Data collection method. Researchers have conducted various experiments using Ford hardware system here. UAVs that is using drones technology and the unmanned ground vehicles, mobile machines such as load-haul-damp, LHD and last but not the least is fixed camera such as surveillance camera.

Drones are unmanned aerial vehicle can also be used in underground and open cast mines as a way to improve safety, efficiency and productivity. And these drones are typically equipped with sensors and camera and are controlled remotely by a human operator or through autonomous programming. So, this is an image of the drone operates in an underground mines. Unmanned ground vehicle. Unmanned ground vehicles are becoming increasingly popular in underground mines as a way to improve safety, efficiency and productivity.

And these vehicles are equipped with sensors and cameras and are typically controlled remotely by a human operator or through autonomous programming. This is an unmanned ground vehicle. So, it is basically self-propelling. It basically advances in the zone where it is needed already been given command and it can efficiently goes and take the image and that image will be useful for different purposes.



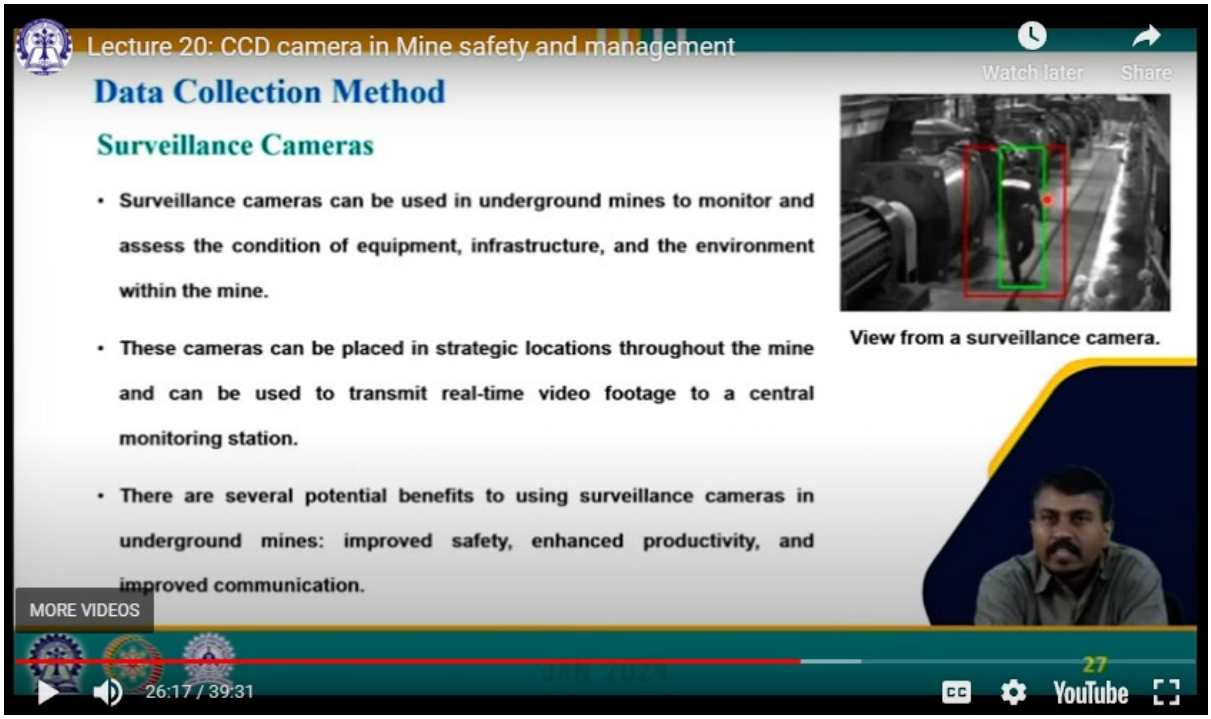
Mobile machine. A load-haul-damp that is LHD is a type of underground mining equipment that is used to load-haul and dump material within an underground mines. So LHD is typically used to transport materials such as ore, waste rock, coal within the mines. The material is then transported to a designated dumping location where it is unloaded using the bucket or a conveyor belt. LHDs are commonly used in underground mines to improve efficiency and productivity. So, this is a typical image of LHDs working in the underground mines.



And here you can see the image that has been captured by the LHD. So, these camera image will be useful for assessing the productivity and functionality of the LHD and for other purpose as well in the underground mines.

Surveillance camera. The surveillance camera can be used in underground mines to monitor and assess the condition of equipment, infrastructure, and the environment within the mine. So, these camera can be placed in a strategic locations throughout the mine and can be used to transmit real-time video footage to a central monitoring station. There are several potential benefits to using the surveillance camera in the underground mines, particularly to improve the safety, enhancing the productivity and improve communications in the underground mines.

This is basically a surveillance camera. This surveillance camera is basically detecting that a miner is moving in the particular vicinity of the mines. So here using some kind of AI technology, we can also assess that whether this particular miner has taken all the PP kits that is required, helmets, belt, light and everything. So using this image we can process, we can detect objects and based on that we can alert, yes, this particular miner is basically defaulted.



So this kind of operations, this kind of applications are also there in the mines nowadays. Algorithmic part that I have already mentioned one. So some of these algorithm, particularly the YOLO algorithm that I have already given you the example, can be used for the object detection. This is basically can be used in the RGB camera image as well as in thermal imaging, that is infrared imaging data for electric locomotives movements, stone falling and pedestrian detections. HOG algorithm is basically for the pedestrian detection and SBM algorithm for enhancing the underground visual places and pedestrian detection. Image segmentation and thresholding is used for overhead boulder detection, pedestrian detections. Navigation and mapping algorithm is used for the RGB image, stereoscopic image, thermal image and from the leader image as well for anti-collision, exploration, path planning, solutions, road sign recognitions, there are some alerts, location estimation method and trajectory controllers. So these are basically the purpose, different type of purpose and few algorithms that is nowadays used.

Surveillance and monitoring. CCD camera can be strategically placed around the mining site to monitor entrances, exits and perimeter areas for unauthorized access.

And equipment monitoring, cameras can be installed on heavy machineries and equipment to monitor their operations and identify any potential issues or malfunctions. Emergency response. CCD camera can capture real-time footage of an incident or emergencies providing valuable documentation for incident investigation and improving the overall response to emergencies. This particularly might be useful when new machines are installed and that is operated and machines are within the guaranteed periods. So, when there are malfunction developed, if there are some video footage, that would give a sufficient evidence that yes, this machine is not properly functioning.

So, it is the responsibility of the part you supplied that particular machine to the mine. So, they will replace. So, these basically also smoothen the process and also it will help the mining machinery company to identify where from the fault basically originates by analyzing these video footage.

Personal safety. Camera can monitor work zones to ensure that employees are following safety protocols and wearing the required protective gears that I have already shown you in few slides before.

That using this camera we can detect that yes, the spectacles, the helmet, and other protective gears, whether that miners are wearing that is required and mandatory so that we can issue alerts and we can issue some kind of notice to that particular miner in the future. So based on these particular applications and use of this technology, management will become easier for the mines management to monitor the progress and movement of different miners inside the mines. And also it will fulfill the regulatory requirements. So using the video footage we can verify the compliance, particularly the safety compliance, the standards, whether we are following the standard operating procedure in a particular site by analyzing the video footage and also workers know that this is we are under the surveillance, so they are also under the compulsions. So, this way, both ways, this will improve the work environment, also it will improve the safety compliance in the mines and also it will ensure that we can avoid the fines and penalties by complying all the rules and regulations during the mine operations.

Training and education. This is a very effective method. Basically using this video footage and the image, particularly some incidents, maybe a roof fall or maybe some machine damage breakage or maybe the wall fall or a support is buckling, this kind of situation may often arise. So, using this image, it basically or maybe some miners was basically very close to the dangerous area that was identified. So basically, using this video footage we can prepare some training materials for our miner that yes, these are the places, these are the points, you basically violated the standard operating procedures. So, from now onwards you can basically follow what to be done. So this image, this data is often useful for creating awareness in the miners. So, this can be used in a positive way in the future. And also it can be used for the new employees that yes, you are going to start a new career in these mines or you are working, so you should also follow these systems, and also you should avoid these things in the future.

Simulation. So, the video feeds from the camera can be used in simulated training scenes to prepare workers for emergency situations. This can be incorporated into the VR system and AR system that we will cover separately in a particular lecture.

Environmental monitoring. The CCD cameras can be equipped with sensors to monitor environmental conditions such as dust levels, air quality and temperature, helping to ensure a safe working environment for the miners.

Environmental monitoring and management. The CCD cameras can be integrated into a centralized monitoring system allowing for real-time remote monitoring of multiple locations within a mine site.

And using the video analytics we can detect the patterns, the anomalies, the trends and providing valuable insights for optimizing the different mining operations towards improving the overall management in the mines.

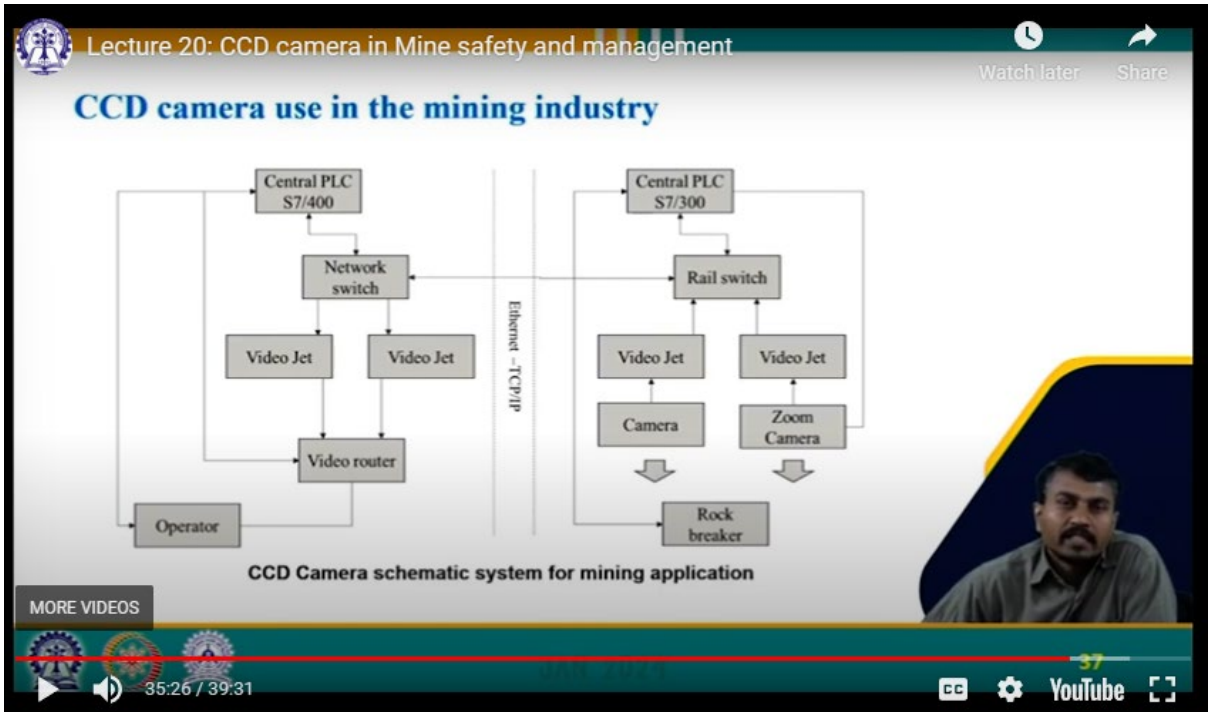
How can recorded footage from CCD camera contribute to training and education? (A) Only as documentation for safety procedures, (B) for live monitoring of the employees, (C) only for creating simulation scenarios, (D) as training material for new employees to understand and adhere to safety procedures and (E) only for surveillance purpose.

The right answer is (D) as training material for new employees to understand and adhere to safety procedures.

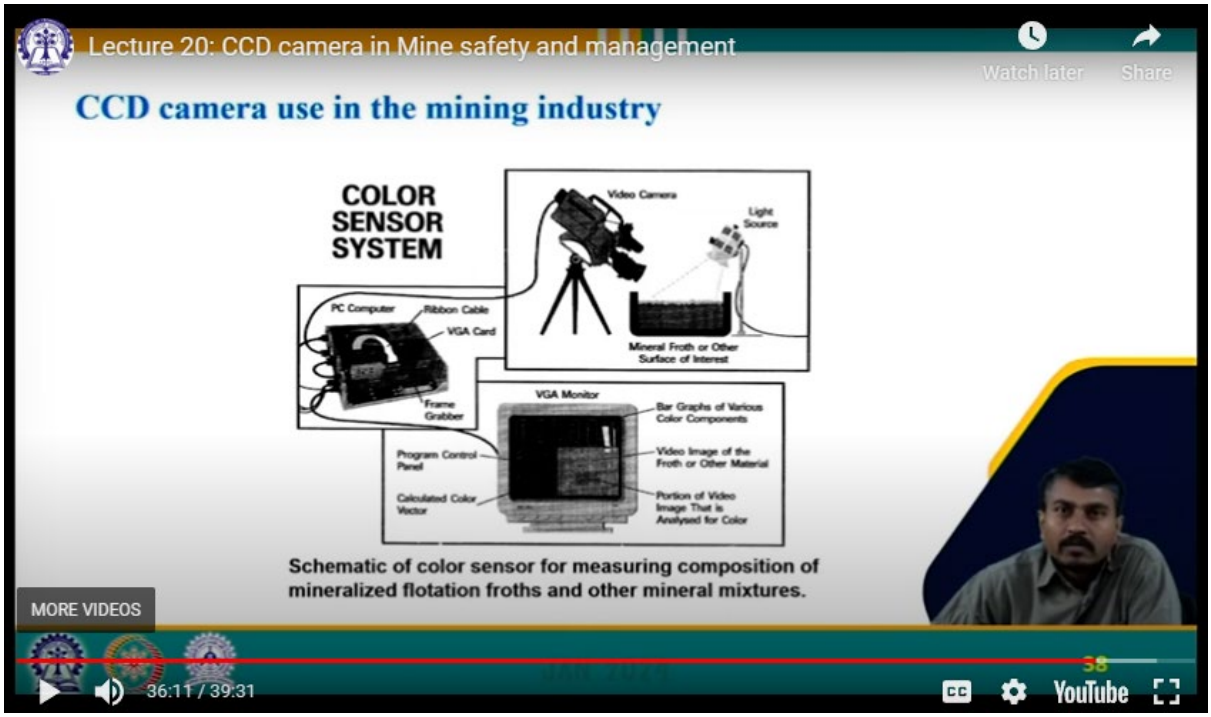
Record keeping. Video footage can be used for detailed investigation into the incident and accidents or near miss, helping identify root causes and prevent future occurrences. So nowadays in the mines root cause analysis is one of the algorithms or methods we follow for diagnosing and analyzing any accidents or why these accident originates. So these video footage will be very good documents for making these methods more and more positive and proactive.

Audit trails. Having a comprehensive records of activities through these video footage can assist in audits and compliance checks.

This is basically an algorithm we have taken from a paper that basically use and using the image processing technique in the feed breakers, whether the how much breaking is basically required based on the image identifications. So, vehicles are basically unloaded on the feed breakers. So based on the size and their identification, rock breakers basically activates to the size. So, this is basically a follow chart that is followed using a path and the logics.

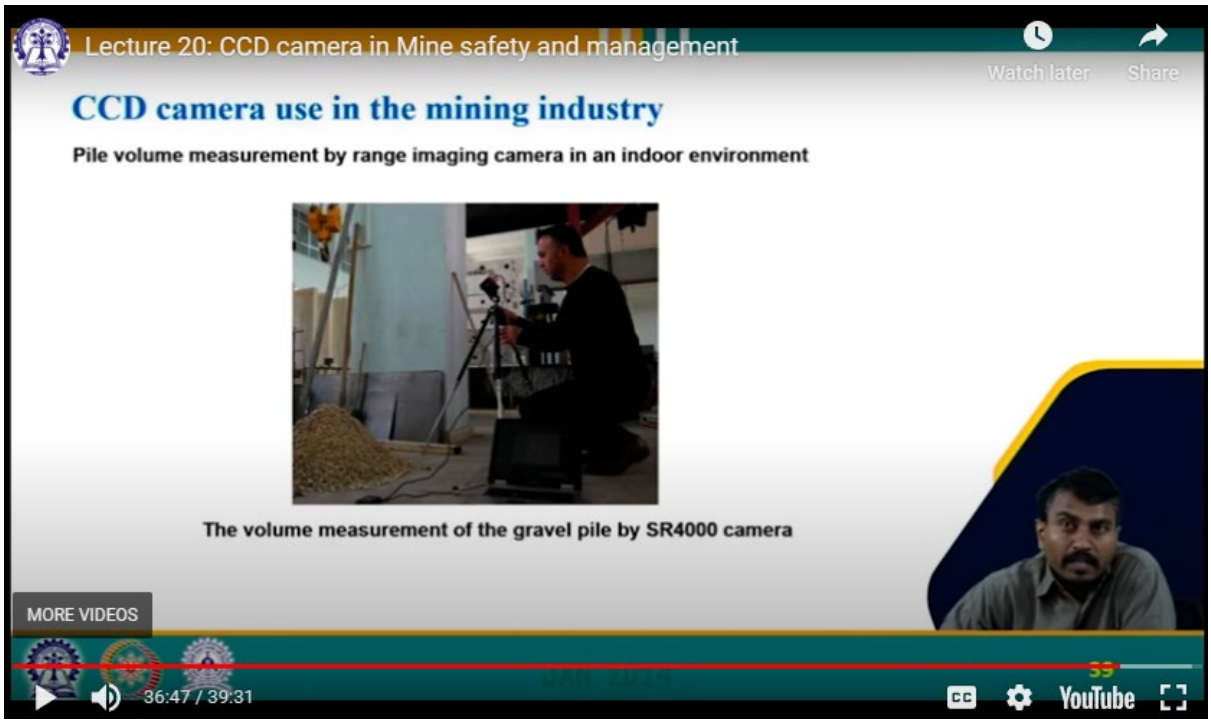


This is a sensing system used for getting some data and the effectivity of the fourth flotation techniques that is used in mineral processing.

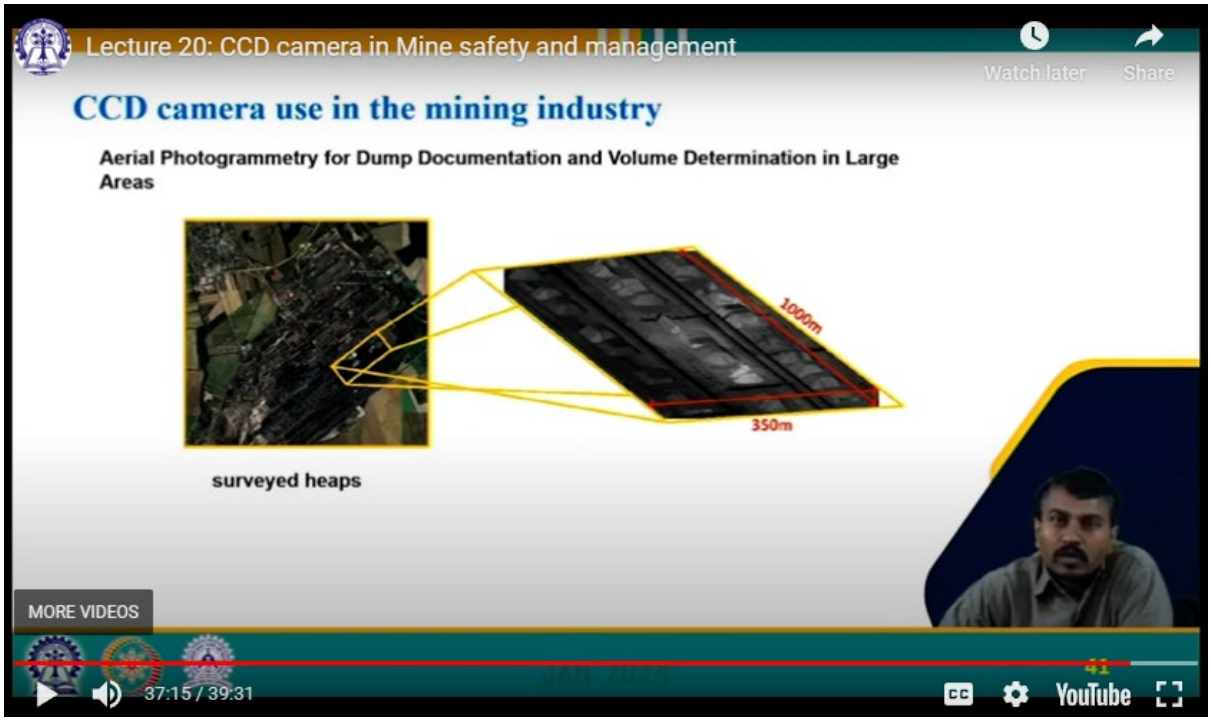


So here basically a camera, visual video camera is fitted and there is a light source and from the top it basically monitors the flotation process and based on that it basically analyze and basically analyze the process of this flotation process. So, this is basically we have taken from case studies.

We can use this CCD camera and imaging technique for pile volume measurement by range imaging camera in an indoor environments. This is basically the pile is image and there is a 3D reconstructed mesh and this is basically created using the image processing techniques.

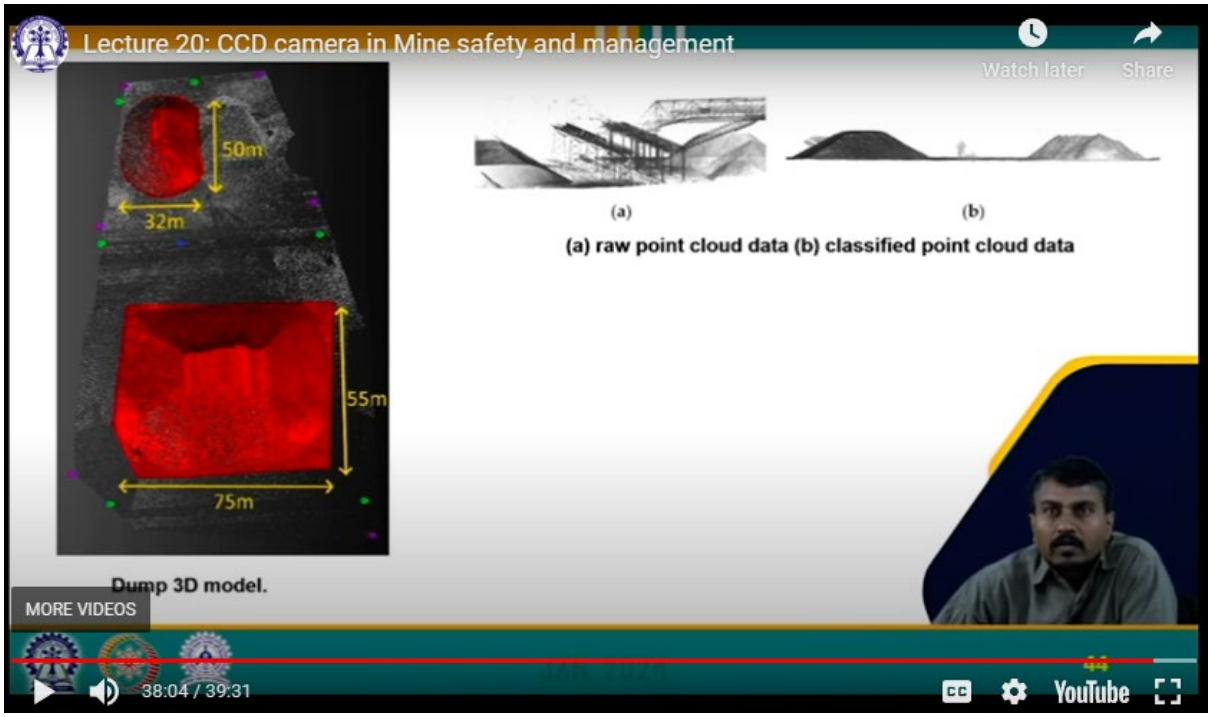


Aerial photogrammetry is used for dumb documentations and volume determination in large areas and these aerial photograph is also used for machine detections from the aerial image where the machine was, whether the number of machine is okay or not.



For auditing purpose we can use also. This is basically the aerial imagery technique, EOV technique that is used for large area surveying and monitoring. This is a workflow using the

TLS and the aerial photography technique for basically volume analysis, surface analysis of a mine particularly for the open pit mines. This is by that we are creating the 3D dumb models using this data and this dumb model can also be used for the processing plants, the material is piled, their quality and their volume also we can assess in real time using the image. Activity estimation of excavation process by productivity assessment.



Point cloud and excavation site before and after video recording. So, we can assess easily how much activity is going on, so we can develop using this image some index of activity going on in that particular site.

These are the references.

So let me conclude in few sentences what we covered in this particular lesson. We have provided an overview of image-sensing technology. We have explored the CCD technology as a technology for image sensor. We have explored the complementary metal oxide semiconductor that is CMS technology, is another image sensor technology. We have discussed the difference between these two technologies, CCD and the CMS. We have examined the method employed for data collection using the image sensors. We have explored the application of CCD cameras in mining operations. We have provided specific instances and use cases of CCD camera within the mining industry.

Thank you.