Mine Automation Data Analytics

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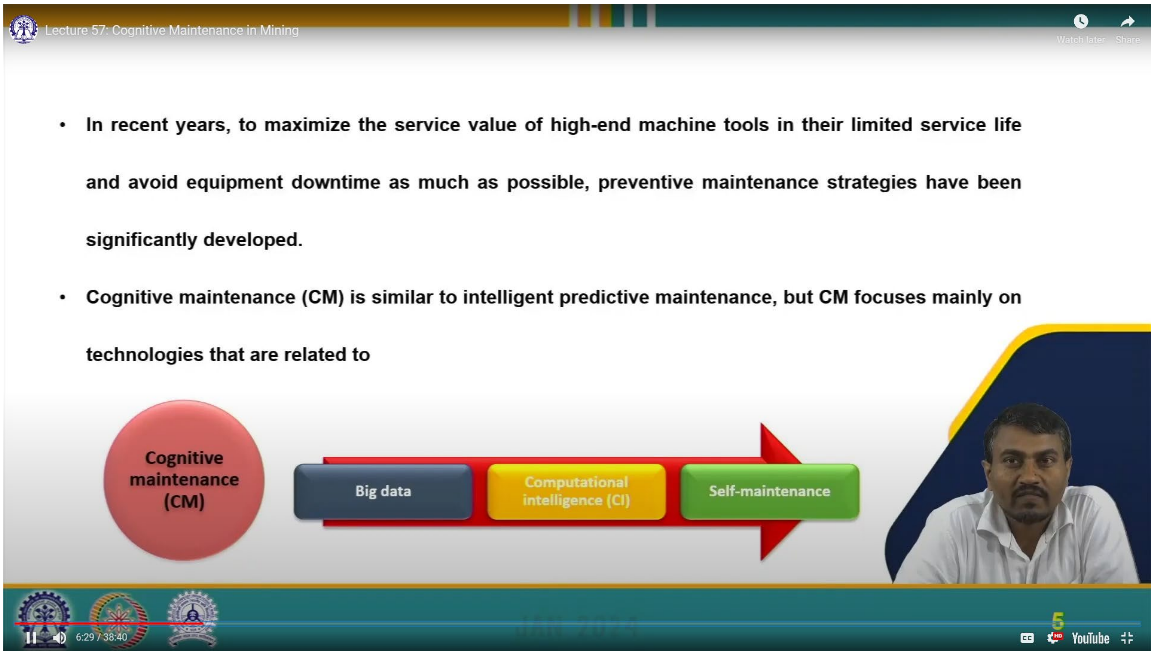
Week-12

Lecture-57

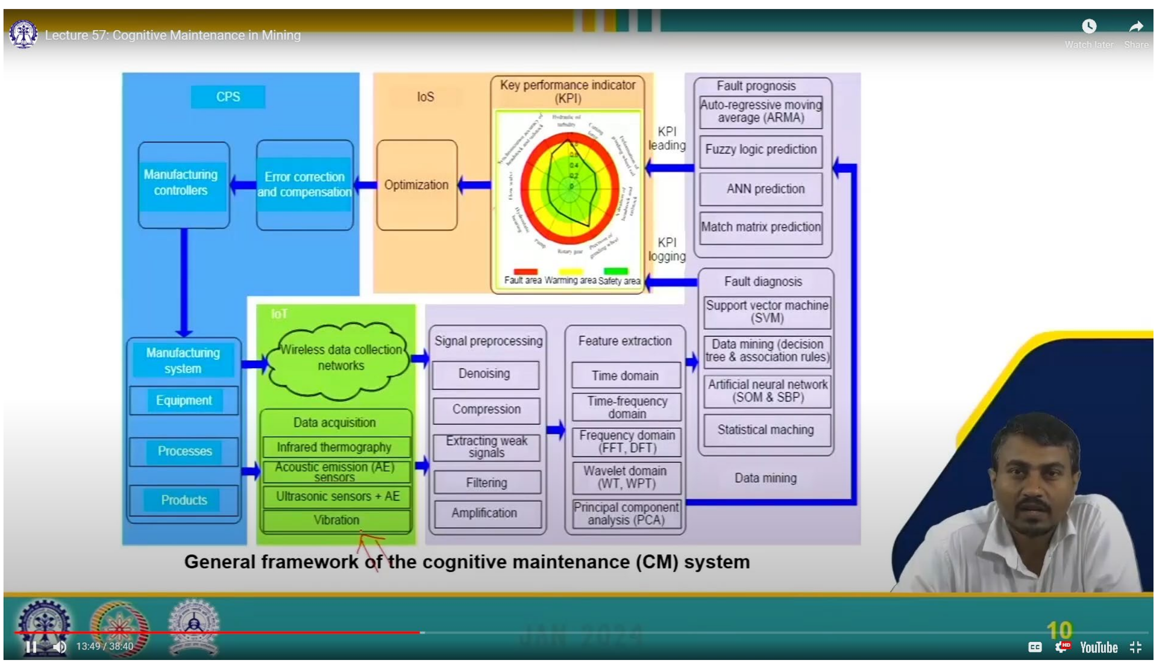
Cognitive Maintenance in Mining

Welcome back to my course, Mine Automation Data Analytics. Today, we will discuss cognitive maintenance. We have already covered in the first part of this course different maintenance strategies for the mining industry. So, in this lesson today, we are going to focus on future-trained machine maintenance, particularly in the mining industry, taking advantage of recognizing the powerful impact AI is making in the industry. So, cognitive maintenance is utilizing the full potential of artificial intelligence for delivering better maintenance, for delivering much higher utilization of the machines, reducing the machine downtime significantly, making the maintenance easier to control from a distance as well. So, in length breadth, we will discuss today the different parts components of cognitive maintenance. So, this is basically the advanced version of the maintenance plan for the mine equipment, it is future-trained. In the coming days, the mining equipment will be integrated with this kind of cognitive maintenance plan. So, in this lesson, we will discuss what cognitive maintenance is, the different frameworks of the cognitive maintenance plan, which the cyber-physical system, the internet of things, data mining, finally the internet of services. So, these are the four main components of the cognitive maintenance plan in mining. Finally, we will deliver the systematic framework for fault diagnosis prognosis because, ultimately, we have to predict before what is going to happen in the machine. So, just like human health, we have different sensory organs, by that, up to a certain limit, our health is self, which means they are developing self-control. So, in the next version of the maintenance plan, that is the cognitive maintenance plans, we are looking for integrating huge amount of sensors collecting huge amount of data that gives us a better insight about the machine behavior, its micro level behavior event so that based on the data we can analyze the performance of the machine. So, modern machines are equipped with many sensors, at the enterprise level, the machine value is also increasing. So, we want to maximize the use of this machine by effectively integrating the maintenance plan through the development of AI in the industry. So, this is basically the crux that AI integrated with the maintenance plan: a huge amount of sensors are integrated to collect the data, collect the status of the machines, deliver a good result, provide an before warning so that we can take action that will help to avoid those kinds of mishaps or faults in the machines. So, because of the high accuracy required in the maintenance, it is very difficult or challenging work for the high-level machines to maintain with a high level of efficiency high level of maintenance. So, here the cognitive maintenance is coming to rescue coming to help aid further progress to the higher end give a higher end of control over the machine maintenance. So, we basically want to integrate the cognitive maintenance plan into machine maintenance to take advantage of the advancements already made in artificial intelligence, we also want to ensure that a huge amount of investment has already been made in the machine. So, we want to utilize the machine to its maximum limit; we want to enhance the service life of the machine to its optimum level. To do that, we need to incorporate something more into the conventional one.

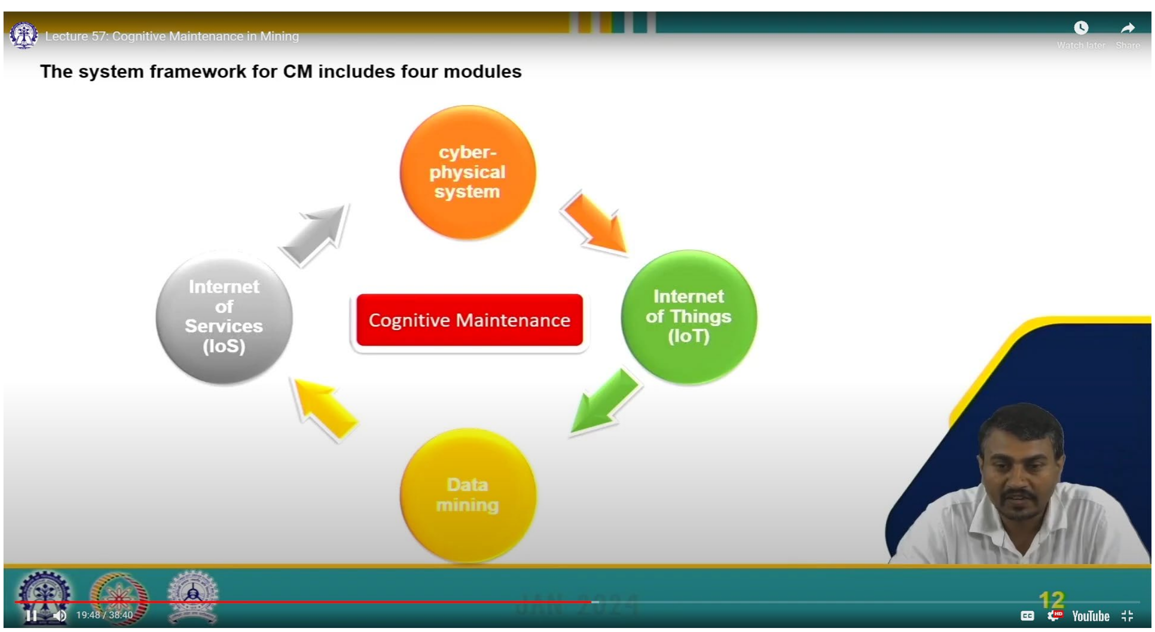


So, the cognitive maintenance strategy is going to take the help of big data, computational intelligence, finally self-maintenance. So, these are the three crux areas in which cognitive maintenance focuses on the maintenance. So, with these advancements, we are collecting a huge amount of data, so it is the task of the engineer the module of the cognitive maintenance plan to understand what kind of pattern is hidden in this data, based on that, let us try to predict what this pattern says. This pattern says to go in which direction, so identify that direction, identify that specific phenomenon, based on that take maintenance. So, in that way, these maintenance kinds of things will become more automotive in the future in the mind of machine maintenance plans.

So, this cognitive maintenance is basically the very important area of the industry 4.0 as well as mining 4.0, as different developments are taking place in the industry 4.0 as well as mining 4.0. The cognitive maintenance strategy is also enhancing upgrading to take higher control over the machine behavior, understanding the machine behavior, predicting the machine behavior in advance so that we can utilize the machine to its maximum limit. So, this CM, which is the cognitive maintenance plan, is not only going to reduce the time of the maintenance but also the labor cost of the maintenance-related work compared to the traditional maintenance methods that are presently prevalent in the mining industry. So, Industry 4.0 is aiming at integrating a huge amount of sensors into the production process to understand the status of the process, the pattern of the process, its conditions, its health. So, we are collecting a we are collecting a huge amount of data in real time, that is a challenge in terms of how to utilize the data. So, here the cognitive maintenance plan is going to utilize this data do the deep data mining algorithm to understand the pattern of the huge amount of data. Data is a wealth, so that wealth we are mining to understand what is there, what kind of pattern is there, what kind of understanding is there. So, based on that, we are going to make an informed decision about the maintenance action of that equipment. So, here we are basically leveraging on the data we have collected; we are utilizing the data in a better way to understand the machine, to work out with the machine, to help the machine reduce downtime, the down time, to make the equipment work for a longer period of time to its optimum limits. So, we are basically going to take advantage of the big data the AI artificial intelligence that is already developing in these cognitive maintenance plans. So, this is basically an advanced stage of the preventive maintenance plan.



So, the framework of cognitive maintenance: So, industry 4. 0 is basically marked by different interconnections of different sensors, that gives us a very clear picture of the physical world, the machinery that operates, all this data is now up on the cloud, in different machine manufacturers, data is also up in the cloud. So, there should be some synchronization, there should be some merging, there should be some kind of cooperation collaboration, that is why nowadays these machine companies are developing the machining centers, these machining centers are the warehouse of the big data, these big data are utilized for the machines for their maintenance for their better utilization to understand the different status of the equipment at different points in time so that we can understand what basically the reason the machines now behave like this. What basic condition that leads to behave the machine like in this way. So, the IoT, its integration, the data in the cloud, the machining center combine to help us understand to a much deeper level the health of the machine. So, the goal of the CM, which is cognitive maintenance, is to maximize the continuous failure-free run time of the equipment, avoid failure downtime, minimize plan-downtime. So, in smart factories, the IoT internet of things avoids the emergence of information. We are not keeping the information there; we are basically collecting that data; we are communicating the data the machining center to the cloud so that a good interface is developed between the machine machine between the machine people to utilize the data for future maintenance, not only future at that level of that time. So, all kinds of factory data we are collecting, including the different sensor data, we process, we basically use it at the enterprise level. So, this CM cognitive maintenance basically combines this multi-source data with advanced predictive models analysis tools to diagnose preventable equipment faults. So, in advance, we are going to predict how the machine will behave, so that will be a big help to the mining industry the mining companies. So, this is basically the framework of the cognitive maintenance plan. If we look into the picture very well, this is the first part; this is the IoT. Here is the main part: we have different sensors, different kinds of sensors, infrared thermography, acoustic emission sensors, ultrasonic sensors, vibration sensors, accelerograms, temperature sensors, pressure sensors, whatever necessary. So, this IoT is basically a kind of integrated wiring on the machines, that helps to collect different data at different points on the machines about their health. So, these data are transferred wirelessly or through our network to the cloud. So, once this data is transferred to the cloud, it is now data, we require processing. So, now this data might be of different kinds of signatures, different kinds of means (wave, frequency, kind of data, text data, digital data, whatever kind). So, now the first step is signal processing, we have to compress if the data size is high, from that, we have to extract meaningful information from this data. So, that is the feature extraction, the next level. So, we have to analyze this data based on the time domain, frequency domain, frequency time domain, or through the wavelet domains or the principal component analysis. So, once this is done, then the data mining part: from that data, we have to understand the fault prognosis, we have to understand the autoregressive moving average of the machine performance, we have to predict the machine performance using ANN or fuzzy logic predictions, we have to do the fault diagnosis using maybe the support vector machines or the different kind of regression algorithm or the clustering algorithm, there is a decision tree or associated rule, we can also apply the statistical tools as well. So, now, based on that, we have the key performance indicator, KPI. So, based on the data that we are collecting through the IoT, it is processed, meaningful information is extracted, then it is processed. Data mining is done, now the KPI, or key performance indicator, of this kind of plot will help us to understand the present status the health of the machine. So, here we are basically developing the fault area warning or area safety in this particular dashboard. So, based on that, we want to optimize the internet of things. Then, based on that, we are basically developing the cyber-physical system at the manufacturing level based on the different kinds of manufacturing controllers, removing the errors, compensating for the errors at the manufacturing center or machining center level. So, here it is interconnected with the manufacturing system, equipment, process, product. So, this is the whole idea of the cognitive maintenance plan or cognitive maintenance of the mining machine. From the manufacturing level to the site level, it is interconnected through the network, the data is transmitted in both directions. So, it is a circular kind of orientation of the data; it goes on on so that we can utilize the machine to its maximum limit. So, we have seen the framework, so within the framework we are collecting the data to know about the health of the machine, based on the abnormality, we are going to identify at which point the abnormal behavior is that or whether these abnormal behaviors lead to machine failure or not. So, this decision-making process is a very important part of the fault diagnosis that will empower our maintenance staff to understand the necessary measures about the impending anomalies or failures via the internet of services that are basically helping to maintain the machine effectively at the site level, we are basically taking prompt action so that we are basically mitigating a kind of failure at the site level. So, this is basically an interactive, collaborative, coordinated effort both by the manufacturing organization as well as the operating organization of the mining companies, this cognitive maintenance plan is working with close cooperation collaboration with these stakeholders in the mining industry.

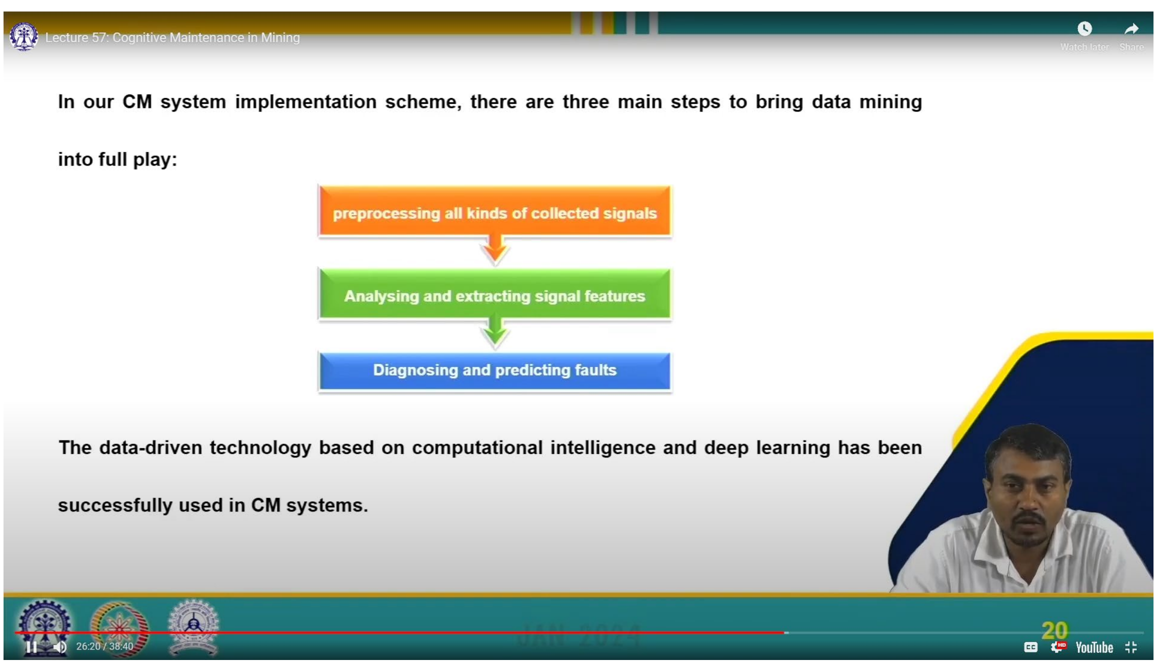


So, the CM basically includes the four modules: the cyber-physical system that we have seen, the internet of things, which is the different sensor integration, the data acquisition part, the data mining,We have to understand what data says all about machine performance, machine health, finally, the internet of services, We have to make a connection with the site level from the manufacturing level machining center so that we can deliver effective maintenance, effective kind of instruction, effective kind of maintenance so that we are predicting some kind of fault may come we are taking recording action so that we are avoiding those kinds of failure. So, this is basically the beauty of this system.

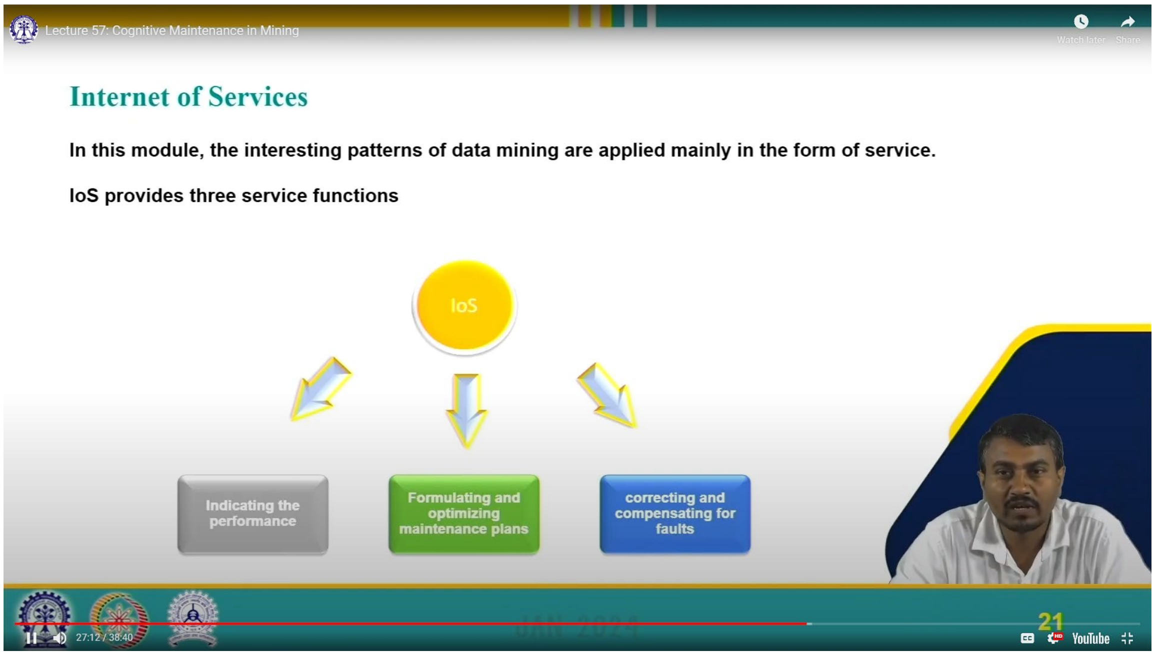
So, the cyber-physical systems (CPS)—what is that? So, this cyber implies the integration of computation, communication, control, it is in the virtual space. The physical indicates a real space, that is a natural humid-made system that is governed by the laws of physics, the management of this earth, different countries rules regulations operate in continuous time. So, the CPS, which is the cyber-physical system, is both cyber- physical-virtual real; they are basically tightly integrated at all scales levels. So, this is the beauty of this cyber-physical systems (CPS). So, this CPS is basically a very crucial part of the industry 4.0 framework the mining 4.0 framework for seamlessly integrating the computational facilities the physical process. It it is employing the embedded computers networks to process data, facilitate communications among the components, control the physical process, continuously exchange feedback to optimize the interplay between the computation physical operations. So, this CPS module is playing an important role in building up the foundation of cognitive maintenance. So, the major responsibility of the CPS module is to give the manufacturing system the function of perception—how the machines behave—that is, the ability to perceive its own state the state of the surrounding environment. So, the entirety of the manufacturing system comprises equipment, production processes, products, with monitoring of the production condition facilitated through the connection of relevant sensors equipment. So, the selection of the sensor depends on the type of data required for monitoring. Which kind of sensor will we select? What kind of data is required for us to understand machine behavior machine health? So, accordingly, we have to select the required sensor at the different points of the machines. So, for example the vibration sensor we can install to understand during the operation of the machines how the machine behaves. We can install the accelerogram to understand how much amount of acceleration on different part of the machines. We can install different kinds of thermal sensors to understand during the operation at what level the temperature goes in the mine machines, or we can also install a temperature sensor to understand how the coolant is behaving during the process. So, additionally, a computer vision system may be utilized for real-time monitoring of the manufacturing process, such as an electronic fence.

So, the next is the Internet of Things-This Internet of Things enables us to get an idea of the interconnection interoperability through the sensors network. So, this function of the IoT module is mainly data transmission. The sensor is collecting data transferring the data to the cloud through a wire or wireless network. So, the data collected by the sensor on the device is transmitted to a local database or cloud center through the IoT for subsequent module calls. So, the equipment in the factory is equipped with a supervisory control, which is the SCADA, to monitor the status of the machine. So, here it is a challenge to integrate the SCADA data into the data module, different equipment sensors are also there to further analyze the status of the machine health. So, here, based on this huge amount of data that is collected through the SCADA, we can mine it, we can apply the analytics tool to understand in greater depth what the status of the machine is, based on that, we can diagonalize the real state of the machine at that point in time.

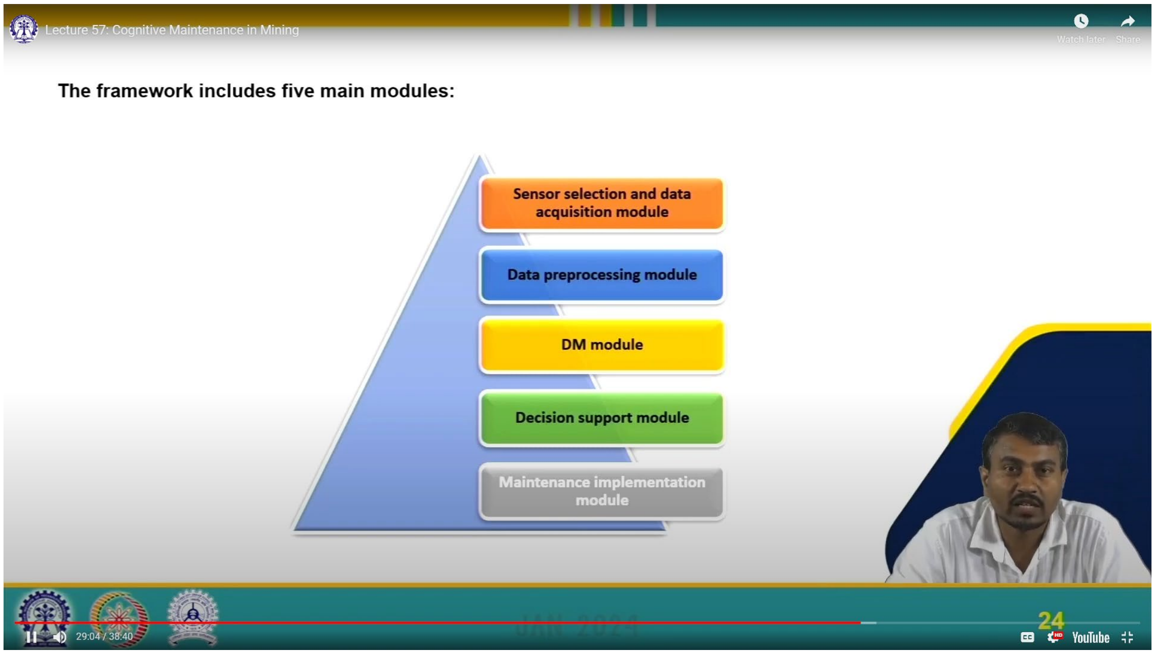
Next is the data mining-So, this data mining is the key very difficult module to implement in the cognitive maintenance plan in the mining industry. So, the cause of the equipment failure is determined here, the degradation of the equipment or the component is predicted based on the strong data analysis the processing capabilities. At this point in this module, we are basically analyzing using the different AI machine learning approaches to understand the machine status, the reason, what kind of action may be taken. So, at the small enterprise level, it is very difficult to implement this process because of the big data issue the installation integration of a large number of sensors at the mining level. So, in this CM, there are basically different parts the CM level at the data mining.



So, first is the pre-processing of all kinds of collected signals. We cannot ignore a single signal. We have to use all these signals except the error one. So, then we have to analyze extract the signal features. This signal says all about the status of the machine. Then, based on that, we have to diagonalize predict the impending faults of the machine. So, this whole approach is data-driven, this whole approach is a scientific approach to understanding machine health utilizing computational intelligence deep learning in the cognitive maintenance module.



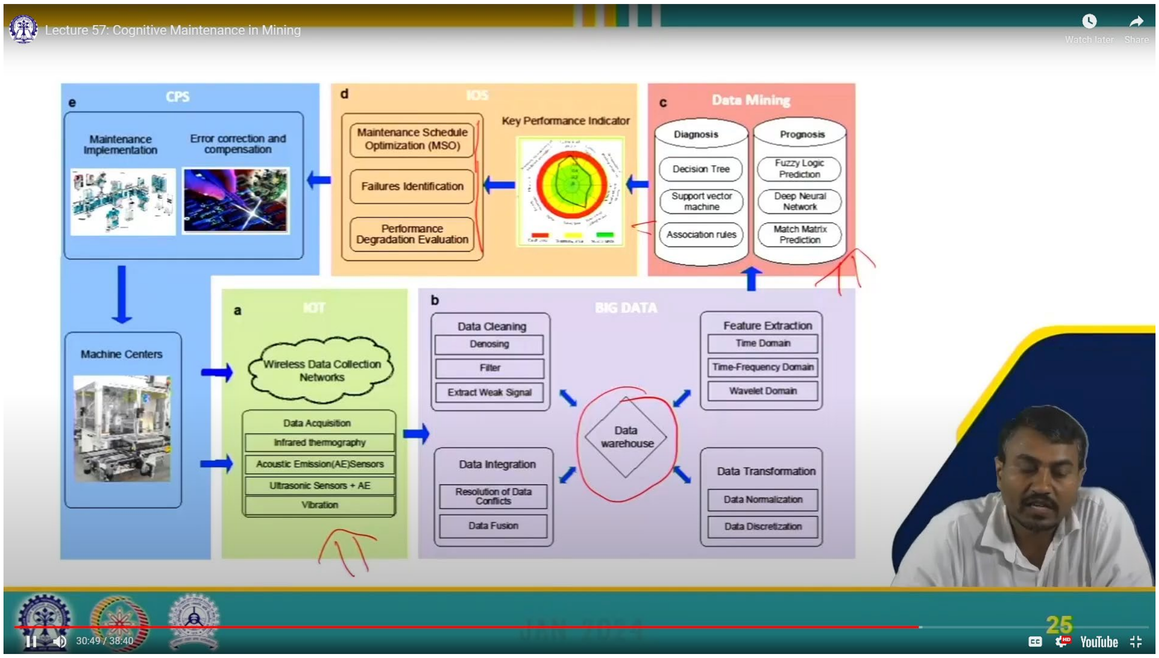
The Internet of Service-So, this module is basically establishing a connection between the manufacturing organization's machining center the site level for a better maintenance plan. So, iOS basically helps us to correct compensate for the faults. Second, it basically involves formulating optimizing a maintenance plan. third, it basically indicates the performance of the machine. So, the iOS is basically a supporting center at the site level of the machine, from the manufacturing level or the machining center level. So, that machine can run continuously, smoothly, seamlessly without any hazards. So, let us go to the systematic framework for fault diagnosis prognosis. So, with the emergence of computational intelligence data mining, we are utilizing this for the impending failure that will come based on the data analysis. based on that, we are optimizing machine performance. So, this system monitors the planned floor assets, links the production maintenance operation systems, collects data gathers feedback from remote customer sites, integrates this data into upper-level enterprise applications. it uncovers the hidden insight about impending failure generates maintenance knowledge. Additionally, it monitors the manufacturing process states predicts equipment condition, that is the beauty. So, through effective maintenance decision-making, it prevents mitigates failure, ensuring equipment personal safety while reducing economic losses. Leveraging fault diagnosis, degrading level performance assessment, a fault prognosis model, it aims for near-zero breakdown enhances company productivity.



So, the framework includes five main modules: the maintenance implementation module, the decision support module, the data mining module, the data processing module. finally, there is the sensor selection data acquisition module. So, sensors collect the data transfer it to the cloud, based on that, we process the data, so that is the data processing module. by processing, we are basically mining out the feature, mining out the status of the machine, based on that, we are basically identifying the status or diagnosing what is the reason for this failure of the machine what kind of parameters lead to these kinds of conditions. So, that is basically integrated with the decision support modules from the machine center level, finally, we are doing the maintenance implementation module to adjust, collaborate, cooperate, coordinate with the site level from the machine centers. So, this is again a more abbreviated version a more challenging version of this cognitive maintenance plan. So, here at the IoT level, we are collecting data. The first level, the second level, is big data through different kinds of sensors. We are collecting a huge amount of data; we record the data warehouse. from this data warehouse, different kinds of data mining processes are integrated, based on that, we are diagnosing the reason for this based on different machine learning approaches. then we are plotting that through the key performance indicator, the status of the machine, the internet of services, here we are integrating maintenance schedule optimization, feature identification, performance degradation evaluation. it is connected through the cyber-physical systems (CPS) to make the whole system integrated cyclic, so the data can be seamlessly transferred from one end to the other end from the machine center itself. So, the machine center is directly connected at the side level of the machine, it is collecting the data, understanding the data, processing the data, optimizing the maintenance schedule. So, this is the end output gives the machine a better, higher life. So, the important part is the sensor selection the data acquisition. So, what kind of sensor will we select, what variety of sensor is required for this to be understood? That is a very important part. So, this data acquisition process transfers the sensor signal into different domains—time domain, frequency domain, frequency time domains—for different kinds of processing. So, the various sensors, such as microsensors, ultrasonic sensors, vibration sensors, acoustic sensors, emit emissions that basically collect information about the condition of the machines. So, the selection of the sensor determines the representation of the machine cell based on the collected data, considering both the specification cost effectiveness. Moreover, with the increase in complexity of the machine system, the sensor network is considered a feasible solution for the diagnosis prognosis system in the machine center, which may include different kinds of sensors.

Data processing module-So, once the data is collected, it is the part of the warehouse where, based on that data, we have to discover what is basically irrelevant data, what is noise, what is unreliable data. We have to remove that so that it will not further cause any kind of problems. So, because if there is a huge amount of error data, that may lead to a wrong conclusion. So, we also have to take precautions about that, we have to process it to the next level.

So, here we have the four parts: data cleaning, then data integration reduction, finally the data transformation with a suitable format. So, the data cleaning-So, it is the process of detecting correcting corrupt or inaccurate records from the database by filling in machine values, smoothing noisy data, identifying or removing outliers, resolving inconsistencies. The data integration-It is the process of merging data from multiple data stores. Careful integration can help reduce avoid redundancy inconsistencies in the resulting data set. The data reduction-It provides a reduced representation of the data set that is much smaller in volume can produce the same or almost the same analytical result. So, here we utilize the different dimension reduction techniques, but we must understand that the principal feature of the data should not be lost. The principal characteristics of the signal should not be lost. So, we are also keeping track of that so that based on that, we can understand the incipient failure of the machines. So, generally, we basically transform the data into three domains: time domain, frequency domain, time frequency domain. Then comes the data transformation. So, data are transformed or consolidated into forms appropriate for data mining, as such, the data mining process may be efficient the pattern we can understand more easily. So, here, the data preprocessing can effectively clean the raw data, reduce the dimension of the data, store it back in the warehouse of knowledge discovery. So, here we have massive data, utilizing different kinds of statistical tools, we can understand the pattern of the data using the data mining process. So, now the data mining module. So, the data mining module has the capability to discover hidden links,



recognize unknown patterns, predict future trends by digging through analyzing an enormous set of data. So, the functions or modules of data mining can be categorized according to the task performed, such as clustering, classification, decision trees, prediction, regression, association. So, generally, the analysis method of data mining can be categorized into three groups: statistics, machine learning, artificial intelligence.

Then, in the decision support module, the main purpose of the module is to visualize the result of the data mining part provide an optimized strategy according to the data mining. So, a general diagram using the key performance indicator is basically done, it basically calls it a it a spider chart, that basically shows us the status the situation of the machine at that point in time. So, this condition of the equipment can be defined at several levels, from 0 to 1. 0 indicates there is no fault, 1 indicates the machine has completed a breakdown. Then comes the maintenance implementation module. In this module, maintenance will be implemented after the decision-makers choose the strategy of maintenance, which can be considered the purpose of the cyber-physical systems (CPS). So, the physical world is transferred into the virtual one for communication, computation, analysis, decision-making via the previous module. So, in this module, the physical world basically reacts to this module implements the maintenance strategy to make zero-defect manufacturing reduce breakdown. Moreover, this module may also include the functions of error correction, compensating, feedback control based on the results of the maintenance decision support module to continue to run the equipment process in a normal condition. different techniques can be used to correct compensate for the error. ANN has widely been used for compensating for backslash errors in the computer control machine center. However, the error correction compensation process are mainly dependent on the type of machine the processes, this module should be integrated with the control device the maintenance management system.

So, these are the references. Let me summarize in a few sentences what we have covered. We have provided an overview of the cognitive maintenance plan to optimize machine performance, we have explored the structural framework of the cognitive maintenance plan that integrates data, the data analytics tool, the predictive modeling tools, the decision support tools for a better maintenance strategy. finally, we have discussed a very systematic approach for diagnosing faults predicting the failure of machines in real time or with time so that we can leverage the cognitive maintenance technique to improve the safety, reliability, uptime of the machines. Thank you.