Mine Automation and Data Analytics

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Week-5

Lecture-23

GNSS Case Studies – Part II

Welcome back to my course, Mine Automation and Data Analytics. In this lesson, we will discuss on the case study of the GNSS and using the GNSS how we can aid in the automation process. So, in this lecture, we will cover the following. In global navigational satellite system technology for automation of surface mines, basically, the case study is of a lignite open pit mine, and we will briefly discuss what these mines and different machines installed and the application of GNSS and how the volume calculation is done. And finally, we will compare the result that we are getting using the GNSS system with the photogrammetric methods and we will compare the accuracy.

So, we will try to illustrate how the GNSS technology can be used in an open pit mine for the surveying purposes and also provide supports in the mining process chain. We have already seen that using the GNSS, we can locate the position precisely. We have also discussed the case studies of the GNSS to map the landslides in mines. So now we are concentrating on the GNSS usage in the machines to estimate to get the day-to-day production value precisely with comparable to other methods. So, this particular study aims to enhance the precision and productivity of the mining equipment, more particularly the bucket wheel excavator and time to time we will basically measure the spatial location of the bucket wheel excavator. So, it is basically a lignite mine. So, bucket wheel excavator are used for the production purposes. So as its move, as its move changes that spatial location is noted time to time and based on that, we are proceeding to the next stage. So, in this case study, we have three number of bucket wheel excavator K800-103, KU-322 and KU-327 and these bucket wheel excavator is equipped with different sensing setup along with the GNSS system and particularly the inclinometer is there and incremental measurement is done time to time speed measurement is there, and there are so many sensors attached to this bucket wheel excavator.

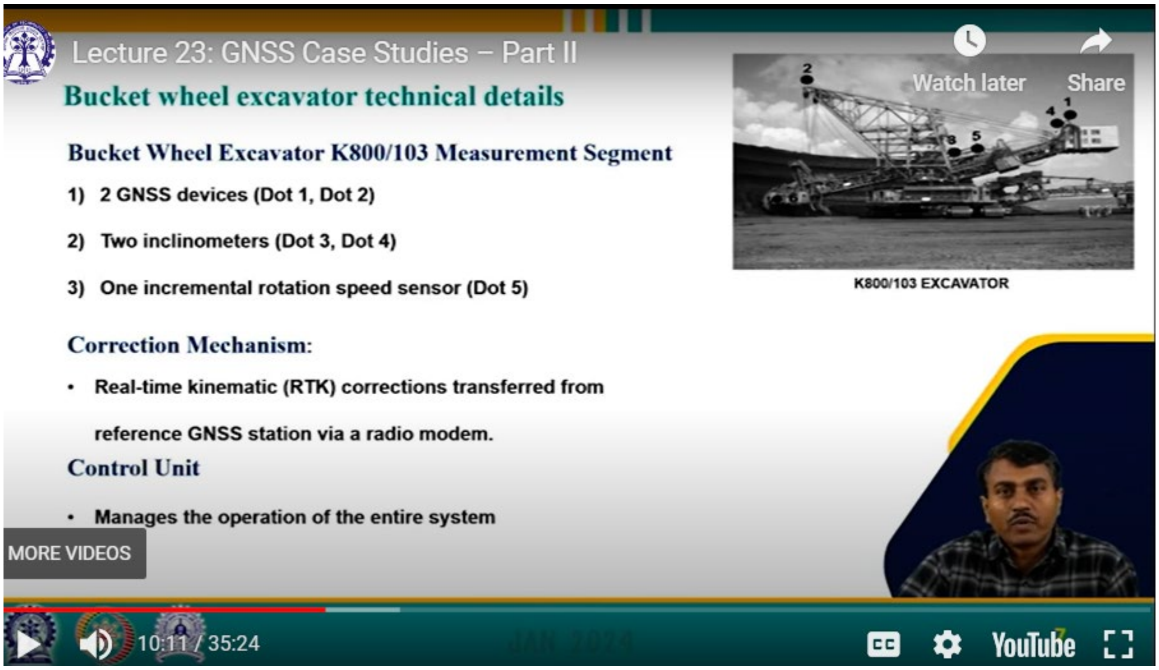
So, this is the site where this case study was conducted. It is a Libus Open pit mines. It is a lignite mine. So, it is situated in northeast of Bohemia and in Czech Republic and as we know and as we know that these lignites basically contributes around 38% in Czech Republic for the power sources basically and so it is a single major contributor for the power sources, energy sources in Czech Republic. So, the performance and optimization of these mine performance is very essential more, particularly in the context of Czech

Republic, Poland and Germany because in these countries lignite is a major source of energy in the power sector. So, this particular setup have these facilities that is the spatial position computed time to time and data saved in the database.

So, time to time, every time the spatial data is computed and it is saved on the base database. And more focus is given on providing better control on the equipment particularly here the experiment is conducted with the bucket wheel excavator only and there are no other machines are attached with this system. So, focus was more on giving more control on this equipment using the GNSS system. Online volume calculation facility is add-on in this particular setup and this has been done using the software basically the KVAS is the software name provided by the manufacturer in line with the bucket wheel excavator and others photogrammetric principles. So, this KVAS software is basically the GNSS mine model developed by the KVAS firm in cooperation with the mine surveyors of that particular mines and the technical university of Ostrava and, that have the following facilities.

It can visualize the excavator 3D position and its movement in real time. So, this software have the facility to visualize the time to time the bucket wheel excavator move in real time and also the 3D x, y, z coordinates. And execution of all described applications. So basically, it has all the facilities that is required for the mines and also, we should remember that these mines is basically supplying lignite to a nearby power station. So, there are issues of sulfur content the energy value of the lignite.

So that also in real time it measures and that is the requirement. So, these facilities are inbuilt in this particular GNSS mine model software developed by the KVAS firm. Bucket wheel excavator technical details. So, this is the typical bucket wheel excavator that is what we are discussing in this case study. So, this is the figure.



So, in this figure we can see there are dots, dot 1, dot 4, dot 5, dot 3, dot 2, dot 6 like this. So, these are the dots. These dots represent installations been done some kind of sensor in these positions. So, let us see what are the sensors in these dot positions. So, this is the bucket wheel excavator model of K800-103.

It is operating since this case study was started. And there are dots 1 and 2. This is the two extreme side of the bucket wheel excavator. This is the front side; this is the back side. So, this comprises two GNSS receivers stated and installed in that particular position.

Then two inclinometer that is 3 and 4. So dot 3 and 4, two inclinometer is there to measure the angle. So that will basically correct the position x, y, z in real-time. One incremental rotation speed sensor is there because based on the speed how much amount of material is conveyed that to be noted. So, everything to be compared.

So incremental rotational speed monitor is also there on dot 5. So, this is the dot 5. Correction mechanism. So, it has the RTK facilities. So real-time kinematics correction is done from the base station, particularly the reference base station of the GNSS, and it is transferred through the radio module and the radio modem to this particular instrument so that we are getting a very accurate spatial location of the bucket wheel excavator.

So, this correction is been done. Control unit. So, manage the operation of the entire system. So, it has those capabilities, add-on, dashboard and visualization screens everything is there. Computation of bucket wheel access position dot 6.

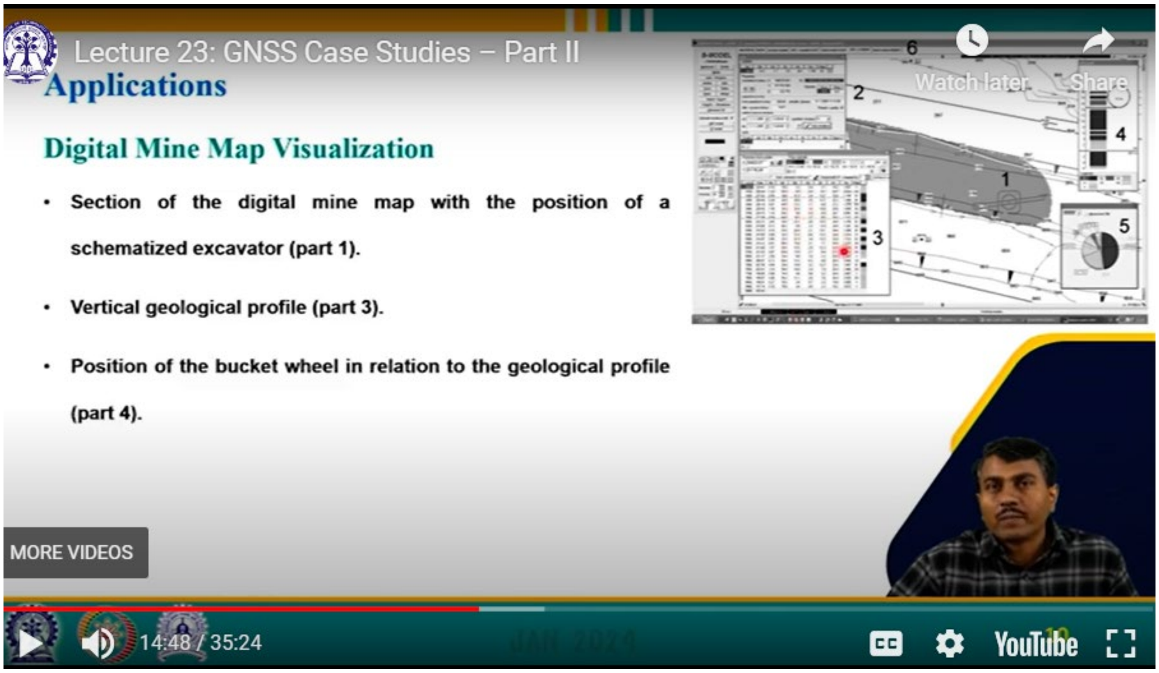
You have seen in the last slide. So, this is basically the 6 dot 6. So, this is basically the sensor. So, it calculate from x, y, z coordinate acquired from the GNSS divides. So based on that it basically says that how much advancement of the bucket wheel excavator is done.

So, it would be updated every time in the software. So based on the sensor data inclination and rotation speed it is done on a 5 second basis. On every 5 second the system is receiving data from the sensors. So, it is updated on the software base database.

Data transmission. So, data transmission we have the GPRS, general packet radio services that is basically the mobile data. So, this is basically used for transmitting the data to the PC server. So, it is basically in the network. So, there is no wire connection with the bucket wheel excavator to the control station.

Data processing. So, evaluation software is basically KVAS GNSS mine model possesses the transmitted data, all the transmitted data of the GNSS, the inclinometer and the speed sensors, and it basically process all these data at different intervals based on the necessity so that it can update the position of the GNSS of the bucket wheel excavator as well as how far advancement is done, whether these advancement is according to the plan or not, that is also taken care of in this particular system. System operation. These basically operate since 2006 December. Initially it is started with a single bucket wheel excavator that is K800 that we have shown and later on the other two model KU model that we have shown. It is basically added in this particular facility since end of 2009.

So right now, these three-bucket wheel excavator is operating. Digital mind map visualization. So, these basically the facilities we have in the KVAS module software. So, what is all about let us see. So, this is basically the software portal, different dashboard, particularly this is the one where basically the bucket wheel excavator operates.



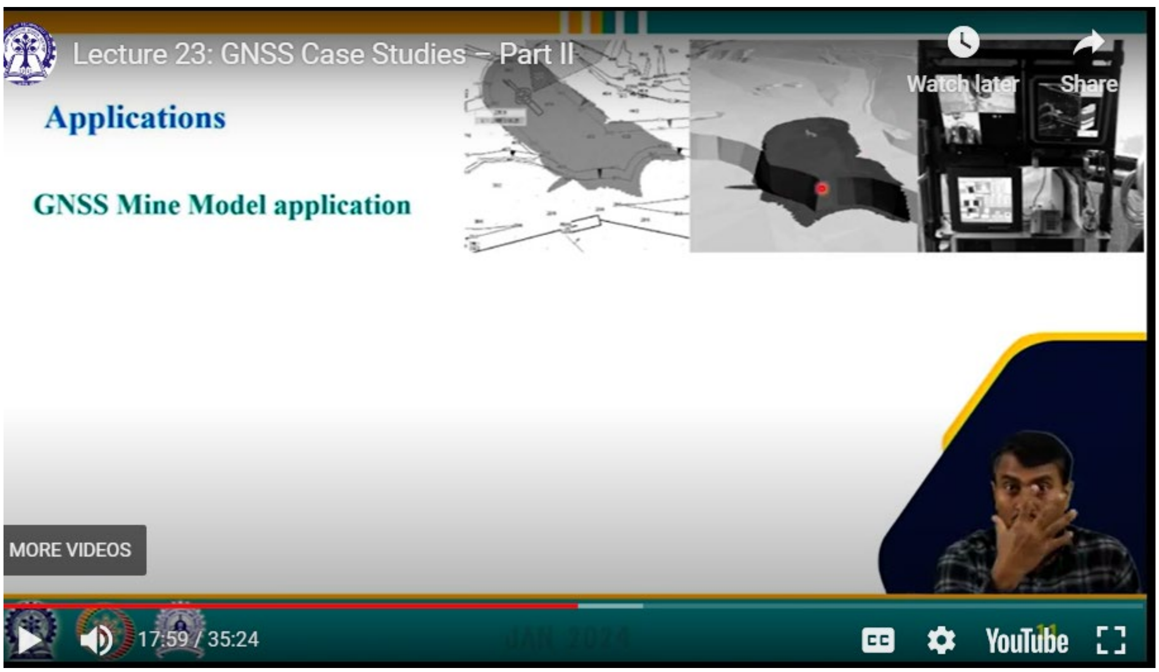
This is basically the geological data, and this is basically the borehole and the position of the bucket wheel excavator, and this is the different kind of advancement done of this particular bucket wheel excavator. So, this is the mine site. So, this software have the facilities to check what was the mine plan and whether this system is moving in tandem with the mine plan and if it is not moving, what is the gap and how these situations, how this system is going to take up that gap and to fulfill the production target. So, section one that is part one as I shown, this is basically the section of the digital mind map with the position of the schematized excavators. This is basically done on the software.

This is the geological data profile in part three. This is the position of the bucket wheel excavator in relation to the geological profile, at what depth it is operating and as far the data is there of these particular mines, maximum depth of these mines is around 200 meters and it is around 4-kilometer length of these particular mines and around 2 kilometre is the width of these particular mines, and it is basically in L-shaped mines. So, production is going this side, then again it will go, and this is a very big mine, and this is basically showing different color-coded representations of individual types of coals based on quantitative parameters, part three and four and five. So, we should also remember that this is basically a mine that supply lignite to the nearby power station for generation of energy. So, there are some necessities of control of sulphur content.

There are also some calorific values of the lignite. So, it is different of different layers. So, we must match during the excavation process what layer of the geology it is attacked, and it is excavated, how far it is mixed with other lignite, and what was the percentage of sulphur in those layers. So, it basically calculates in real time what is the possibilities. So based on that there are some limit that we should supply this percent below sulphur and at least we should ensure this much amount of calorific value is there.

So, proper mixing is required into the supply chain to the power plant. So that also been taken care of in this particular process. So, data is there at different, at different hour number of output it is going. So, the data about the sulphur content, the calorific value, is ingrained in the system. And also mining plans is attached so that we can regularly check the position of the bucket wheel excavator in reference to the mine map and plan.

GNSS mine model application. So, this is a typical application you can see. So, this is the schematized positions of the bucket wheel excavator in the Libous lignite open pit mines. And this is basically showing some of the features of the mine, and here it is basically showing some 3D kind of block, a real block of the mine site. So here this particular portion is under attack.

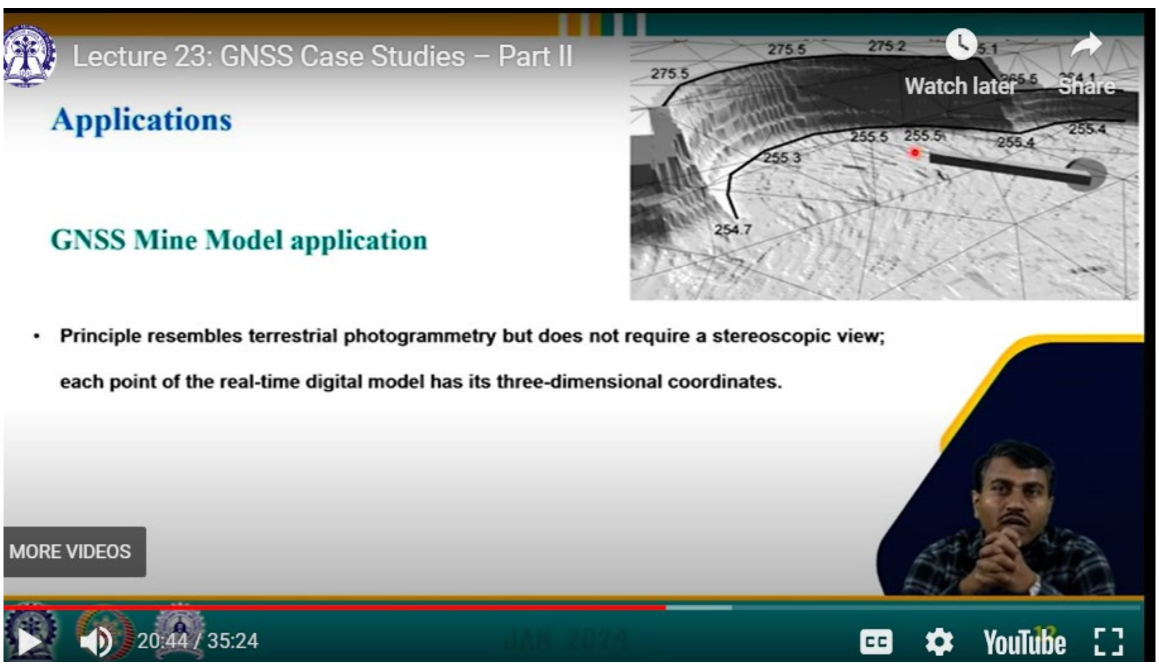


So, this portion will be excavated. So, this is showing in the software. And this is the operator cabin. Operator cabin also have the similar facility to see the advancement of the machine as well as what is the layer it is attacking and what are the details that we have already discussed and we will also going to discuss further. So, all these things, dashboard and their screens are available on the operator cabin. So, operator is also updated time to time what is happening in the process.

So, the GNSS mine model cabin application was developed for use in the excavator operator cabins. So, it allows the operator to monitor the bucket wheel excavator position relative to the mine plan and assist in verifying adherence to the mine plan. So, it always updates whether it is adhering to the proper mine plan, what was scheduled and if any differences, what are the next corrective actions it is taking care of so that always process is going according to the plan. It ensures that. So, this figure illustrates basically the system roles in monitoring adherence to the mining plan.

And also try to remember that this particular system is also keeping watch of other vehicles that is coming in nearby of this particular bucket wheel excavator. So, it has taken account of the obstacle avoidance system as well. So, all this data is updated on the software. So, this figure depicts the excavator cabin with a display screen. You can see showing the GNSS mine model cabin application on here.

So now see these are the facilities we have that this is not on the photogrammetric principle we are working. We are basically having at different point locations and different point locations x, y, z and different point location x, y, z so different point can be connected. So that basically resembles that we are forming some kind of polygons. So, what we need, we need to calculate the volume of the polygons that is the need on this particular software. So, we will discuss how this polygonal volume is basically calculated.

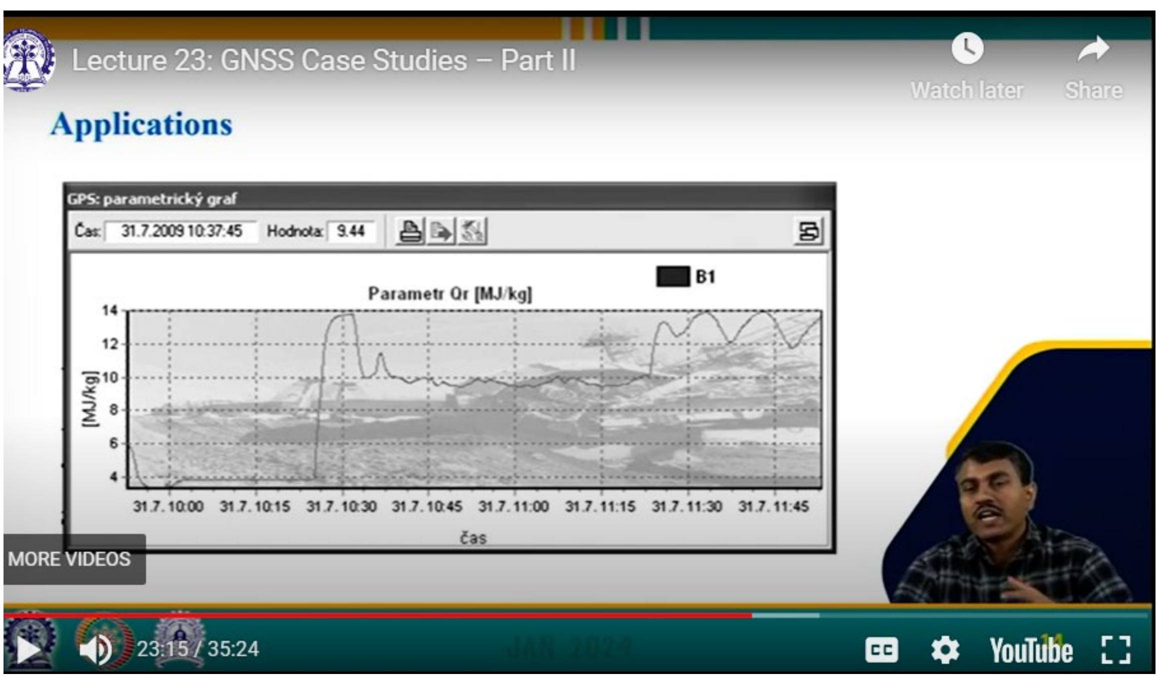


This is basically the principle facilities and principle features of this particular system. So, these particular resemble the terrestrial photogrammetry but it does not require the telescopic view. And each point of the real-time digital model has its three-dimensional coordinates. So, spatial location is known. So, if the spatial location is known, now I can connect.

So, this is basically the earlier position. Now it is advanced to this particular position, top and bottom part. So how much amount of volume is excavated based on the positional shift, we can basically calculate very accurately. So, we will also discuss that. So, user can obtain vector polynoids by moving the mouse cursor beside the measured line lower or upper edge of the bench. So here user have the facility whether whenever you are moving the cursor, you can get the real data, three data x, y, z of different points.

And you can see different points are connected. So, this is the polygons basically shape. So polygonal volume we have to calculate now. See, polyline can be transferred to the digital traded model and the mine mapping system, and it is integrated into the particular model. So, the current status and the history of the qualitative parameters of the coal, elevation of the bucket wheel excavator is wheel is 1 and heating value is 2, and the sulfur content is 3 as derived from the geological model monitoring of some of the important qualitative parameters of the coal in real-time is possible, and that is required that how much is the quality of this coal that is supplied to the power planner whether that is adhere to the standard quality. So, these are basically the data generated over the time and precise data about the percentage of sulfur content of the lignite that is supplied to the power station.

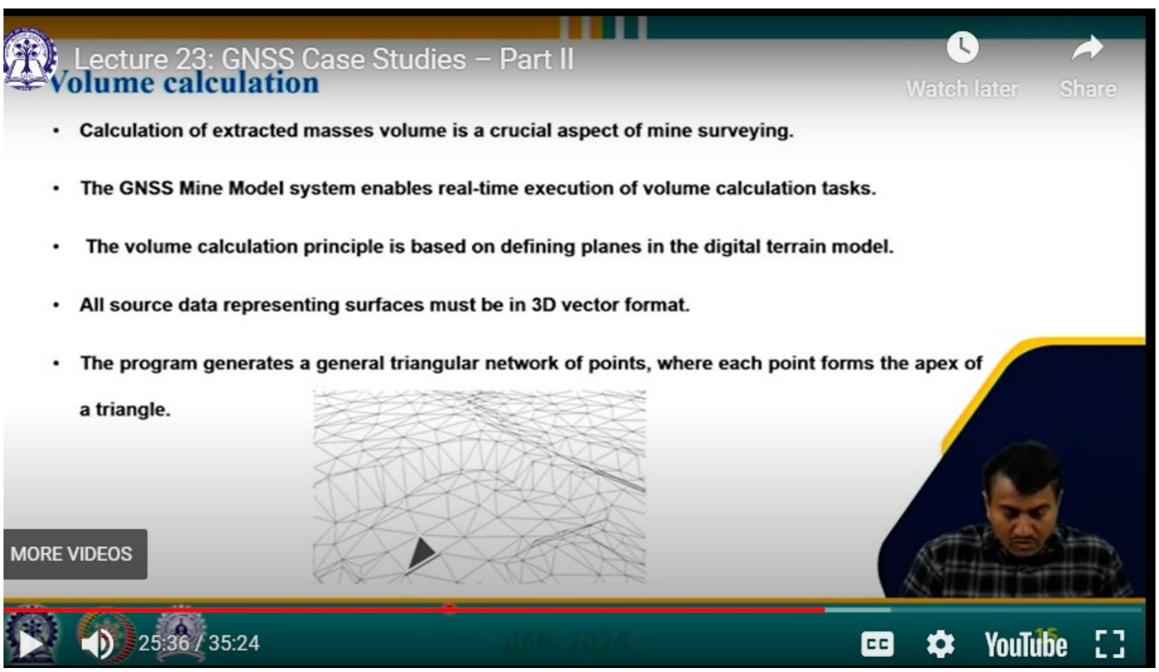
And this is basically the heating value of the lignite. So that is also basically calculates from the geological data. It is not the actual one. This is the geological data have the features, detailed features of different layer what, is the calorific value what is the sulfur content and that basically updated. So, we know that which portion of the geology it is attacked and this is been verified with the geological data that this portion lignite have the calorific value of this, this portion of the lignite in the geological model have sulfur content of this.



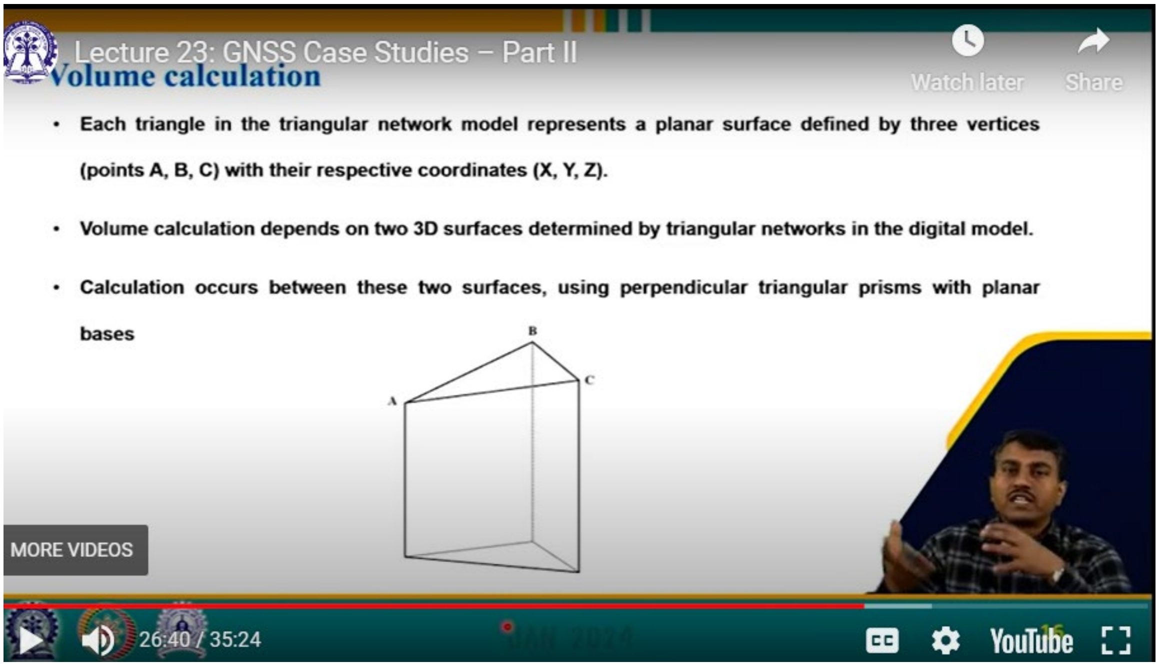
So, the software calculates according to that. Now, let us concentrate on the volume calculation. So, the calculation of extracted masses volume is a crucial aspect of the mine survey, and it is required because this is basically integrated with the payment process to the party who is basically in the process of excavating the material sometimes in different mines. So that will help to the surveyor department to check how much volume is excavated, how much amount of payment is done and whether the volume that is excavated is very precise and accurate. So, the GNS-MINE model system enables real-time execution of volume calculation tasks.

This is the feature. The volume calculation principle is based on defining planes in the digital terrain model. So, this is basically we are defining plane initially the plane was suppose baseline is x. Now you are moving to the x1, y1 and z1. So, you are moving. So, based on the baseline, you will basically create a triangle or polygon, and you will calculate the volume.

So, all source data representing the surface must be in 3D vector format, and the program generates a general triangular network of points where each point forms the apex of the triangle of a triangle. So, you can see here is the triangle. So, there are three points. Similarly, it has in the bottom also a triangle and three points.



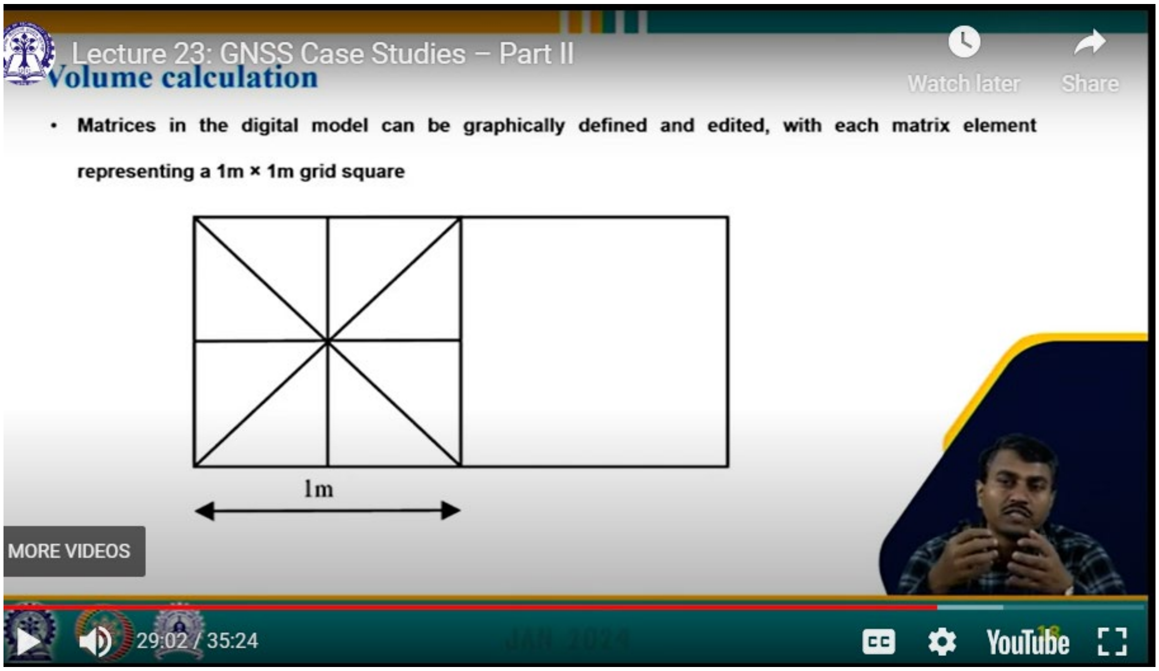
So, these three points data is known. Bottom three points data is known. Now I can calculate easily following a cylindrical volume like that and it can be done for other polygon as well. So, each triangle in the triangular network model represents a planar surface defined by three vertices, points A, B and C, with respective coordinates of x1, y1, z1 or x2, y2, z2 like that. So, volume calculation depends on two 3D surface where bottom and upper determined by the triangular network in the digital model and the calculation occurs between these two surface using the perpendicular triangular prism with planar base. So, this is basically the intent of the volume calculation.



So, this is the top part, this is the bottom part. So, what is the volume of this particular part? So, it basically added to the next polynomial and next polygon. What is the volume? So elemental volume finally added and how much volume is excavated that is calculated based on this. So total volume is computed by iteratively summing elementary volumes over all elements of the triangular grid. So, the triangular element we have shown here. So here we have shown the triangular element. Similarly, here also some triangular element, here also some triangular element, here also some triangular element, here also some triangular element.

So, all these elemental volumes will be added and finally total volume can be calculated following these principle. So, the system continuously compute extracted material volume based on these principles. So that is very easy; no sophisticated other technologies use only the GNSS and a few sensors. So, it utilize dynamic GNSS map, a feature of the KVAS software which employ partial index matrix to dynamically define and modify the surface elements over time. So, the dynamic GNSS map describe the area affected by mining using a parametric model of a cylinder simplifying the complex shape of a bucket wheel.

So, this method ensure quick indexing of area element and efficient data transmission over the computer network. So, the matrices in digital model can be graphically defined and edited with each matrix element representing 1 by 1 meter grid square separate. So, some basic assumption is there. So based on that this particular software calculates.



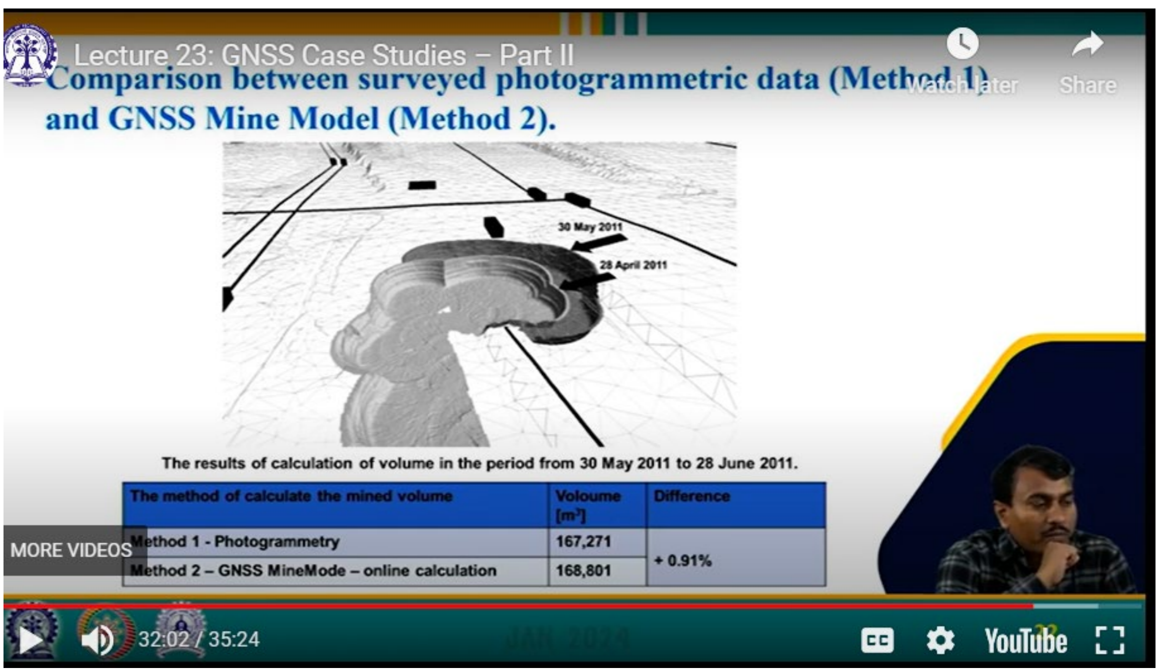
So elemental small volume grid is basically fixed 1 meter by 1 meter. So, resolution is basically 1 meter by 1 meter. So, this is basically an approximation of the process. So definitely there would be some amount of error but that error finally it is not very significant that is basically the intention of this case study. So, this is basically the bucket wheel excavator position you can see, and the material is basically on the belt conveyor.

So, belt conveyor convey the material. So, the KVAS software knows how much amount of material is on the belt conveyor is been put and what was the quality of the material. So, online inspection of the system can be established using this system as well. So inactive matrix elements are activated when the bucket wheel excavator cylinder model passes through. So, these models are generated.

So now when it is passes through this particular element is activated. So now we will calculate on this particular active node. So, upon activation, all 8 elementary areas associated with the active-matrix element are positioned onto the initial terrain model, and each area corresponds to 1 meter by 1-meter square and copies the terrain characteristics. An intersection between the newly positioned surface element and the cylinder model surface area is calculated. So, area where this intersection result in change in elevation are modified and reflected in the new elevation value. An elementary triangular prism is created based on the modified elevation values, which serve as the basis for volume calculation.

Now let us see the comparison between the surveyed photogrammetry data. There is a base data method one and the case study data that is GNS model method 2. They have compared and basically these changes data is updated at each 5 second interval of the 3D monitor stations of the spatial location where the bucket wheel excavator operates. An intersection of the computation, the intersection between the bucket wheel excavator position and the elementary planes where it is activated and affected, and triangular elements are computed at each change. An elementary volume accumulation, so elementary volume accumulated during the sampling interval are crucial for subsequent total volume calculation over the selected time period.

So, this is basically the data. Now this particular case study showcasing the data of around one month. So, the result of calculation of volume in the period from 30th May 2011 to 28th June 2011, nearly a month data they have compared and it has been found that there was only 0.9% difference with the standard method, photogrammetry method, total volume excavated.



0.9% it is not so huge. So, this model, this method, it is pitched that it is a kind of alternative to the available system and it is a very sophisticated one and huge amount of data is generated and calculation is also much more easier and things are transmitted, updated at regular interval to the PC server system. So that enables the system to automatize the whole process and monitor the system very easily and that basically enhance the system safety as well. Volume check the mine surveyor, so they check monthly the extracted material volume by the mine surveyor. So, the surveying method for volume measurement, so digital aerial photogrammetry is used for as surveying method for volume measurement. So, verification process, so the digital aerial photogrammetry method one is employed to verify the calculated volume obtained from the GNSS mine model methods.

So, from the aerial data, as a real data they again reconstructed and calculated the actual volume and the volume we are getting from this case study, they basically check and that is basically the difference is only 0.9% in a one-month data of these mines.

So, these are the references.

So, let me conclude in a few sentences what we have covered in this particular lecture. Enhance safety, so real-time positioning data of the GNSS minimize collision risk enhance overall safety in surface mine operation. Autonomous navigation, GNSS enables the automation of mining vehicles, optimizes routes, and reduces downtime for increased operational efficiency. Operational efficiency, the integration of GNSS technology streamline mining operations, improving coordination, reducing idle time and enhancing overall workflow efficiency. Resource utilization, GNSS provides accurate location data, maximizing resource utilization in surface mining, directly impacting productivity and profitability. Future prospect, the integration of GNSS in surface mining not only address the current challenges but also set the stage for future advancement with collaboration between technology developers and mining expert driving innovations.

Thank you.