Rapid Manufacturing
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Lecture – 13
Reverse Engineering (Part 2 of 2)

So, continuing with the Reverse Engineering lecture we initially saw the definition, importance, application and contact, non-contact processes.

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So, we also saw the 3D scanning processes.

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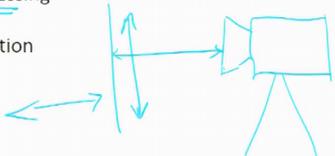
For example, we saw all the steps: acquisition, alignment, meshing, post processing and simplification. So, this lecture we will be more focused towards hardware: introduction on hardware, RE hardware, contact, non-contact and destructive type.

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So, talking about hardware and software which is very very important; the hardware suppose, if there is a hardware which captures a signal with a noise then the software can be used for removing the noise. But, if the hardware could not even acquire some data

software always works on the hardware generated data. You can have a higher end version software which can work to the finest accuracy.

But the acquired data itself is not to the highest resolution, the software cannot improvise the resolution of the product or the resolution of the reverse engineering point cloud data. RE hardware is used for RE data acquisition. There are three main technologies of RE data acquisition: contact, non-contact and destructive.

Outputs of the RE data acquisition are 2D cross section images and point cloud data. These are the two things 2D cross sectional images. So, 2D cross sectional image means suppose let us assume you have an object you slice the object. So, now what you have is you have layer of information; every layer of information is when you try to cross sect it and locate on the other way around.

So, you try to get a 2D information for example, this slice information I try to view like this. So, here is the date of information which is there in this particular slide; so, 2D cross section image and point cloud that defines the geometry of any point. RE software transforms the RE data of produced by RE hardware into 3D geometric models. The RE data processing chain can be one of the two types of 3D data: it can be polygon or it can curves ok.

It is basically the mathematics, the data processing chain can be one of the two types it of the 3D data. It can be polygon or it can be curves; polygon models are commonly used for rapid prototyping, laser milling, 3D graphics, simulation and animation. So, polygon model are commonly used for rapid prototyping techniques.

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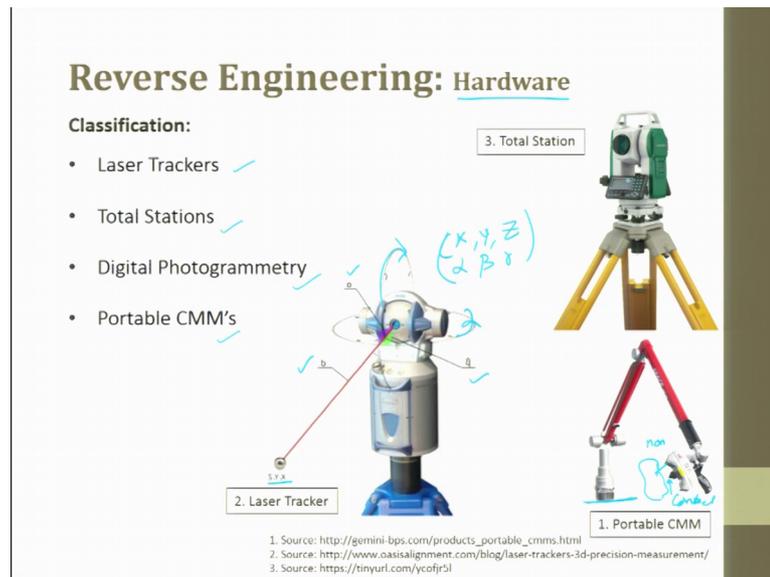
So, when you look at the hardware they are classified into four types. One is laser tracker, then it is total station, the third one is going to be digital photogrammetry and the last one is going to be portable CMM. So, portable CMM this is what is a portable CMM. This CMM can be fixed in any plane and then you can start acquiring the data for of a given object. Again here you can see it is contact and you can also use laser which is a non-contact type. So, this can be used to acquire data and collect the point; this is you have contact type as well as non-contact type.

So, portable CMM is now becoming very handy. The other one is going to be the laser tracker. This is a laser tracker which can do all actions of your hand, it can have pitch, it can have yaw, it can have roll. So, you can roll in this plane; it can go around in this plane and it can start getting data. So, you can get x y z data you can get a b and c data. So, you have 6 data points to get so, you can get x it gives x y z alpha beta and gamma. So, this 6 datas you can get using this laser tracker. So, this is your total station which generally we use it for a civil engineers use it.

So, the total station you can have a laser which is focusing on those points. And, you have this; the display where in which you can try to do some soft computation and then try to get the output.

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The contact methods uses sensing device with mechanical arm CMM and CNC machines to digitize a surface. So, the data collection technique point to point sensing with touch trigger probe installed on a CMM machine or articulated mechanical arm to gather coordinate points of a surface. So, this is what point to point sensing; you touch the surface of a product or a part and now what you do is when you have a product like this, you touch it at one point then you move and then touch it at the other point. So, this is what you are discretizing the data and you are trying to do point to point sensing with a touch probe.

So, I told you earlier so, this probe when you touch; so, here if suppose you assume that there is a contact circuit here this circuit breaks and then you try to get the x y z data. The CMM provides more accurate measurement data compared the articulated arm, but due to lack of number of degrees of freedom it cannot be used to digitize complex surfaces. CMM are very commonly used to form engineered products wherein which their features are basically it can be divided into line and a circle or line and then arc or a curve. So, if I can try to digitize the a very complex figure into a set of lines and a set of curves; then by using CMM I can easily measure those data.

If you have to measure biological samples for example, a leaf a leaf, a heart, a skin or something like that. So, then CMM will find it difficult because, it does not have the freedom of negotiating itself in measuring certain intricate datas one can be undercut

data the other can be internal datas. For example, undercut data is something like this. So, this is an undercut data which is very difficult for a CMM to access it. So, this is undercut data or you can also have inner grove data which is used for measuring. Analogous sensing with scanning probe installed on CMM or CNC machines are also available today.

The scanning probe provides a continuous deflection output that can be combined with the machine position to derive the location of the surface. This scanning probe I discussed about the atomic force microscope. Scanning probe provides a continuous deflection output, the probe moves up and down the laser hits can be combined with a machine position to derive the location of the surface. The scanning speed is analogue a sensing it up to 3 times faster than point to point. So, you should understand analogue a sensing scanning speeds are 3 times faster than the point to point sensing data.

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Point processing; so, importing the point cloud data; so, x y z data x y z alpha beta gamma data is got reducing their noise. So, what you get here is signal and noise. So, next one is you have to reduce the noise and you have to amplify the signal. So, then once you do that the signal whatever you have is all of the signal whatever enhancement we have all is these are all raw data. This raw data has to be converted into information. So for example, I have data like this; now all these data are converted into a curve. So,

defining a curve what I do is start point end point and some radius I give. So, with 3 points or 3 information I am able to reduce the number of point datas and then store it.

These tasks are performed using a range of predefined filters. Multiple scans are sometimes needed to ensure all the required points are scanned. A wide range of commercial softwares are available for this job. The output is clean, merged, point cloud data set in the most convenient format. So, this is also very important converting into a format this is otherwise called as unique format which can be used by multiple people. For example, CNC machine CMM machine you can have rapid prototyping machine and then you have the data file star dot STL; this can be used at every place. So, that is what is the convenient format or it is called as a unique format unique format or a neutral file format.

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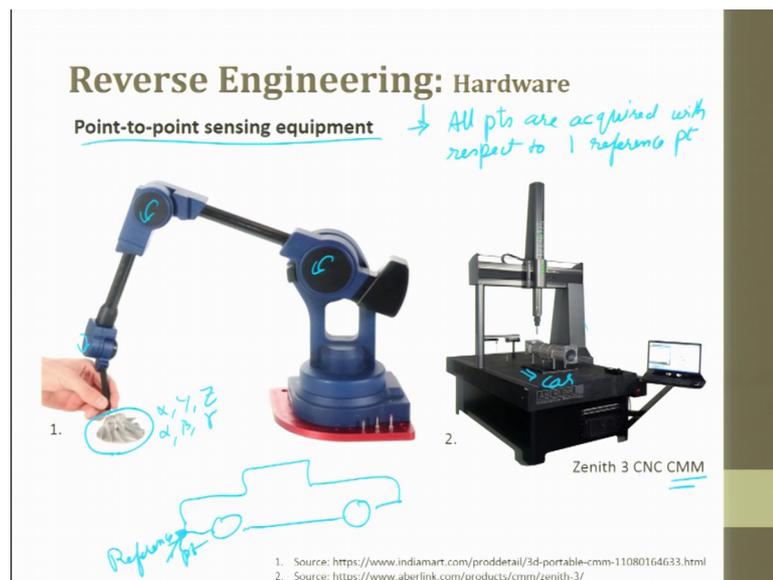
So, this is how we use point to point sensing. So, this is a CMM machine coordinate measuring machine which I was talking to you it is it is a structure of gantry type. So, you can also have column type, you can also have a cantilever type. Depending upon your requirements you can decide, it can do components like this, it can also be car complete car can be placed under the CMM and you can start get the data points. What is the big advantage of this fellow or this fellow as compared to the normal conventional measuring instruments usage; is you get all the data points with respect to one reference.

So, the best part of CMM all data points all points are acquired with respect to 1 reference point.

So, in the entire car whatever we talk about we get all the data with respect to this single point which is a reference point ok. This makes the life very very easy, any deviation with respect to this point you can have. So, that can be used to measure and we can correct it and improvise our system. So, a code this is Zenith 3 CNC, 3 axis CNC machine or a CNC CMM.

And, this is a articulate robo you can have and which is also falls in the same domain of portable CMM type; here we have a closer picture of it. So, you see here is an encoder, here is an encoder and here is an encoder. So, these 3 encoders try to negotiate nullify the errors, nullify the signal and convert into data points which are with reference to one plane.

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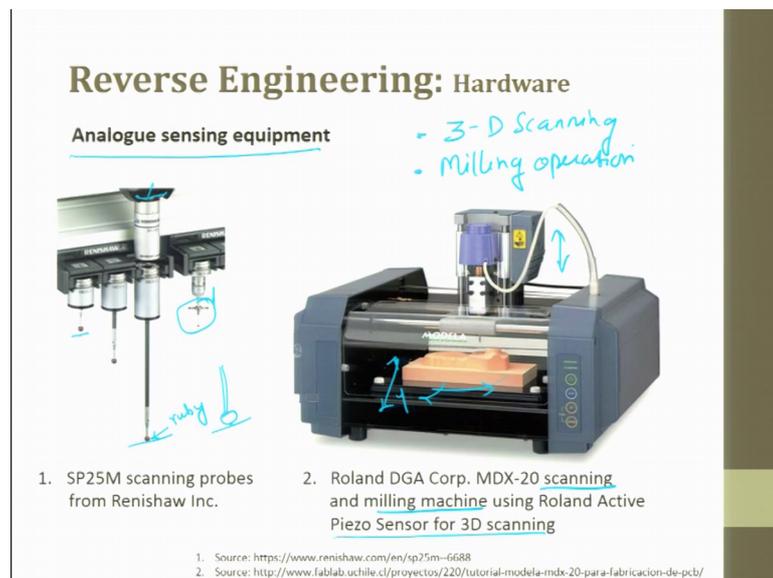
So, analogous sensing devices you can also see these are the probes, the probes as I told you it can always have a tip which is flat, but when there is a tip flat you will not have a point contact data. In order to have point contact data we converted into a ball; so always you get a point data here. So, you can see here the tip of the CMM is made out of ruby; ruby is nothing but alumina. So, this alumina when it touches a surface, if this is a probe which touches and here you will have a connector circuit breaker or a contact breaker

which tries to break the circuit and you try to get the data. So, you can see here different different types: a long probe, a short cylinder probe, a start type probe.

You can choose which one you want for your requirements and then you can started for using. You can also see that here is a Roland DGA corporation MDX 20 scanning and milling machine. So, you can scan, you can use this machine for scanning as well as for milling; these are integrated machine ok. So, it has a piezo sensor for 3D scanning.

So, you can use a 3D 3D scanning device and moment you scan something, the same work piece or the same place can be also put with another spindle and you can do milling operation. So, either you can move this fellow scanning up and down or you can move the milling in up and down this bed up and down know. In this case this is only moved and you have the x data here and the y data here.

So, here this machines are used for the typically, if you see these machine are called as rapid manufacturing machine where I put a data I put a product. For example, this blade or this turbine blade I put it in the space and then what I do is first, I measure the data then I convert that all the measure point cloud data into CNC program. Then put a block there I can machine the same part whatever you did reverse engineering.

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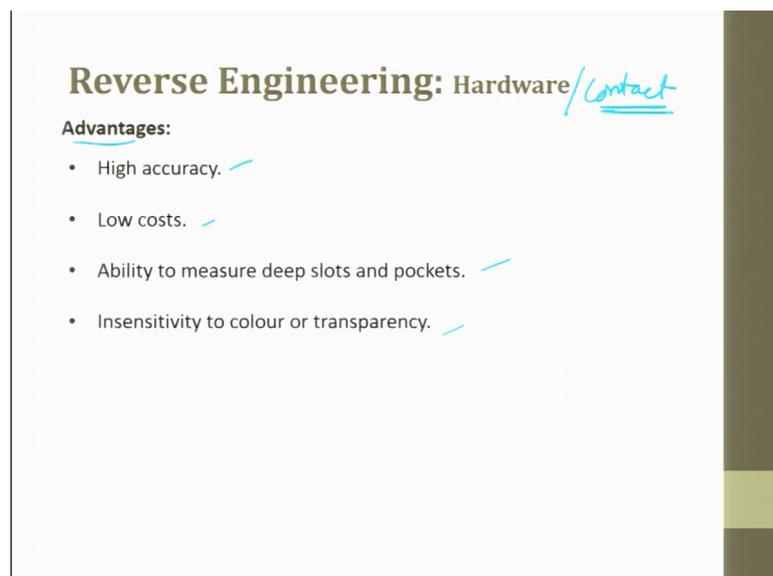
Reverse Engineering: Hardware/Contact

Advantages:

- High accuracy.
- Low costs.
- Ability to measure deep slots and pockets.
- Insensitivity to colour or transparency.

So, reverse engineering hardware advantages are going to be highly accurate, it is low cost, ability to measure white slots and pockets and insensitive to colour or transparency. So, these are some of the advantage of hardware type which is contact ok.

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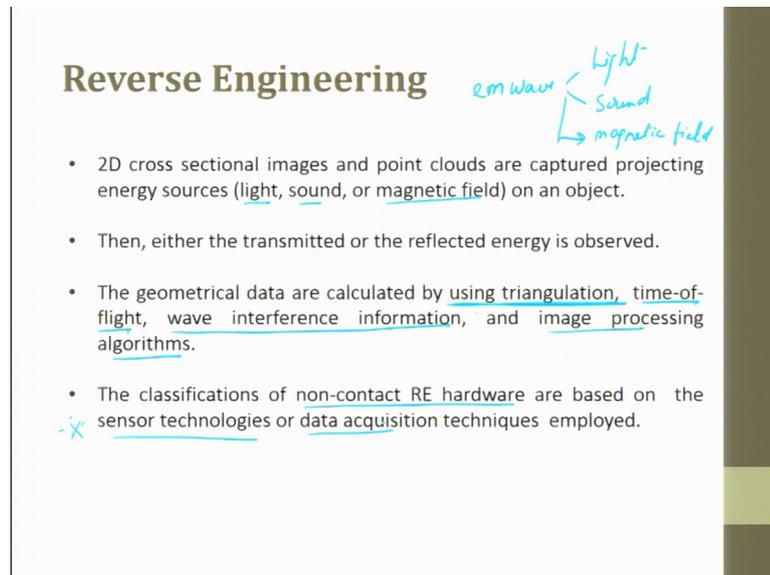
The 2D cross section images and point cloud data are captured projecting energy sources like light, sound and magnetic field. You can use any of the electromagnetic wave electromagnetic waves, you can use light, ultrasonic can be used and you can also use magnetic because, electromagnet are 90 degree (Refer Time: 14:46).

So, you can use magnetic field also. So, you can use these sensors energy sources to measure the point cloud data. Then either the transmitter or the reflecting energy is observed. The geometric data are calculated by using triangulation technique; this is the very very important technique which is used is triangulation technique ok.

Triangulation technique, time of flight, wave interference information or image processing algorithms are used wherein which you can try to see the sudden gray change contrast change and sharp edges all those things you can use. These are geometric datas which are used for calculating the information. The classification of non-contact RE hardware are based on the sensor technology or data acquisition technology employed So, these are the two important factors: sensor technology and data acquisition techniques are two important technologies which are used which is used to decide which reverse engineering technique to do.
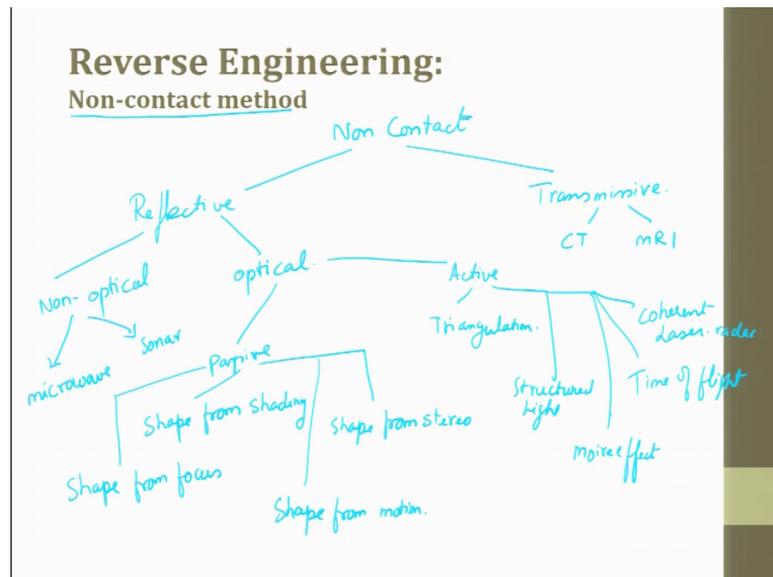
So, let us now draw the non-contact method classification ok. So, non-contact method non-contact; so, it has reflective transmissive. Then here it has non-optical and optical, then it can be used microwave sonar ok. And, optical passive shape from shading, shape from stereo, shape from focus, shape from motion ok. Optical technique these are passive technique, these are active techniques. So, in active technique we use triangulation, we use structured light, we use Moire fringe Moire effect, then time of flight, then we use laser ok. So, transmissive we use CT or MRI; Computed Tomography or it is Magnetic Resonance Imaging ok.

So, this is the classification of non-contact methods; they are primary classified into reflective and transmittance and in transmittance CT and MRI falls in this category. So, when you talk about reflective non-optical and optical come into the existence. Non-optical you can use microwave, sonar, audio all these things you can use; when you talk about optics there are two types: one is active another one is passive. So, passive is shape from stereo, shape from shading, shape from motion, shape from focus are done. When you talk about active triangulation techniques structured light is used Moire effect is used, time of flight is used or coherent laser radars are used as non-contact techniques for doing reverse engineering.

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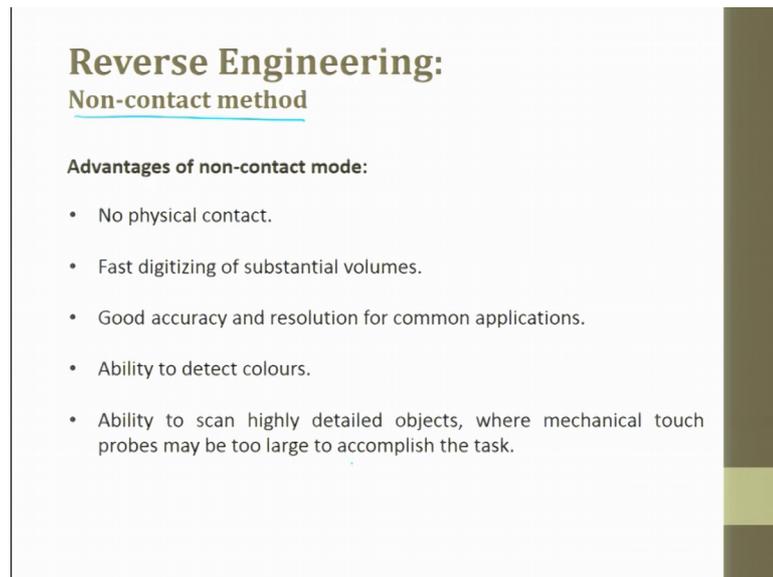
So, what are the advantages of non-contact as compared to that of contact. So, you have no physical contact, fast digitizing of substantial volume can be done, very fast by using non-contact, good accuracy and resolution for common applications can be done. Ability to detect colour it is possible which was not possible using contact type and ability to scan highly details objects where, mechanical touch probes may be too large to accomplish the task we can use or non-contact method for measurement.

So, the ability to scan highly detailed object where, mechanical touch probe may take two larger time to accomplish the task; we can use this non-contact scanning techniques to do it.

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Triangulation technique most laser scanners use straight forward geometric triangulation technique to determine the surface coordinates of an object. So, let us take a simple schematic diagram; this is the laser or light whatever it is and then you have a camera ok. So, this two have a constant distance, then you are trying to watch an object which this is an object and this is a straight line, this is a straight line.

So, this line is the height z. So, this line the distance between this line is b and this angle is alpha and this object is moving at a distance, at a time or a speed of t vector objectives moving time, moving time or acceleration whatever it is. Triangulation is a method that employs locations and angle between the light source and the photosensitive CCD. So, this is what is CCD to calculate the coordinates. So, this object ordinates x y z can be calculated by using this triangulation technique.

There are two variants of triangulation schemes used in CCD camera: single and double CCD camera. A device transmits a light spot on the object at a defined angle a CCD camera detects the position of the reflected point on the surface. So, that is single camera system what I have drawn is a single camera system. You can also use a double camera system. Two CCD cameras are used: one CCD camera another CCD camera this is CCD CCD ok.

The light projector is not involved in any measurement function and may consist of moving light spot or line moving strip pattern or a static arbitrary pattern is also used. So, with this time of flight we can try to find out what is the distance and we can also try to get the x y z points. So, double camera is used, single camera this techniques if we use a handheld reverse engineering tool to measure the distance of the entire car. So, then you can either use a single camera system or a double camera system to do reverse engineering and measure the spots.
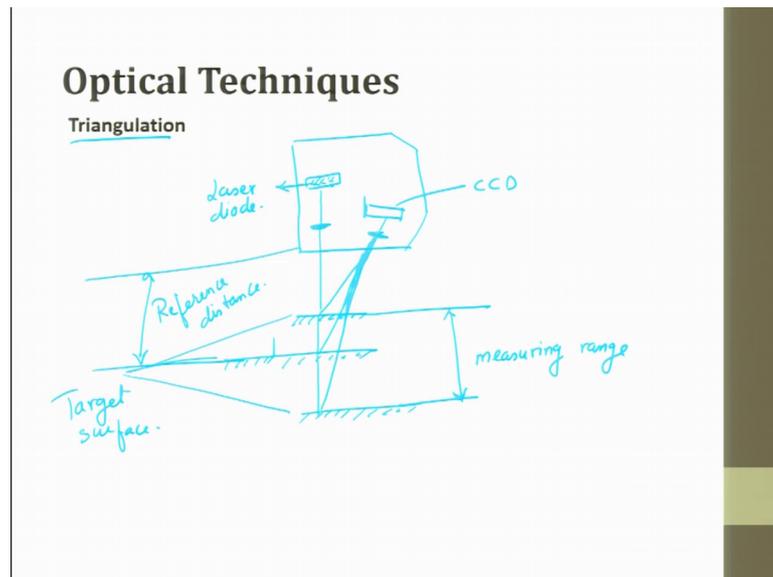
So, when we are talking about optical technique triangulation; let me draw the instrument schematic diagram of the instrument. So, you have a laser, this is a laser diode or a diode laser and then you will have a CCD CCD camera and then you have a light. So, there is a lens and here there is a lens. So now, you are trying to hit at surfaces. So, these are the target surfaces and this is the reference distance right. So, the light hits from here goes from here, the light hits from here goes through goes to here, light hits from here and goes to here ok.

This is the measuring range measuring range ok. So, this is how instrument looks like. This is the reference distance, this is the measuring range you have, these are the target surface. The light from the laser passes through a lens and then hits at the target surface and gets reflected back. So, these are all reflected lines which passes through this lens and it goes to a CCD.

In the illustration above a higher energy light source is focused and projected at a pre specified angle theta on to the surface of an object. The photosensitive device sensors the reflection from the illuminated point on the surface. Fixed baseline length L between the light source and the camera is known from the calibration; youths keep changing it to the requirements.

So, using the geometric triangulation form the known angle theta, the focal length of the camera F, the image coordinate of the illuminated point P, and the fixed baseline is L. So,

the position of the illuminated point Pi with respect to the camera coordinate system can be calculated as Z equal to equal to F L by P plus F tan theta where, X is equal to L minus Z tan theta ok. By using this formula we can be able to use the triangulation technique and try to find out the coordinates.

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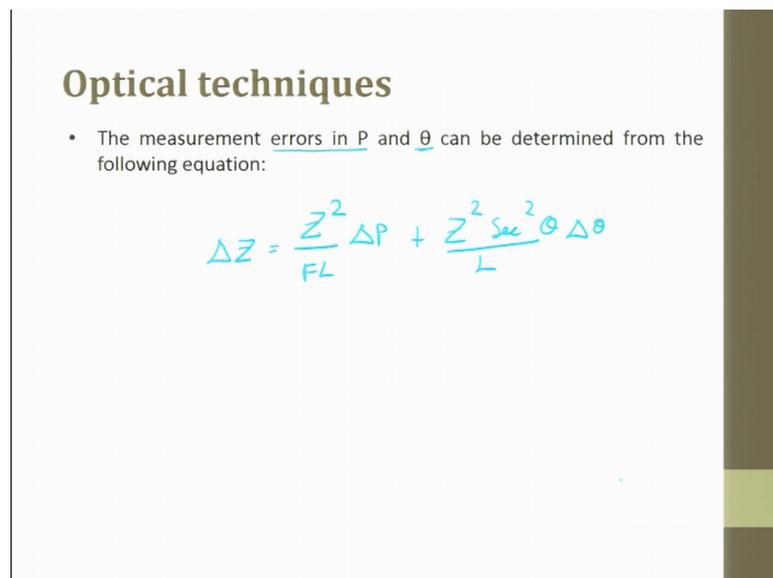
Optical techniques

- The measurement errors in P and θ can be determined from the following equation:

$$\Delta Z = \frac{Z^2}{FL} \Delta P + \frac{Z^2 \sec^2 \theta}{L} \Delta \theta$$

To measure the error in P and theta can be determined from their following equations delta Z equal to Z square by F L delta P plus Z square sequence square theta divided by L del theta. So, this is used to measure the error in P and theta; with this we can try to figure out the error and start working on it, doing those corrections and try to get the xyz data out of it.

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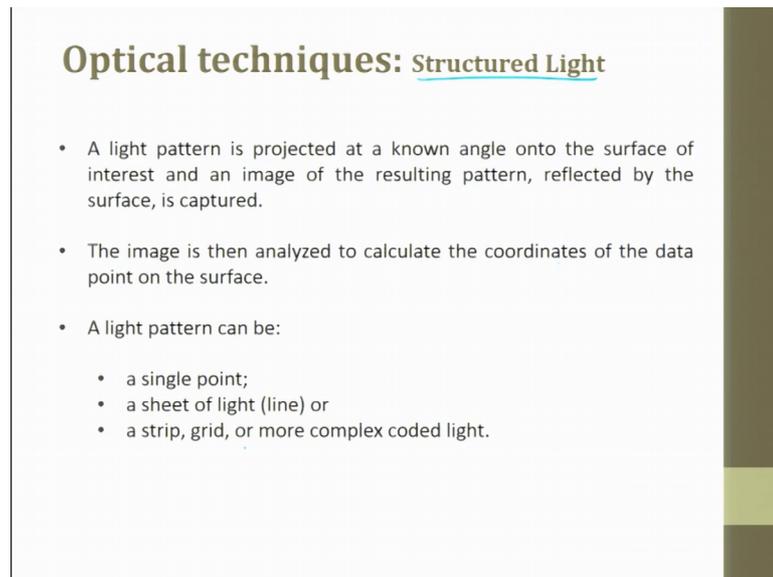
Optical techniques: Structured Light

- A light pattern is projected at a known angle onto the surface of interest and an image of the resulting pattern, reflected by the surface, is captured.

- The image is then analyzed to calculate the coordinates of the data point on the surface.

- A light pattern can be:

  - a single point;
  - a sheet of light (line) or
  - a strip, grid, or more complex coded light.

The other technique one was triangulation technique, the other technique is using a structured light. The light pattern is projected at a known angle on to the surface of the interest and image of the resulting pattern reflected by the surface is captured.

So, you throw a structured light on top of an object then from there what gets reflected you start doing it. The image is then analyzed to calculate the coordinates of the data points on the surface. The light pattern can be a single source, sheet of light or a strip grid or more complex coded light.

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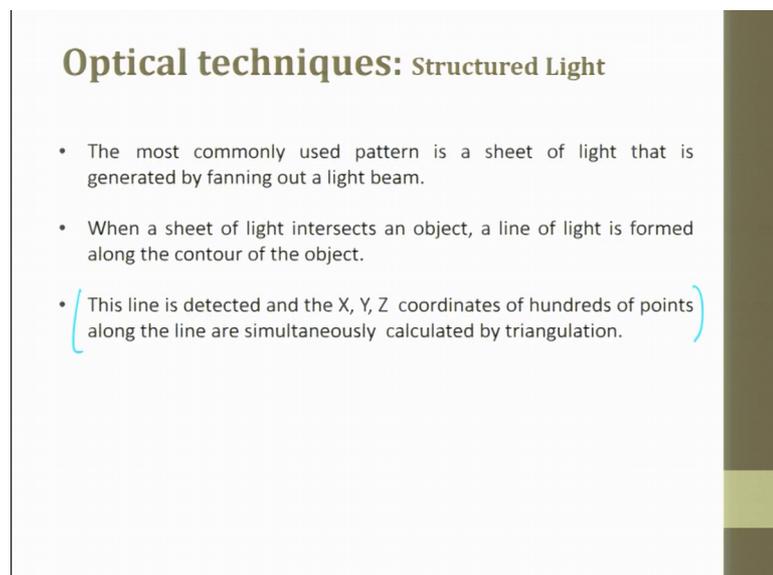
Optical techniques: Structured Light

- The most commonly used pattern is a sheet of light that is generated by fanning out a light beam.

- When a sheet of light intersects an object, a line of light is formed along the contour of the object.

- This line is detected and the X, Y, Z coordinates of hundreds of points along the line are simultaneously calculated by triangulation.

The most commonly used to pattern is a sheet of light that is generated by finding out your light beam. When a sheet of light in intersects on object a line of light is formed along the contour of the object. This line is deducted from and the X, Y, Z coordinates of hundreds of points along the line are simultaneously calculated by triangulation technique. This is very important, they are calculated by triangulation technique and then you try to get the output.
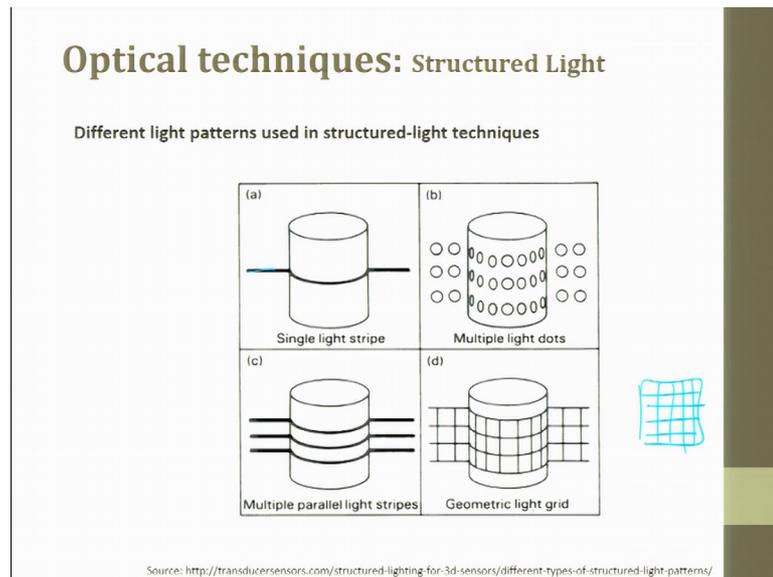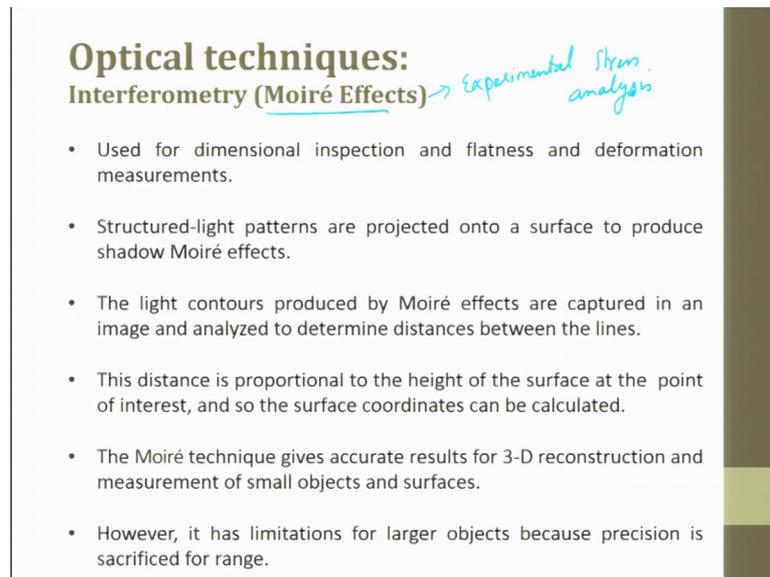
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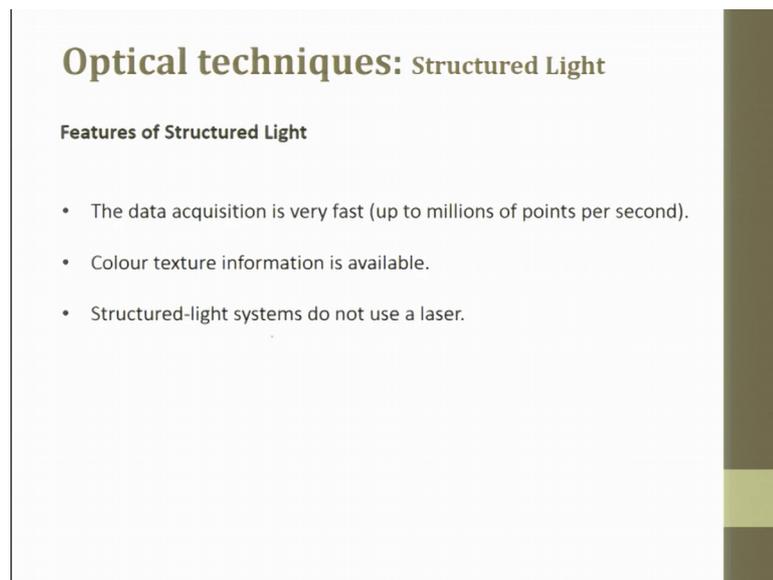
The features of a structured light: the data acquisition rate is very fast, the colour texture information is also available, structured light system do not use a laser light.

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So, you can try to get better insight informations also. Different light patterns used in structured like techniques are single light strip this is what is single light strip, multiple light dots which we have used with when the light reflects you can start measuring that and then get the data.

So, multiple parallel line strips are there, geometric light grids are made. So, basically you make a grid of light and allow the grid of light to fall on the object; then you try to take the reflection from the object and then you gather the data. So, when the sheet of interest of an object a line of light is formed along the contour of the object. This line is deducted on the X, Y, Z coordinates of hundreds of points along the lines are simultaneously calculated by triangulation technique.

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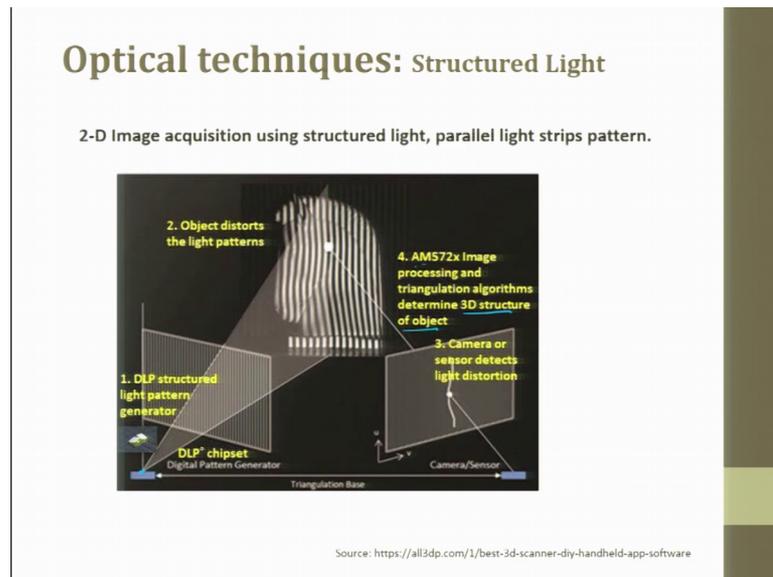
So, this is a simple 2D image acquisition using structured light parallel light strip patterns. So, you see here this is DLP structure light pattern generator. So, you generate and then it passes through that chipset DLP chipset and then here is the object which distorted with the line pattern. This strip is projected here and then what happens is you try to capture the data through a camera sensor detector light distortion; you try to do that. And then what we get is finally, AM5272x image processing and triangulation algorithm determines the 3D structure of the object.

So, this is a complete cycle. So, you have DLP structured light pattern generated from here passes through chipset or a mask and then this is projected onto the object which is white in colour ok. And, then this is captured by a camera. The camera has a software wherein which it does triangulation techniques and acquired the data.

We can also use interferometric techniques. So, this is the third; first we saw laser, then we saw that is triangulation, then we saw structured light. The third one is interferometric pattern which is Moire effect. Used for dimensional inspection and flatness and deformation measurement. When we have to do very precise measurement we always go for this interferometric techniques and Moire effect. Structured light patterns are projected onto a structure to produce shadow Moire effects.

The light contour produced by Moire effects are captured in an image and analyzed to determine distance between the lines. The distance is proportional to the height of the surface at the point of interest and so, the surface coordinates can be calculated. The Moire technique gives accurate results for 3D reconstruction measurement of small objects and surfaces. However, it has a limitation for large object because precision is sacrificed for range.

So, generally this Moire effects are used for experimental techniques, for experimental stress analysis. People use this Moire effect photoelasticity effect; so, by that what they do is this stress or strained object find out the Moire fringe pattern shift from there they try to calculate the values.
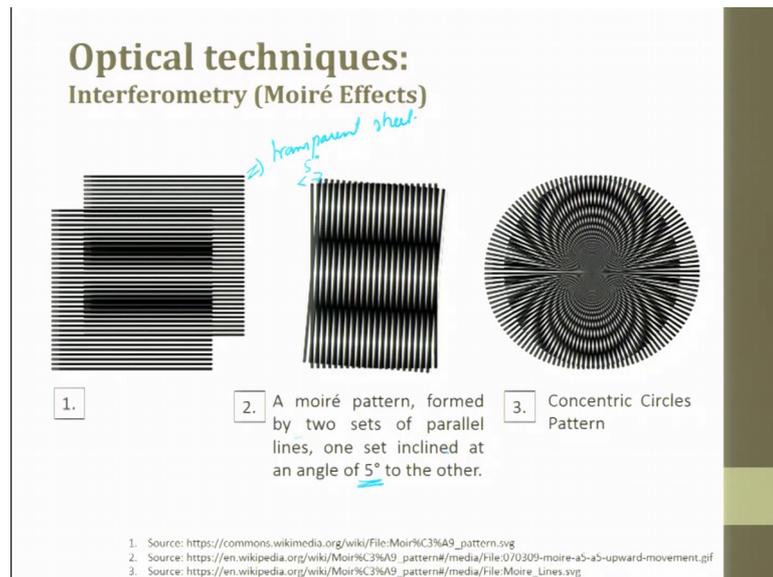
So, this is a typical Moire fringe pattern. So, you see here same fringe patterns are kept or you can say this is a transparent sheet. Transparent sheet wherein which we have just photocopied on a transparent sheet and the same thing we have made one more of the same pattern on another sheet. Now what I do is, I slide those two sheets at an angle.
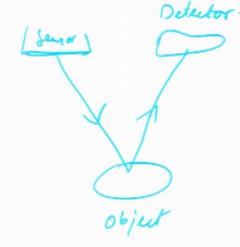
So, a Moire pattern formed by two sets of parallel lines one set inclined at an angle of 5 degrees to the other. So, this is what is the inclination angle 5 degrees. So, you try to get a fringe pattern, this is for linear you can also do for concentric circle patterns So, now, if you start counting the lines . So, from this counting of lines you can try to find out what is the depth of information you are trying to take.
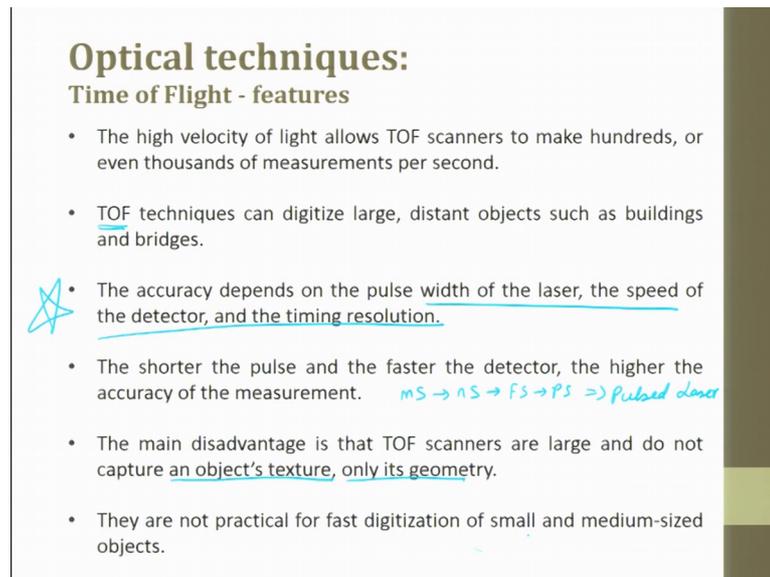
So, the next technique is time of flight. The principle behind time of flight implements it to measure the amount of time that a light pulse takes to travel to the object and return. For example, I have a sensor here I have an object here, I have a detector here. Time of flight at what is the time it takes for a light or from a source to hit at the object and from the object it goes back to the detector ok, it goes to the director. So, this is called as time of flight.

The principle behind time of flight implementation is to measure the amount of time that a light pulse laser electromagnetic radiation takes to travel to the object and return back. The distance D of the object from the laser would then be equal to approximately one half of the distance of the laser pulse travel D equal to C into 2 t. So, D equal to C into t by 2 ok. What is t? t is the time taken, C is the speed of light. So, with this you can try to find the time of flight.

The high velocities of light allows time of flight scanners to make hundreds or even thousands of measurements per second; very fast scan rates are very fast and these techniques are exhaustively used. Time of flight is used in acoustic sensor, it is used in ultrasonic sensor the light is also used. Time of flight techniques can digitize large distant objects such as building and bridges. So, if you want to do a Taj Mahal completely scanning of it and doing a reverse engineering we use the time of flight technique. The accuracy depends upon the pulse width of the laser, the speed of the detector, and the timing resolution.

So, pulse width, speed and timing is very important. Shorter the pulse faster is the detector, the higher is the accuracy of the of the measurement. So, from microsecond we go to nanosecond we go to femtosecond we go to picosecond. So, if you go down in the pulsed laser wherein which the pulse timing shorter the duration. So, you will try to get higher accuracies; it can be done faster higher accuracies. But, the amount of data which is to be handle will be very large.

The main disadvantages that the time of flights scanners are large and do not capture an object textures only its geometry it takes. It captures and object texture only in its geometry. They are not practically for fast digitization of small and medium sized objects.

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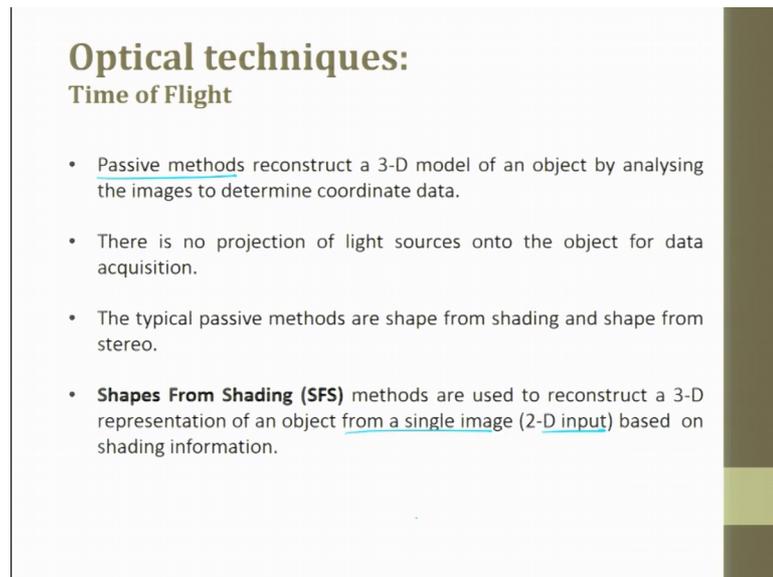
So, in this we have two techniques: one is passive and other one is active. So, passive method reconstruction of 3D model of an object by analyzing the image to determine coordinate datas, we use this passive technique. There is no projection of light source on to the object for data acquisition. The typical passive method are shape from shading shape from stereo it can be used. Shapes from shading methods are used to reconstruct a 3D representation of an object from a single image 2D input based on the shading information.

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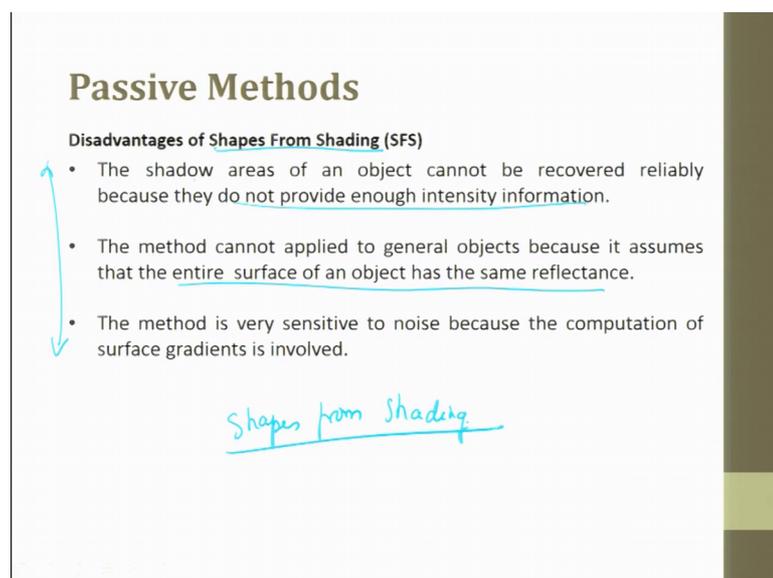
So, the disadvantages of shapes from shading; the shadow area of an object cannot be recovered reliably because they do not provide enough intensity information. The method cannot be applied for general objective because it assumes that the entire surface of the object has the same reflectance. The method is very sensitive to noise because the computation of the surface gradient is involved. So, these are the disadvantages of shapes from shading.

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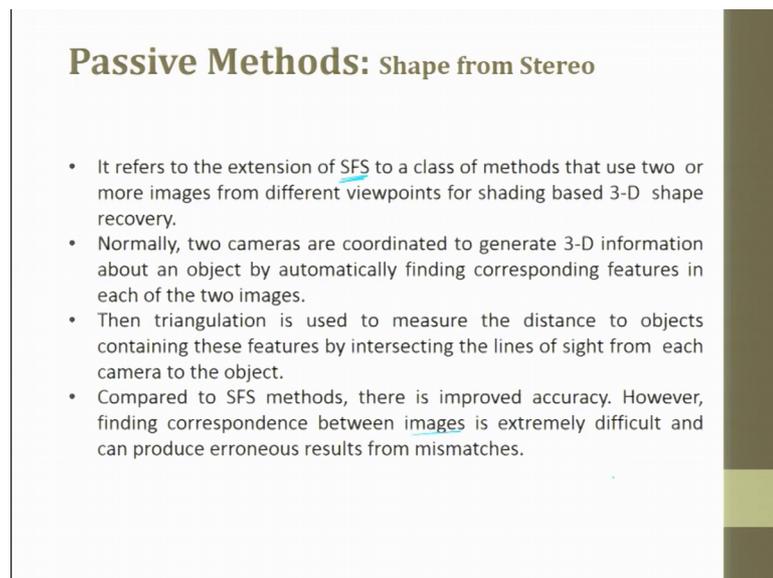
Shapes from stereo it refers to the extension of a surface to a class of methods that uses two or more images from different view points for shading based 3D shape recovery. Normally, two cameras are coordinated to generate a 3D information about an object by automatically finding corresponding features in each of the two images.

Then triangulation is used to measure the distance to objects containing these features by intersecting the line of sight from each camera to the object compared to SFS methods there is improved accuracy. However, finding correspondence between images is extremely difficult and can produce erroneous results from mismatches.

With advent of frequency modulated coherent laser radar based instruments large scale geometries can be measured precisely. A typical commercially RE machine in this category is metric vision system which provides accuracy up to 16 micron. As the laser light travels to and from the target, it also travels through the reference plane of captured optical fiber in environmental control board. The two parts are combined to determine the absolute range to the point.

Non-optical techniques: non-optical techniques is we do not use light, but we use other source of energy here we talk about acoustic and microwave radars. So, acoustic sensors uses frequencies in kilo hertz, the wave is passed through the solid object or the distance is measured through acoustic or microwave radars. The principle of 3D reconstruction is measuring distance from the sensing device to the object by measuring the time delay between the transmitted on the return signal.

So, this is the time of flight technique is used and then they try to figure out the delay in time from there they try to find out the distance, from that distance x y z coordinates can be done. Sonar techniques are normally used in 3D underwater mapping, which provides mariners with a major advantage in obstacle avoidance and navigations; so, 3D underwater mapping using sonar techniques. Acoustic interference or noise is often a problem as it is determining the focused point location.

A radar is typically intended for use with long range remote sensing especially in airline application so, radars. So, that is why you see military applications they always use radars. They are long range remote sensing devices are used to detect the distance and the distance and the time is also known. What in what velocity the object is moving that also can be found out. In 3D reconstruction application a radar is used to measure distance and map geometrical areas to navigate and to fix positions at sea.

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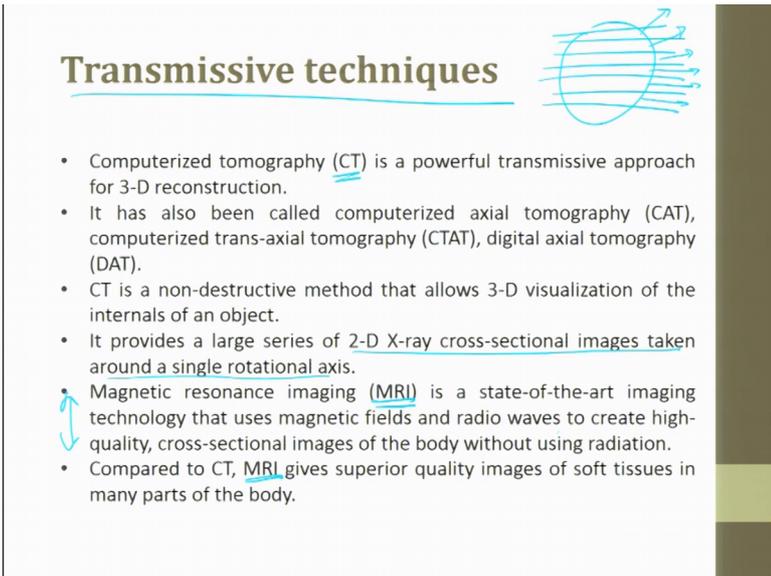
Transmissive techniques

- Computerized tomography (CT) is a powerful transmissive approach for 3-D reconstruction.
- It has also been called computerized axial tomography (CAT), computerized trans-axial tomography (CTAT), digital axial tomography (DAT).
- CT is a non-destructive method that allows 3-D visualization of the internals of an object.
- It provides a large series of 2-D X-ray cross-sectional images taken around a single rotational axis.
- Magnetic resonance imaging (MRI) is a state-of-the-art imaging technology that uses magnetic fields and radio waves to create high-quality, cross-sectional images of the body without using radiation.
- Compared to CT, MRI gives superior quality images of soft tissues in many parts of the body.

The transitive techniques computerized tomography is a very powerful tool transmitting approach of 3D reconstruction. It can also be called as computerized axial tomography or computerized trans axial tomography, digital axial tomography etcetera etcetera. CT is a non-destructive method that allows a 3D visualization of the internal of an image. So, what you do you have an object you slice the object. So now, after you slice you have layer by layer sliced information each information will have an x y data.

And now by looking at each x y data you can we construct a 3D object or you can look at each layer what is the information it has and what is the data or a crack if there is anything there in the product you can try to do it. So, CT is a non-destructive method that allows a 3D visualization of the internal of an object. It provides a large series of 2D X-ray cross section image taken around a single rotational axis. The magnetic resonance imaging is a state of the art imaging technique that uses magnetic field and radio waves to create high quality cross section images of the body without using radiations.

So, this is the other technique. These two techniques are effectively used to for human scanning internally human body scanning internally. Compare to CT and MRI gives superior quality informations of soft tissues in many parts of the body. So, people always prefer to take an MRI data, but basically if you look at MRI data or CT data you can try to reconstruct the object and also try to find out internal flaws which are present.

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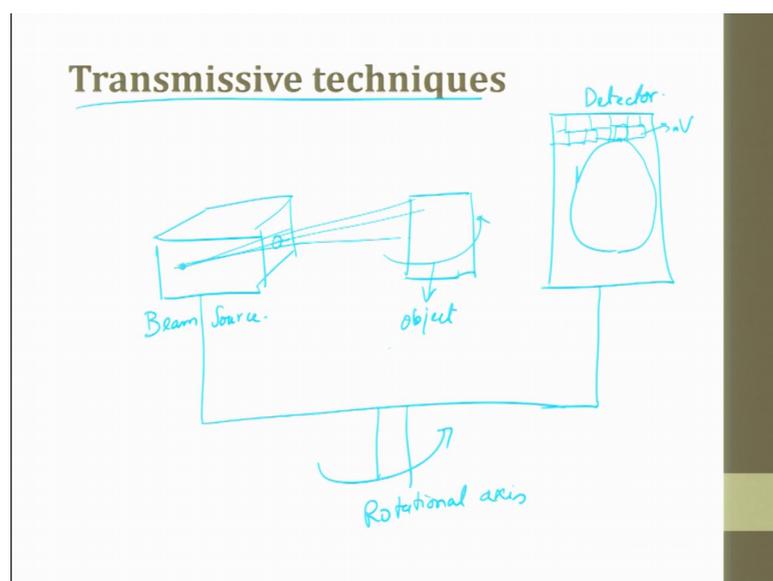
So, here the schematic diagram of this technique is like you will have a source, you will have a source which is a beam source you will have a beam source. So, you will have an object. So, through this you will have the array going out and then you will have the object and then you will have a detector. So, this is the beam which tries to hit at the object. So, this is the object whatever it is a 3D object which can be for example, this object can be rotated.
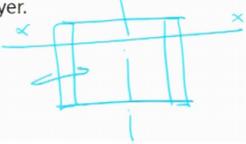
So, here is a detector ok. So, the entire beam and the detector at a fixed distance can be used and this can be the rotational axis, it can be rotated rotational axis it can rotate. So, in the detector what you get is you would be get the image it is something like an image getting projected on the detector, but here you will have this beam which hits the detector. So, this detector is divided into several pixels.

So, from the pixel you will try each pixel you will try to get a frame of data. So, this data will be in milli volts or some voltage and dot will be used to scan and get the data. Suppose, if you decide not to rotate the beam source and the detector you can rotate the object alone and get the data; so, either you rotated at the middle keep these to fixed or keep this object fixed beam and the detector goes around. So, you have a scintillator which tries to take that voltage data and then it tries to convert it into a plane of data.

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So, pixel pixel datas you get; the last technique of discussion is going to be destructive method. In destructive method the RE destructive method is used for a small and a

complex object in which both internal and external features are required to be scanned. For example, I have a cylinder I have a cylinder I have to measure the internal as well as the external details. So, I will try to do a destructive way of cutting the sample recording the data and getting the features.

So, the RE destructive method is used for small and complex objects in which both internal and external features are required to be scanned. A CNC milling machine exposed 2D cross section slice image which are then generated by a CCD camera. The scanning software automatically converts the digital bitmap image to edge detected points as well as the part is scanned. The remodeling of the part 2D slice image of the part are gathered by destroying the part layer by layer and you try to get the information.

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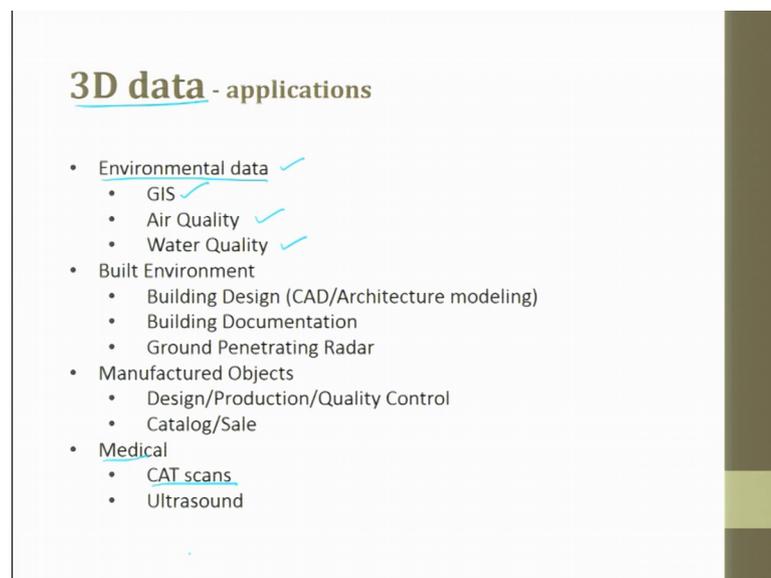
The 3D data wherever it is used it is used for environmental data GIS is used, air quality, water quality we try to use the environmental data where, all these places 3D data plays a very very important role air quality data water quality data. Building environment we have building design CAD and architecture modeling we use 3D data, building documentation we use 3D data. Ground penetration penetrating radar we use 3D data, manufacturing objects, design, production, quality control we use 3D data. And catalogues and scales we use 3D data, medical we use CT scan and ultrasound we also use 3D data for application.

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The raw data will be in textual form, image form surface, 3D spatial, N-dimensional which has time and sensor data. So, there is a derived raw data derived data from this you do at dy by dx and you get that is derived data. You have modeled data, you have technical data, you have file formats and applications these are the different data forms which are used while we are started working in 3D applications. So, researchers annotations to permit reconstruction and bookmark information documenting searches and interactions can be done.

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Metadata is the other new form which is available. Traditional textual information will be available in Dublin Core or COPARES etcetera. Non-statistical information audio video etcetera will be available 2D data from new and existing sources will be used. 3D data point cloud and modeled data will be used, multidimensional data vector, sensor, time etcetera will be used for generating the reverse engineering data.

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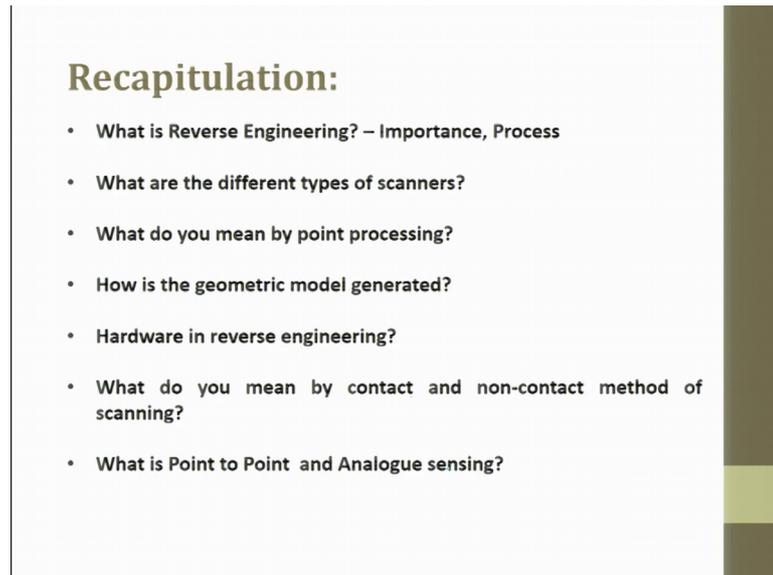
To recapitulate what we have seen in the entire reverse engineering lecture series is what is reverse engineering? What is its importance and processes? What are the different types of scanners which we use? What do you mean by point processing? What is geometric model generation? Hardware in reverse engineering you saw, what do we mean by contact and non-contact methods of scanning? What is point to point an analogous scanning? So, these are some of the topics which we covered in this lecture.
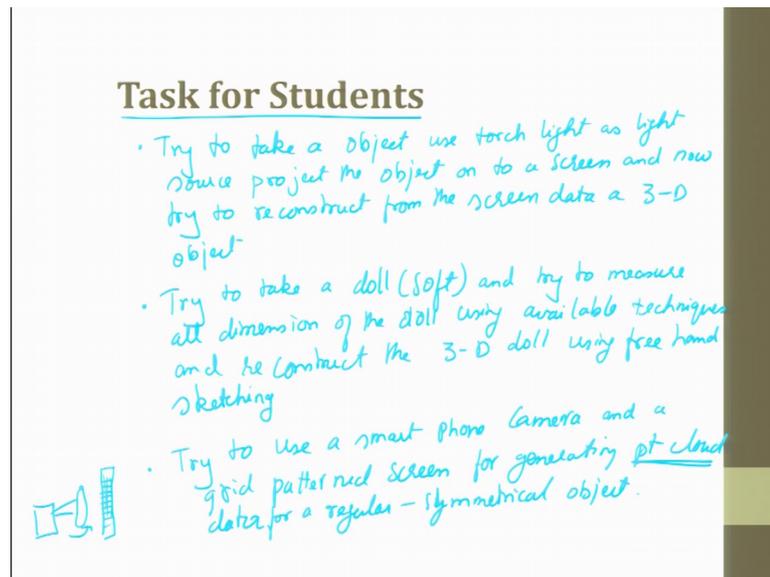
Task for students: try to take a object and use torch light as light source project the object on to your screen and now try to reconstruct from the screen data a 3D object. Try to take a doll soft doll and try to measure all dimensions of the doll using available techniques like scale whatever and reconstruct the 3D doll using free hand sketching. Third one, try to use a smart phone camera and a grid patterned screen for generating point cloud data for a regular symmetrical object ok.

So, here what do I mean? I mean that you have to have your camera your object and then you will have a screen where you have made grids. Try to project it on from the grids you know the data and then try to calculate the point cloud data. If you want you can rotate the object and get more details. If you try doing these techniques now, you will start appreciating how much technology has gone ahead in reverse engineering ok.

Today because of the invent of all the non-destructive techniques like CT and MRI; the doctors are able to locate where there is a cyst or where there is an a leakage of fluid inside the brain, inside the body, the tissue response. All these things are able to do because of the non-destructive techniques which have come like CT, MRI get those details and they are able to operate or attack the spot where there is a leak or where there is a cyst ok.

So, all these things could happen because of these advancements in reverse engineering. Reverse engineering is a very big tool which is used today for rapid manufacturing. So,

what has happened is over a period of time today, doctors have started using reverse engineering tools. They take the MRI data CT data, give it as an input to a rapid prototyping machine. They reconstruct the object completely and see where is this is cyst, how to access it without damaging the other parts of the body. How to quickly attack and how to quickly they could cure the patient and release them from the hospital at the earliest.

So, a reverse engineering, non-destructive tool is becoming a major boon for doctors and also for medical care; apart from your regular engineering structural applications.

Thank you very much.