Rapid Manufacturing
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Lecture – 12
Reverse Engineering (Part 1 of 2)

Welcome to the next lecture on Reverse Engineering. The name itself clearly states that you have to split it into reverse engineering. Reverse do from top to bottom reverse and then do engineering of it, so that is reverse engineering. And reverse engineering place a very important role when we talk about rapid manufacturing. Many a times we have a product, we have to understand the product. So, what we do is we try to take the product measure the dimensions, redraw the CAD part and then we will try to produce it, find out where is a mistake and then start using it or improvising it.

So, when we wanted to implement quality function deployment. Or when you want to do house of quality you want to measure. Or if you want to improvise your product, if you want to reduce the size so then what we do is major times we do reverse engineering. So, this will try to reduce the product life cycle time and it leads to rapid manufacturing.

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So, in this lecture we will try to cover reverse engineering, definitions, it is importance, application, and various processes. So, then we will see 3D scanning process hardware then introduction reverse engineering hardware in terms of contact, non contact, and destructive. So, there is something called as non destructive and destructive. Destructive means you are damaging the work piece or you are damaging the product. And then try to take from the damage product you are trying to do understand what is the mechanism of failure or understand what is the shape what is the size.

But the component cannot be reused the product cannot be reused moment you break it. So, contact non contact and destructive. If you say that this falls in non contact by touch. And then I try to take the measurements whatever I want and make a good use of it. So, now, those things are called as non destructive methods.

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So, what is reverse engineering? Reverse engineering is a process of obtaining a geometric CAD model from 3D points acquired by scanning digitizing existing part or product. For example, I have a part I buy a toy. So, maybe that toy there is a part which got broke a feature. So, let us take a toy like this and I have lost this hand in the toy. So, now, I cannot use this toy. So, what I do is I take the toy try to measure all the data in terms of geometric, when I say geometric dimensions is also included so I do all those things. And then I tried to get the data for this hand.

So, then I know if I do the mirror image of this hand I will try to get this hand also. Now because of reverse engineering I could completely scan, I can redo the broken part. So, if I have to redo it I try to use the technique called as reverse engineering. So, it is a process of obtaining a geometry CAD model. So, when I talk about geometric CAD model we always talk about 3D model only ok.

Because 2D you have to do it in isometric you have to cut and paste and then you try to get a 3D or if you can directly draw a 3D model it is good. 3D model from 3D points so that means, to say the points are the whatever points you get it will be in x y and z 3D points ok. Acquired by scanning or digitizing what do you mean by that we have a product, we have a part, then we have a camera, and then what we get is point.

So, this is a weight age you have a part you scan this is this is for digitizing camera this is for digitizing or taking a picture. So, camera and then you try to get up point. So, we try to convert the part which is in 3D into 2D data or into 3D data and then we try to collect the points. So, the points are also called as point cloud data. Point cloud data so there will be a cloud of points, like what is the cloud several water droplets forming a cluster form of clouds. So, in the same way cloud of data points will be there. So, we acquire all of them from the existing part or a product so that is reverse engineering.
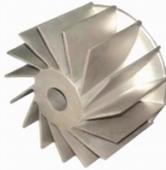
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So, importance: we cannot start from the very beginning to develop a new product every time. So, that is true, when we go through modular concept also that is what we said we

split into several modules and each module will have a library function we pull out the library function. So, we can all the related data for the product. So, this will try to reduce the product life cycle time and this will accelerate rapid manufacturing.

So, every time we cannot start from the very beginning to develop a new product every time. So, we need to optimize the resource available in our hand. And reduce the production time keeping in view the customers requirement ok. So, this is, suppose we try to find out that there is a product already existing in market and people are very happy with it. And now you the people find it only one problem is they say it is very expensive.

So, what you as a industrialist or a as an engineer who works on rapid manufacturing will quickly does take the product and then split into several small assemblies then split the sub assembly into several parts. Now you try to scan the parts scanned subassembly then put it in the product and scan it. Now, at each stage what you do is you write down all the functions and then for those functions you also try to put the costing.

And now you will see where exactly is maximum casting and then you start working on how can we reduce the price and work on the part, without sacrificing the performance. So, the so for that what we do is we use exhaustively reverse engineering. For such cases reverse engineering is an efficient approach to significantly reduce the product life cycle. So, you can see this is a impeller with of a pump which is scanned relooked. And then you start trying to understand, do analysis and try to find out where the failure has happened or you some other company has made you scan it and try to get the data.

From the data what you do is you try to do 3D model, 3D model you give it to cam then you start machining it and then getting into the data. So, all these things reverse engineering could be accelerated because it is in digital form. So, moment in digital I can modify the data or I can change slash filter the data to get what I want exactly and then start using it.

Is reverse engineering legal? People always ask this question because some we are the product which is already existing, we try to scan and copy the part. Please understand if you exactly copy it is illegal. If you do reverse engineering try to understand what is the existing part or a product of your company or some other company. And try to find out what is the problem in those part or how do I improvise it and then customize it to the customer requirement or change the product to meet out the customer requirement then that is not illegal ok.

So, whenever we try to do reverse engineering we should keep it in mind if we used it for betterment of the part or the product then it is legal. If you copy the same and manufacture it is illegal ok. So, it is also often lawful to reverse engineer a product or a process as long as it is obtained legitimately. If the product is patented it does not necessarily need to be reverse engineer as patents require a public disclosure of invention. It should be mentioned that just because a piece of product is patented.

That does not mean the entire thing is patented there may be parts that remained undisclosed. So, if you want to improvise if you want to have a additional patent on the existing one. So, take the existing part and then understand what is the functions improvise it and then start getting it done. So, the reverse engineering in a nutshell can be legal if you use it for customization of part slash product. And then second thing is improvising the existing improvising, existing product performance.

If you do that then this reverse engineering is always a legal one ok. Customization of the part or the product means, suppose if there is a product which is already working, but which fails at regular intervals of time. So, now we have to find out why there is a problem and how do we improvise it and moment you improvise it you try to when you improvise it itself it means that you are trying to customize to the customer requirement. So, and then you try to get it done. So, here reverse engineering is exhaustively used. And within the company if you want to improvise it, it is also used.

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So, the fundamental use of reverse engineering; is to get the feel of the product in terms of dimensional accuracy. This helps in improvisation to determine the flaws of a product. In other words the reverse engineering process in itself is not concerned with creating a copy or changing the artifact in some way. It is only an analysis in order to deduce design features from products with little or no additional knowledge about the procedures involved in the original production.

So, this is very very important this is very important. Even when the product reverse engineer is that of a competitor the gold may not be to copy them, please understand this is very very important, but to perform competitors analysis. So, to find out this is what is the competitors product lagging. So, if I can improvise that then my product will have a better sale; only for that you can use. I repeatedly say if you exactly copy one to one and if you produce it that is illegal.

If you try to copy and improvise the design then it is for the betterment of the product to perform in the market it is agreed ok. So, that is what we are trying so, may not be to copy them, but to understand say for example, when we do a new product release new product release we do lot of cut and paste technology. For example, we try to take some amount of knowledge from x product, some amount of knowledge in y products, some amount of knowledge from z product.

And then what we do is we integrate the knowledge of x y and z into our product. It is not copy exactly when I copy x part x part of a product a and y part of a product b and z part of a product c x y z are assumed that these are the technologies I am going to take from three different products and I am going to integrated in my product. When I start integrating you will see lot of changes will happen in your existing design.

The interface between x y and z has to be completely different when you put it into your product and get the output done. So, when you try to cut technology is also and paste it into your product there will be a paradigm shift in the output of the product because you are not exactly copying product a x product b y and product b c z. I mean x y z are portion of a b and c, you are not trying to take exactly that and then paste it in your product and produce a product which will never work.

You have to do then customization, then you will see completely will a different technology. A simple example is for example, you pick up tire from car, you pick up an engine from another car, you pick up a bucket seat from a third car. When we try to pick from product a tire from product b engine product c a bucket seat and when you try to integrated into your product. So, it will be completely new product because you have only taken a portion of the product right.

When you take a portion and then put it into your product when you try to make a car this will never be like a product a car it will never be like a product b car it will never be like a product c car; it will be a new car of it is own. So, here what did we do was we found out the tire which is used in car in product a is the best the tire means the tire assembly completely. Then engine, engine assembly completely then bucket seat it is assembly completely.

So, when you try to integrated in your product you will see completely a new one. The customer will have a satisfaction like a bucket seat satisfaction like that of product c we

will have a engine performance of product b. Wherein which the tire which is getting integrated will be of product a. So, when we tried putting it everything together you get a completely new product ok. For example, recently when I visited one of hotel in the nearby town, I found out pretty interesting there was a, item in the menu card with says pasta dosa, pasta dosa.
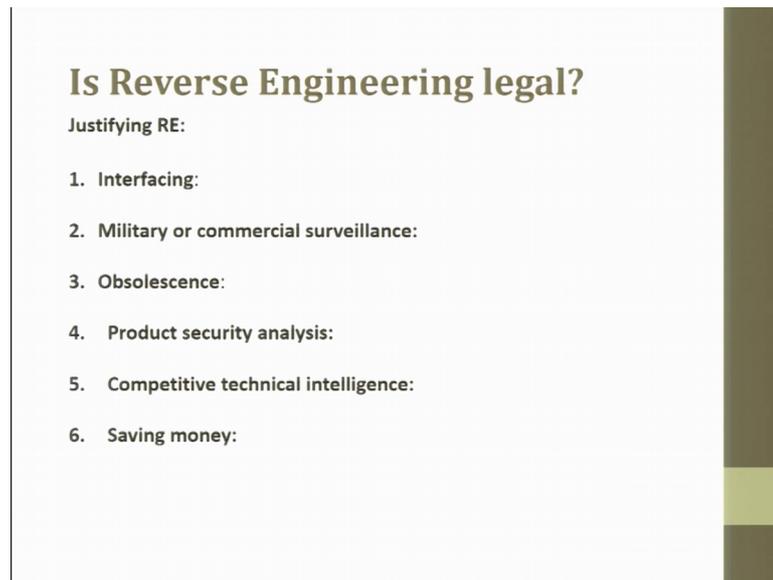
So, dosa is a concept which is taken from south India and pasta is an Italian concept. So, now this person who offered me the product or the item food item he has integrated dosa plus Italian pasta. He has not exactly taken only dosa and Italian pasta if he does add two different things independently then it might not get along with the taste. So, what he has done is; he has added some more customization between the dosa layer and the pasta layer.

So, this has made the entire jelling very tasteful and the taste gradient is being maintained from Indian taste to Italian taste you while eating the product you can realize. So, here a new menu is been released wherein which there is a cut and paste acknowledge between these two. And the cook or the chef whoever it is has put his innovation in making the taste gradient between these two and customize it to the requirements.

So, if he wants to do that he can always do reverse engineering. So, he can go to south India get the get the recipe of how to make dosa, go to Italian somewhere and then try to get the recipe whatever it is ok. So, here he did two things and he understood these two and then he improvised. So, reverse engineering is always legal. Provided you try to change or customize or improvise the existing product. If the product can be internal the product can be a competitive whoever it is according to your choice ok.

For example, when we talk about ram which is used in computer there are 100 different companies of ram. You can pick anyone an interface it with your desktop computer and start using it, you have several PCB's right you have several graphical cards. So, you pick the best graphical card, the best ram performance, and the best whatever it is and then put it into your system and you try to get the maximum comfort while operating your desktop.
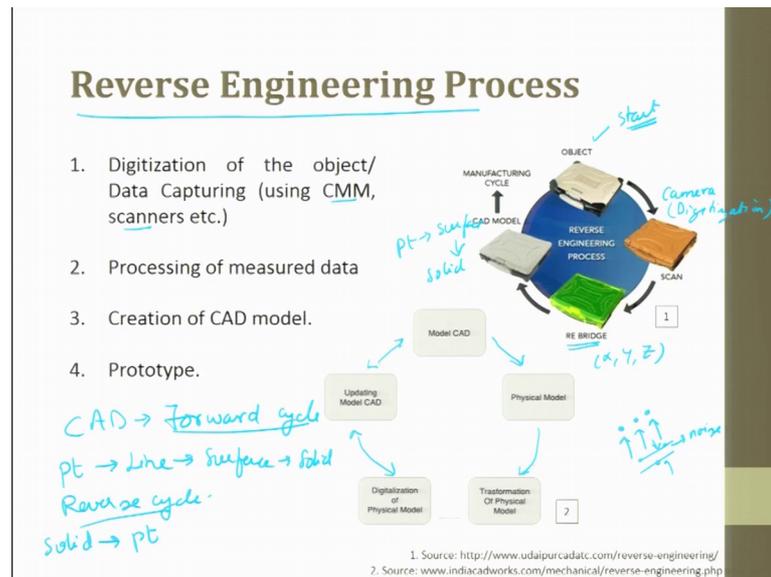
Is Reverse Engineering legal?

Justifying RE:

1. Interfacing:

2. Military or commercial surveillance:

3. Obsolescence:

4. Product security analysis:

5. Competitive technical intelligence:

6. Saving money:

So, here is it is also reverse engineering. So, it interfacing is a place where they do revere engineering and in military or commercial surveillance they do lot of reverse engineering. When we have an obsolescence product if you want to produce it for example, we have a bearing which is used in a machine which is 50 years old the bearing count off. So, no company in the existing world is producing such bearings which was the peculiar type bearing. So, it was an obsolescence product nobody was ready to give as a service.

So, what we did was, we took the old one did reverse engineering understood the parts then we may fabricated our own and then we have put back to machine into action. So, for this we try to do reverse engineering. Product security analysis there also we do reverse engineering, for competitive technical intelligence we do reverse engineering, and saving money also we do. So, this saving money is to reduce the product life cycle time. And to understand the processes which are attached to it in a very quick fashion we have used reverse engineering.

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So, in the reverse engineering process it is a cycle. So, you will start, this is a start point you will always start with an object ok. Then you will scan by using a camera or whatever camera or a photograph whatever it is. When you try to take a 2D we try to take images from several directions, we try to stitch them together and then form a 3D part. If you directly do it by 3D it is a different story. But ultimately if it is 2D or 3D it works on points.

So, these points are converted 2D or converted into 3D and 3D you tried to convert into surface. And this surface when you joined a surface you form a solid when we do look into it back we will give you the object. So, then what we do is we use reverse engineering RE bridge and then we try to make a CAD model. So, this is canning, this is a camera doing. So, there is all these is got into now x y z data ok. This x y z data is given back into a CAD, wherein which the CAD is used to convert point to surface, surface to solid.

And you also have to do some amount of patchwork, doing a patchwork on top of this data reverse engineer data is a big challenge. You have to smoothen out the noise because there can many useless or there can be internal reflections. And when there is an object where the depth data changes so abruptly so then also you try to get a noise data. So, here we apply lot of filtering techniques and then try to make a CAD model.

And the CAD perfectly made as a solid can be used for rapid prototyping can be used for rapid manufacturing. That means to say you make a direct tool indirect tool and then try to take a product and you can also send it to CNC machines for a manufacturing cycle ok. And in reverse engineering the camera does the portion of digitization ok. Digitization of an object slash data capturing using various techniques contact type and non contact type technique is done, so this is 1 ok. So, then we try to take the data and process the data.

So, CAD model, so this is intern so it goes like this. So, physical model; from physical model we transform the transformation of physical model which happens here. So, the processing of data happens. So, digitizing of the physical model happens. Then what we do is we create the CAD model and then we try to make prototypes ok. If you see typically CAD in the forward cycle we have points, points leading to line, line leading to surface, surface leading to solid we do that.

So, here what happens in reverse engineering cycle we have solid, we generate points and then we start going. So, it is just the reverse of it ok, but all these things could happen because our CAD softwares today have become so, versatile and it has got lot of inbuilt features wherein which you can do small noise corrections all those things. What are noise? Noise which I am trying to say suppose if there is a point here here here and when the light falls on it and when it reflects back instead of getting this if you have a varying depth happening.

So, then there is a variation in the signal so this is called as the noise. You are supposed to get good data points, good data points which forms an object is called a signal. And some random noises which are inbuilt that those are nothing, but the error these errors are because of internal reflection of laser. Or when you touch the data point if the probe slightly slides off, or if it is circular or if there is a depth which you cannot measure if the depth is very high. So, then you cannot measure the feature depth is very high and very small features are there. So, then we have lot of noise data to smoothen it out.

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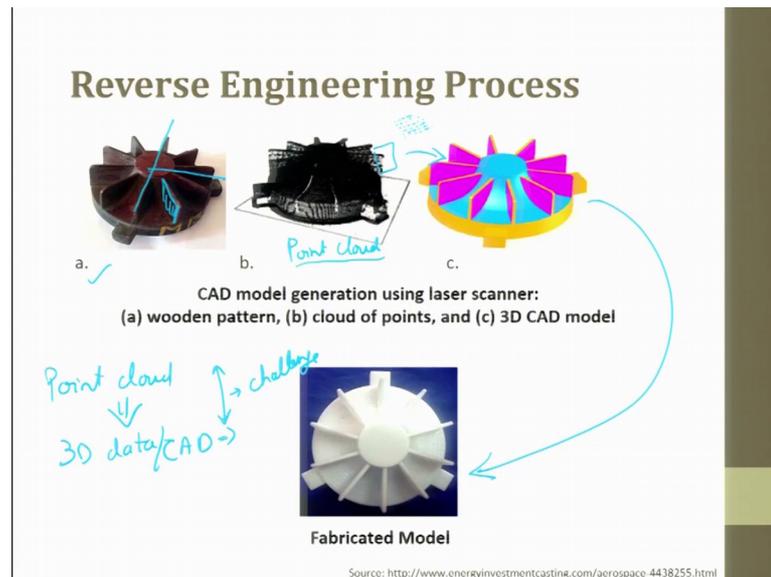
So, this is how a typical CAD model generator using laser scanner is. So, then what happens this is the wooden pattern which is the raw information or which is the made object in front of you. Then what we do is when we do reverse engineering of it. So, we convert the solid into a cloud of points this is called as point cloud data or cloud of points point cloud data, point clouds. So, what you see is if you zoom it and see you will see lot of discrete points.

So, you will see a lot of discrete points, this points are called as point cloud data. And from the point cloud data we work on it do corrections whatever I said signal to noise ratio apply filters all these things then what we improvise and then what we get is a CAD model. So, if you look at it this is the solid object which is available, this is the model CAD model which is got after you do from the point out that is what if you see here we have said very clearly that RE bridge.

So, RE bridge is this fellow and then what we do is; we have developed a CAD model. And from the CAD model what we do is we directly go for rapid manufacturing or rapid prototyping prefabricate a model ok. Assume that this wood is very esthetic or it is very ancient. So, now, we have made a replica of this in our mold and which this can be used for making several thing. The other thing is today there is lot of initiative spend by UNESCO there are ancient artifacts which are getting deteriorated over a period of time because of various natural reasons ok.

So, all those now UNESCO has come forward or UN nation have come forward or archaeology society of India has come forward. They have said that let us do reverse engineering of all the existing fabulous statues and artifacts. So, what they have done they have collected the data points point cloud data is available. And now what government is decided is using those point cloud data can be shrink or expand the CAD file.

The moment you can shrink and expand the CAD file from this point cloud data they have started making lot of souvenir artifacts which gives them the feel of India ok. So, that is what has happened today. Government has started doing lot of reverse engineering of the existing product, but their intention is to preserve the data for good use. So, there they do not try to improvise, they just try to take the actual and try to store it somewhere. And in many places the parts are getting damaged the statues are getting damaged or a parts are getting deteriorated.

So, what they do is they (Refer Time: 27:13) off that part remove those defective parts. And try to do reverse engineering replica of it to patch up the details and try to clean up to make up actual a damaged one back into actual thing for that also they do reverse engineering. So, where do they play more is this part. So, they play exhaustively on collecting point cloud data and from point cloud converting a 3D data or 3D CAD. This is a huge challenge, from here to here is a huge challenge it is not so easy, see here it is a engineered part.

So, in engineered part you can always take only half of the data or even you can take a quarter of the data and you can say spin it off, revolve you will get the same thing. And here you know if it is a straight line if we can measure the depth I can sweep this and get the data. But in reality when there is a 3D object where there is varying radius. For example, your face varying radius so getting point cloud data is a challenge. And then working of the data converting or smoothening out effect is very difficult.

So, there are two types of scanning techniques these techniques are nothing, but reverse engineering tool we can say. So, this scanning can be done by contact type the scanning can be done by non contact type. Moment I say contact; that means, to say I can use your probe touch the part and try to get the data. For example, you can use your CNC machine itself to touch and get data out of it. For example, CNC machine you write a program manufacturer part.

Now, what you do is you put your probe maybe a tool which is conducting, to put a tool there and assume they are workpiece is a metal you try to give a polarity of positive or negative to it give the reveres of the workpiece polarity to the tool. And now you go very close to it and touch it. And whenever you touch it you give the resistance goes to infinity. So, you when you touch it what happens you can make a beep sound and you can start recording the data x y z data.

And if you do not want to use a CNC machine you want to use a original machine where you do not want to touch and give all those electrodes and all. Then what we do is we try to convert the CNC machine into a coordinate measuring machine. This is coordinate measuring machine ok. This is a CNC machine wherein which there is the tool is now you have probe, the probe in turn is attached to a spindle.

There what you do is moment it touches a part it can be; conducting, non conducting, whatever it is. Moment you touch the part what it does is this probe has a contact which

is there in this spindle, it breaks the contact and immediately x y z data points are record. So, that is how a CMM works ok. The CMM cannot be used more exhaustively on soft materials for example, rubber when you want to make black colour washers or gaskets which is used in prestige which is used in a pressure cookers which is used for ceiling to flat metal faces, if you want to seal it we always put a gasket in between.

So, if you want to measure the dimensions or the form accuracy is of these things it is very difficult because these gaskets and washers are soft. And when you try to touch it, it will try to deform the objects and moment you try to get the data of the deformed object. When you reconstruct the object you will see that there will be a lot of error in the data points. So, you washers so black for rubber material you cannot use the CMM. So, we have to use something like a non contact technique.

And here since it has to touch every point say when you touch three points you try to get a plane. So, when you touch several of these points you try to get a line. So, it is comparatively slow when you take care of the non contact. Then the other restriction is, suppose you have your probe of diameter, diameter maybe dia 6 millimeter. So, when this cannot enter a feature which is of 3 millimeter. So, it will only scribe it on top and it will say it is a straight line.

So, this also puts a restriction on a getting the data points, fine tune data points is not possible ok. So, one way of scanning the work piece and getting the data is going to be through contact technique. The other way is going to be through noncontact technique. Moment you say non contact life is the one major fellow which comes in which comes handy to you. So, again in light there are two lights, one is called as coherent light and the other one is called as white light.

Moment you say coherent we always use laser and moment we say white light then you put a prism then you try to take a particular wavelength and start using it. So, laser can be used optics can be used CCD charged coupled devices sensors cameras can be used to capture the data. So, where do we find difficult highly shiny surface as well as highly rough surface then surface parallel to light access cannot be scanned properly.

So, here is a technique wherein which laser is used for measuring the profile topology whatever it is. So, here we have a laser this is nothing, but an atomic force microscope; atomic force microscope. Wherein which if you want to get data of nanometer range or

arm strong range you can start using this atomic force microscope. So, here there is a laser which hits on the pro back side wherein which here you have put a reflecting surface.

So, the laser hits and then this reflects the laser and it tries to fall on a diode, this diode is a photodiode which is divided into four parts. So, moment the either the table moves the work piece moves or the probe moves you will see there will be a get deflection attached to it this deflection is recorded in the deductor. So, moment there is a laser with hits on the back side of the work piece it reflects you know the principle of what if this is there and this angle also will be equal.

So, incident ray reflective ray. So, then this falls on the deductor, this deductor is divided into four parts; there will be a shifting happening here. Based upon the shifting you can try to find out what will be the topological difference in data. You have a voltage recorder; this voltage recorder tries to give you the data points from there. You get one line of data you get several of these lines if these lines stritch to each other they form a surface.

So, that is where we are using if you have a surface very rough which or a very flat surface which cannot be detected by the probe this technique will not give you data. Other way around is if you remove this probe itself directly allow laser to hit and reflect that is also possible. And again if the surface is very flat and very shiny, then you will not get a data probe. So, this is a major limitations and this is the major limitation of contact type. But these two are the most prominent scanning techniques which are available, contact scanners and non contact types scanners.

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For a ideal scanning process; the scanning procedure has to be divided into five steps; very important it has to be divided into five steps. Acquisition of the data is important for example, I try to scan this object which is a pen holder. And I get all the data, but if I tilt the object like this and keep and try to take the data. So, now, all the data points whatever I have got is inclined data at an angle.

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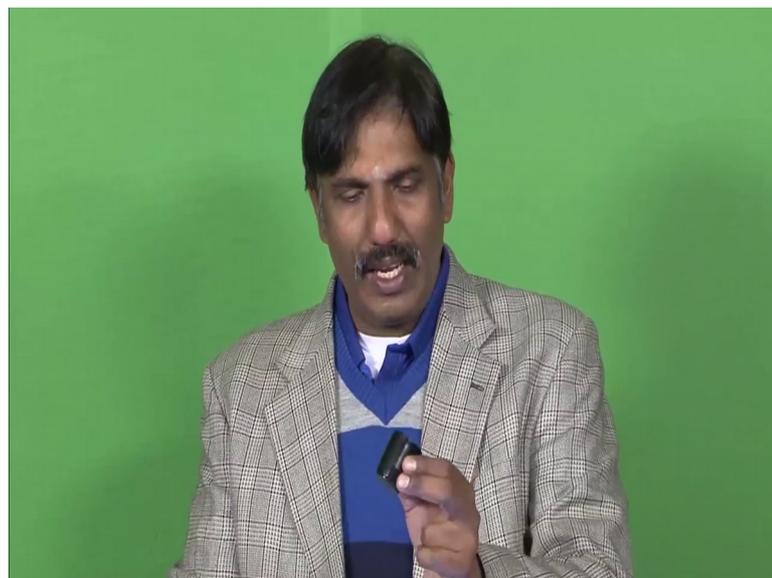
So, I not only have to acquire the data, but also align the data with respect to some reference. Then only what happens whatever data points have got in inclined can be

corrected later so that I can reconstruct this object. So, when we talk about scanning procedure it is not very trivial, it needs lot of skill. The first thing is you have to any sensor if you have to use first thing any sensor or a measuring device you have to use you have to first step is to calibrate.

Calibrate and see whether the sensor is working proper, here it is the scanner so we try to calibrate. So, how can you calibrate you try to have a scanner we are talking about non contact type. So, you have a camera you have a camera. So, this camera what we do is we try to keep the object known distance and we try to take the data points. And from here what we do is then we try to do at varying distances. And then vary in heights then we try to get the data points we do first calibration we do calibration.

After the calibration is over then we start acquiring the data. When we acquire the date we try to collect the whole data whatever is there. Then what we do is we try to align the data to some reference point. Then what we do is we try to do a mesh generations. So, that we can try to understand how is the surface getting mesh generation.

Then from the mesh generation what we do is we try to do post processing and at last what we do is we try to do simplification try to remove all the data after post processing convert the 3D object into a library function for later use whatever it is so that is simplifications. So, we do acquisition of data, alignment of data, mesh generation, post processing, and simplification. So, by and large when we do any non contacts scanning we have to do a calibration.

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So, what is acquisition of data? Acquisition is the first fundamental step in which the acquired image is created in the software as a set of data points. So, you can see here so there is a laser which comes here laser which comes here and laser which comes here. And then you have one more laser which is used for aligning or this laser can come from here, this will can be the data points which can go get acquired. And this blue whatever is the laser is used for aligning or calibration whatever it is.

So, the acquisition is the first fundamental step in which the acquired image is created in the software as a set of points. These points define a 3D representation of the part of the object that has been framed and hit by a light pattern generated by the projector ok. For this reason it is advised to proceed with the acquisition of a wide part of the object first postponing the acquisition of details and missing parts in the following moments. So, for example, if you have a car completely so you might have doors, and you might have windows, and so all those details will be minor details like handle another things will be there.

So, if you want to look for all details in one shot it will be very difficult. So, what do say is first they say you take a wide parts scan of the complete object and then you start working on minute details then try to get both of them stitched in a software. So, then you get all the data continuously. Once a rough 3D reconstruction has been obtained the scanning can be improvised by adding more views that correspond to small or missing

features. Try to get the overall picture and then try to comet to these parts. And try to acquire as much of data as you can and then try to do it. So, this operation is called acquisition the first step.

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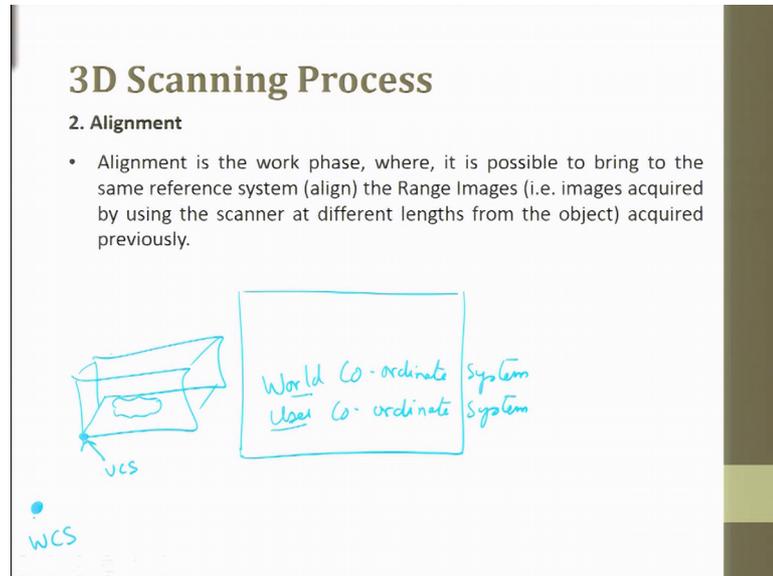
Alignment; alignment is the work phase where it is possible to bring out to the same reference system; the range image that is the image acquired by using the scanner at different lengths from the object acquired previously. So, alignment is something very very important ok. So, basically what we are trying to do is when you try to use CAD also you have something like you have world coordinate system. And then you have user coordinate system, you have world coordinate system you have user coordinate system.

So, now, what you do is you try to collect the data in terms of user coordinate system and then transform the data to the world coordinate system so, that you can try to have proper referencing of the features in a part in terms of user and world. For example, you have a object the entire object will be drawn with respect to the world coordinate system. But when you have to look for other details so, this is called as user coordinate system and here suppose we have some features then with this you try to draw this feature and later you transform it to the base.

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Then when we talk about alignment there are two types of alignment; manual alignment and global alignment. The process is manually helped by the identification of three corresponding point between the two acquisition taken into account so that is called as manual. So, here identification of three corresponding points between the two acquisition, three corresponding points between the two acquisition two settings, two frames taken into account. So, that is done manual alignment.

Global alignment besides the manual alignment that work with identification of three corresponding points, another alignment tool called as global alignment is also available. It is advised to run this command after having manual alignment all the range images in this way the alignment of each acquisition is optimized with respect to the other. So, we will have a separate lab demonstration on this reverse engineering. So, where the concept of manual alignment and global alignment will be much more clear.

Then from the data whatever you have got first you have acquired the data then you have aligned the data. Now, you have to get the point data into a surface data. So, when you have to do it a surface data we will always try to do a mesh generation. Once a significant number of range images have been acquired and aligned in order to create a 3D model as complete as possible. The next step is to generate a triangular mesh.

The mesh generation converts a set of 3D points range image to a data constituted by a set of triangles called mesh. So, 3D points this will be x y z. So, you will try to take it it can be in one plane it can be in varying plane. So, for example, you can see all these things are measures. So, the mesh is first useful data that can be elaborated and exported in the available format ok. So, mesh generations of first was acquiring the data.

So, this is what we have seen till now; acquiring the data, then aligning the data, then what we do is mesh generation. When we try to do mesh generation only we try to see how close is the figure data digital data to reality we can see after the mesh data. We can validate your mesh data with respect to the original and see how much is the deviation which is the tough task. But this is how we do it, mesh is to generate convert a set of 3D points to a data constituted by a set of triangles that is nothing, but mesh.
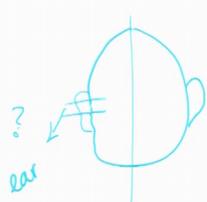
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Next we do post processing; post processing is every operation that involves the enhancement and finishing of the meshes. So, here they call it as patch work patch work. Patch work on a CAD data today there are several tools also available to do patch work. So, what it does is it sees extreme point of the data and it is next sees other extreme point of the data then it tries to smoothen the data. Or it try to look at one set of data points and then the other set of data points if there is a missing data point.

For example in a phase, it comes like this so here is a data which is missing. So, immediately what it does it tries to develop a data depending upon the radius and looking into the form of the object it tries to apply some sense and try to join these two points. And here maybe there is a ear component which the system might not know, it will just draw straight lines and close. So, you will have a ear here you might not even have a ear here.

So, working on these data is called as patch working and this is a post processing. Many a times what we do is we see that and then we try to take a symmetry of it. And then a manually somebody works and then tries to get a ear data on the other side such that it looks feasible. And ear data is only a very crude representation such big data's are just for understanding there will be a small data point missing. So then they do a connect of these two data points based upon the radius prior radius after it tries to find the best fit and then it tries to draw curve in it ok.

So, these jobs are called as post processing jobs. It is purpose is to prepare a complete and a flawless 3D object ready to be exported. So, moment you do post processing; now whatever you get the data is the final data which can be used for any further operation. It can be used for prototype it can be send to machine, it can be send to quality check, it can be done for packaging design, it can be done for logistic arrangement. So, all these data can be exported people can work on it and people can close the data. These operations should be chosen depending on the result to be achieved and they can affect more or less the 3D model.

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And the post processing we can have make manifolds. So, this involves solving the possible topological issues that can be attributed to the presence of a triangular edge shared by more than two faces. So, if you want to so this thing when you are studying about CAD model validity, CAD model validity we study about this manifolds. So, for example, you have a triangle you have another triangle coming like this. So, these two triangles are different different in different faces.

Now this has to be attached this has to be attached. So, how do you do it? So, this involves solving the possible topological issues that can be attributed to the presence of triangular edges shared by more than two faces. So, if you see one above each other it is linked. So, the other thing is deduction and repair intersection of measures or triangles.

Solving some possible topological issues attributed to the triangles that intersect other triangles of the mesh surface this is also one of the post modeling.

Then filling up holes detection and fixing of missing parts on the mesh surface it automatically fills the missing part with the surface composed of triangles that propagates the nearby shaped and texture information. So, that is what I said a radius there a radius here it tries to approximate and draw a line with this radius and this radius. So, it tries to draw an average and tries to connect these too filling holes.

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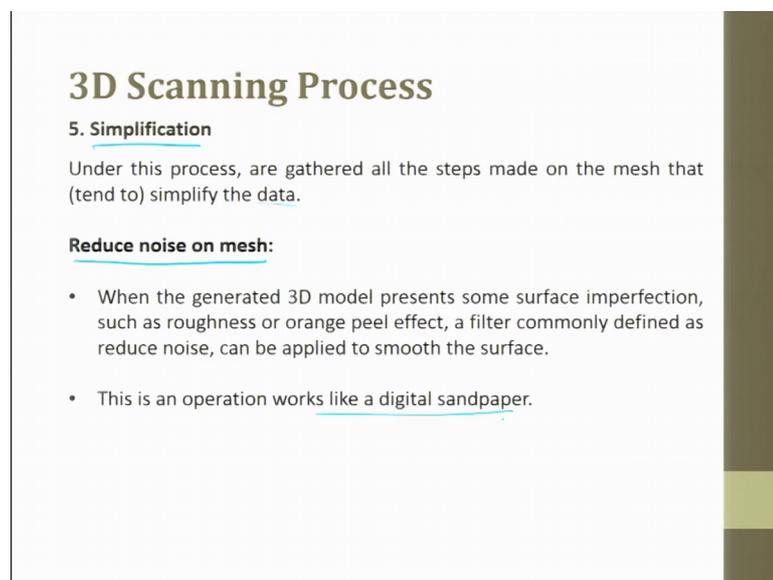
And the last one is simplification; under this process all are gathered, all the steps made on the mesh that simplifies the data. So, here reduction noise on mesh when the generated 3D model presence some surface imperfections such as; roughness, orange peel, effect of filter commonly defined as a reduce noise, can be applied to smoothen the surface that is simplification. This is an operation work like a digital sandpaper so you try to finish it up.

Under this process are gathered all steps made on the mesh that simplifies the data, mesh decimation reduction of the number of mesh triangles. So, that smaller the mesh higher will be the precision. This operation can be done forcing a tolerance that guarantees that the decimated 3D model does not differ more than this value from the original model ok.

So, this tries to guarantee, it is done in order to have a more manageable file that is quicker to elaborate with the post processing tools and of smaller dimensions thus easier to share on the internet and with less occupancy on the hard disk without losing a 3D model detail. So, what it means is let us assume you have made an object ok.

This object now will be simplified in to a form for example, I have now made it into a rectangle. And I will say where are the points where some amount of reduction has to happen rectangle. So, the corners for reduction I will say where you have to reduce material reduction and then I will try to say where all holes have to be placed.

So, now, what has happened rather than storing so much of small small small datas and mesh datas I have generalized it into a rectangle corner for production and then whole. So, basically what happens is we are trying to use Boolean operations on simple geometry to get the data stored.

So, advantages it occupies minimum data it can be quickly called it can be quickly work and it can be smoothened very fast. So, here when we do that we also have some

approximations, how much approximation do you permit such that you can still get back the same object.

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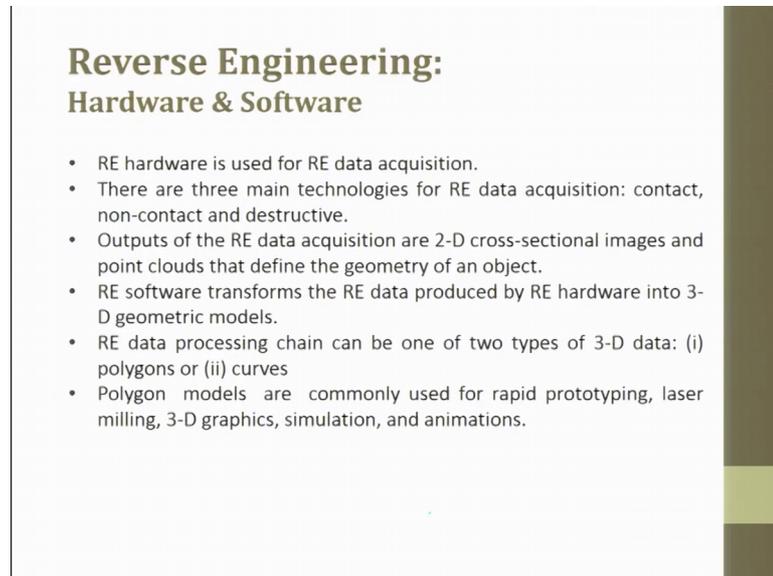
Reverse Engineering:
Hardware & Software

- RE hardware is used for RE data acquisition.
- There are three main technologies for RE data acquisition: contact, non-contact and destructive.
- Outputs of the RE data acquisition are 2-D cross-sectional images and point clouds that define the geometry of an object.
- RE software transforms the RE data produced by RE hardware into 3-D geometric models.
- RE data processing chain can be one of two types of 3-D data: (i) polygons or (ii) curves
- Polygon models are commonly used for rapid prototyping, laser milling, 3-D graphics, simulation, and animations.

So, we will continue in the next class. seeing more of hardware, reverse engineering hardware and software.

Thank you very much.