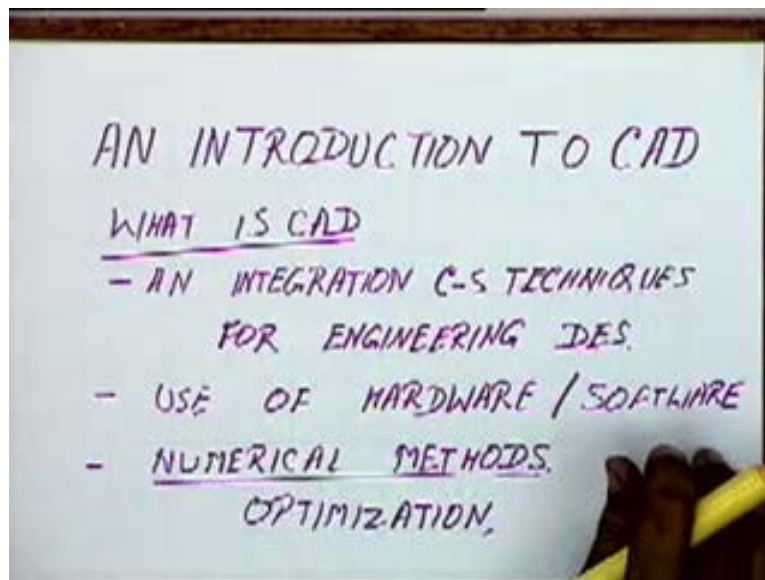


Computer Aided Design
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Lecture No. # 01
An Introduction to CAD

Today we are basically going to introduce a subject of computer aided design. In computer aided design, we normally refer to a number of different kinds of activities.

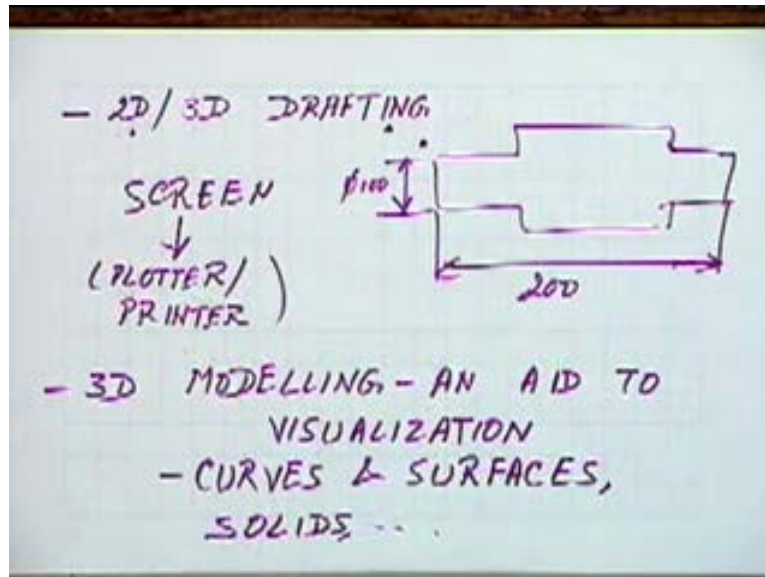
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Before we go on to the any of those activities, I first want to briefly describe what is normally referred to as computer aided design. In computer aided design we basically talk of integrating computer science techniques with or integrating computer science techniques for engineering design. What that means is any kind of use of computers in the design activity is referred to as computer aided design. This includes a wide variety of usage, this includes a wide variety of techniques that are used some are computer graphics techniques, some are simply using computer as programming tools. We will see what are the different activities that can come under these or what are the different computer science techniques or computer techniques which have been used under the design domain. This use would include use of both hardware as well as software. When you are talking of hardware different kinds of hardware have been used in terms of the screens that you have, the input devices like I think you all familiar with the mouse. The other input devices maybe a ball or maybe a light pen, there are other output devices like plotters. So different kinds of hardware are relevant which are specifically meant for CAD activities. Different kinds of software which have been developed which are different kinds of modelling software we will be talking of that in detail. Then if you talk of different numerical techniques, numerical methods, when I talk of numerical methods I include optimization, I even include the normal programming or instead of talking of automation we just program a particular activity where we are using the computer as a number crunching machine.

All those activities are what I include under numerical methods. They can include matrix multiplication or where very large matrices are involved, they can include solution of partial differential equations, they can include optimization techniques all these are what I cover under numerical methods.

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When you talk of CAD after numerical methods, the next thing that is normally including under CAD is what is referred to as drafting which is either 2 D or 3 D drafting. When we say drafting what we mean is the normal drawing work that is done. You have all done a course on engineering drawing. Whatever drawing you do on a drawing board, the same instead of doing it on the drawing board you do it on a computer that means if you have to draw lets take a very simple example if I want to draw the shaft and I want to give it a dimension something like this and maybe some length over here which is let's say, if I want to give it a set of dimensions like this I can make an engineering drawing out of this on the drawing board. Instead of using the drawing board I can do the same thing on the computer using Auto CAD or using some other drafting package. This drawing consists of a set of lines that have been drawn here, the set of arrow heads, the set of text that has been written and so on. In this each entity is a line or an arc if you are drawing or if you have an arc over here that will be an arc, so each entity is a line or an arc.

An entity is not the complete shaft, we don't have the concept of a shaft right now, we have just drawn a set of lines in a set of arcs. This is what we mean by drafting. These lines can be 2 dimensional lines or they can be 3 dimensional lines but they are essentially lines and arcs. And we use these lines and arcs to make a complete figure on the computer. Once we make a complete figure on the screen, from the screen I can take a printout using maybe a plotter or a printer. So that is where CAD specific hardware comes into picture. We have specific hardware meant for plotting, we have specific hardware meant for printing. The screen will normally be a high resolution screen like a VGA monitor or something like that and the basic application is the drafting application that we were talking about. So this is 2 D or 3 D drafting.

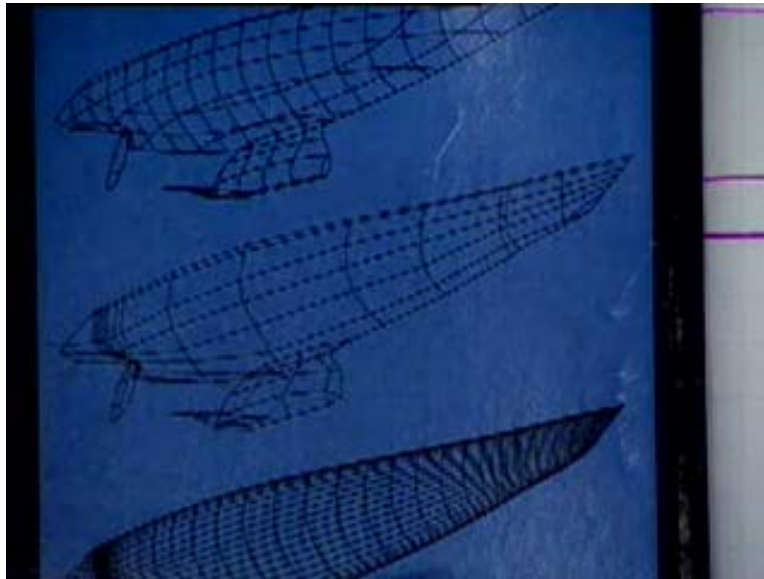
The other kind of activities that are normally included in CAD is what we call as 3 D or even 2 D modelling. When you are taking of 3 D modelling, we essentially talk of representing this object. Now if we are talking of shaft over here, we are talking of representing this object as a three dimensional object. If we have it as a three dimensional object let's take this pen, I took this example yesterday also. If I talk of this pen and I represent it as a three dimensional object on the computer, I can take views from any angle. If you are taking a front view you can take a front view like this, if you want to take a top view you can take a top view. If you want to take an isometric that is a view roughly at this angle or something like this, you can also get an isometric view. If you want to take sections, you can take sections. So you represent it as a 3 D model and then take different sections, different views, get the different views and then dimension them accordingly so this is what you mean by 3 D modelling. I will just show you some of the slides from these texts. Can you see it on the monitor?

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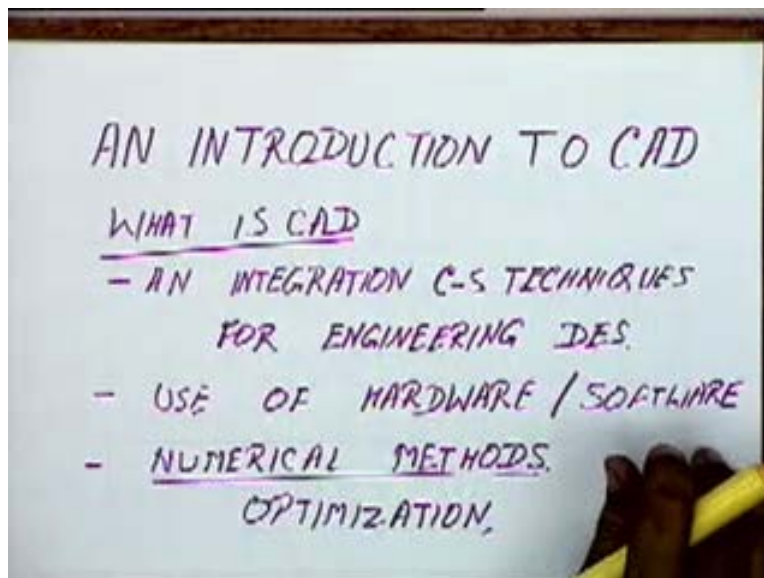
Now in this you will find a complete scene which has been modeled on the computer. You see a dining table which has been set, different objects which have been placed. Now each of these objects has been modeled using some of these techniques. We were able to use this model to visualize what the table would look like. Here it's a flight simulator, we are able to use this model to see what the scene is like, what are the different objects there and so on, to see it from different angles and to get a feel of the actual situation. We can have some more examples.

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These are objects of different shapes but modeled using different techniques. This model looks very different from the model that you have just saw. In this the surfaces have been modeled by a mesh of wires, it's a wire mesh kind of model, wire mesh kind of display that is being used but this is also a 3 D model, it's a 3 D modelling technique which has been used here. So the other CAD activity is 3 D modelling and this is a major part of what we mean by computer aided design. Often people refer to this as drafting as computer aided design.

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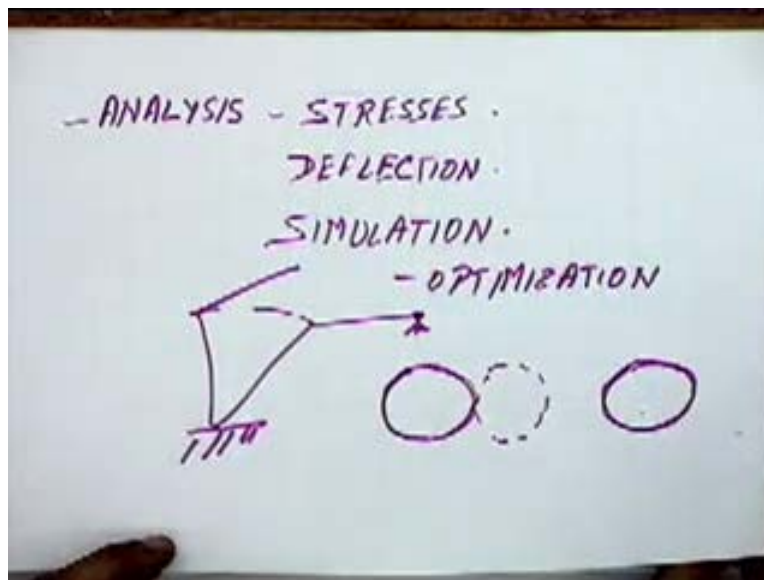


Some people even refer to just numerical methods also being computer aided design because even in numerical methods you are using the computer as an aid for designing but the major part

this activity of computer aided design comes under this realm of 3 d modelling. When you are talking of modelling, it is an essentially an aid to visualization. You want to visualize the object from different angles see different corners, see whether different parts are interfering or not that is what we mean by an aid to visualization. So modelling, we use as an aid to visualization then when you talking of modelling, we are trying to model the different curves and surfaces. If you are modelling a complete solid, you also have to model the curves and surfaces that come on it. For example in this object you are seeing the surfaces which form this solid. If you want to represent this solid, we also have to represent the curves and surfaces which from a part of the solid. So when we talking of 3 D modelling it is not just representing the solid as such, you also have to represent the curves and surfaces which constitute that solid or which define that solid. So under 3 D modeling, we represent curves, surfaces, solids and so on, all this comes under 3 D modeling.

Now once we have represented a 3 D model, the next question that comes up is that what do we do with the 3 model. one we have already said we will use it for visualization, you want to visualize the object on the screen, it will help us give a feel of the situation and we will able to see whether different parts are interfering, whether the particular part in motion is interfering with something else or not and such things. So one use is visualization but another very important use of these CAD models is in analysis. Once we have the model of a particular object, we should be able to analyze it for the different forces that are acting on it the different forces, the different displacements that the object will be going through and so on.

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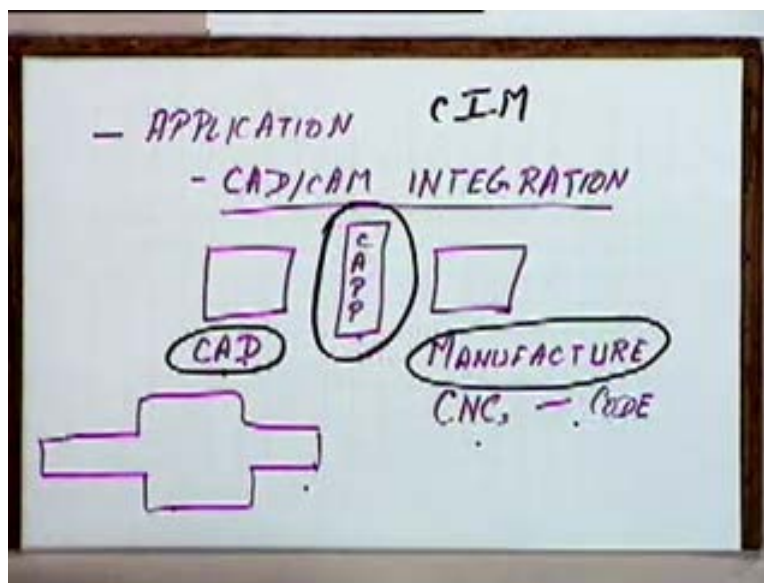


Now this analysis can be analysis for stresses, you can analyze it for deflections. We can also when we are talking of analysis we can actually simulate the objects in actual use that means by simulation what we mean is let's say if we have a simple mechanism like this maybe it's a part of a robo arm or something like that with some maybe gripper attached to here. Now this robo arm is moving in space, from this position maybe it goes to some position like this, the path that I take this link rotates like this along with that this link is also rotating simultaneously.

We want to be able to visualize how this object, how this mechanism would move in actual space. So we want to simulate its motion and then actually animate it on the screen and see how the motion will take place. So that is what we mean by simulation, we want to simulate the motion of an object. In very important application of this kind of analysis is let's say if we have one object, this object can be very complex object maybe car or a bus and we have another object which is maybe another car or maybe a two wheeler or something like that, they meet in a head on collision. Once they will collide there will be some deformations, there will some forces on the passengers, there will be some stresses on them, stresses on the different parts of the body so we want to estimate, we want to see what will happen in the crash that is crash simulation that is also another type of analysis. All that can be done if we have a model of each of these objects, if we have some representation for this object, some representation for this object, if we have some representation for this set of links for this robo and so on. So all this comes under computer aided design.

We are using the computer as a tool for designing each of these objects and we essentially modelling these objects first then using it for analysis using special tools for each of these kinds of analysis. And of course in another analysis, we have already mentioned optimization. If we have the model of an object, we can use it for optimization, we can use it for optimizing the size or weight and so on for different criteria. So the model that is created that model can be used for any of these activities.

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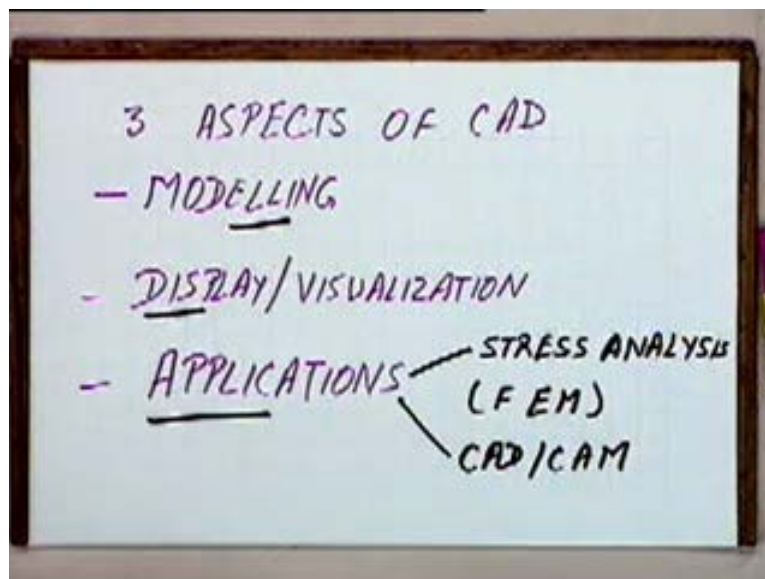


Other than analysis an important application of these CAD models is applications of CAD models are in the areas of what we call as CAD CAM integration. In CAD CAM integration essentially we are talking of let's say this is an initial stage what we call as CAD where we are developing the model, we are analyzing the model and finally designing a particular object then we have the manufacturing stage. Within the manufacturing stage let's say we have a set of CNC machines, this object has to be manufactured on the CNC machine.

For manufacturing this object on the CNC machine, for this CNC the CNC code has to be generated, has to be written down. This code will depend on the object that has been modeled; it will depend on the set of manufacturing steps that have to be carried on. If we have the model for an object, we can use that model to generate this code and to get an interface, to have automatic interface between CAD and CAM that means directly by a CAD model let's say if we are talking of a shaft, if this shaft is represented internally in a proper manner then from this representation of this shaft, from the model of this shaft we can directly get the NC code that will be required to make it. We will be able to generate a process plan, between CAD and CAM we will have a stage called what is referred to as computer aided process planning. For making a process plan for this, the CAD model that has been made that will form the input for that. So CAD models will form an input for computer aided process plan and will also be used for generating the NC code.

In case if we are talking of an integrated manufacturing environment, in the integrated manufacturing environment, this CAD CAM integration plays a very vital role. So under the applications this CAD CAM interface and of course computer aided process plan, these form a very major application for the CAD models. In fact there is a whole area which is normally referred to as CIM computer integrated manufacturing. It refers to CAD, it refers to the process plan that is being generated and it refers to the manufacturing stage. This complete stage, this complete cycle comes as a part of CIM computer integrated manufacturing. There are other aspects also to CIM, we won't get into that but the CAD model that has been created forms the basic links for each of these stages in CIM. If you talking of an integrated manufacturing environment, the CAD model is the starting point.

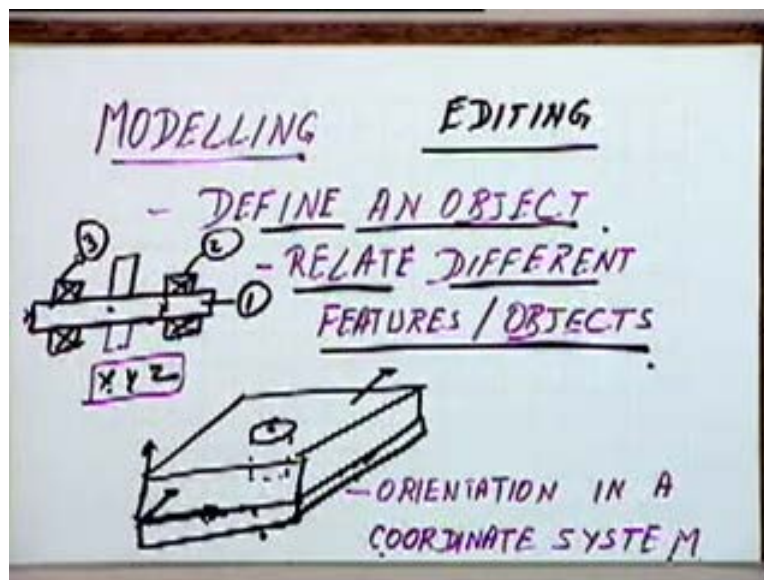
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So if we summarize from this the three important aspects, the first important aspect is what we refer to as modelling. The second is what we refer to as the display or visualization. You have modelled an object, you want to display it, we want visualize it and the third is what we refer to as applications.

The applications would be CAD CAM applications, stress analysis applications, CAD simulation applications and so on. In addition to these we have also mentioned numerical methods as an important part of CAD. Quite often CAD is referred to as numerical methods and optimization but as a part of this course, we will not be touching upon this part. In this course we will essentially be talking of computer aided design as starting from a CAD model, we will be talking of modelling and its applications. We will not be going into numerical methods optimization and other such techniques. This course is going to talk mainly of computer aided design as consisting of modeling, as consisting of its use and display and applications. The applications or the main application that will be talking of would be stress analysis and we will be talking of the finite element method. and the other application would be CAD CAM integration which we might touch upon. So these are the three different aspects of CAD which we will be touching upon as a part of this course. We will briefly see what are the different activities that come under each of these three.

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So when we are talking of modelling, under modelling the first thing that we want to do is to define an object. We take a simple object, we want to define it on the computer, we want to define it using some modelling techniques. The first thing that modelling deals with is how to define an object, that is going to be the first important part of modelling. When we are talking of defining an object, we were essentially saying that we want to relate the different features; I will just the different features of an object relate different features or relate different objects. For instance if you consider this shaft, now this shaft is supported on a set of bearings. When you want to model this complete system, we have to define this shaft as one object, this bearing as the second object and this bearing maybe as a third object and in addition to that there might be some mountings on it maybe there is a gear here or a chain and sprocket here or something like that and something else connected on the other end, so there might be different objects connected on them. When we you are modelling this complete scenario, each of these objects would first be defined.

Then we have to define the relationship between these objects that means this shaft is next to this bearing and is touching it on this surface. So let's say if for this object we are defining this as an origin and for this bearing maybe we are taking this as the origin for this bearing. We will like to define that this bearing is located at a particular xyz value with respect to this origin so that defines a relationship between this bearing and this shaft. This relationship is a geometric relationship with respect to adjacency, with respect to which object is next to the other object and so on. It defines the geometric location of the two objects with respect to one another.

Similarly if you are talking of this mounting which can be a let's say chain and sprocket or a gear, we will have to define this sprocket whose origin is here is at a certain location with respect to this point. This is what we mean by we have to relate different objects; we have to relate them with respect to one another. Relate different features let's say if you are talking of a simple block like this, on this block let's say we have a through hole, this hole is a feature on this block. We will have to relate that this block let's say whose origin is at this location, this is the origin this hole this feature is at a particular orientation with respect to this origin at a particular distance.

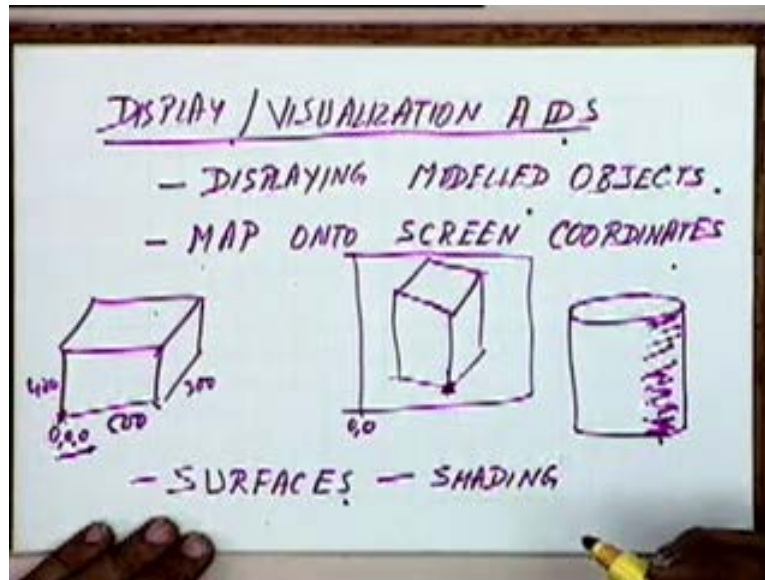
This hole is at let's say this face, on the top face. This hole is a vertical hole and is a through hole. All this information has to be available when you are talking of defining this objects that is what you mean when you say relate different features. This hole is one feature, this top face of this object is the second feature, you have to relate the two together saying that this face is next to this hole. The basic idea that I want to convey right now is that when you are trying to relate the different feature and objects, a lot of information has to be stored in that model. So when you are talking of modelling that includes a lot of information, is not just defining this object as maybe a block, a lot of information goes into it. So unless we are able to relate these features, we will not be able to use this object in any situation.

Unless I know that this hole is at the so and so location is a vertical whole and is a through hole, unless I known all this I cannot get the manufacturing sequence for it. For finding of the manufacturing sequence for making a hole, I need to know the location I need to know the direction of the hole and I need to know how deep it is. So unless all that is known to me, I will not be able to use this model for any realistic propose that is why we say that when we are talking of defining an object, we have to relate different features of the object. And another thing related to this that I have already mentioned is that we have to talk of orientation in a coordinate system.

We define a coordinate system that let's say this is the origin for the shaft, this is the origin for the bearing, the two are or this origin is at a location xyz with respect to this origin, all that is with respect to a particular coordinate system. So whenever we are talking of modelling you are doing that with respect to a particular coordinate system, you have to define a coordinate system and give all our dimensions with respect to that system. And then once a model has been made in any say design situation, the model will never be static, meaning that the model will change from time to time. I have made this model but then I find you know the thickness of this plate is too small, so now I want to increase the thickness so I want to go and make a change. The moment I want to make any change that means let's say I want to change the thickness. In this figure I will have to increase this size, this size, make this change, this change and rub out all these. If I am doing on the drawing board I will have to make all these changes.

So when I am talking of making these changes, we refer to this process as a process of editing, editing an existing model or making changes in an existing model.

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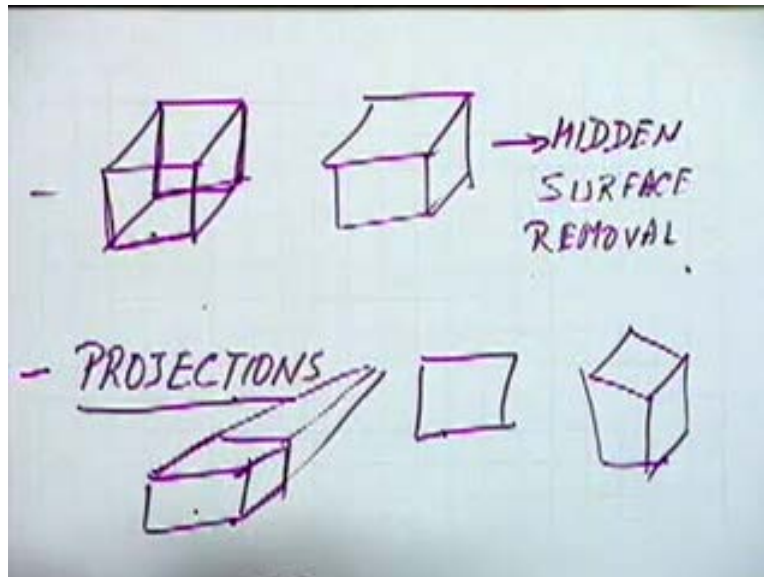


So once a model is available then we talk of what I refer to as display or visualization aids. When you are talking of display, we are talking of displaying model objects. When you are talking of displaying the model objects what we basically want to do, if this object we want to map it onto screen coordinates. That means if you have a simple block like this the block let's say for this block I am taking this as the origin, the width is maybe 500, height is 400 and the depth is maybe 300. If I am taking a particular view in which maybe let's say an isometric view something like this. Now this view has to be drawn on the screen. So, on the screen the orientation of the location of each of these points has to be defined. So on this screen if I am taking this as my 0 0, I have to decide this 0 0 0 over here has to map to which point on this screen. That means every point of this block has to be mapped down to a screen location that is what we mean by mapping onto screen coordinates.

If I am able to map every point on this block then I can draw the object on the screen. So when we are talking of displaying a visualization of that object, we are basically talking of taking the model object, for each and every point we find a corresponding point under screen coordinates that is what you mean by display. In this display if we have surfaces then these surface might have to be shaded. If I have a simple cylinder like this, for an engineering view of this cylinder I need not bother, I can just take a front view and a top view and make my three orthographic views but for visualization I might like to get a shaded view. If I am taking a shaded view it will look something like this depending on where the light is placed. So when you are talking of displaying I should be able to take any object and display it on the screen, show it on the screen depending on what is the location of my light source, what is the nature of the surface whether it reflects a lot of light or whether it is a diffusing kind of surface and so on.

So when you are displaying surfaces, we will talk of issues like shading and we will talk of what is referred to as hidden surface removal.

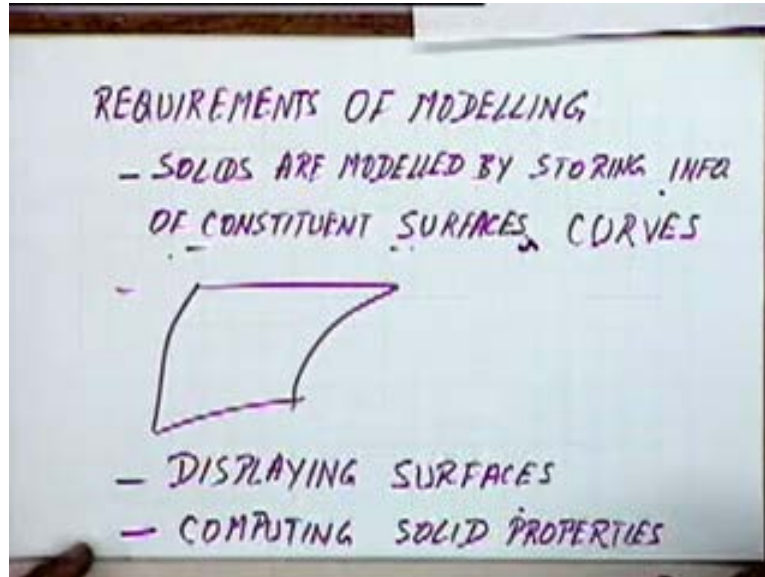
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If I am trying to make a view of a simple block, I am displaying all the surfaces this is what the view would look like. And it is easy to see that this view is confusing, it is not easy to make out which surface is in the front which surface is at the back. I can't make out whether this surface is in front or whether this surface is in front. So normally we like to remove the hidden surfaces, the surfaces at the back which are not visible, the edges which are not visible we like to remove those lines and edges. So instead of drawing it like this, we like to draw it just like this. This should improve the clarity of the presentation, it will help in visualization.

So when we are talking of display, we like to remove hidden lines. This is normally referred to as hidden line removal or hidden surface removal. Then when we are talking of display, we will also like to talk of projections. If I take an orthographic view or a front view, simple front view of this object, I will get a rectangle. If I take an isometric view, I will get a view which would be something like this. If I take maybe perspective view, I will get a view which would be something like this. If I have modelled this object that is if I have given the geometric description of each of the surfaces and each of the edges, if all that information is available with the computer I should be able to generate any of these views depending on the direction from which I am looking, depending on my specifications given. I should be able to do these projections. We will be seeing methods for each of these tasks. We will see how projections can be obtained, we will see how hidden surfaces can be removed, we will see how simple display of lines and curves can be done. We will also see how the shading can be done, all these techniques we will be covering as the part of this course.

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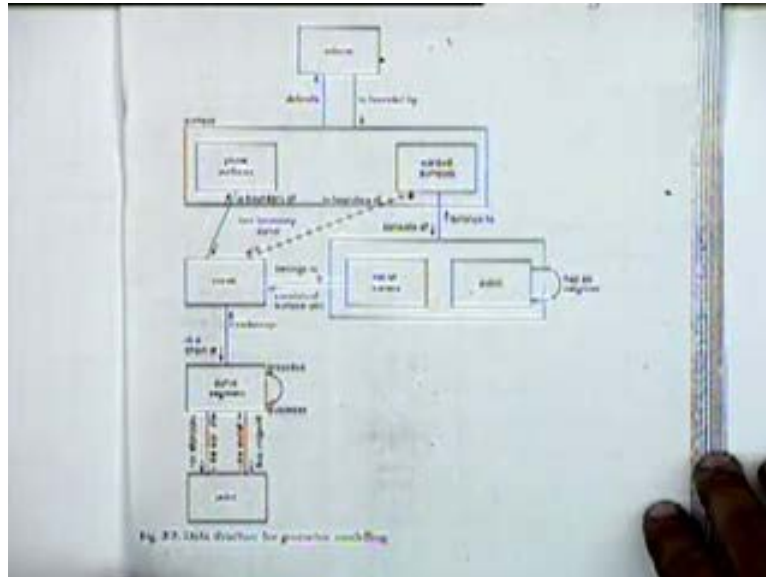


So from all this we can conclude that if we are talking of modelling, modelling has different requirements. The first is that solids are modelled or have to be modelled by storing information of constituent surfaces. If I have any solid, I cannot represent the solid unless I am able to represent the surfaces because my different features will be on the surfaces. If I have a hole or if I have slot, if I have **glove** they will all be on the surfaces. So all my surfaces will play an important role in defining the solids, so we say that solids are modelled by storing information of constituent surfaces.

Similarly when we are talking of displaying surfaces, we will also have to talk of curves. If I have surface like this, I cannot represent this surface unless I am able to represent the edges of this surface. So if I am talking of surfaces, curves are also equally important. Then if I am representing or if I am storing information of with respect to surfaces and curves this would help us in firstly displaying these surfaces. Now this would help in displaying surfaces that means if I have to display any object, how do I display a solid? The only I can display the solid is by displaying all the boundary surfaces. In the simple example when I am trying to display this solid, what I am basically doing is I am displaying each of these surfaces one after another, so I cannot display a solid unless I am able to display the surfaces. So storing information of constituent surfaces is going to help us in displaying the surfaces. It will also help us in computing solid properties.

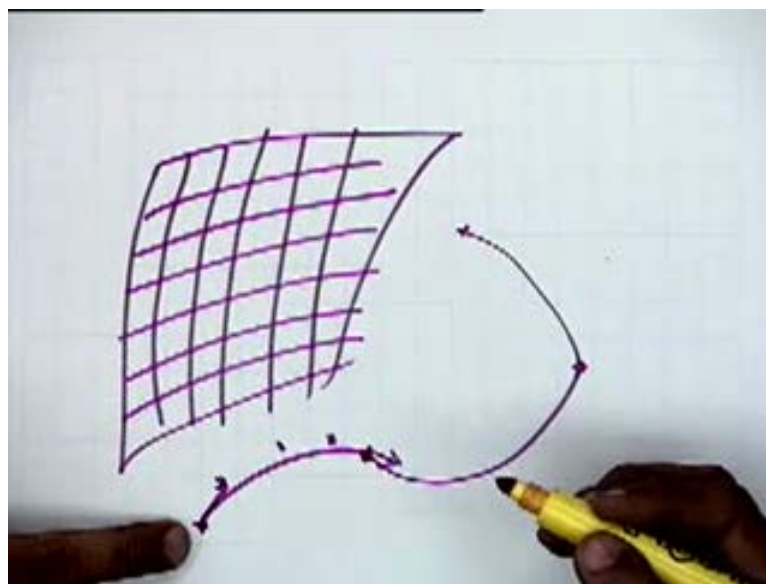
What we mean by solid properties? For this object, if I want to find out the weight of this object or if I want to find out the volume of this object, the moment of inertia of this object I should be able to do that. I cannot do that unless I know what are the bounding surfaces. If I know the bounding surfaces I can find out the weight, I can find the moment of inertia and so on. So this information is going to be important in computing the solid properties. Then I have already mentioned that solids are modelled by storing information surfaces and surfaces will be modelled by storing the information on the curves. So this relationship between solids and curves is well represented by this diagram.

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Are you able to see it clearly? [Conversation between Student and Professor – Not audible (00:44:41 min)] Essentially what it says is if you want to represent any volume, a volume is delimited by or is bounded by a set of surfaces. Surfaces can be either plane surfaces that is planes or they can be warped surfaces, warped surfaces or curved surfaces. Whether they are plane surfaces or whether they are warped surfaces, their boundary will be different kinds of curves. So if you have a curve can be a boundary for a warped surface or it can be a boundary of a plane surface. We can also have a family of curves which define a surface, a network of curves or a set of curves which define a surface.

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For instance if we take a set of curves like this, we say this is an family of curves. One set of maybe cubic curves in one direction, another set of cubic curves in the second direction and this defines a surface patch. So we can have a network of curves or we can have patches which can define a warped surface or which can define a three dimensional surface. A curve can consist of a set of curve segments. What you mean by a set of curve segments? We have a curve from one point to a second point then we have a different kind of curve from this point to the next point and in another kind of curve from here to here and so on. So a curve can consist of a set of curve segments like this, so curves can consist of a set of curve segments and curve segments would be defined by end points, end points or the geometric properties.

So if you want to represent a solid or volume, this solid or volume will be represented by surfaces which are represented by curves which are in turn represented by curve segments which consist of points. If we have to describe solid modelling techniques, we cannot describe them unless you have some idea of how to represent curves and surfaces. The basic method of representing any solid is always going to have methods of representing curves and surfaces embedded in it. So the basic idea is that when we talk of modelling surfaces or modelling solids before that we will be talking of curves and surfaces and their modelling techniques. So in this course we will first talk of different methods of, when we talk of modelling we will first be talking of different methods of representing curves, different methods of representing surfaces and then we will talk of different methods of representing solids. [Conversation between Student and Professor – Not audible (00:48:35 min)] What is your question again? You defined curve segments being defined by end points. That is to say curves may essentially lines.

I am glad to you have put that question. Actually instead of end points I should have said control points that is the better way of saying that. If we have a curve starting from this point, ending at this point, here if I just specify two points, I can only have a straight line between them but if I have a set of control points, I can have a set of points here. This is the set of control points which define this curve then I can have a curve either a cubic curve or a higher degree polynomial curve depending on the modelling technique I am using. If I am using five points or if I am using ten points, I will have a curve of the corresponding degree. So the curve will be modelled not just by the end points but by a set of control points or if I am just giving the end points and also be specifying something in addition to that maybe the direction of the tangent over here or some such related information. Maybe I will specify the direction of the tangents plus I will specify that this is the second degree curve then maybe end point, just end point would be sufficient. But the basic idea in this figure is that if I have to represent a curve segment, I cannot do that without storing the relevant points in line. The relevant points will be the set of control points including end points, including some other information in terms of tangents and so on. So here it won't just be the end point or the start point and the end point but it will be also be a set of control points which will be important for every curve. Any other question? So if they are no more questions then I will end now and we will start from this point in the next class.