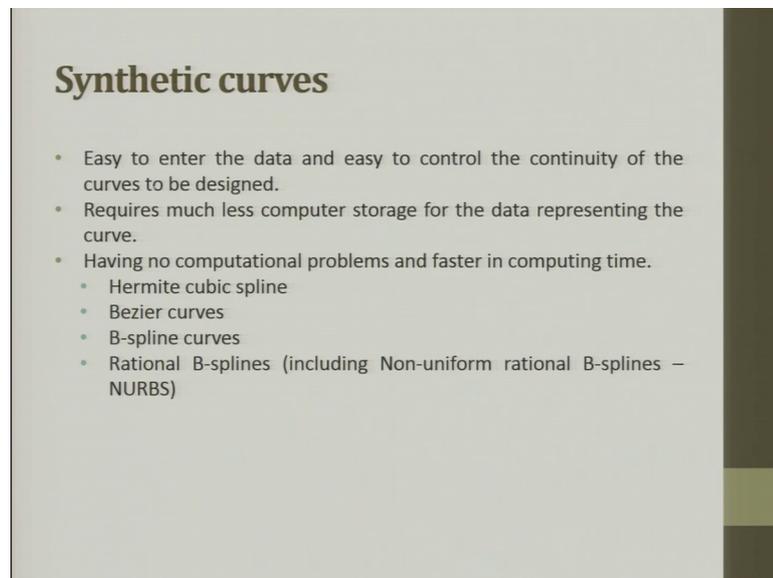


Rapid Manufacturing
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Lecture – 39
Rapid Product Development, CAD (Part 3 of 3)

Welcome back to the lecture on Computer Aided Design and Manufacturing.

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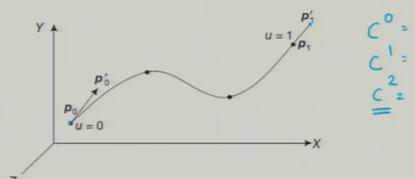
So, whatever we studied till now we studied curves, then we studied of the data points which are generated and from that data points we are trying to form these curves. So, these things which cannot be mathematically represented are called as synthetic curves. So, curves can be divided into two, one is analytical and another one is synthetic. Analytical means where there is a clear definition of equation available.

So, where there is no clear definition of equation available, then we go for synthetic curves. Easy to enter the data and easy to control the continuity of curves to be to be designed we use this synthetic curves; requires much less computer storage for the data representing the curve. Having no computational problem and faster in computing time we have this Hermite cubic spline Bezier curves B spline and rational B spline curves coming into existence.

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Hermite cubic spline

- Hermite cubic splines are the more general form of curves that can be defined through a set of vertices (points).
- A spline is a piecewise parametric representation of the geometry of a curve with a specified level of parametric continuity.
- Each segment of a Hermite cubic spline is approximated by a parametric cubic polynomial to maintain the C^2 continuity (See Fig. below).



Chang and Wysk, Computer-aided manufacturing, Prentice Hall PTR, 1997.

Hermite cubic spline: in Hermite cubic spline are more general form of curve that can be defined through a set of vertices points. These are this can be represented by a set of vertices points. Spline is a piecewise parametric representation spline is a representation of the geometry of a curve with a specified level of parametric continuity.

So, moment I said cubic it is the third order. Each segment of the Hermite cubic spline is approximated by a parametric cubic polynomial to maintain a C square C 2 continuity. I will give it with you guys to read or I will share you a reading material about C 0 C 1 and C 2 continuity. So, then you can appreciate what is C 2 continuity.

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Hermite cubic spline

- The parametric equation of a Hermite cubic spline is given by
$$p(u) = \sum_{i=0}^3 C_i u^i \quad u \in [0, 1]$$
- In an expanded form it can be written as
- $p(u) = C_0 + C_1 u + C_2 u^2 + C_3 u^3$
- Where u is a parameter, and C_i are the polynomial coefficients.

So, the parametric equation of a Hermite cubic spline is given by $p(u)$ is a summation of this. So, cannot $C_i u^i$, where u takes the value from 0 to 1. In an expanded form the same equation can be represented like this and u is a parameter C_i is a polynomial coefficient these are all polynomial coefficient. So, if you wanted to work in simple form or an algebraic form or a long hand form. So, then we will take it by this, but in computers what we do is we always try to convert this into a matrices form.

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Hermite cubic spline

- In matrix form
$$p(u) = \begin{bmatrix} 1 & u & u^2 & u^3 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -3 & 3 & -2 & -1 \\ 2 & -2 & 1 & 1 \end{bmatrix} \begin{bmatrix} p_0 \\ p_1 \\ p_0' \\ p_1' \end{bmatrix}$$
- $p(u) = \{\mathbf{U}\} [\mathbf{M}] [\mathbf{P}]$

And generally Hermite cubic spline is expressed in this form in matrices where one u u square u cube these are the u which is taken this is the coefficient that is C i j and these are the points.

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Bézier curves

- This can be written in matrix form as

$$p(u) = \begin{bmatrix} u^3 & u^2 & u & 1 \end{bmatrix} \begin{bmatrix} -1 & 3 & -3 & 1 \\ 3 & -6 & 3 & 0 \\ -3 & 3 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} p_0 \\ p_1 \\ p_2 \\ p_3 \end{bmatrix}$$

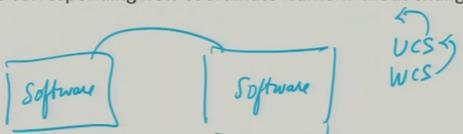
- $p(u) = \{ \underline{U} \} \underline{[M_B]} [P]$

So, in Bezier what happens is you can see that the same if you want to express in the same matrices. You can see here busy Bezier matrix. These are the points and you have this u which are there.

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Bézier curve properties

- The Bézier curve passes through the first and last control points while it maintains proximity to the intermediate control points.
- As such the entire Bézier curve lies in the interior of the convex hull of the control points.
- If a control point is moved the entire curve moves.
- Being polynomial functions, Bézier curves are easily computed, and infinitely differentiable.
- If the control points of the Bézier curve are transformed, the curve moves to the corresponding new coordinate frame without changing its shape.



So, Bezier curve properties the Bezier curve passes through the first and the last control point while it maintains proximity to the intermediate control points. As such the entire Bezier curve lies in the interior of a convex hull of a control point. In this is what we study in mathematics concave and convex hull. If we are control point is moved, the entire curve moves. Being polynomial function Bezier curve are easily computed and infinitely differentiable.

You can split if the control points of the Bezier curve are transformed the curve moves to the corresponding new coordinate frame without changing its shape. So, this gives you a freedom of transferring it from one software to the other software without any difficulty. Or you have a user coordinate system you are a world coordinate system. From the world, you go to user coordinate system from user you go to another user coordinate system. The object whatever you have created will be shifted without any deformation or change.

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B-splines

- B-Splines can be of any degree but in computer graphics the degree 2 or 3 are generally found to be sufficient.
- The 3rd order polynomial equation requires 4 sets of data.
- The polynomial between x_i and x_{i+1} can then be defined as

$$f_i(x) = a_i + a_{i-1}x + a_{i-2}x^2 + a_{i-3}x^3$$
- Substituting the values of x_i and x_{i+1} in the above equation, we get and solving for the constants

This spline can be of any degree, but in computer graphics the degree of 2 or 3 are generally found to be sufficient. You can go to nth degree you will have more data. When you have more data you will also have more errors coming here and there. So, it is better to stop with 2 and 3 and you also make it computationally little easy. The third order polynomial equation requires 4 set of data points where you are talk about 3D. The polynomial between x_i and x_{i+1} can be defined as a function of x a_i plus a_{i-1}

x_{i-2} and x_{i-3} . Substituting the value of x_i and x_{i+1} in the above equation we get to solve for getting the constants.

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B-splines

- B-spline curves have the flexibility of choosing the degree of the curve irrespective of the number of control points.
- With four control points, it is possible to get a cubic Bézier curve, while with B-spline curve one can get a linear, quadratic or cubic curve.
- B-spline also uses the basis (blending) functions and the equation is of the form $0 \leq u \leq u_{\max}$

$$p(u) = \sum_{i=0}^n p_i N_{i,k}(u)$$

The B spline curve have the flexibility of choosing the degree of curve irrespective of number of control points. With four control points it is possible to get a cubic Bezier curve with which B spline curve one can get a linear quadratic or a cubic curve. A B spline can also be used the bias function or the blending function in the equation to get to this form.

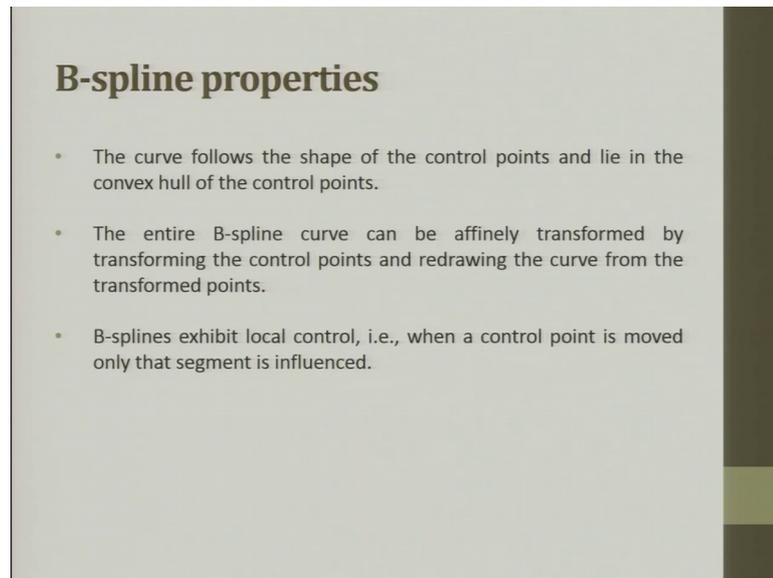
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B-spline properties

- The plotting of B-spline curve is done by varying the parameter u over the range of knot values (u_{k-1}, u_{n+1}) .
- The knot vector adds flexibility to the curve and provides better control of its shape.
- Partition of Unity: For any knot span, $[u_p, u_{p+1}]$,
- Positivity: $\sum_{i=0}^n N_{i,k}(u) = 1$ $N_{i,k}(u) \geq 0$ for all i, k and u .

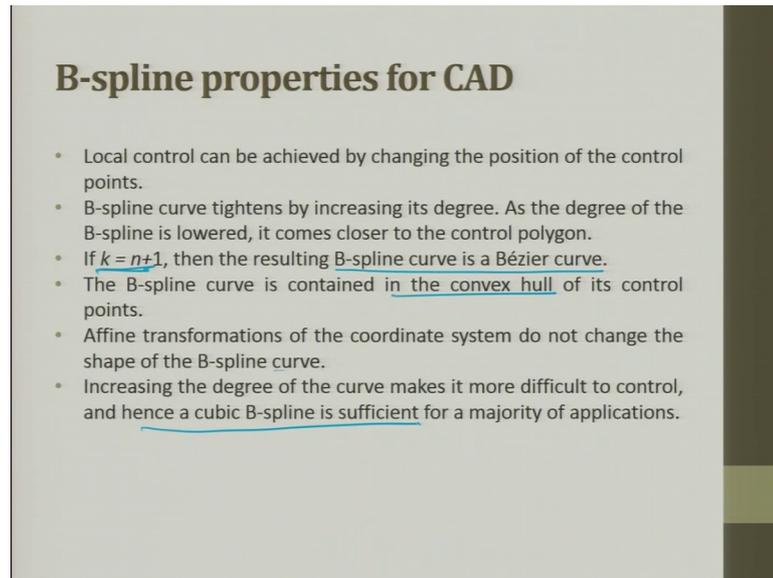
The B-spline properties: the plotting of a B-spline curve is done by varying the parameters of u over a range of knot values. The knot vector adds flexibility to the curve and provides better control of its shape. The partitioning of unity for any knot span u_i and u_{i+1} you get this. The positivity is the, this value this is how it is represented.

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The curve follows the shape of a control point and lies in the convex hull of the control point. The entire B-spline curve can be affinely transformed by transforming the control points and redrawing the curve from the transformed points. These splines exhibit a lot of local control which is not there in Bezier.

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B-spline properties for CAD

- Local control can be achieved by changing the position of the control points.
- B-spline curve tightens by increasing its degree. As the degree of the B-spline is lowered, it comes closer to the control polygon.
- If $k = n+1$, then the resulting B-spline curve is a Bézier curve.
- The B-spline curve is contained in the convex hull of its control points.
- Affine transformations of the coordinate system do not change the shape of the B-spline curve.
- Increasing the degree of the curve makes it more difficult to control, and hence a cubic B-spline is sufficient for a majority of applications.

The B spline properties for CAD the local control can be achieved by changing the position of the control points. You are now getting into fragmenting the curve and moving each individual fragment. The B spline curve tightens by increasing it is degree has the degree of the B spline is lower it becomes close to the control polygon. If k is equal to n plus 1 then the resulting B spline curve is a Bezier curve.

If k is n plus 1 then the resulting Bezier is a B spline. If the B spline curve is contained with in the convex hull of which control points, then the this is very important. Affine in transformation of the coordinate system do not change the shape of a B spline curve. Increasing the degree of the curve makes it difficult to control hence cubic B spline is sufficient enough to do majority of the applications

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Rational Curves

- A rational curve utilizes the algebraic ratio of two polynomials.
- They are important in CAD because of their invariance when geometric transformations are applied.
- A rational curve defined by $(n+1)$ points is given by

$$\mathbf{p}(u) = \sum_{i=0}^n \mathbf{p}_i R_{i,k}(u) \quad 0 \leq u \leq u_{\max}$$

- Where $R_{i,k}(u)$ is the rational B-spline basis function and is given by

$$R_{i,k}(u) = \frac{h_i N_{i,k}(u)}{\sum_{i=0}^n h_i N_{i,k}(u)}$$

So now, what is happening we found out that B spline also has some difficulty in order to get out of the difficulty we went to rational curves. A rational curve utilizes the algebraic ratio of 2 polynomials. They are important in CAD because of their invariance when the geometric transformations are applied. This point is very, very important, this brings a difference between or the advantage of B spline B spline on this.

Rational curves rational gets this advantage. The rational curves defined by $n + 1$ point is give by $p u$ in this form where u takes value between u_{\max} where i, j is a rational B spline basic function and it is given by this function.

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NURBS



- Uniform cubic B-splines are the curves with the parametric intervals defined at equal lengths.
- The most common scheme used in all the CAD system is the non-uniform rational B-spline (commonly known as NURB), allowing a non-uniform knot vector.
- It includes both the Bézier and B-spline curves.
- Rational form of the B-splines can be written as
$$\mathbf{p}(u) = \frac{\sum_{i=0}^n w_i p_i N_{i,k}(u)}{\sum_{i=0}^n w_i N_{i,k}(u)}$$
- where w_i is the weighing factor for each of the vertex

The uniform cubic B spline are the curves with the parametric intervals defined at equal length. The most common scheme used in all CAD systems is there non uniform rational B spline. Allowing an non uniform knot vector. It includes both Bezier and B spline in NURBS. So, the rational form of B spline can be written in this form and where w or the weightages. So, it gives you more freedom for locally changing the curves.

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NURBS

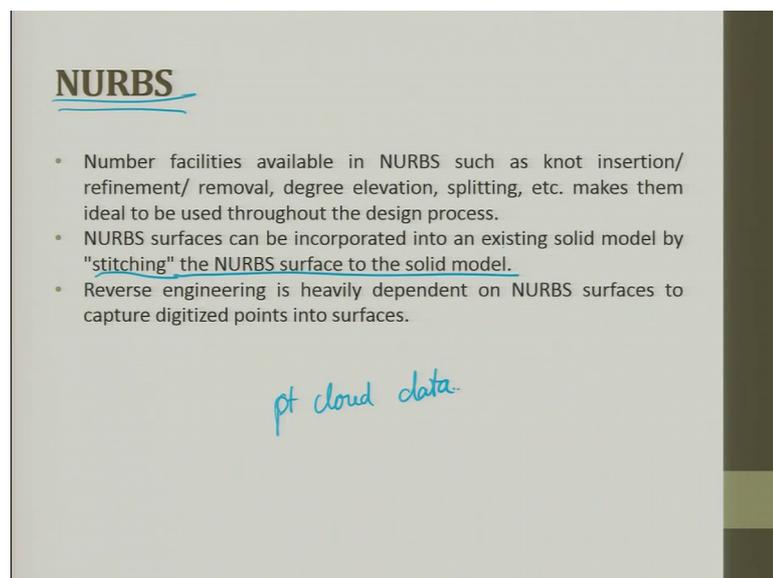
- They have all of B-spline surface abilities. In addition they overcome the limitation of B-spline surfaces by associating each control point with a weight.
- Uniform representation for a large variety of curves and surfaces. This helps with the storage of geometric data.
- NURBS are invariant during geometric transformations as well as projections.
- NURBS is flexible for designing a large variety of shapes by manipulating the control points and weights.
- Weights in the NURBS data structure determine the amount of surface deflection toward or away from its control point.
- It makes it possible to create curves that are true conic sections. Surfaces based on conics, arcs or spheres can be precisely represented by a NURBS surface.
- Evaluation of NURBS is reasonably fast and numerically stable.

NURBS they have all B spline surface abilities. In addition, they overcome the limitation of B spline surfaces by associating each control point with a weight. Uniform

representation of large variety of curves and surfaces can be done by using NURBS. NURBS are invariant during geometric transformation as well as projections. NURBS is flexible for designing a large variety of shape by manipulating the control points and the weights.

The weights in the nurb data structure do determines the amount of surface deflection towards and away from the control points. It makes it possible to create curves that are true conic sections. Surface based on conics arcs and spears can be precisely represented by NURBS. So, more and more and more flexibility is given for the curves such that you can try to make it a free form curves. So, the evaluation of NURBS is reasonably faster and numerically stable.

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NURBS

- Number facilities available in NURBS such as knot insertion/ refinement/ removal, degree elevation, splitting, etc. makes them ideal to be used throughout the design process.
- NURBS surfaces can be incorporated into an existing solid model by "stitching" the NURBS surface to the solid model.
- Reverse engineering is heavily dependent on NURBS surfaces to capture digitized points into surfaces.

pt cloud data

Number facilities available in NURBS: such as not in intersection refinement removal, degree of evaluation, splitting makes it more and more flexible through the design process.

NURBS are faces can be incorporated in the existing solid works by stitching the NURBS surface to a solid. So, if you want to add a packs; if you want to add a packs to the solid surface. It is possible reverse engineering is heavily dependent on NURBS so, where in which you have a point cloud data.

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Problems with NURBS

- Analytical curves and surfaces require additional storage.
- NURBS parameterization can often be affected by improper application of the weights, which may lead to subsequent problems in surface constructions.
- Not all geometric interrogation techniques work well with NURBS.

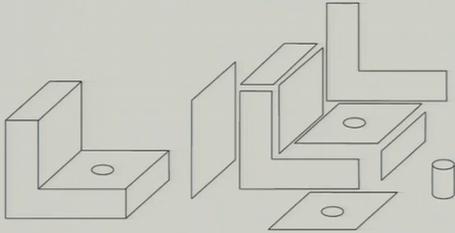
So, the problem with the NURBS is analytical curves and surface requires additional storage. NURBS parameterization can often be affected by improper application of weightages which can lead to subsequent problems in the surface construction. Not all geometric in interrogation techniques works very well with the NURBS. So, NURBS also has it is own difficulty.

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Types of Solid Modeling

There are six basic types of solid modeling representations;

1. **Boundary Representation**
 - The object is represented by the means of the bounded faces that enclose it.
 - Each face is represented by its bounding edges and vertices.

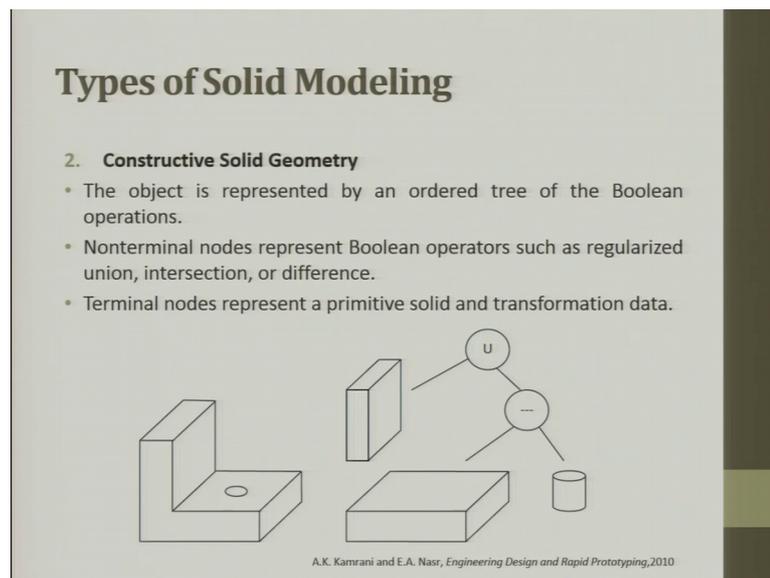


A.K. Kamrani and E.A. Nasr, *Engineering Design and Rapid Prototyping*, 2010

When we talk about solids; so, all these things we are talking about 2D synthetic curves. When we talk about solid models there are 6 different varieties of solid model. The most

common one which is boundary representation, this is a solid the solid is divided into several boundaries. So, each boundary is stored. The object is represented by means of a bounded face that is enclosed here. So, this solid is bounds each boundary. And when you want to do some fluid analysis now boundary representation is very important. Each face is represented by it is bounding address and vertices. So, an object split into several boundary.

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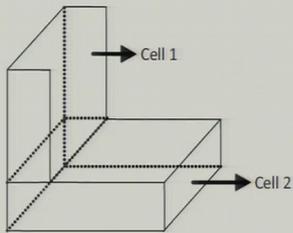
Next is constructive solid geometry which we discuss. So, constructive solid geometry is the representation by the order tree following a Boolean operation you try to get the of solid model. Non-terminal nodes represent Boolean operations such as regularised union intersection or different. The terminal nodes represents a primitive solid and the transformation data. So, this is how it is that the solid can be drawn through constructive solid geometry. There are it is not a unique way there are several ways the Boolean operation you can use several ways to represent a solid.

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Types of Solid Modeling

3. Cell Decomposition

- The object is represented as the sum or union of a set of cells into which it is divided.
- The disjoint cells can be of any shape and size.
- This representation technique is the base of finite element modeling.



A.K. Kamrani and E.A. Nasr, *Engineering Design and Rapid Prototyping*, 2010

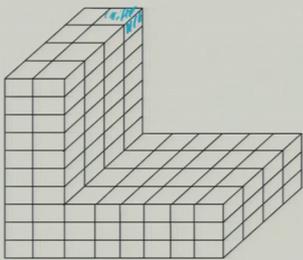
The third one is cell decomposition. The object is presented as a sum or union of set of cells into which it is divided. So, it is divided into cells. So, each cell the disjoint cells can be of any shape and size. This representing technique is based on the finite element modelling. So, cells are used to when you tried used in finite element the cell decomposition method is also exhaustively used too.

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Types of Solid Modeling

4. Spatial Occupancy Enumeration

- The object is represented by a list of the cubical disjoint spatial cells that it occupies.
- This is the special case of the cell decomposition where the shape of the cells is cubical.



A.K. Kamrani and E.A. Nasr, *Engineering Design and Rapid Prototyping*, 2010

Spatial occupancy enumeration: the object is represented by a list of cubical disjoint space this is a disjoint space. This is a space special case of cell decomposition previous

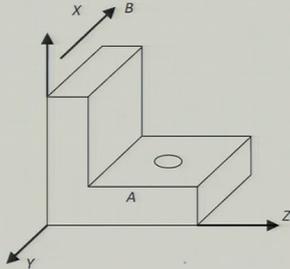
one, where the shape of the cell is cuboidal, this is cuboidal you can also have any other shape this is cuboidal. So, this way of representing a solid is special occupancy.

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Types of Solid Modeling

5. Primitive Instancing

- The object is represented by a set of solid primitives such as cuboid, cylinder, cone, etc.
- Each primitive is usually defined parametrically and located in space.



A.K. Kamrani and E.A. Nasr, *Engineering Design and Rapid Prototyping*, 2010

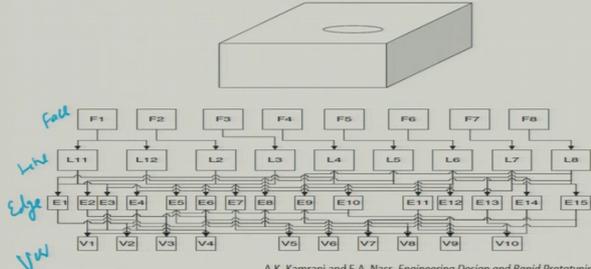
Then it is primitive instancing. The object is represented by a set of solid primitive such as cuboid curves cones etcetera. Each primitive is usually defined parametrically and located in a space. So, this becomes a representing a cube in a parametric form is easy. I take a primitive with respect to parametric and then I joint to get a shape.

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Types of Solid Modeling

6. Sweeping

- The object is represented by moving a curve or a surface along some paths.
- This method is useful to model constant cross-sectional parts and symmetrical parts.

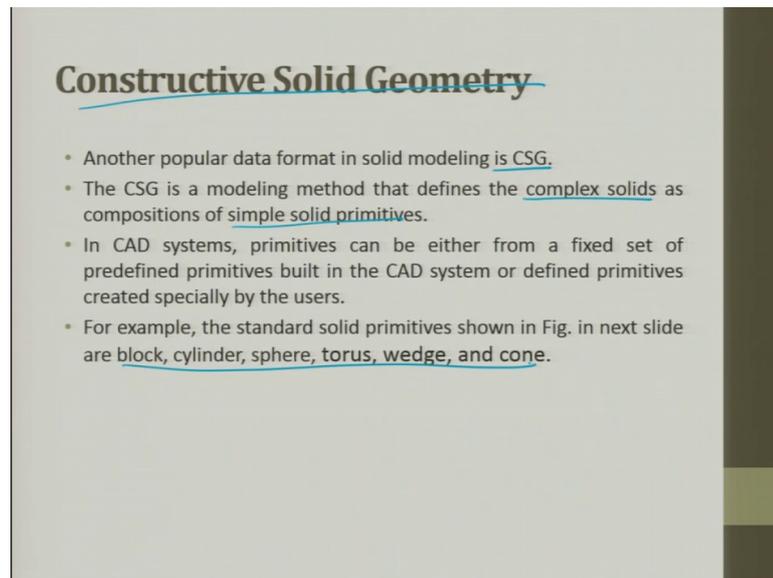


A.K. Kamrani and E.A. Nasr, *Engineering Design and Rapid Prototyping*, 2010

Sweeping which we have already seen sweeping can be used in making a solid model. The object is represented by moving a curve or a surface along a some path. The method is useful to model constant cross section parts and symmetrical paths.

So, you can see here how the edges are formed. So, you can see vertices these are vertices. Vertices to edge, edge to line, line to face this is the last way or representing a solid model. So, all these 6 methods are used to represent a solid.

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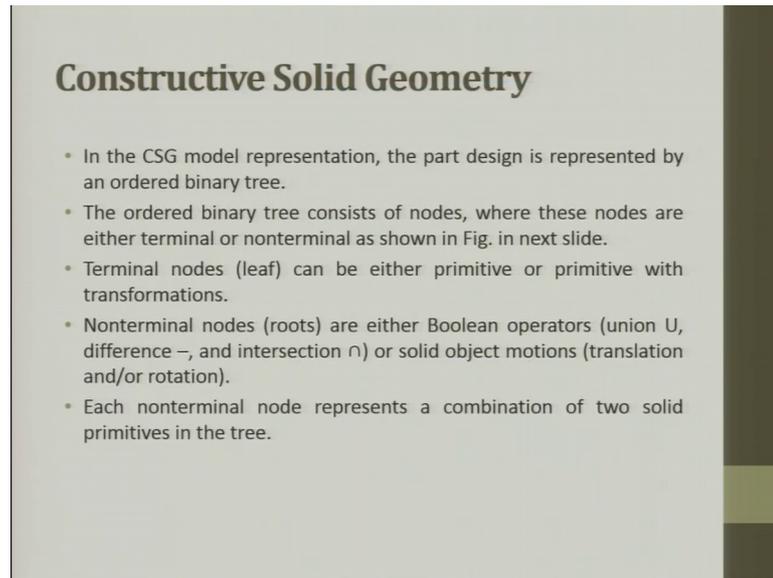


Constructive Solid Geometry

- Another popular data format in solid modeling is CSG.
- The CSG is a modeling method that defines the complex solids as compositions of simple solid primitives.
- In CAD systems, primitives can be either from a fixed set of predefined primitives built in the CAD system or defined primitives created specially by the users.
- For example, the standard solid primitives shown in Fig. in next slide are block, cylinder, sphere, torus, wedge, and cone.

So, constructive solid geometry which is otherwise called as CSG the CSG is a modern method that defines the complex solid shape as composition of a simple solid primitives. So, here simple solid primitives are already discussed in the previous lectures.

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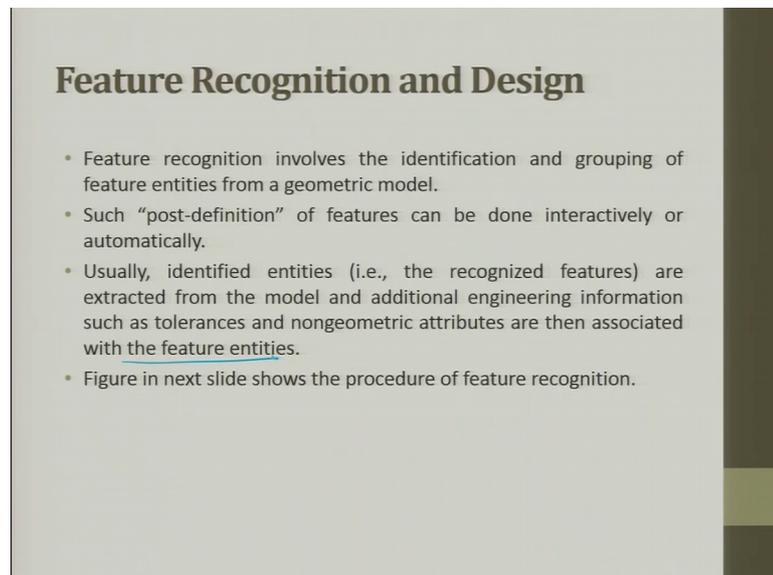


Constructive Solid Geometry

- In the CSG model representation, the part design is represented by an ordered binary tree.
- The ordered binary tree consists of nodes, where these nodes are either terminal or nonterminal as shown in Fig. in next slide.
- Terminal nodes (leaf) can be either primitive or primitive with transformations.
- Nonterminal nodes (roots) are either Boolean operators (union \cup , difference $-$, and intersection \cap) or solid object motions (translation and/or rotation).
- Each nonterminal node represents a combination of two solid primitives in the tree.

So, I have also listed it out here. So, the terminal nodes can be either primitive or or a primitive with transformation. Non-terminal nodes are either Boolean operation or a solid object motion. So, it is non-terminal nodes represents a combination of two solid primitives in trees.

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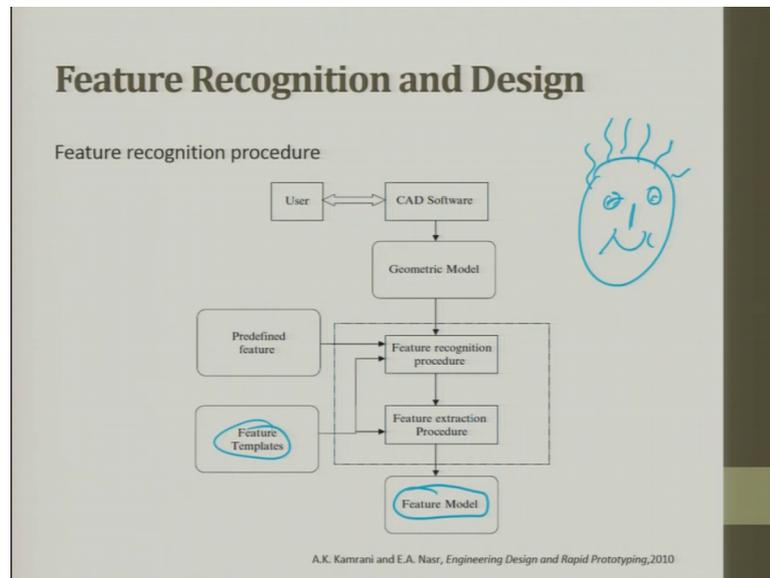
Feature Recognition and Design

- Feature recognition involves the identification and grouping of feature entities from a geometric model.
- Such “post-definition” of features can be done interactively or automatically.
- Usually, identified entities (i.e., the recognized features) are extracted from the model and additional engineering information such as tolerances and nongeometric attributes are then associated with the feature entities.
- Figure in next slide shows the procedure of feature recognition.

The last one is the feature recognition and design. The feature recognition involves the identification and grouping of features feature entities to get geometric model. Such post definition or features can be done interactively or automatically

So, as soon as the CAD is drawn the feature extraction is done. Usually identifying entities are extracted from the model and additional engineering information such as tolerance and non geometric attributes are then associated with the feature entity.

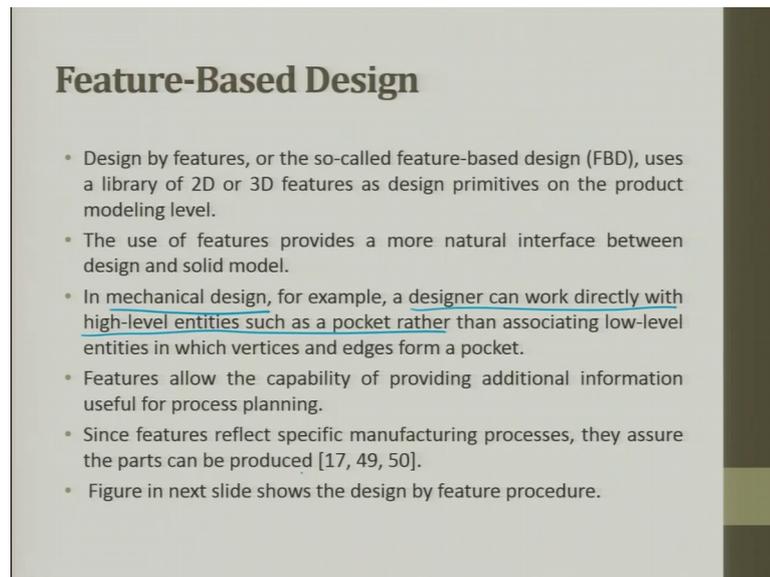
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So, you can see here a used a CAD software you have a geometric model. So, the feature recognition procedure is followed. Feature extraction procedure is followed. And then what you get is a feature model. So, the predefined feature is here and the feature template is here. So, you what you do is you try to, for example, I told you already I have a face

So, it quickly goes there is a template it quickly goes identifies what are all the features are same. And then it starts doing it suppose hair is there. So, it all predefined features are already available. So, it splits it moment it sees the full CAD model, it gets into it divided into some models or features. And, each feature is a recognition is one and then extraction is 2. Recognition extraction this goes back and forth. So, recognition is based on the feature I nose mouth hair template feature templates are extracted procedures are there. So, we do it and then finally, what we get is a feature model.

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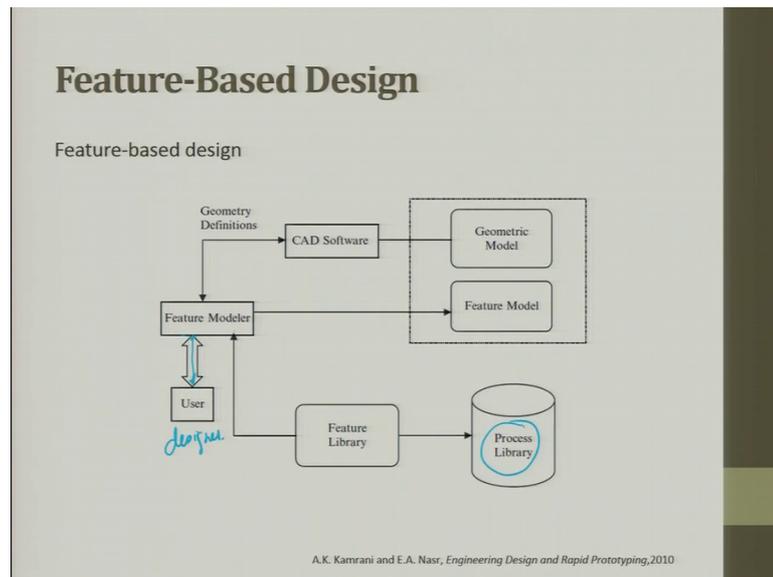
Feature-Based Design

- Design by features, or the so-called feature-based design (FBD), uses a library of 2D or 3D features as design primitives on the product modeling level.
- The use of features provides a more natural interface between design and solid model.
- In mechanical design, for example, a designer can work directly with high-level entities such as a pocket rather than associating low-level entities in which vertices and edges form a pocket.
- Features allow the capability of providing additional information useful for process planning.
- Since features reflect specific manufacturing processes, they assure the parts can be produced [17, 49, 50].
- Figure in next slide shows the design by feature procedure.

The feature based model design by feature or so called feature based design used a 2D or 3D feature as design primitives on the product model. The use of feature provides a more natural interface between design and solid. In mechanical design for example, a designer can work directly with the high level entities such as pocket rather than associated low level entities in which the vertices and edges form your pocket.

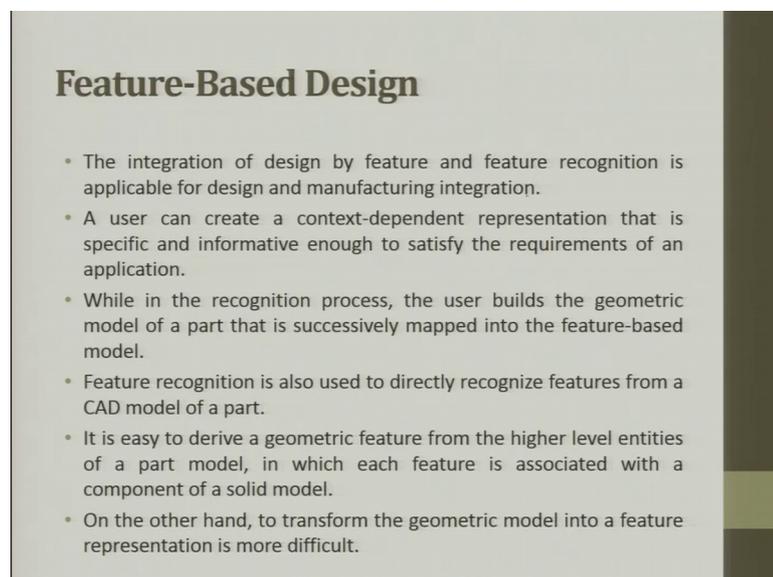
So, in mechanical design you see here. The designer can work directly with the high level entity as a pack that is what I said in a face I rather than curves and lines talking about. The feature allows the capability of providing additional information useful for the planning. Since the manufacturing reflex specific manufacturing process the assure the path can be produced.

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So, the feature based design. So, you see here a CAD software geometric model feature model. So, feature you pick it up from the feature library is there a process library is there you try to get and then see what is going on

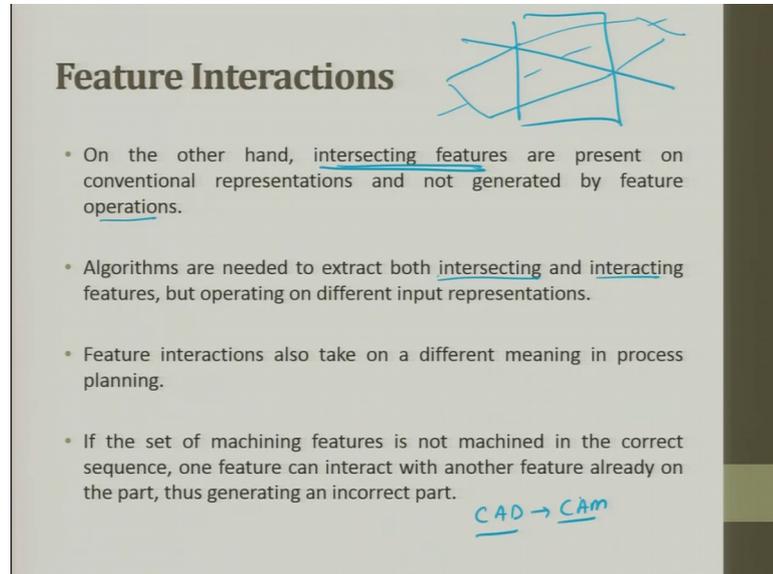
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The integration of design by feature or feature recognition is applicable for design and manufacturing hydration integration. The user can create a context dependent representation that is specific or inform to enough to satisfy the required application.

While, the recognition process the user builds the geometric model of a path, that is successfully mapped in the feature based ok.

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Feature Interactions

- On the other hand, intersecting features are present on conventional representations and not generated by feature operations.
- Algorithms are needed to extract both intersecting and interacting features, but operating on different input representations.
- Feature interactions also take on a different meaning in process planning.
- If the set of machining features is not machined in the correct sequence, one feature can interact with another feature already on the part, thus generating an incorrect part.

CAD → CAM

So, on the other hand intersecting features; these are very important intersecting features are present on the conventional representation and not generated by the feature operation. Intersecting features I have a cup I have a year. This is intersecting feature the handle getting integrated are represent. The conventional representation and not generated in feature operation the algorithms needed to extract both intersecting and interacting features by operating on different input representations are available today. So, with this we try to do feature in interaction and feature extraction interaction and extraction is done and we try to get the 3D object.

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Feature Interactions

- The feature interaction problem can be treated as a problem of feature relationships.
- There is no existing feature recognition system that could recognize all types of 3D solid primitive features and their various interacting combinations.
- The remainder of this section defines the problem of interacting features with an example. Interacting features are very common on manufacturing designed objects.
- As shown in Fig. in next slide, there are six features on the raw material of the workpiece.

The feature interaction problem can be treated as a problem of feature relationship. What is the relationship with respect to edge and a face? So, that is what is relation problem with the relationships. There is no existing feature recognition system that got recognise all 3D solid primitives as of today. The remainder of the section defines the problem of of the interacting features with an example. The interacting features are very common on manufacturing design objects

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Feature-Based Design

- Design by features, or the so-called feature-based design (FBD), uses a library of 2D or 3D features as design primitives on the product modeling level.
- The use of features provides a more natural interface between design and solid model.
- In mechanical design, for example, a designer can work directly with high-level entities such as a pocket rather than associating low-level entities in which vertices and edges form a pocket.
- Features allow the capability of providing additional information useful for process planning.
- Since features reflect specific manufacturing processes, they assure the parts can be produced.
- Figure in next slide shows the design by feature procedure.

Feature based design. The design by features are so, called feature based design uses a library of 2D and 3D features as design primitives on the product modelling level the use of these features provides a more natural interface between design and solid model. In mechanical design for example, if there is a pocket so, this pocket is fully taken into existence rather than splitting it in to lines and planes.

The feature allows the capability of providing additional information used for process planning. So, when we try to do CAD solid model and then leave it for the CAM software to decide it quickly recognises individual features and then it extracts and links it with the process parameter. Since features reflect simple manufacturing process, they assure that the path can be produced. So, this is how the procedure is. So, you have your CAD software where in which you do geometric modelling and you have a feature modular. This comes and does a extraction of the feature modeller which feature modelling and then this talks to the user is the designer

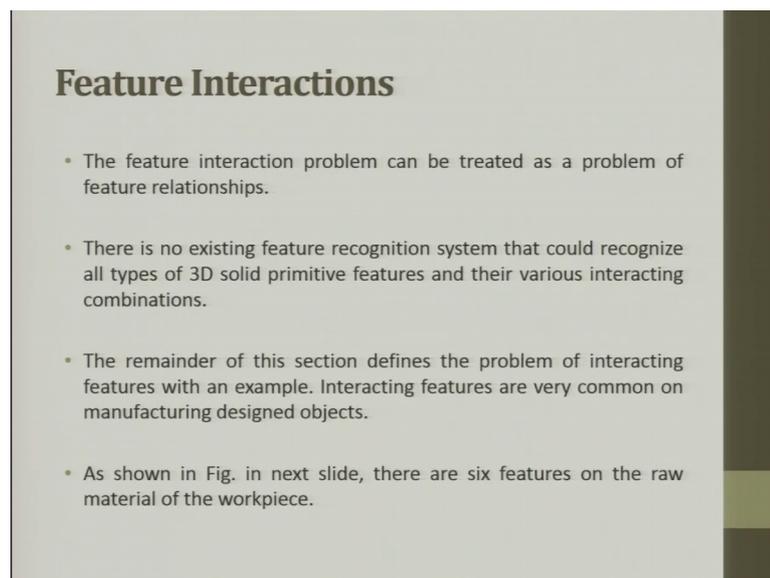
So, you have this CAD software which has this 2. Feature modeller does this and then this feature modeller always tries to get the information from the feature library, which is intern attached to your process library. Just by knowing the feature you see now the process is pulled out and you try to get it. So, this is a simple schematic diagram of feature based design. The integration of design by feature and feature recognition designed by feature and feature recognition is applicable for design and manufacturing integration today. So, design feature is a designer one feature recognition application is the manufacturing one. A user can create a context dependent representation that is specific and informative enough to satisfy the requirement of the application.

While in the recognition process, the user builds the geometric model of your path that is successfully mapped into the feature based model. The feature recognition is also used to directly recognise features from the CAD model. It is easy to derive a geometric feature from a higher level entities of a path model in which each feature is associated with their component of a solid body. On the other hand, to transform the geometric model into a feature representation is very, very difficult. Intersecting features are represented on conventional representations and not generated by feature operation. Intersecting features are always a challenge always a challenge. For example, you have a cylinder you have a plain cut set and then you get an ellipse.

And now if you so, called this ellipse is attached to some other cylinder. So, then it is an interesting feature if it goes like this a cylinder and other cylinder going ok. Intersecting features are represented on conventional representation and not generated by feature operation. There are several algorithms are used today to for extracting both intersecting and interacting features. The feature interaction also takes a different means in the process planning.

If the set of machining features is not machined in the correct sequence no feature can interact with another feature already in the part thus generating an in correct part. So now what are we talking about CAD to CAM link we are talking about. All these things are rapid manufacturing just doing CAD alone does not matter for a for manufacturing. So, doing CAD and transforming the data to CAM and doing it automatically needs all these feature recognition model.

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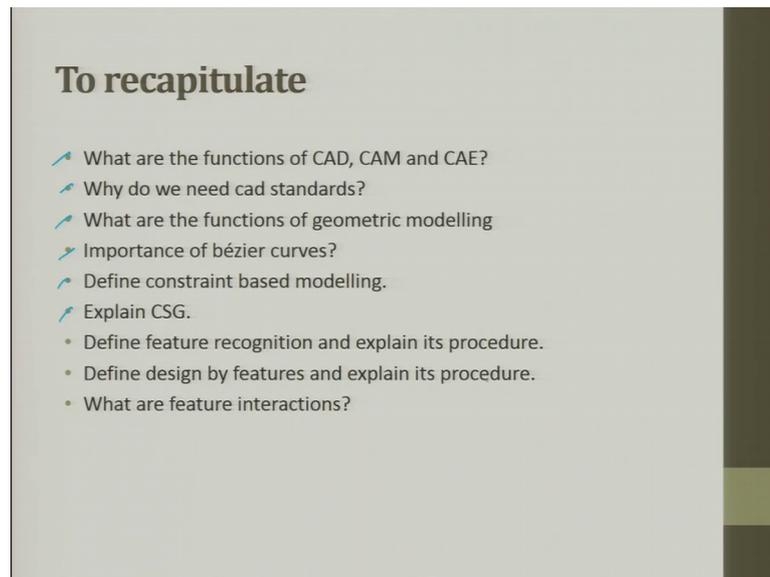


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In this lecture what all we saw was in a entire CAD, we saw what is the function of CAD CAM what are the CAD CAM standards what are the function of geometric modelling importance of synthetic curves Bezier B spline NURBS. Then define constructive solid geometry constrain base model explain CSG then feature recognition, then what define design by feature and explain and explain it is procedure, what is feature interaction. So, these are the topics we saw in this lecture of CAD. This is very important, if CAD does not exist CAM does not exist if CAM does not exist rapid manufacturing does not exist. In CAM comes r p also CNC machining ca e ca q whatever you say.

All these things come from CAD. So, if you know to represent CAD properly then the next step is taken care. CAD you have geometric simple geometric and complex you have analytical surface and free form surface or synthetic surfaces. So, in analytical surfaces parametric forms can be done. In synthetic surfaces you have to work on features like curves. So, these curves are B spline Bezier NURBS all these representations you have to use for use for developing a free form surface using synthetic curves. When you till now we were only talking about a single curve.

Suppose you have a big curve and we have discretizing it into several small curves and the radius of each curve is changing then the problem of first getting continuity and then smoothness of the continuity and control points in each arc curve is a challenge. Then we have done this then we have taken it to the next level feature recognition. Today the talk

of the town is feature recognition through CAD is a talk of a town, one is extraction of details, the two is interaction or when there is a intersection of details then how do you extract those features. This is what we saw in this lecture.

Thank you very much.