# IE 111 Computer Aided Engineering Drawing 

Introduction to 3-D Modeling

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## (D) 2-D Modeling versus 3-D Modeling



Just a drawing of the object


Like a
Real
Object

## Advantages of 3-D Modeling

E Ease of visualization from any view point.
$\square$ Ease of creating 2D views.

- Creation of photo-realistic images, animations and virtual reality presentations.
U Use of geometry for computational analysis, e.g. FEA.
U Use of geometry for CNC manufacturing processes.


## Model Definition

Solid model consists of;
Volumetric information (what is on the inside of the 3-D model)
Information about the surface of the object.


# 3-D Modeling Techniques 

$\square$ Primitive Modeling
$\square$ Constructive Solid Geometry Modeling
$\square$ Boundary Representation Modeling
$\square$ Constraint Based Modeling

## 3-D Modeling Techniques

$\square$ Primitive Modeling

- Objects are described using basic geometric forms
$\square$ Constructive Solid

> Primitives are used as a starting point for modelling Their parameters can be edited after creation Geometry Modeling
$\square$ Boundary Representation Modeling
$\square$ Constraint Based Modeling


## (2) 3-D Modeling Techniques

-Primitive Modeling
-Constructive Solid
Geometry Modeling

- Uses basic geometric forms
- Relationships between primitives are defined with Boolean operations.
-Boundary Representation
Modeling
-Constraint Based Modeling



## 3-D Modeling Techniques

## Boolean Operations

Effects of order of operands in a difference operation


## 3-D Modeling Techniques

## Boolean Operations

## Boolean operations on adjoining primitives



## 3-D Modeling Techniques

$\square$ Primitive Modeling

- Constructive Solid Geometry Modeling

$\square$ Boundary Representation Modeling
- Surfaces are the basis defining the solid.
$\square$ Constraint Based Modeling


## 3-D Modeling Techniques

## Boundary Representation Modeling

Exact versus faceted surfaces

Curved surfaces hinder model performence. For that reason, some modelers approximate curved
 surfaces with a series of planes. That is called faceted representation.


## 3-D Modeling Techniques

$\square$ Primitive Modeling
-Constructive Solid Geometry Modeling

aBoundary Representation Modeling
-Constraint Based Modeling

- Model is based on modifiable features.

Constraints:
A-Notches at top are symetric at size and location
B-Holes are equally spaced no farther than 4 cm apart.
C-Slot is at constant distance from the top and its depth is equal to depth of the notch.
D-Radiused corners have radius equal to one-fifth of height of part.

Modifications:
1-Overall length is incraesed from 19 cm to 21 cm 2-Height is incraesed from from 5 cm to 6 cm 3-Right-hand notch is doubled in depth.

How does the constrained part respond to modifications?

## Constraint Based Modeling

Responce to modifications: 1-Left-hand notch doubles in depth to match the notch on the right.
2-There are four equally spaced holes instaed of three.
3-The slot is still the same distance from the top, but it has increased in depth to match the new notch depth.
4-Radii of the corners have incraesed to stay onefifth the hight of the part.


## (D) Constraint Based Modeling



## Features from Generalized Sweeps

Many features can be made through the use of sweeping operations. In sweeping operation, a closed poligon, called a profile, is drawn on a plane and is moved or swept along a defined path for a defined length.


Right


Oblique


No!

## Features from Generalized Sweeps

## Examples of revolved sweeping operations

The resulting geometry is dependent

(B)

(C)

## Creating a 3-D Model Using Sweeping Operations

## Creating a solid model using sweeping and Boolean operations



Step 4



Completed Object

## Working with 2-D Planes in a 3-D Space

## - Workplane

- All geometry in a model is located and oriented relative to a 3-D coordinate system. World Coordinate System is explicitly defined and available.
- In order to work with 2-D plane in a 3-D space, we must define a workplane to construct a portion of the object located on that plane.
- To do that, we must define a local coordinate system (User Coordinate System) whose X \& Y axes ( $\mathrm{U} \& \mathrm{~V}$ ) are placed on the workplane.


## Workplane

## Mutually perpendicular workplanes


(A)

(B)

(C)

## Workplane

$\square$ Using the UCS
To draw a geometric shape, e.g. A circle on the 'side' of the wireframe model, you would start by
creating a new user coordinate system (UCS) whose $x$ and $y$ axes lie on the plane of the relevant side.


## Workplane



## Local coordinate system



## Workplane

Locating a workplane by the faetures of the model

(A)

(B)

## Workplane




Tangent and Orientation

## Common methods of creating new workplanes



Offset / Parallel


Angle

## Working with 2-D Planes in a 3-D Space



Object
Workingplane is the inclined face of the object


## Workingplane is the front face of the object

## Working with 2-D Planes in a 3-D Space



Workingplane is the inclined face of the object

UCSFOLLOW=1


Workingplane is the front face of the object

UCSFOLLOW=1

## Primary Aproaches of 3-D Modeling

## $\square$ Wireframe Modeling


$\square$ Surface Modeling


## Solid Modeling



## 3-D Modeling

## Wireframe Modeling

The vertex and edge list of a wireframe model


Vertex List

$$
\begin{array}{ll}
V_{1} & (0,0,0) \\
V_{2} & (1,0,0) \\
V_{3} & (0,1,0) \\
V_{4} & (0,0,1)
\end{array}
$$

Edge List

$$
\begin{aligned}
& \mathrm{E}_{1}<V_{1}, V_{2}> \\
& \mathrm{E}_{2}<V_{2}, V_{3}> \\
& \mathrm{E}_{3}<V_{3}, V_{1}> \\
& \mathrm{E}_{4}<V_{1}, V_{4}> \\
& \mathrm{E}_{5}<V_{2}, V_{4}> \\
& \mathrm{E}_{6}<V_{3}, V_{4}>
\end{aligned}
$$

## 3-D Modeling

## Wireframe Modeling

A wireframe model using circular and linear edges


| Vertex List | Edge List | Type |
| :---: | :---: | :---: |
|  | $\mathrm{E}_{1}<\mathrm{V}_{1}, \mathrm{~V}_{2}>$ | Circular |
| $\mathrm{V}_{1}(-1,0,1)$ | $\mathrm{E}_{2}<\mathrm{V}_{2}, \mathrm{~V}_{1}>$ | Circular |
| $\mathrm{V}_{2}(1,0,-1)$ | $\mathrm{E}_{3}<\mathrm{V}_{3}, \mathrm{~V}_{4}>$ | Circular |
| $\mathrm{V}_{3}(-1,5,1)$ | $\mathrm{E}_{4}<\mathrm{V}_{4}, \mathrm{~V}_{3}>$ | Circular |
| $\mathrm{V}_{4}(1,5,-1)$ | $\mathrm{E}_{5}<\mathrm{V}_{1}, \mathrm{~V}_{3}>$ | Linear |
|  | $\mathrm{E}_{6}<\mathrm{V}_{2}, \mathrm{~V}_{4}>$ | Linear |

## 3-D Modeling

## Wireframe Modeling

Example of a wireframe model lacking uniqueness


The same edge and vertex list can describe different objects, depending on how the faces are interpreted.


## 3-D Modeling

## Wireframe Modeling



Which face is in front and which is in back?

## Wireframe Modeling in 3-D

## Specifying a position in 3D space

- Drawing in 3D is essentially the same as drawing in 2D. The same commands work in the same way. The only difference is that you use the z component in the Cartesian coordinate system along with the $x$ and $y$ components. So the origin would be: <0,0,0>
- In 2D CAD there is only one plane on which you create your drawing, so any 'selecting click' with the cursor or pointer will automatically pick off that plane. In 3D there are an infinite number of possible planes, so the situation becomes much more complicated.


## Wireframe Modeling in 3-D

$\square$ Creating lines in 3D using coordinates

- Use the line command to draw lines to model the wireframe, entering the coordinates on the command line.
- You can create most entities in 3D, as in 2D, by specifying point positions required using absolute or relative coordinates.



## Primary Types of 3-D Modeling

$\square$ Wireframe Modeling $\sqrt{ }$

$\square$ Surface Modeling


## $\square$ Solid Modeling



## Solid Modeling

$\square$ Solid modeling provides the same display information as surface and wireframe modeling. It also offers the advantage of representing the entire volume of the design.
$\square$ The model can therefore be analysed for volume related properties such as;

- mass,
- moments of inertia,
- center of gravity, and
- the model data can be used for 3D CNC machine programming and 3D FEA.


## Creating Primitive Solids

## $\square$ Box

$\square$ Cone
$\square$ Cylinder
$\square$ Torus
$\square$ Wedge
$\square$ Pyramid

## $\square$ Sphere



## 2D Outlines Suitable for 3D Models

When constructing 2D outlines suitable as a basis for constructing some forms of 3D model, select a tool from the Home/Draw panel.
$\square$ If constructed using tools such as Line, Circle and Ellipse, before being of any use for 3D modeling, outlines must be changed into regions with the Region tool.
$\square$ Closed polylines can be used without the need to use the Region tool.

## 2D Outlines Suitable for 3D Models

1. Construct the drawing given below using the Line and Circle tools.
2. Enter region or reg at the command line. Select the objects whose outlines will be converted to surfaces. Call the Union tool from the Home/Edit panel. Selects the three objects for union.
3. Call the Union tool from the Home/Edit panel. Select left rectangle and circle.
4. Call the Subtract tool, also from the Home/Edit panel.

5. 3 regions

6. Union of 3 regions

7. Subtract region from Union Select the union and then right rectangle.

## Creating Complex Solids

$\square$ Extrude

- Constant cross-section
- along a straight line
$\square$ Revolve $\square$
- Constant cross-section
- around an axis of revolution
$\square$ Sweep

$\square$ Loft $\square$
- Multiple cross-sections
- along a space curve

- Constant cross-section
- along a space curve


## Extrude Tool

1. Draw the regioned outline.
2. Make layer Green current.
3. Call Extrude.
4. Place in the Layers \& View/3DNavigation/SW/lso metric view.
5. Call Zoom and zoom to 1. 6. Place in Visual Style/Realistic.


Current wire frame density: ISOLINES = 4 in the prompts sequence when Extrude is called. The setting of 4 is suitable when extruding plines or regions consisting of straight lines, but when arcs are being extruded it may be better to set ISOLINES to a higher figure as follows:

Command: enter isolines right-click

- Enter new value for ISOLINES <4>: enter 16 right-click
- Select objects to extrude or [MOde]:
- If mo is entered as a response to this prompt line, the following prompts appear:
- Closed profiles creation mode[SOlid/SUrface]<Solid>: _SO which allows the extrusion to be in solid or surface format.


## Extrude Tool



## The Revolve Tool

1. Construct the closed polyline.
2. Make layer Red current.
3. Set ISOLINES to 24.
4. Call the Revolve tool from the Home/Create panel.


## The Revolve Tool

1. Make layer Yellow current.
2. Place the screen in the 3D Navigate/Front view. Zoom to 1.
3. Construct the pline outline.
4. Set ISOLINES to 24.
5. Call the Revolve tool and construct a solid of revolution.
6. Place the screen in the 3D. Navigate/SW Isometric. Zoom to 1.
7. Place in Visual Styles/Shades of Gray.

## The Revolve Tool

1. Make Green the current layer.
2. Place the screen in the 3D Navigate/Front view.
3. Construct the pline .The drawing must be either a closed pline or a region.
4. Set Isolines to 24.
5. Call Revolve and form a solid of revolution
 through 180 degree.
6. Place the model in the 3D Navigate/NE Isometric. Zoom to 1 .
7. Place in Visual Styles/Conceptual.


## Sweep Tool

- With the SWEEP command, you can create a new solid or surface by sweeping an open or closed planar curve (profile) along an open or closed 2D or 3D path.
- SWEEP draws a solid or surface in the shape of the specified profile along the specified path.
$\square$ You can sweep more than one object, but they all must lie on the same plane.
- When you select an object to sweep, it is automatically aligned to the object that is used as the path.


Sweep Tool


IE 111 Computer Aided Engineering Drawing - Introduction to 3-D Modeling

Creates a 3D solid or surface in the space between several cross sections.


## Loft Tool

Path curve


Cross sections with
Lofted solid

Cross sections with path
Lofted solid
 guide curves

## Creating Composite Solids

$\square$ Primitive objects can be added together or subtracted to make more complex solid objects called composite objects.
$\square$ Boolean operators such as union, subtract and intersect can be used in creation.



## Feature Planning Strategy

Geometric decomposition for features

How geometry is decomposed into features depends on an overall strategy for model use.

(B)

## Feature Planning Strategy

Feature ordering affects final geometry


The order in which features reside in the feature tree can affect the final part geometry.

(A)

(B)

## Dublicating Part Features

## Linear and radial arrays

Array copy counts usually include the original plus the number of copies.

(B)

## Viewing the Part Model

## Elements of projection system

Projection plane

## Viewing the Part Model

View camera operation
The view camera captures a projection of the model on the image plane.


## View Camera Strategy

Parallel versus perspective projection

The closer the camera is to the object, the wider the angle of view and the more severe the convergence.


What Is Seen


Parallel Projection


Perspective Projection


## View Camera Strategy

View commands that do not involve changing the viewpoint

Pan and zoom commands do not change the projection of the model.


Zoom Out


Zoom In


Pan

## (D) View Camera Strategy

Different options for rendering a model

There are many options for how to depict hidden edges and tangents.


Orienting the workplane coincident with the viewplane

Workplanes often are used to orient the view camera.


## View Camera Strategy

Good and poor viewing practice for modeling

The choice of view should be feature driven. Which view best depicts the features being operated on?

(A)


No!
Severe distortion of depth

(C)


Yes!
Important
features are true size and shape

Associativity between 3-D model and 2-D drawing

With bidirectional associativity, changes in the 3-D model are reflected in the drawing and vice versa.


## Analysis

- Visual inspection
$\square$ Protoyping
$\square$ Kinematics
Mass Properties Analysis
$\square$ Finite Element Analysis
$\square$ Ergonomics


## Analysis

Processing a model for rapid prototyping

A solid model needs special preparation before a rapid prototyping machine can create a physical model of it.

CAD Model

(A)

Tessellated Model


STL
(B)
(STereolithography) format

Sliced Model


## Analysis

## Finite Element Model



## Analysis

## Human interaction and ergonomic simulation within a 3-D car



## Analysis

Modeling the incremental fabrication of a part

Virtual 3-D models can be used to simulate the manufacturing process.


## Analysis

Planning tool paths using a virtual 3-D model

Tool paths can be troubleshot on virtual models without risking damage to expensive equipment.


## Circular Sweep (Revolve)

Sketch the resulting solid model if the given profiles were to be circularly swept 360 degrees about the Y axis. Use grid snap.

(A)

(D)

(B)

(E)

(C)

(F)

## Linear Sweep (Extrude)

Sketch the resulting solid model if the given profiles were to be linearly swept 2 units along the $+Z$ axis. Use grid snap.


## (D) Boolean Operations

Given the three overlapping solid primitives, make an isometric sketch of the resulting solid after applying the following Boolean operations: A-B-C.


$$
A-B-C
$$



## Problem 4.6 (Figure 4.51)

Create the objects given below using solid modelling techniques.

(A)

(D)

(B)

(E)

(C)

(F)

## Solid Exercise 1.dwg

Create the objects given below using the top view dimensions.


Cylinders R5 Box $120 \times 60 \times 50$ height 10


## Primary Types of 3-D Modeling

## $\square$ Wireframe Modeling $\sqrt{ }$ <br> 

$\square$ Surface Modeling

$\square$ Solid Modeling $\sqrt{ }$


## Surface Modeling in 3-D

## $\square$ Surfaces

- Have no thickness.
- Have two sides (or faces) and they have edges (or boundaries), much like a sheet of paper or a piece of cloth does.
- can be shaded and can be used to provide good visual representations of solid objects.
$\square$ Creating basic surfaces
- Surfaces fall into two main categories, the flat, planar ones and the freeform type, based on curves.


## 3-D Modeling

## Surface Modeling

## Swept surfaces



Generating swept surfaces by sweeping generator entities along director entities.


## 3-D Modeling

## Surface Modeling

Complex surface
A more complex surface can be created by sweeping directrix along a curved generatrix.

(A)

(B)

## 3-D Modeling

## Surface Modeling

Revolved surface
A directrix can be rotated about an axis between 1 and 360 degrees.


## 3-D Modeling

## Surface Modeling

Lofting to define a surface
Lofting uses two or more directrix curves to define a surface.


## Creating Basic Surfaces

## $\square$ 3dface

- The 3dface tool will create a triangular or flat quadrilateral surface from points specified by you.
- You can select the points on the display using the object snap facility or enter their absolute or relative coordinates.
- To shade the model you can use the shade command.
- To hide geometry that is hidden by surfaces use the hide command.


## Creating Complex Surfaces

$\square$ Extrude

- Constant cross-section
- along a straight line
$\square$ Revolve $\square$
- Constant cross-section
- around an axis of revolution
$\square$ Sweep

- Constant cross-section
- along a space curve
$\square$ Loft $\square$
- Multiple cross-sections
- along a space curve



## Solid Exercise 2.dwg

In most cases, if you extrude a closed object, the result is a new 3D solid. If you extrude an open object, the result is a surface.

1. Using the Line tool from the Home/Draw panel construct the
 outline.
2. Call the Extrude tool and window the line outline ( $\mathrm{Mo}=\mathrm{Su}$ ). 3. Extrude to a height of 100.


## Extrude Tool

In most cases, if you extrude a closed object, the result is a new 3D solid. If you extrude an open object, the result is a surface.


3D Solid


3D Surface

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## Extrude Tool



## Extrude Tool



## (2) The Revolve Tool




## Semi-ellipse based on $180 \times 100$ axes



## Solid Exercise 3.dwg


$\rightarrow \| \frac{4}{4}$


Semi-ellipse based on $180 \times 100$ axes


## Sweep Tool



## Solid Exercise 4.dwg

1. Construct the pline outline in the 3D Navigation/Top view.
2. Change to the 3DNavigation/ Front view, Zoom to 1 and construct a pline as a path central to the outline.
3. Make the layer Magenta current.
4. Place the window in the 3D Navigation/SW Isometric view and click the Sweep tool icon.


## Sweep Tool



Swept polyline
Polyline vertex stretched to change profile


## (D) Loft Tool

Creates a 3D solid or surface in the space between several cross sections.


## (2) Loft Tool



## Solid Exercise 5.dwg

1. Set Cyan as the current layer.
2. In the 3D Navigate/Top view, construct the seven circles at vertical distances of 30 units apart.
3. Place the drawing area in the 3D Navigate/SW Isometric view.
4. Call the Loft tool with a click on its tool icon in the Home/Modeling panel .
5. Place in Visual Styles/ Shaded with Edges.


## Solid Exercise 6.dwg

Working to the dimensions given construct an extrusion of the plate to a height of 40 units.


## Solid Exercise 6.dwg



## Solid Exercise 7.dwg

Working to the polylines given, construct the Sweep shown below.


## Solid Exercise 7.dwg



## Solid Exercise 8.dwg

Construct the cross sections as shown in the right-hand drawing working to suitable dimensions.
$\square$ From the cross sections construct the lofts shown in the right-hand view.

- Create the box
- Create the cylinder
- Create the body of revolution from the top three circles


Create a sphere using the Sphere tool and locate it on top of the body of revolution.


## Solid Exercise 8.dwg



## Solid Exercise 9.dwg

Construct the solid model


## Solid Exercise10.dwg

Construct the solid model


## Solid Exercise11.dwg

Construct the solid model


## Solid Exercise12.dwg

Construct the solid model


## Solid Exercise13.dwg

Construct the solid model


## Solid Exercise14.dwg

Construct the solid model


## English - Turkish Dictionary

\(\left.$$
\begin{array}{|l|l|l|l|l|l|l|}\hline \text { 3-D modeling } & \text { 3-boyutlu modelleme } & \text { Virtual reality } & \text { Sanal gerçeklik } & \text { Center of gravity } & \text { Ağırlık merkezi } \\
\hline \begin{array}{l}\text { Wireframe } \\
\text { modeling }\end{array} & \begin{array}{l}\text { Tel çerçeve } \\
\text { modelleme }\end{array} & \text { Surface modeling } & \text { Yüzey modelleme } & \text { Solid modeling } & \text { Katı modelleme } \\
\hline \begin{array}{l}\text { User } \\
\text { coordinate } \\
\text { system }\end{array} & \begin{array}{l}\text { Kullanıcı (yerel) } \\
\text { koordinat sistemi }\end{array} & \begin{array}{l}\text { Moments of } \\
\text { inertia }\end{array} & \begin{array}{l}\text { Eylemsizlik } \\
\text { (atalet) } \\
\text { momentleri }\end{array} & \begin{array}{l}\text { FEA (Finite } \\
\text { Elements } \\
\text { Analysis) }\end{array} & \begin{array}{l}\text { Sonlu elemanlar } \\
\text { analizi }\end{array} \\
\hline \text { mass } & \text { kütle } & \text { extrude } & \begin{array}{l}\text { Itip (kalıptan) } \\
\text { çıarma } \\
\text { Çok kesitli } \\
\text { yükselti }\end{array}
$$ \& revolve \& path \& Bir eksen etrafında <br>

döndürme\end{array}\right]\)| Yol, yörünge |
| :--- |
| sweep |
| süpürme |

