Reliving my Geometric Modeling days -☺

Yogesh Kulkarni

Introduction

Introduction

How to model real world objects? - Design

How to put forth ideas in visual manner – Communication

How to verify that design serves the purpose – Analysis

How to get it made? – Manufacturing

All of the above can happen without Computers. But

Better if assisted by Computers/Software

That’s why : Computer Aided < > (CAx)

History

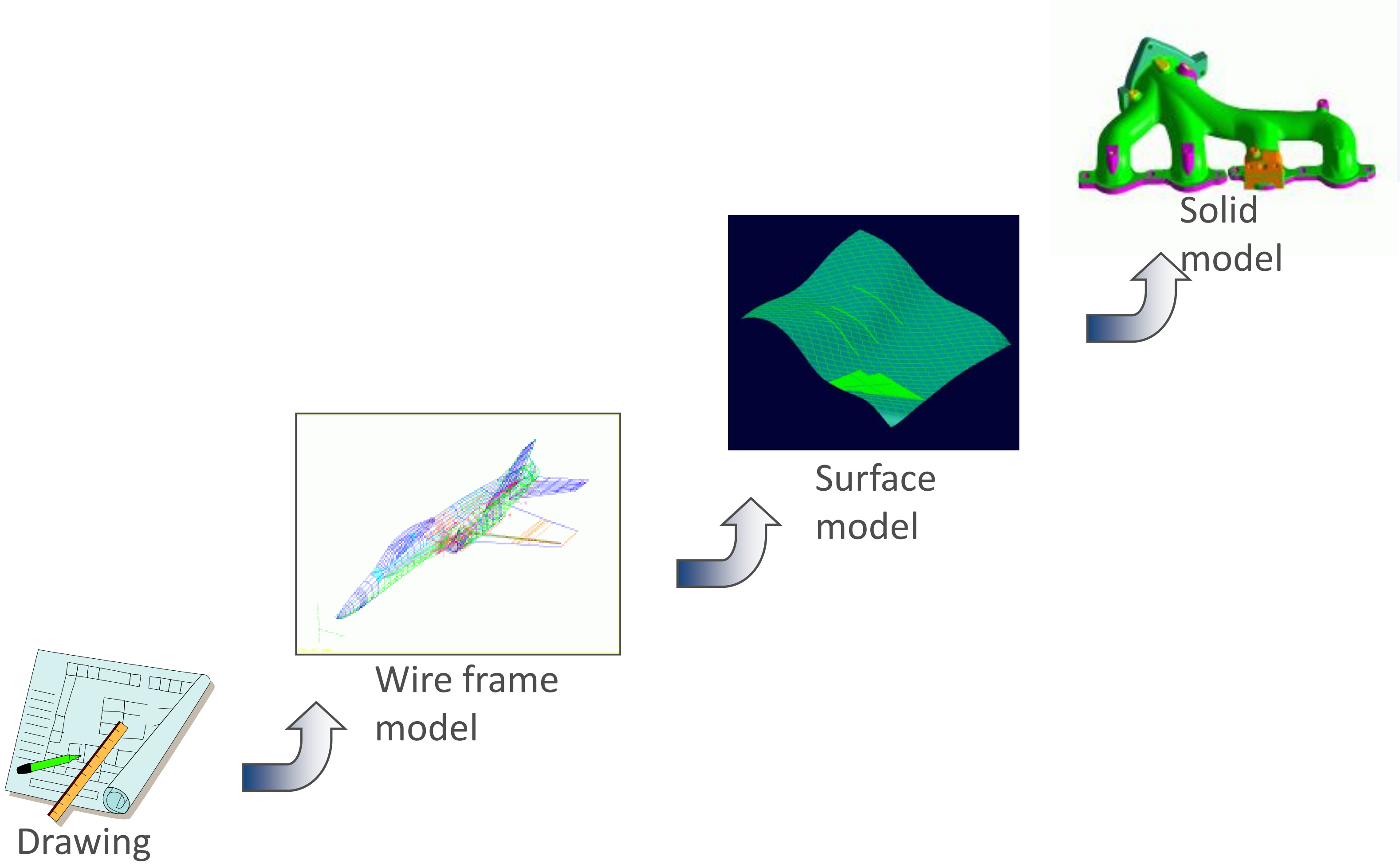
The first source of CAD resulted from attempts to automate the drafting process.

These developments were pioneered by the General Motors Research Laboratories in the early 1960s.

CAD became more widely used after 1970 because of technological advancements.

CAD allowed users to design products much quicker without the production of an actual product.

Evolution of CAD Technology



Manual Drafting

Since 1970’s: electronic drafting board

Manual Drafting

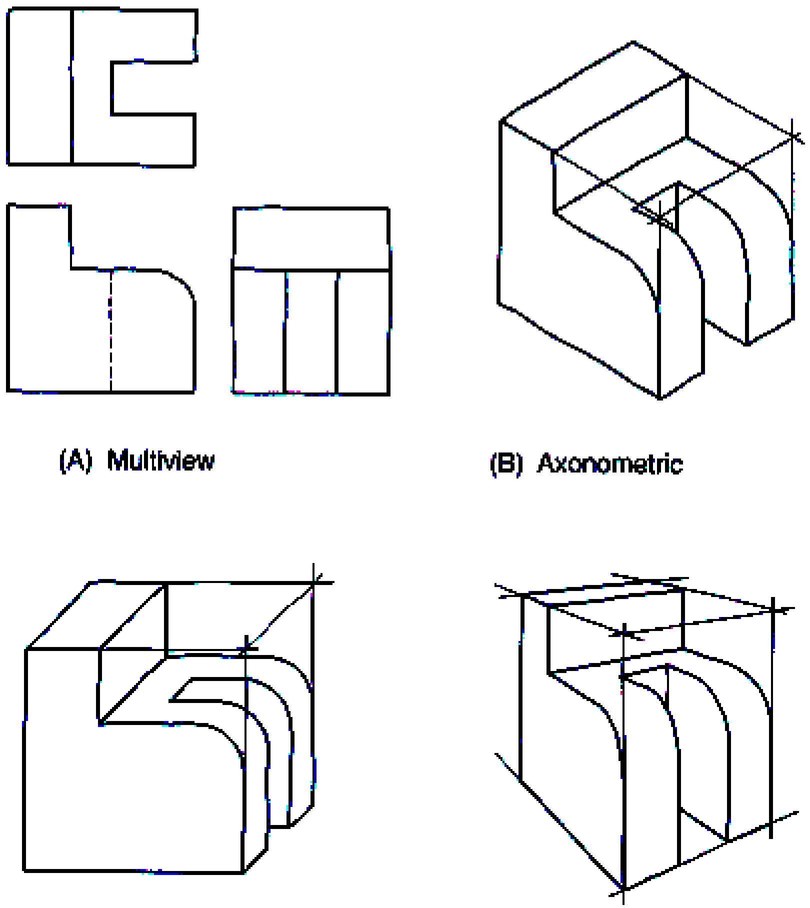
2D representations used to represent 3D objects

- multi-view drawings
- pictorials

Standards and conventi … uilt from drawings

Drawings created manu

Difficult to visualize, err



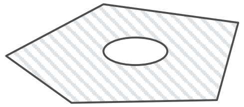
(A) Multiview (B) Axonometric (C) Oblique (D) Perspective

CAD - Types

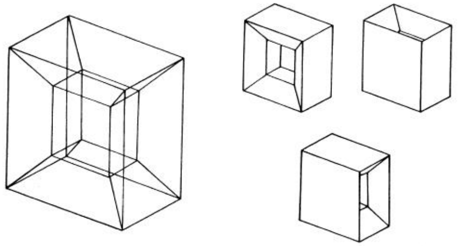
2D model: Point, line, circular arc, planar curve

3D model

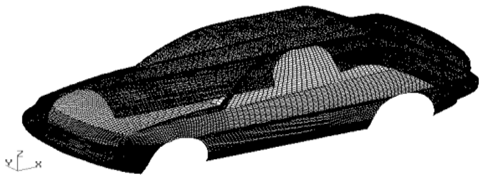
- Wire frame

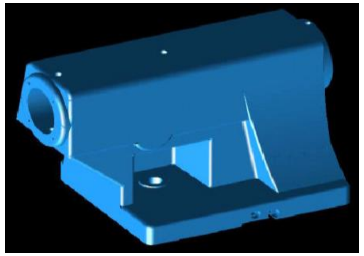


- Surface



- Solid





Advantages and Disadvantages of each?

2D CAD

Simply replaces manual drawing

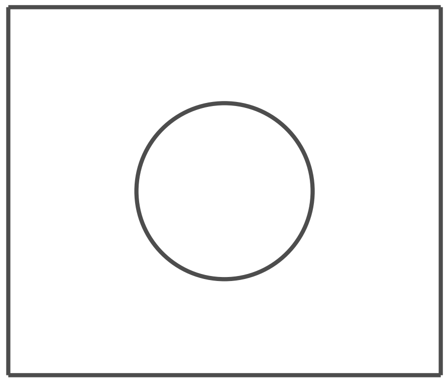
Provides a set of drawing tools to create 2D elements

- Lines, circles, arcs, etc.

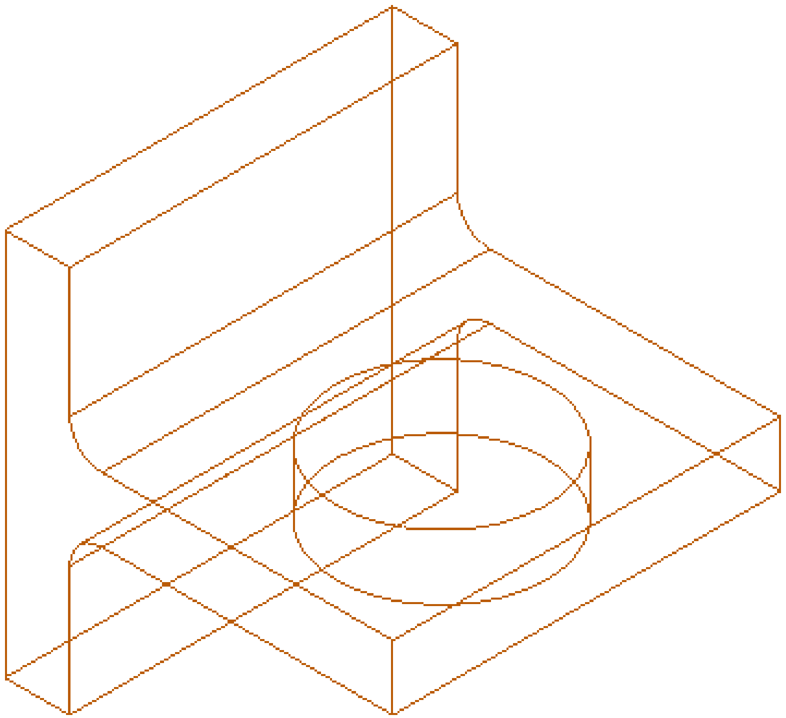
More accurate, easier changes to drawings

Still no 3D representation of the object

Example: AutoCAD



Wireframe



Early 1980’s: wire frame geometry

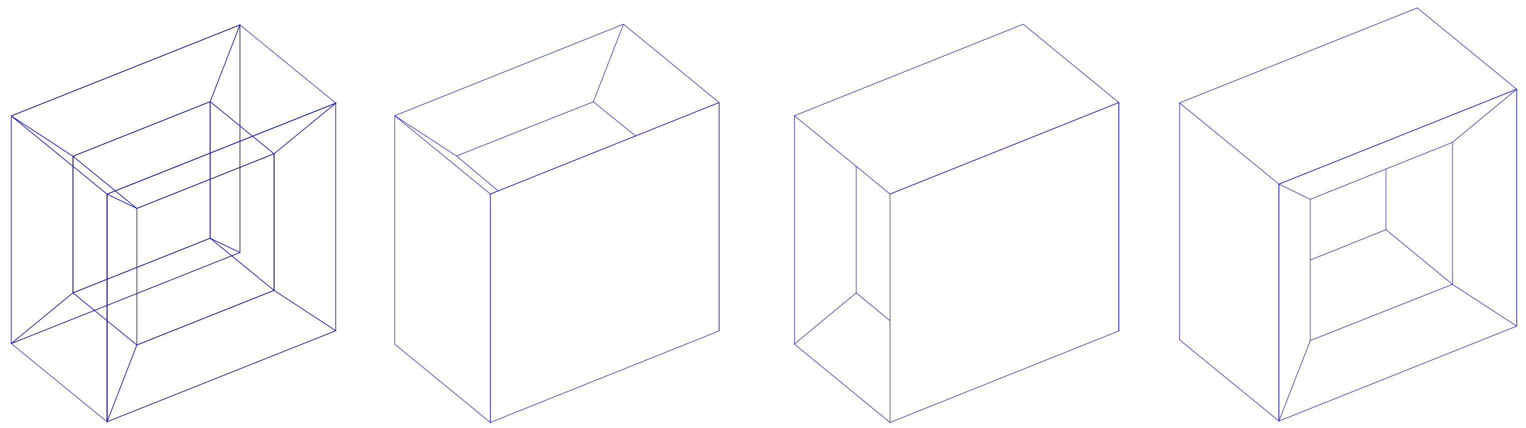
3D Wire frame Modeling

Geometric entities are lines and curves in 3D

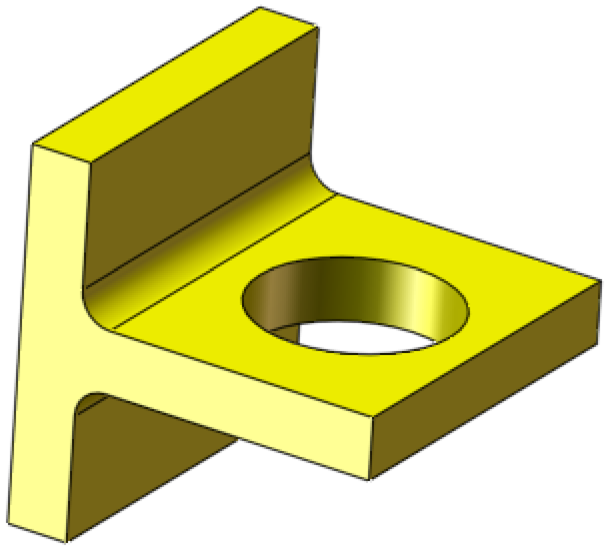
Volume or surfaces of object not defined

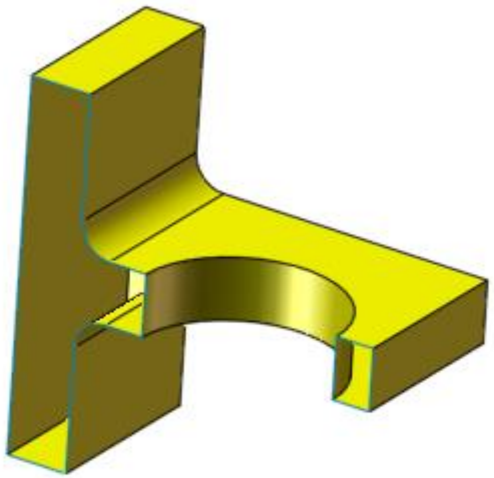
Easy to store and display

Hard to interpret - ambiguous



Surface Modeling

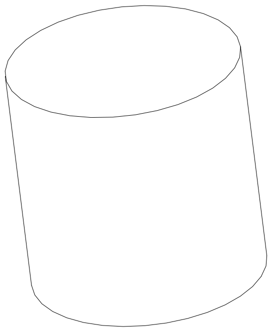




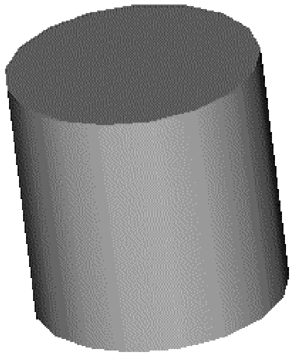
Late 1980’s: Surface Modeling

Surface Modeling

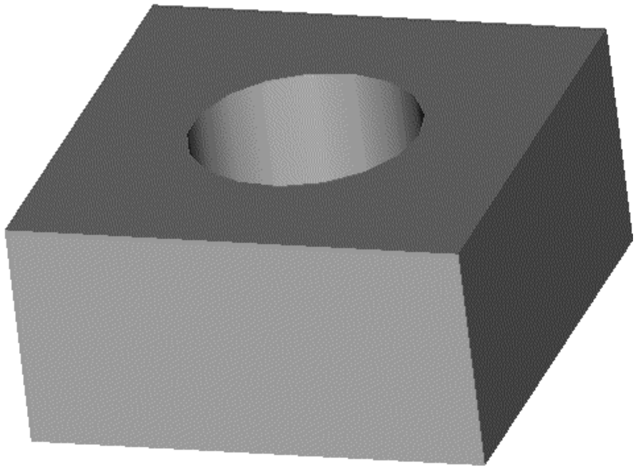
- Geometric entities are surfaces in 3D
- Surfaces have no thickness, objects have no volume or solid properties
- Surfaces may be open
- Hard to interpret – no information on the interior



A cylindrical surface

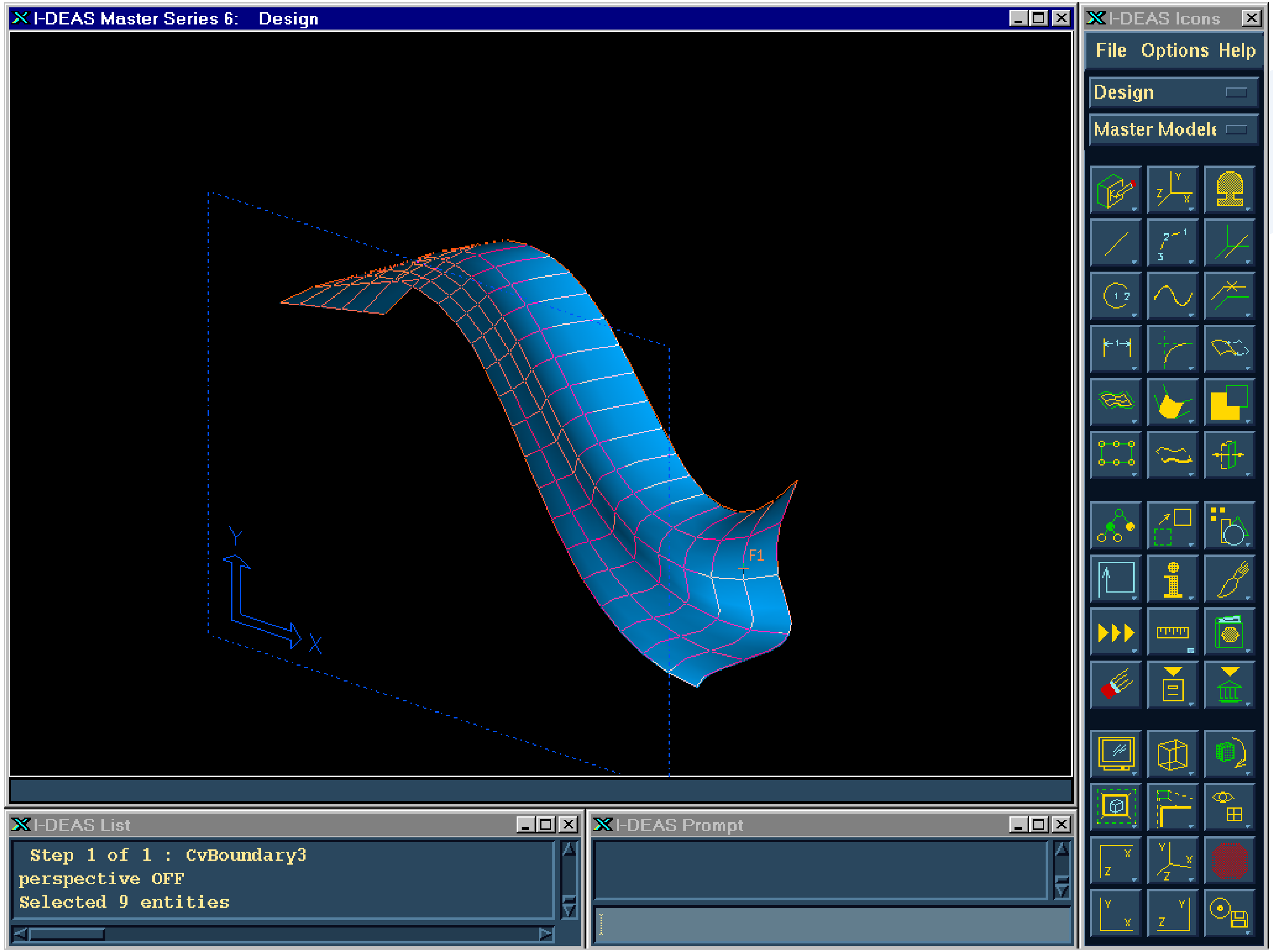


May represent a solid cylinder



or a hole

3D Surface Modeling



A Surface Model created using Alias StudioTools

Surface Model created using Rhino

Why draw 3D Models?

3D models are easier to interpret.

Less expensive than building a physical model.

3D models can be altered easily, create more concepts.

3D models can be used to perform engineering analysis, finite element analysis (stress, deflection, thermal…..) and motion analysis.

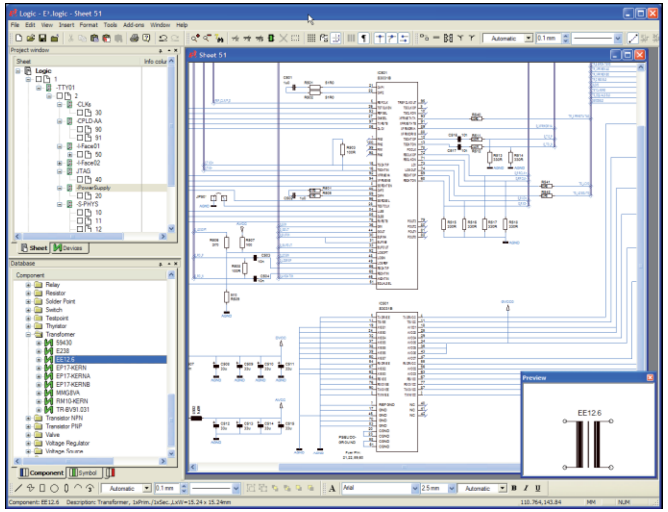
3D models can be used directly in manufacturing, Computer Numerical Control (CNC).

2D Applications

Drafting – sketches, architectures, Drawings

Art – Sketches, painting

Electronic layouts, circuit design



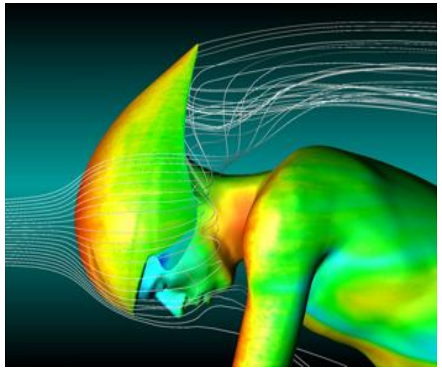
3D Applications

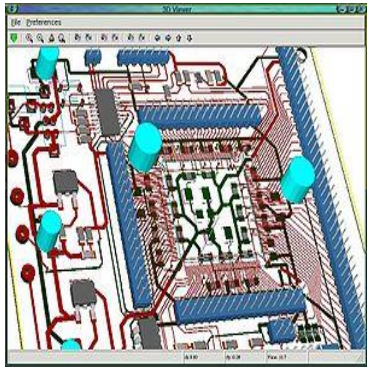
CAD (Computer Aided Design)

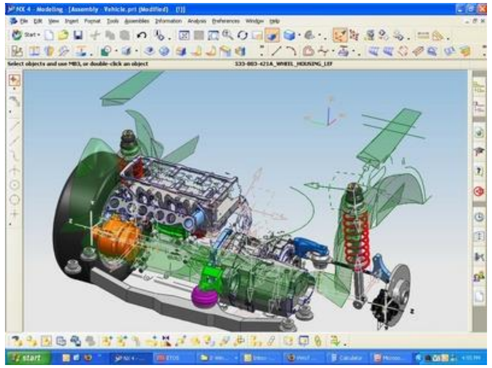
CAM (Computer Aided Manufacturing)

CAE (Computer Aided Engineering) Finite Element Method

CG (Computer Graphics)



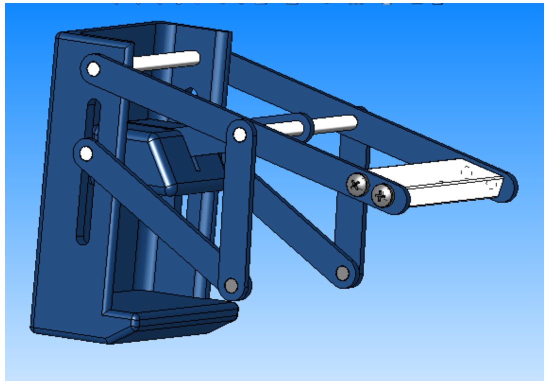


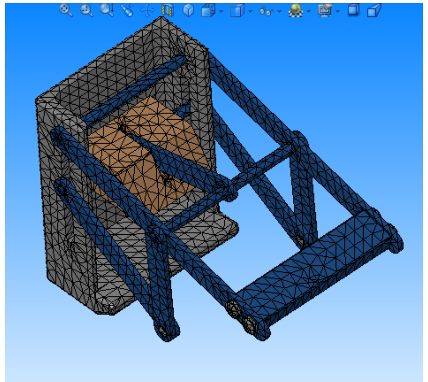


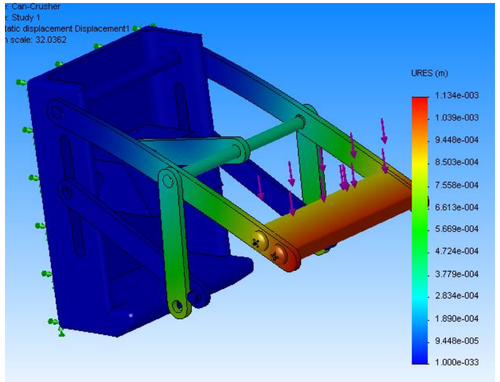
Basics of Finite Element Analysis (FEA)

A complex problem is divided into a smaller and simpler problems that can be solved by using the existing knowledge of mechanics of materials and mathematical tools

Modern mechanical design involves complicated shapes, sometimes made of different materials that as a whole cannot be solved by existing mathematical tools. Engineers need the FEA to evaluate their designs







Computer Numerical Control (CNC)

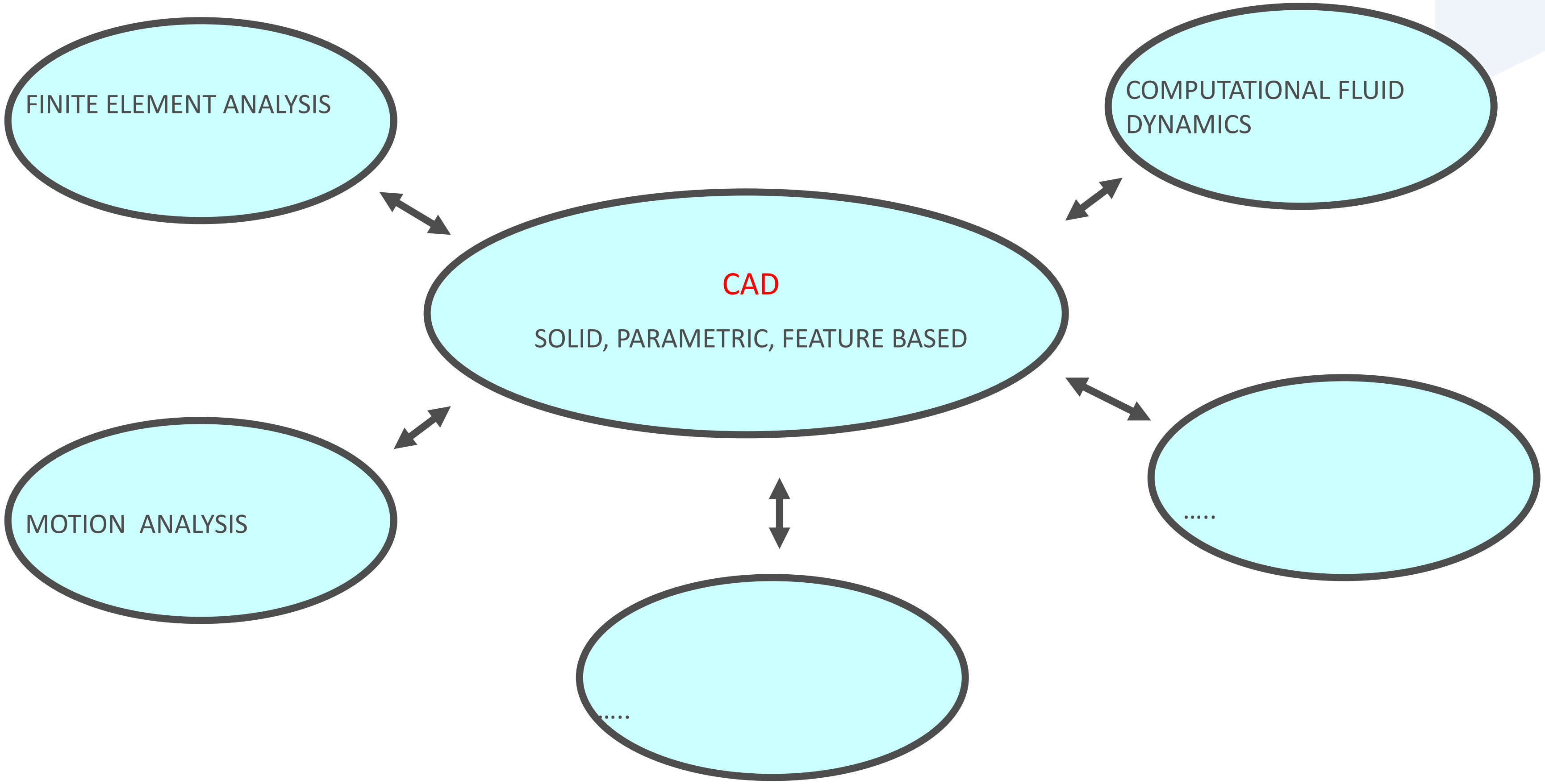
A CNC machine is an NC machine with the added feature of an on-board computer.

Modelling

Solid, parametric, feature based modeling

- Complete and unambiguous
- Solid - models have volume, and mass properties
- Feature based - geometry built up by adding and subtracting features
- Parametric - geometry can be modified by changing dimensions

MODERN CAE TOOLS



Solids

What is Solid?

Define Solid?

How would you represent Solid in software (data model)?

Properties of Representation Schemes

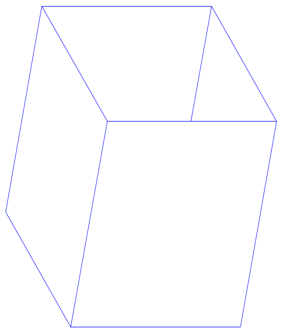
Geometric coverage: - objects that can be described using the representation scheme.

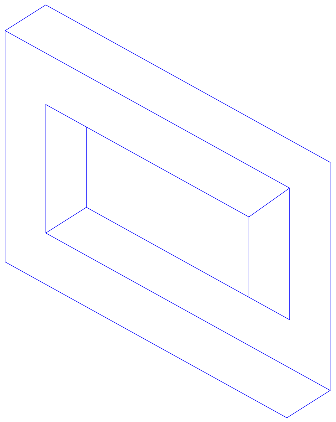
Validity - A representation scheme must designate a valid solid.

Completeness - a representation must provide enough data for any geometric computation performed.

Uniqueness - a solid may have more than one representation.

Un-ambiguity - a valid representation should model exactly one solid.





Cloud of points

The simplest form

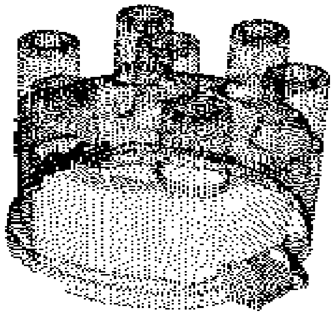
Unorganized / organized points

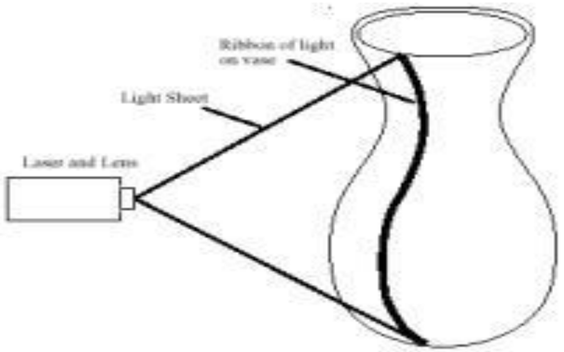
Too many points to represent the desired shape

Hard to handle → further processing is required

Obtained by digitizing

- CMM (coordinate measuring machine)
- Laser range scanner
- …





Mesh

Most popular approximation model

Graphics, RP, CAD/CAM, DMU, CAE

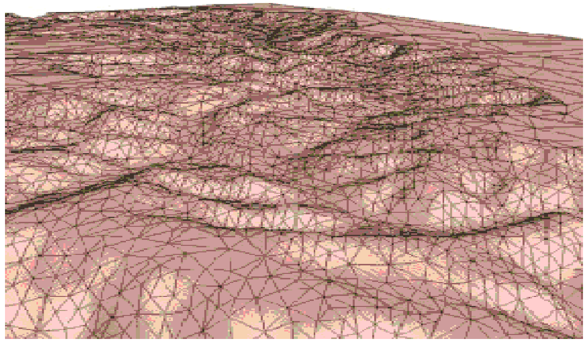
Hard to handle

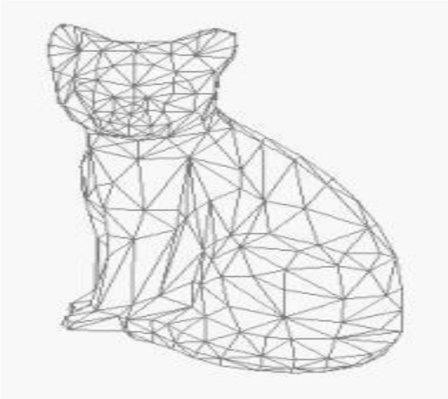
Triangular mesh, Quad mesh, General polygonal mesh

Create mesh by

- **triangulating** cloud of points
- **faceting** exact surface model

Example: 123D Catch

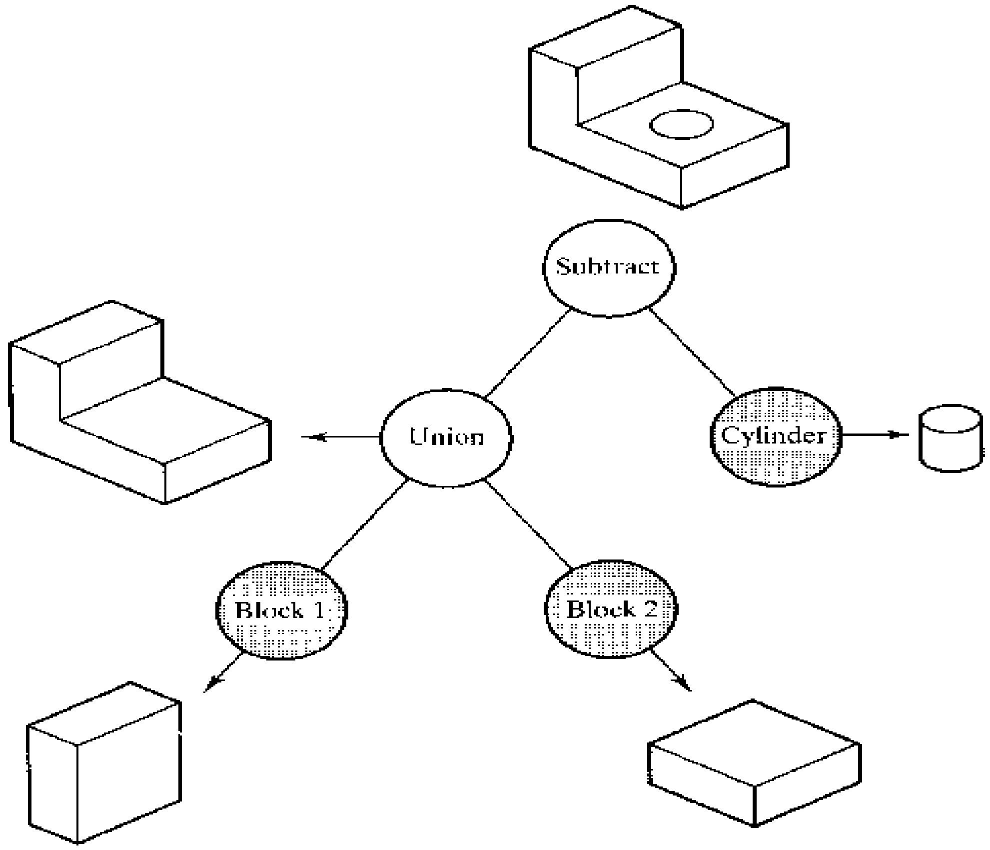




What to store : Modeling procedure

Procedural model: CSG (Constructive Solid Geometry)

Primitive solids with Boolean operation

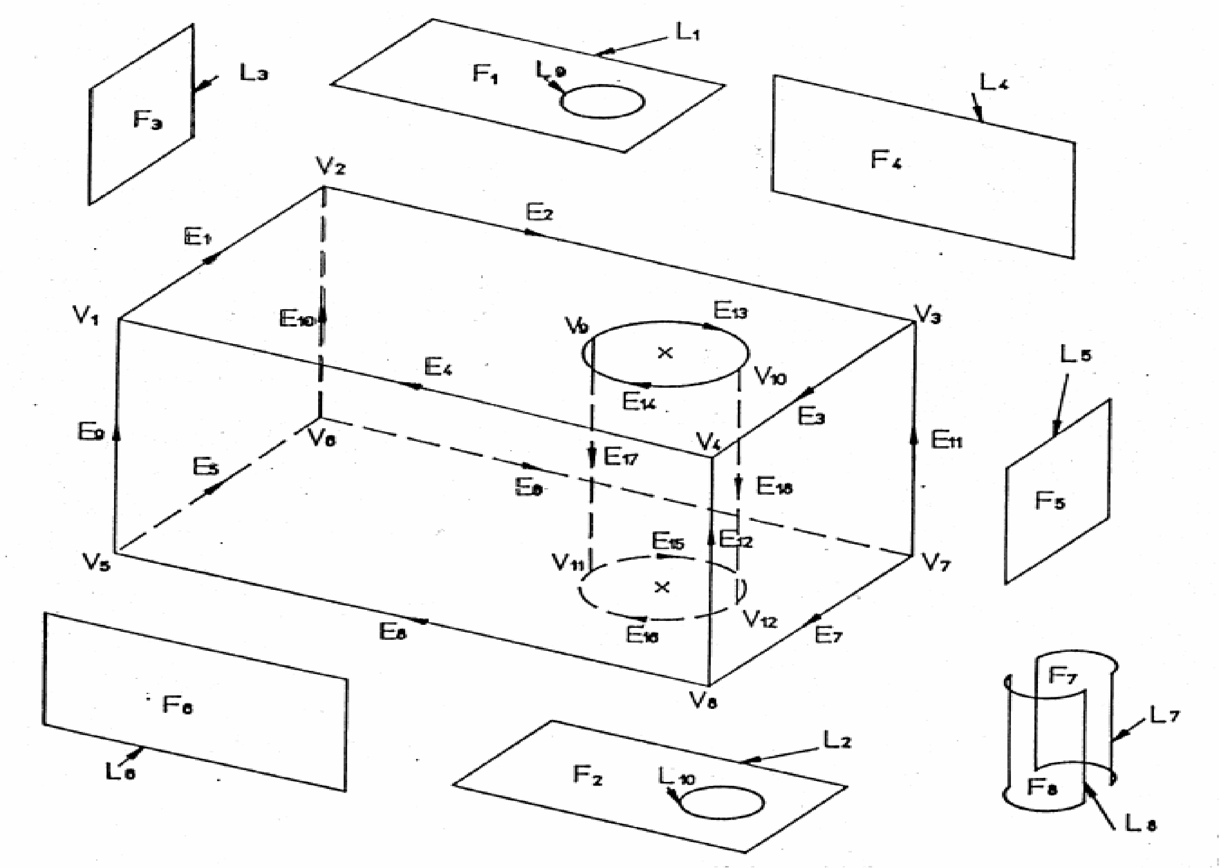


What to store : result

B-Rep (Boundary representation) model : Modeling using bounding surfaces

Topology : connectivity

Geometry : shape



B-Rep model

Topological element

- Vertex
- Edge
- Loop (Edge list)
- Face
- Lump
- Body

- Geometrical element
  - Point
  - Curve
  - Composite curve
  - Surface, trimmed surface
  - N/A
  - N/A

Euler-Poincare formula:

For a polyhedron

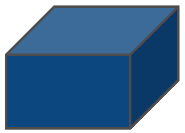
$$V - E + F - 2 = 0$$

V = Vertices

E = Edges

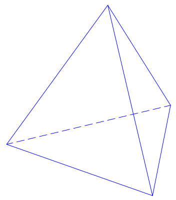
F = Faces

e.g. a block



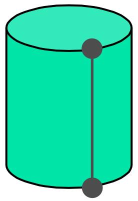
$v = 8, e = 12, f = 6$

a prism



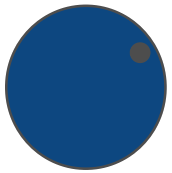
$v = 4, e = 6, f = 4$

a cylinder



$v = 2, e = 3, f = 3$

a sphere



$v = 1, e = 0, f = 1$

Extension of solids

A solid can have holes

A face may have a loop or ring of vertices `floating‘, i.e. unconnected by edges to the other vertices of the face

$$V-E+F-H=2(C-G)$$

V = Vertices

E = Edges

F = Faces

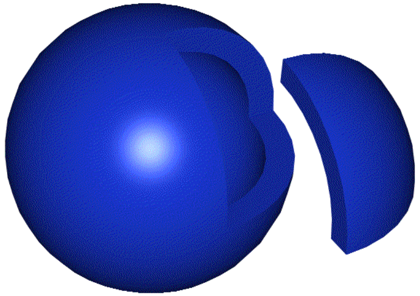
H = Holes in faces

C = Components (or shells)

G = Genus (holes through solid)

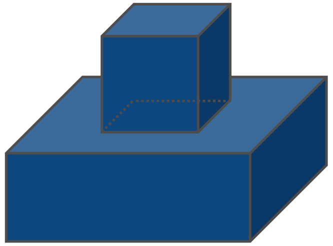
Extension of Euler-Poincare formula to 2-manifolds

“Tweaking” (deformations, twistings, and stretchings but not tearing, or cutting) solids modifies the solid without changing the topology or the above numbers.



A hollow sphere
(an object with 2 shells)

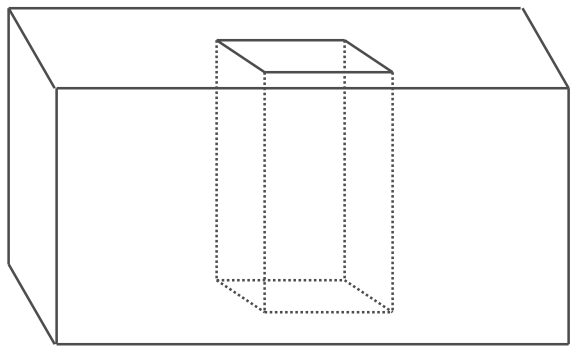
Object with 1 hole



Object with 1 ring

A solid with holes and loops

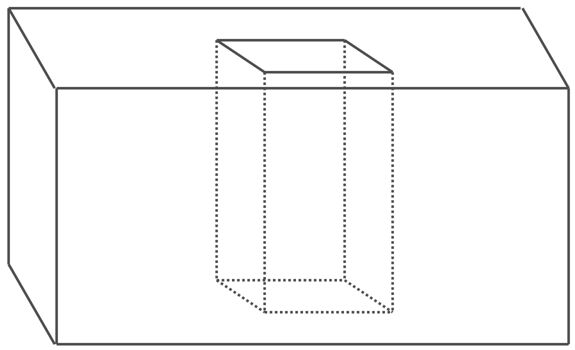
Quiz



icertis Applied Cloud

A solid with holes and loops

Answer



F = 10(6 plus additional 4)

V = 16, E = 24

R = 2 (as its through hole)

H = 1

10 + 16 = 24 +2 +2 –2(1)

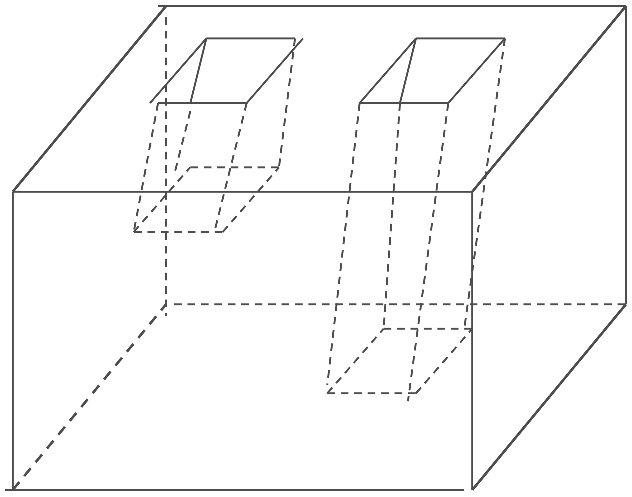
26 = = 26

A solid with holes and loops

Example

$$V - E + F - H = 2\,(C - G)$$

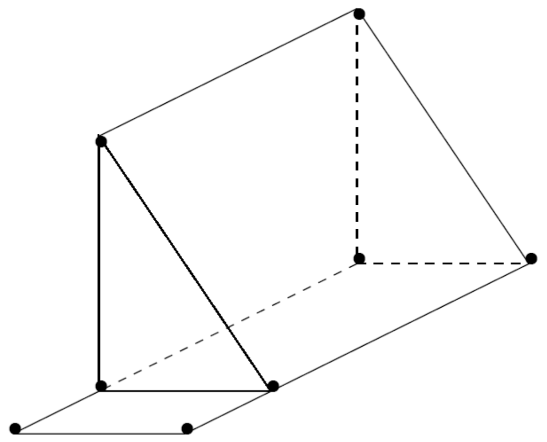
$$24 - 36 + 15 - 3 = 2(\,1 - 1)$$



Euler Poincare' Formula

Necessary but not sufficient condition for a valid representation.

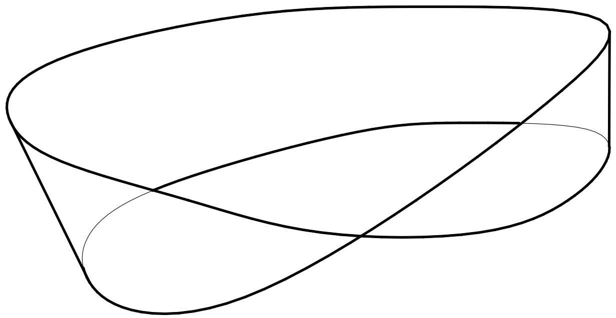
Example: 8 vertices, 12 edges, 6 faces

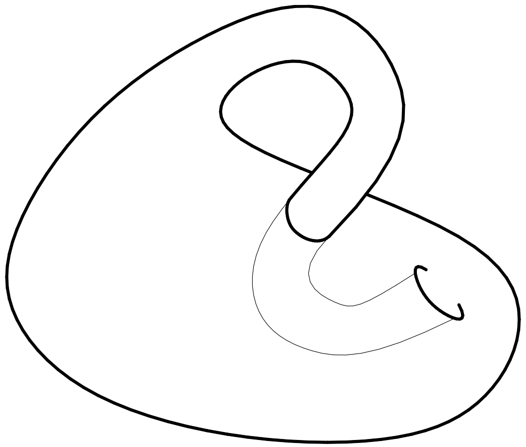


Manifold & Non-Manifold Representation

Manifold surface: - A manifold surface is orient-able if two different sides of the surface can be distinguished. e.g. Orientable surface: sphere, torus

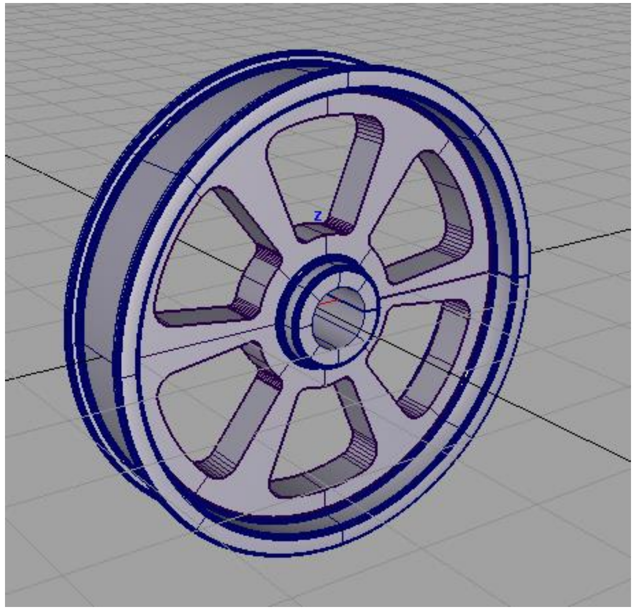
Non-orientable surface: Mobius strip, Klevin bottle

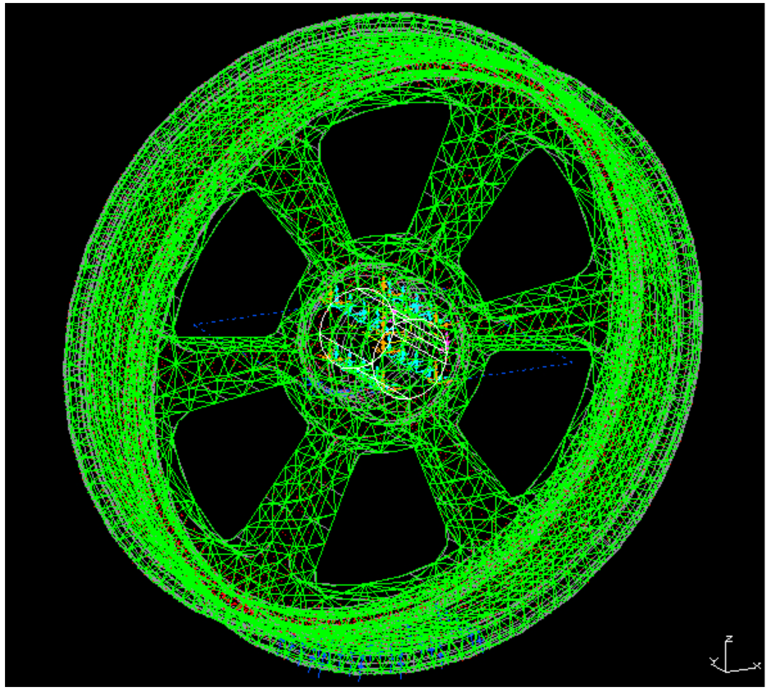




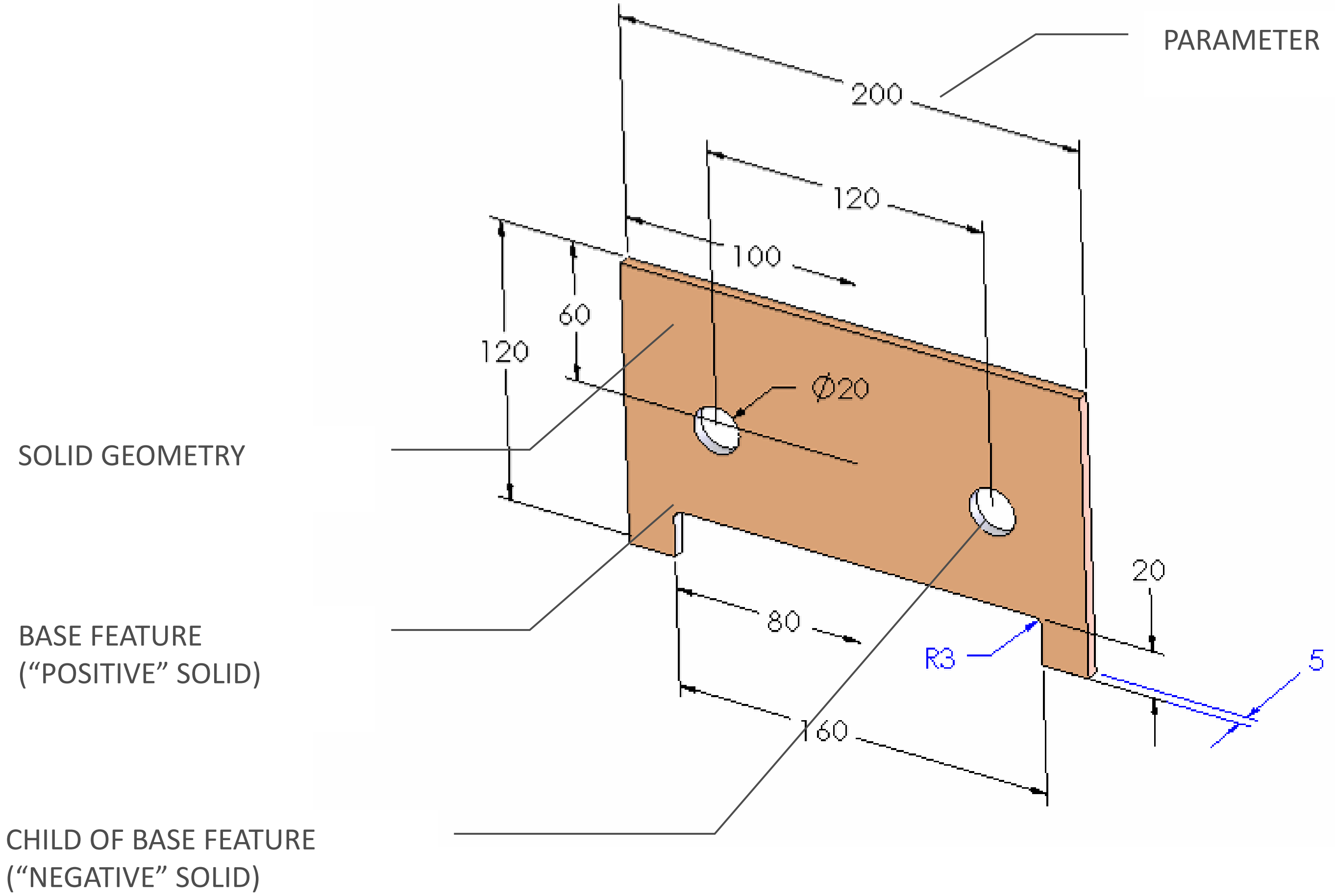
Brep vs Mesh

The object is represented by subdivision/discretization such as mesh and other geometric primitives.





Parametric, Feature-based Solid Model



panel 01.SLDPRT

Solid, parametric, feature-based Modeling Software

High-end (more powerful)

- NX (UGS)
- Catia (Dassault Systémes)
- Pro/Engineer (Parametric Technologies Corp.)

Mid-Range (easier to use)

- Solid Edge (UGS)
- Inventor (Autodesk)
- SolidWorks (SolidWorks Corp.)

They all work basically the same way

Feature-Based Solid Modeling

Parts modeled by adding **features** to a base part

Features represent “operations”

- holes, ribs, fillets, chamfers, slots, pockets, etc.

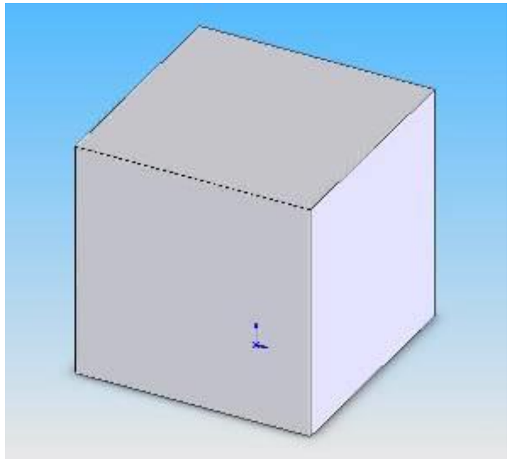
Material can be added or subtracted

Features can be created by extrusion, sweeping, revolving, etc.

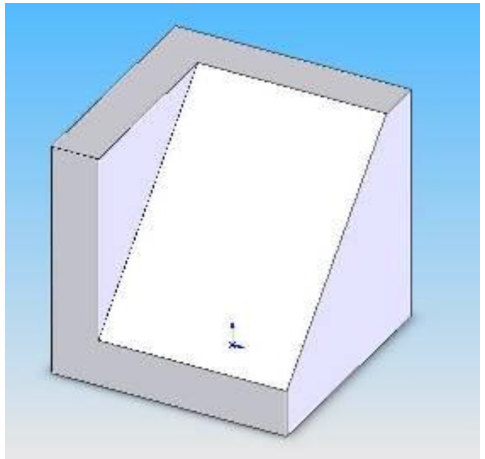
Feature-based Modeling Process

Create base part

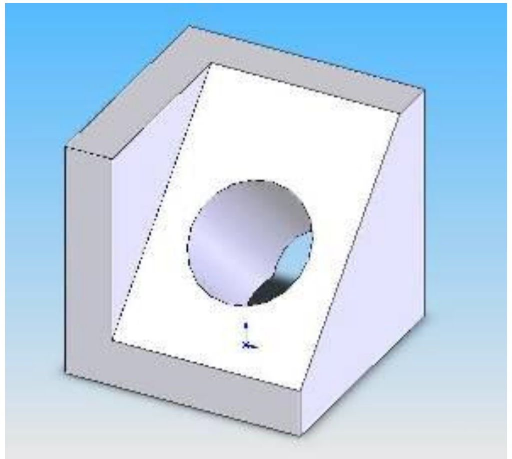
Add features until final shape is achieved



Extruded Base

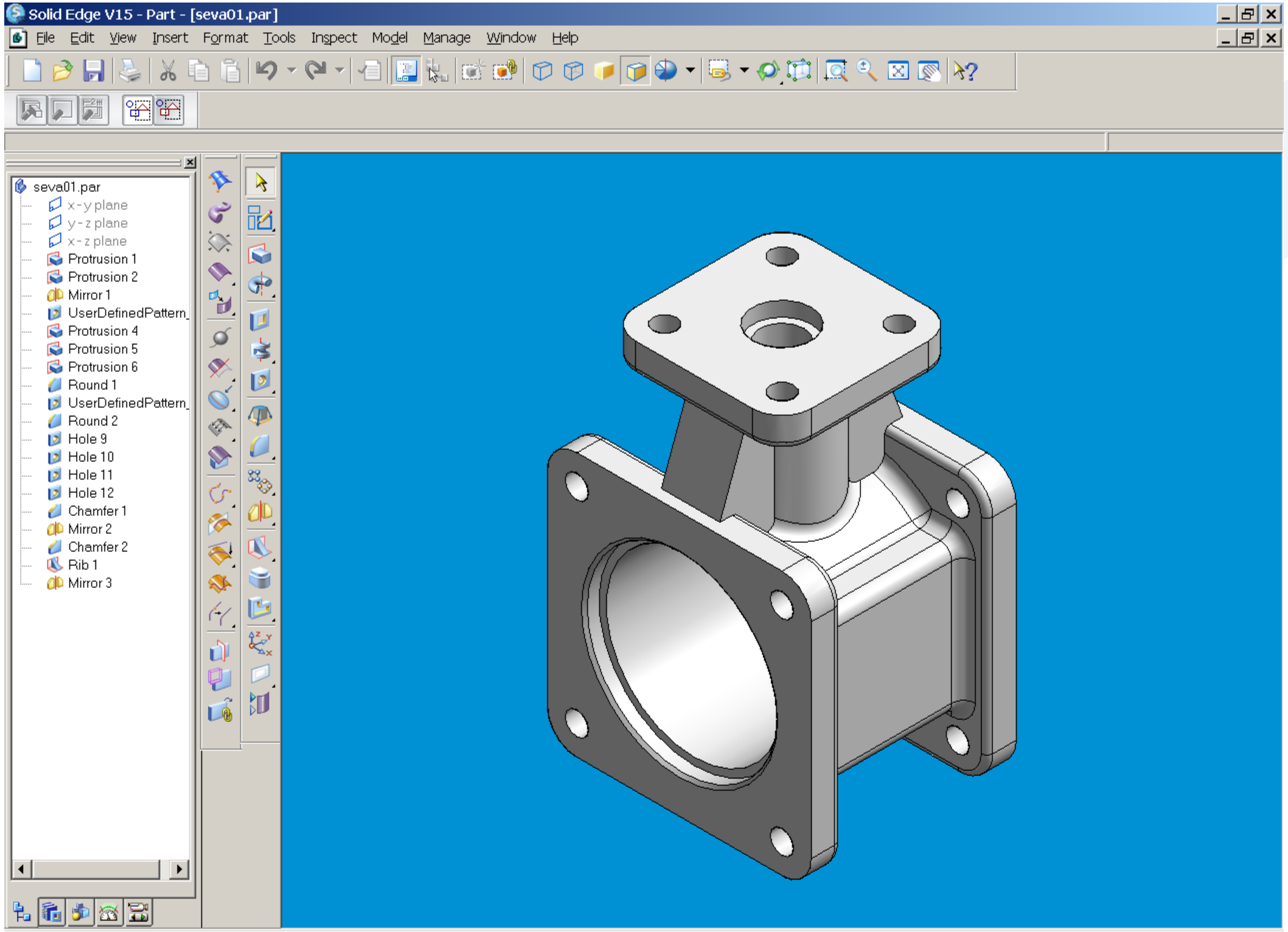


Extruded Cut



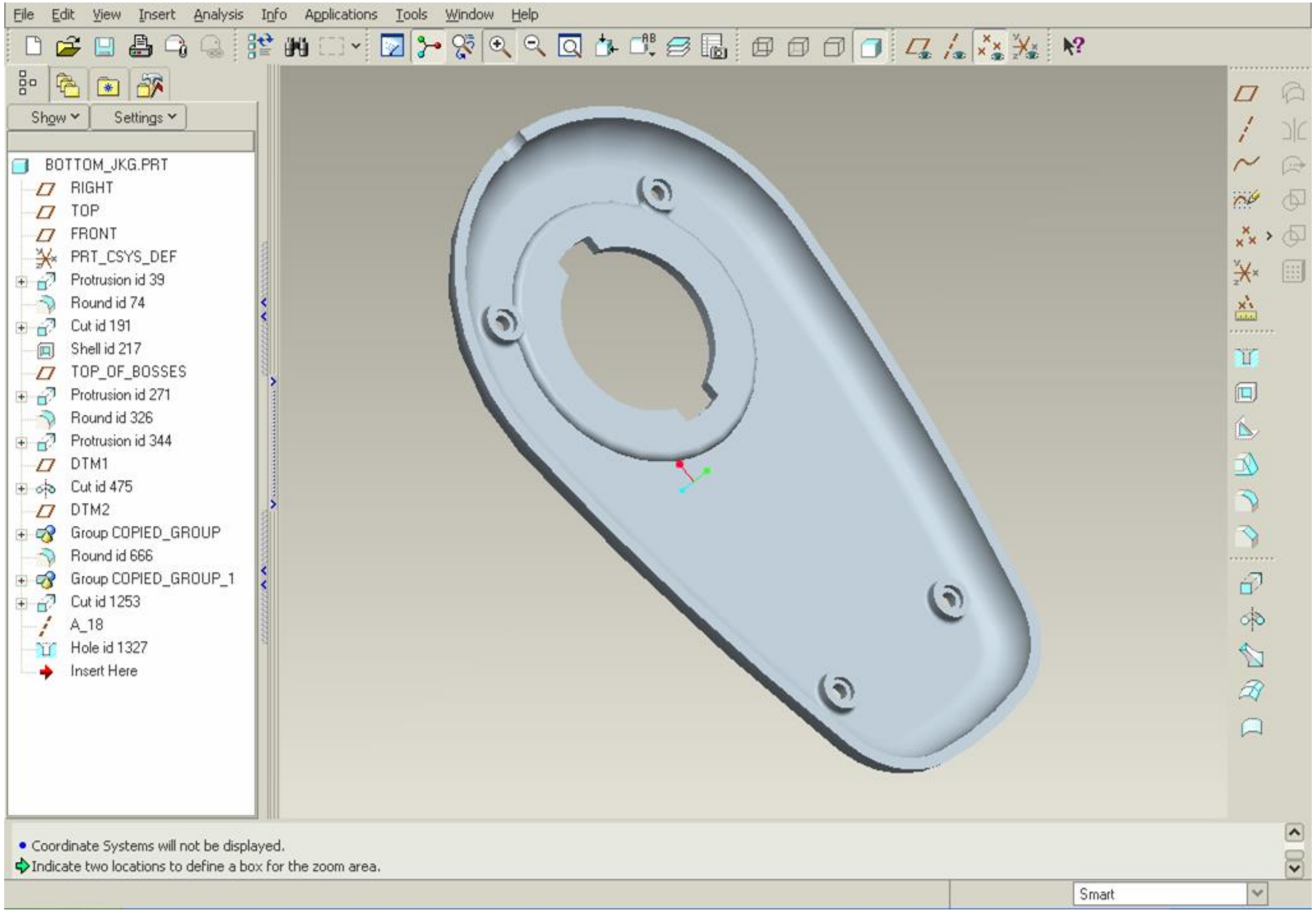
Extruded Cut

SolidEdge

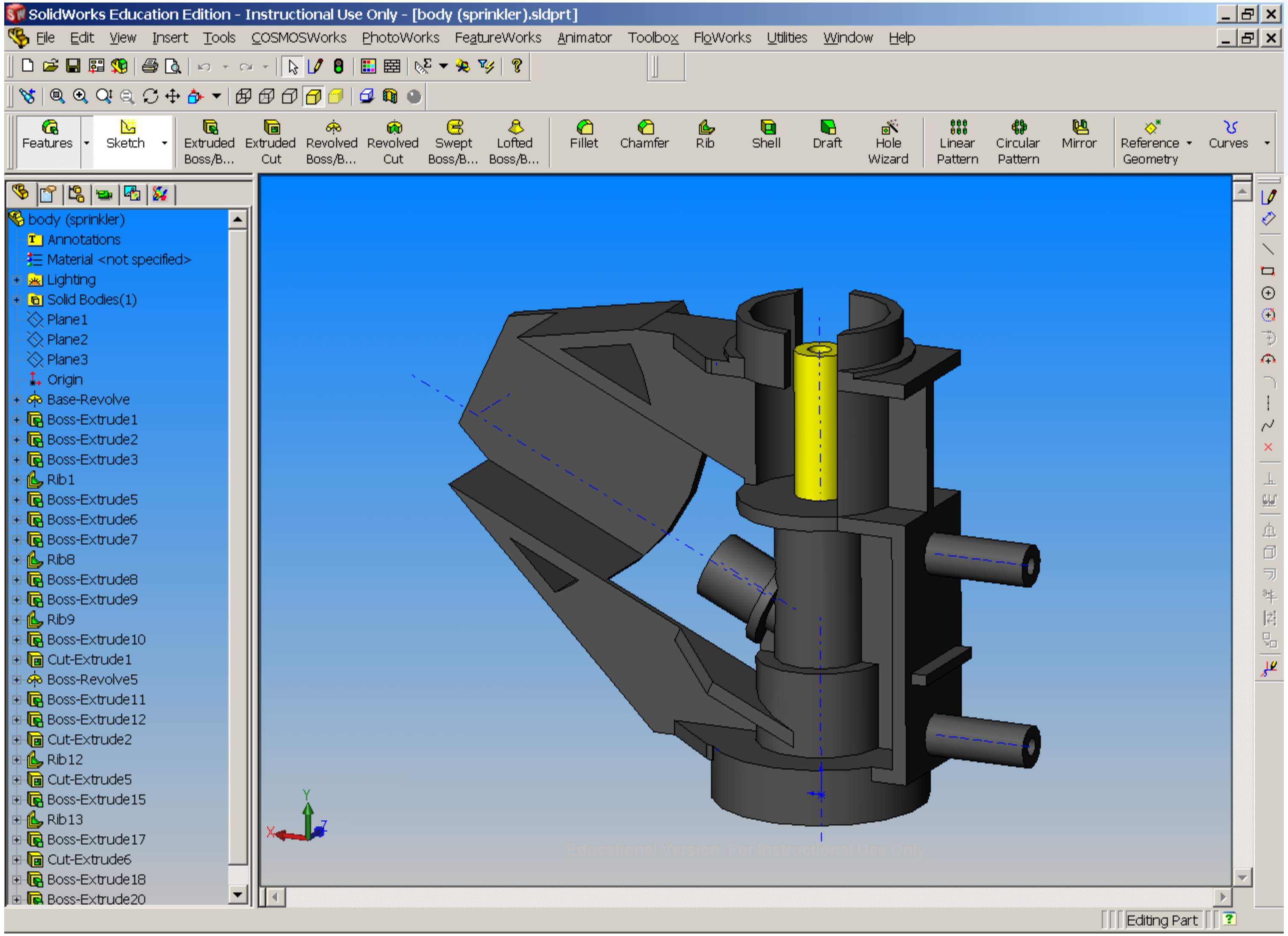


Solid Edge V15 - Part - [seva01.par]
File Edit View Insert Format Tools Inspect Model Manage Window Help
seva01.par
x-y plane
y-z plane
x-z plane
Protrusion 1
Protrusion 2
Mirror 1
UserDefinedPattern_
Protrusion 4
Protrusion 5
Protrusion 6
Round 1
UserDefinedPattern_
Round 2
Hole 9
Hole 10
Hole 11
Hole 12
Chamfer 1
Mirror 2
Chamfer 2
Rib 1
Mirror 3

Pro/E Wildfire



SolidWorks

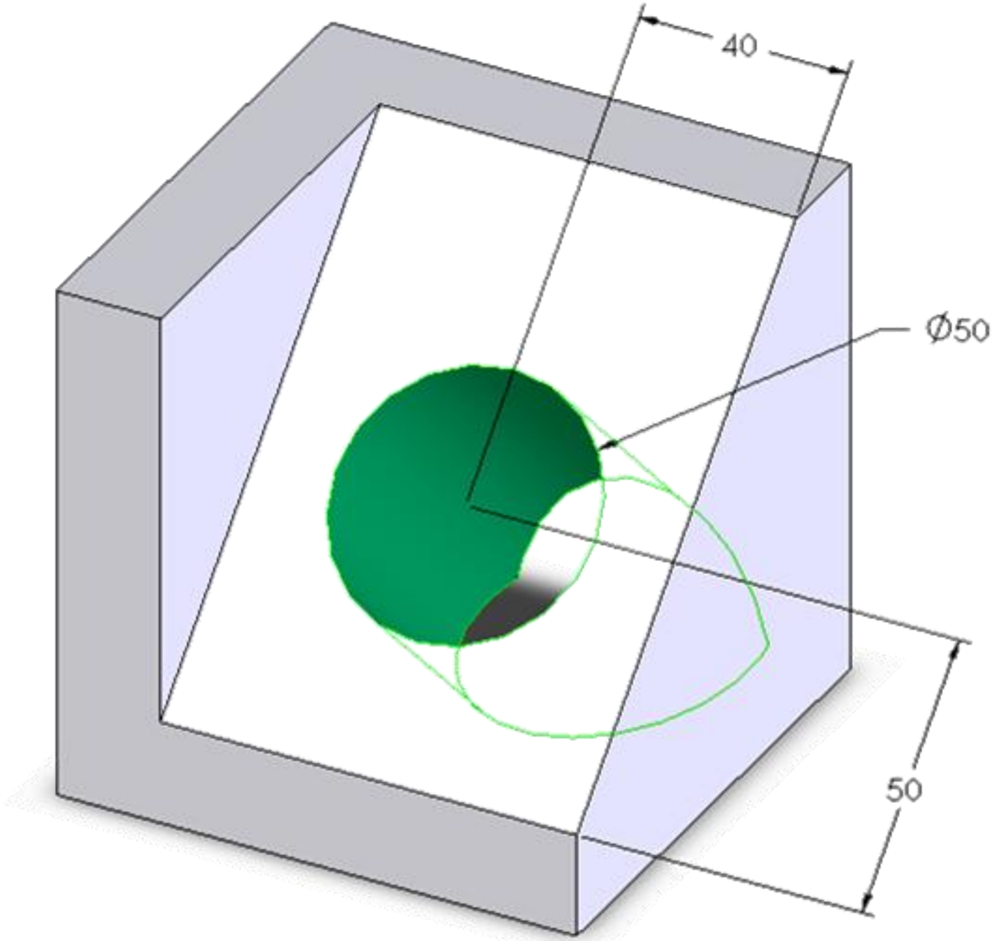

SolidWorks Education Edition - Instructional Use Only - [body (sprinkler).sldprt]
File Edit View Insert Tools COSMOSWorks PhotoWorks FeatureWorks Animator Toolbox FloWorks Utilities Window Help
Features
Sketch
Extruded Boss/B...
Extruded Cut
Revolved Boss/B...
Revolved Cut
Swept Boss/B...
Lofted Boss/B...
Fillet
Chamfer
Rib
Shell
Draft
Hole Wizard
Linear Pattern
Circular Pattern
Mirror
Reference Geometry
Curves
body (sprinkler)
Annotations
Material <not specified>
Lighting
Solid Bodies(1)
Plane1
Plane2
Plane3
Origin
Base-Revolve
Boss-Extrude1
Boss-Extrude2
Boss-Extrude3
Rib1
Boss-Extrude5
Boss-Extrude6
Boss-Extrude7
Rib8
Boss-Extrude8
Boss-Extrude9
Rib9
Boss-Extrude10
Cut-Extrude1
Boss-Revolve5
Boss-Extrude11
Boss-Extrude12
Cut-Extrude2
Rib12
Cut-Extrude5
Boss-Extrude15
Rib13
Boss-Extrude17
Cut-Extrude6
Boss-Extrude18
Boss-Extrude20
Editing Part

Modifying Parts

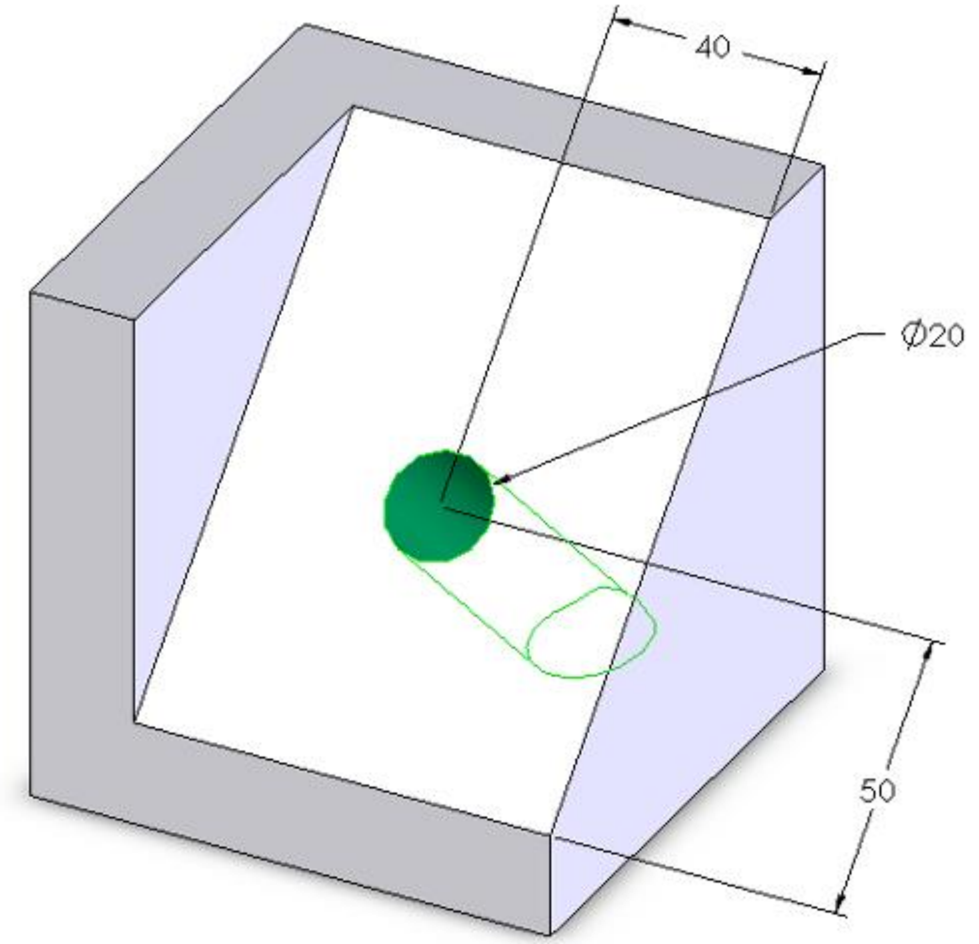
The part is created from the history tree

Features can be added, deleted and re-ordered

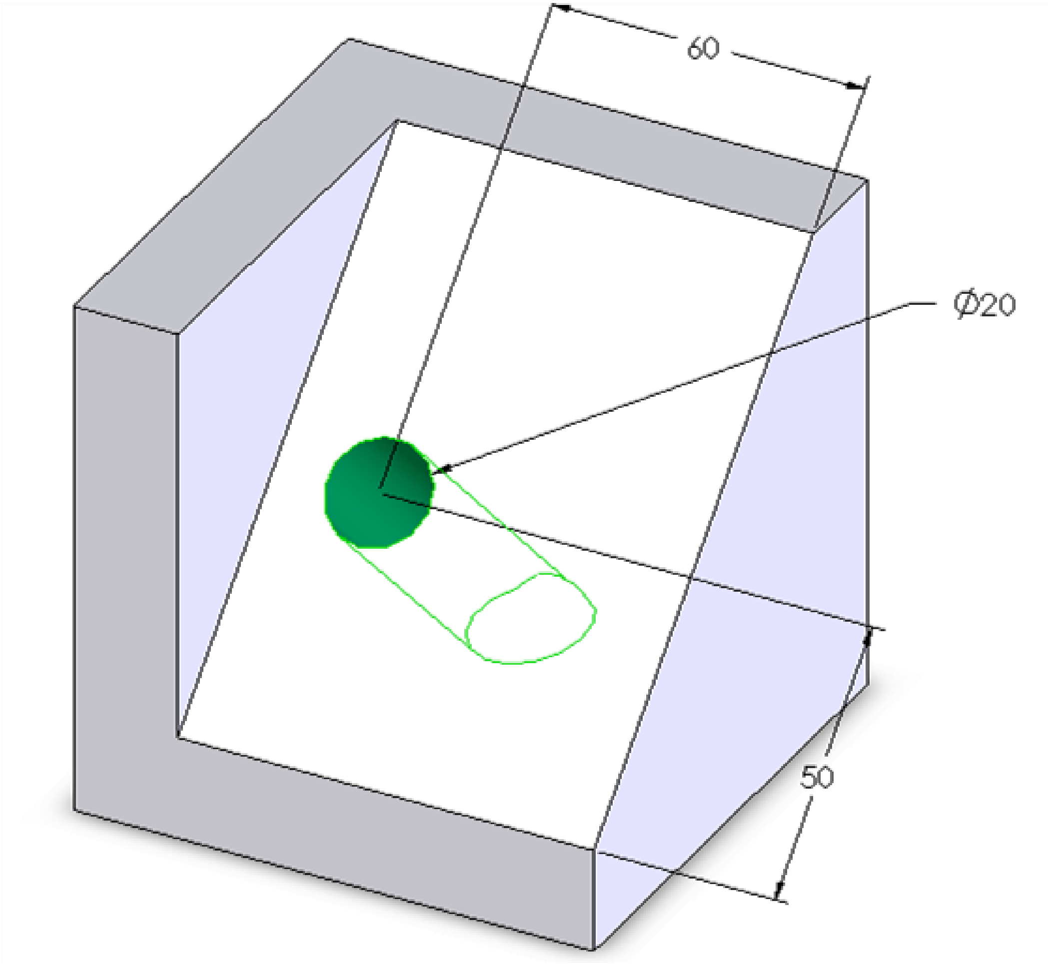
Feature parameters can be changed



ES1050 part 01.SLDPRT



ES1050 part 01.SLDPRT



ES1050 part 01.SLDPRT

Summary

Most CAD systems use solid, parametric, feature-based modeling

Parts are modeled by adding features to a base feature

Features can be easily added, deleted and modified

Next time you see a shape…

think how it must have been built!!

References

Ken Youssefi, “Introduction to Solid Modeling”

Texas A & M, “Design Intent and Modeling Tools”

Paul Kurowski, ‘Computer Aided Design (CAD)”

Thank You!

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