3D Modeling

Yogesh Kulkarni

Introduction

Introduction

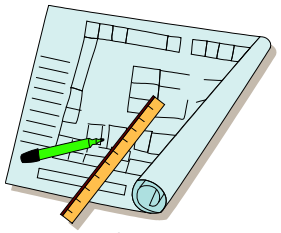
- How to model real world objects? - Design
- How to put forth ideas in visual manner – Communication
- How to verify that design serves the purpose – Analysis
- How to get it made? – Manufacturing
- All the above can happen without Computers. But
- Better if assisted by Computers/Software

- That’s why : Computer Aided < > (CAx)

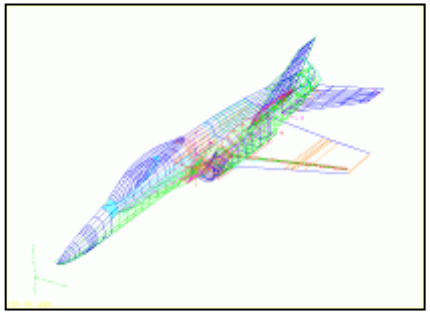
History

- 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.

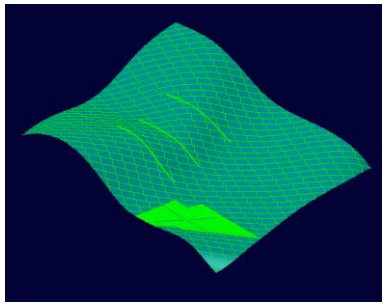
Evolution of CAD Technology



Drawing



Wire frame model



Surface model

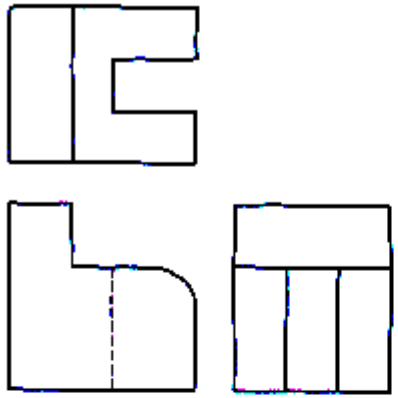
Solid model

Manual drafting

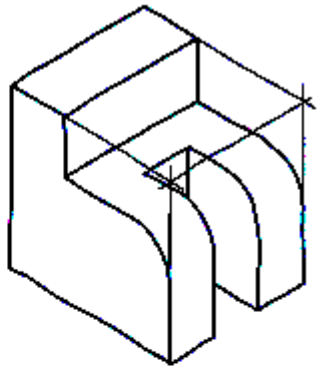
Since 1970’s: electronic drafting board

Manual Drafting

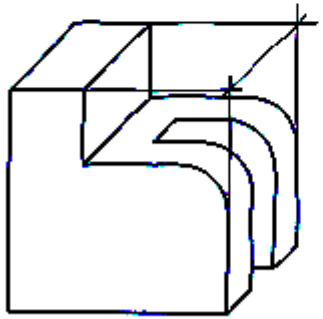
- 2D representations used to represent 3D objects
  - multi-view drawings
  - pictorials
- Standards and conventions developed so that 3D object could be built from drawings
- Drawings created manually or using 2D CAD
- Difficult to visualize, error-prone, time-consuming



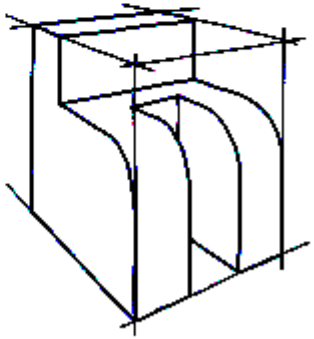
(A) Multiview



(B) Axonometric



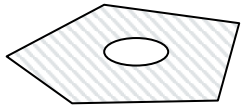
(C) Oblique



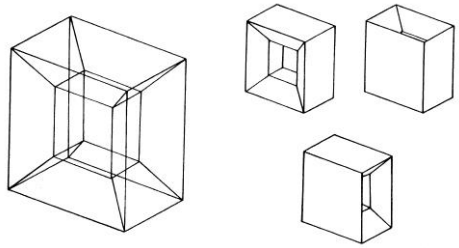
(D) Perspective

CAD - Types

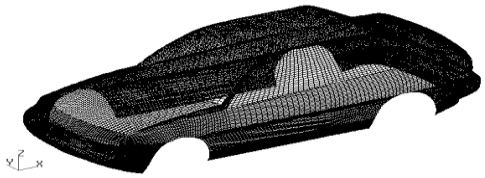
- 2D model: Point, line, circular arc, planar curve



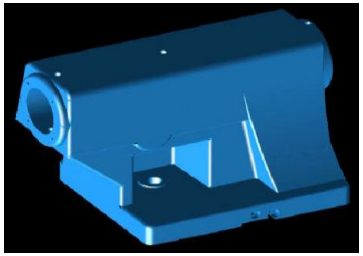
- 3D model
  - Wire frame



  - Surface



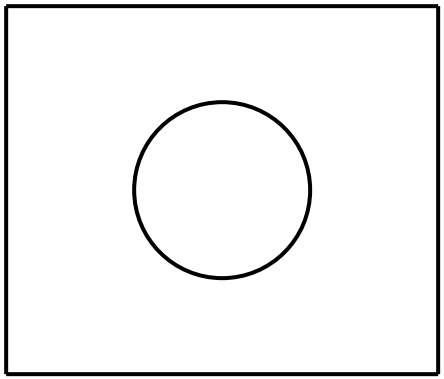
  - Solid

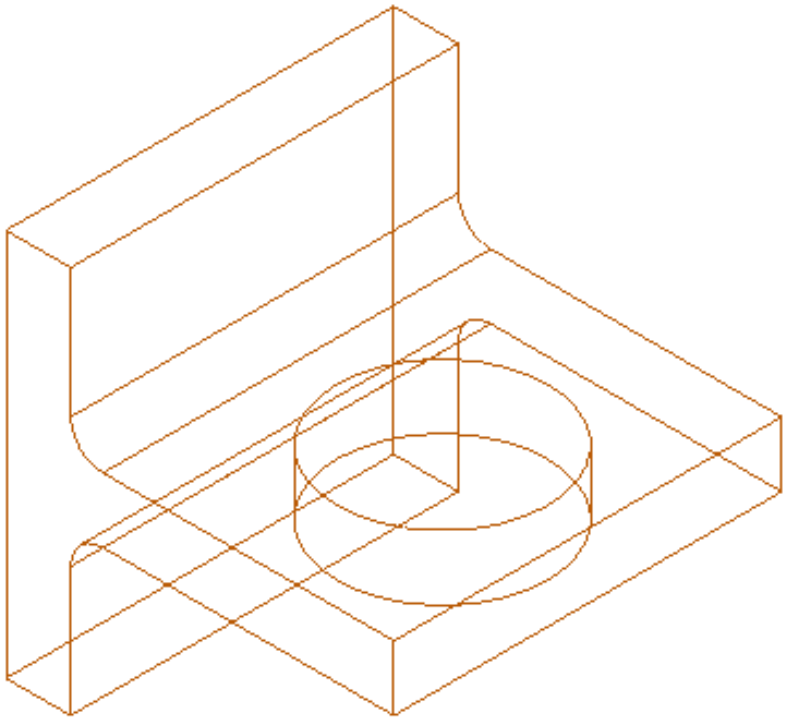


Advantages and Disadvantages of each?

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

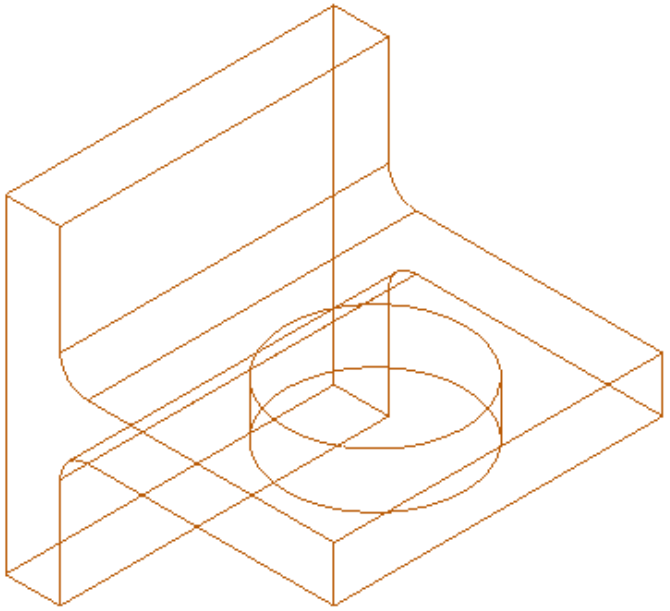




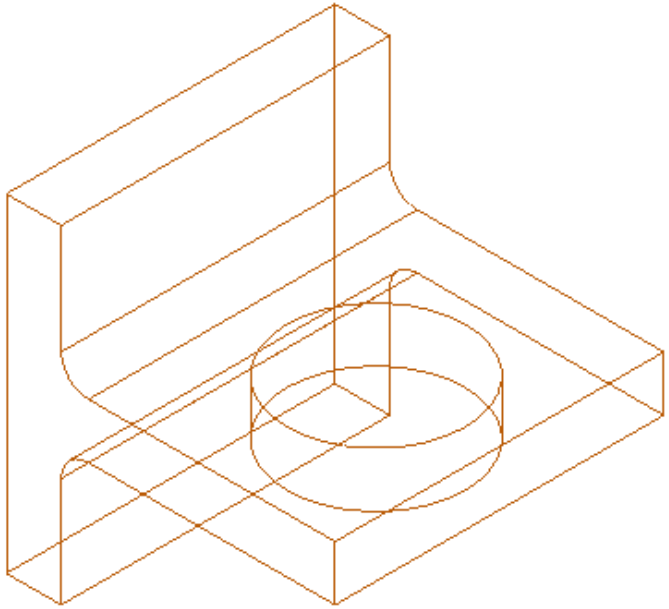
Early 1980’s: wire frame geometry

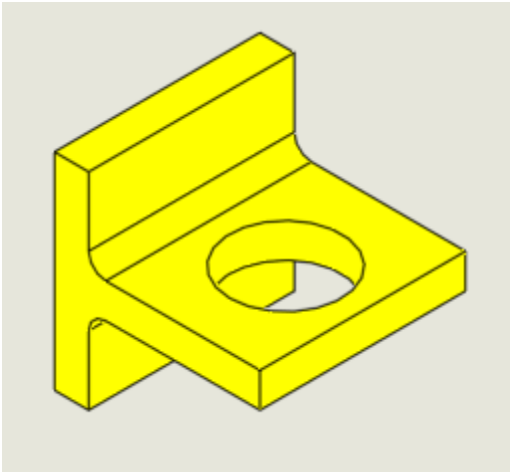
3D Wire frame Modeling

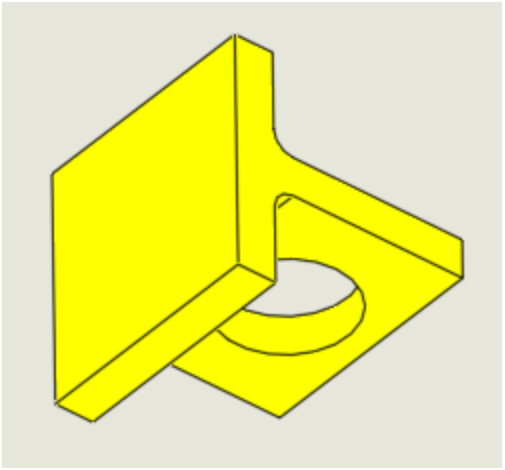
- Geometric entities are lines and curves in 3D
- Volume or surfaces of object not defined
- Easy to store and display
- Hard to interpret - ambiguous



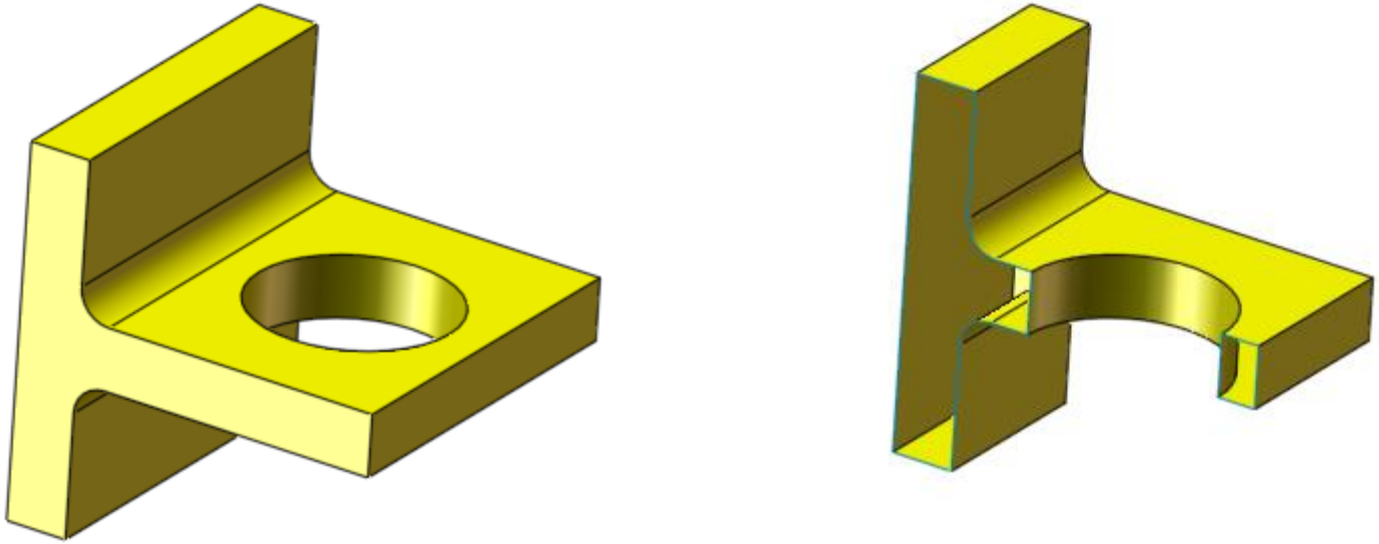
What is this?







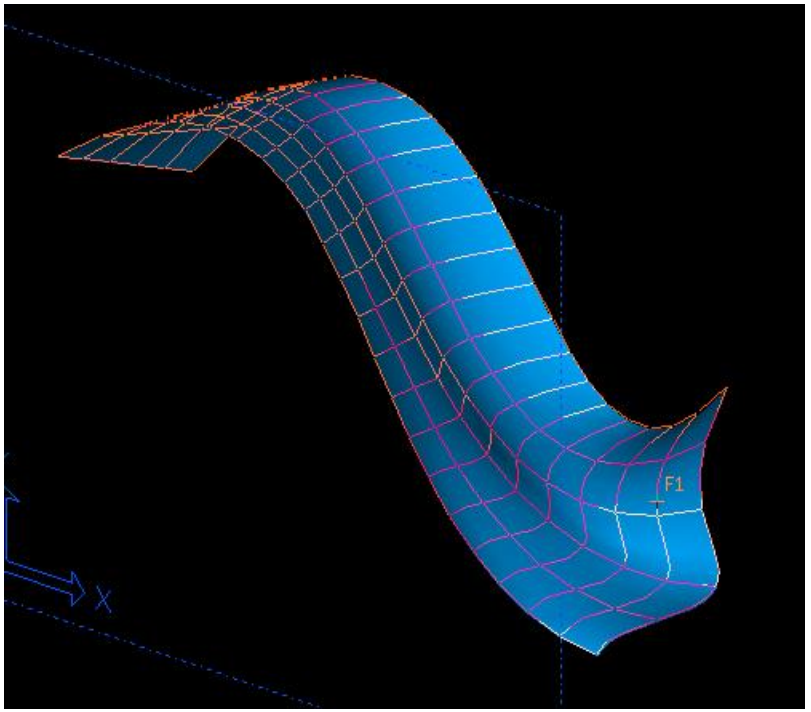
Problems with wire frame models



Late 1980’s: Surface Modeling

3D Surface Modeling

- Models 2D surfaces in 3D space
- All points on surface are defined
  - useful for machining, visualization, etc.
- Surfaces have no thickness, objects have no volume or solid properties
- Surfaces may be open



A Surface Model created using Alias StudioTools

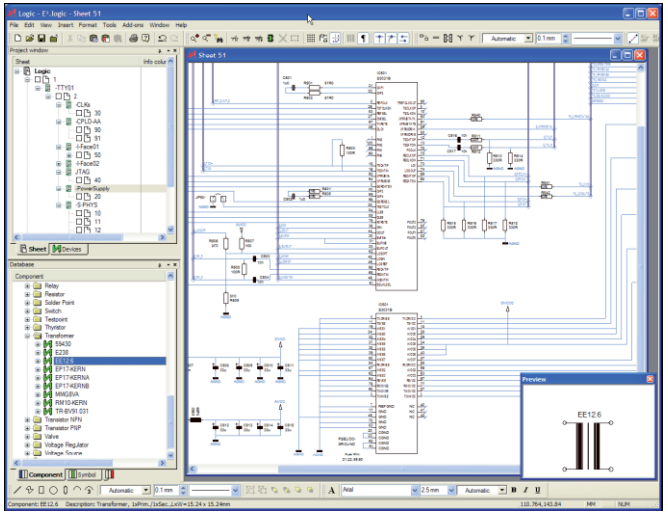
Surface Model created using Rhino

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

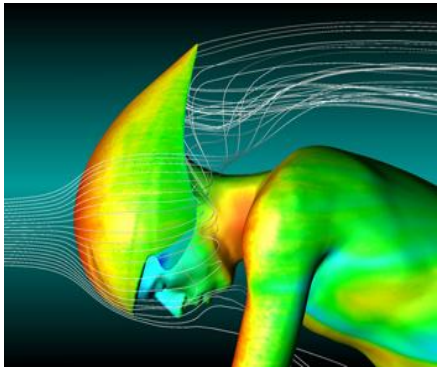
- Drafting – sketches, architectures, Drawings
- Art – Sketches, painting
- Electronic layouts, circuit design

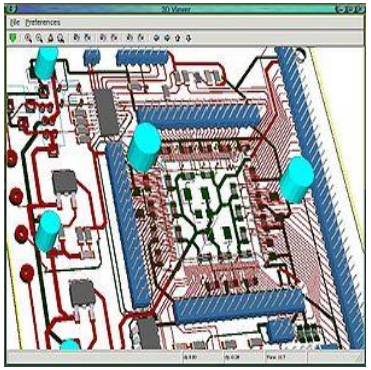


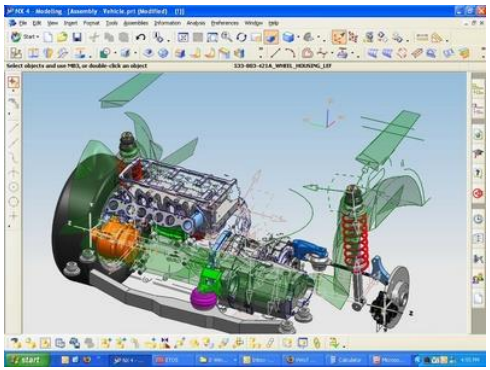
AUTODESK.

3D Applications

- CAD (Computer Aided Design)
- CAM (Computer Aided Manufacturing)
- CAE (Computer Aided Engineering) Finite Element Method
- CG (Computer Graphics)

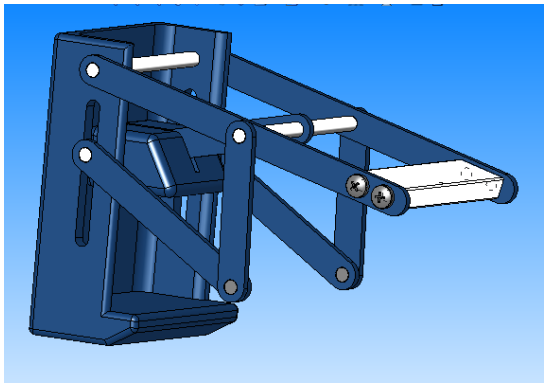


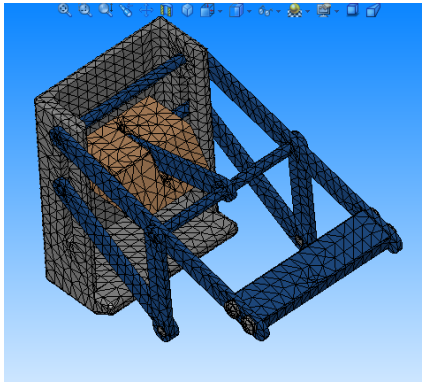


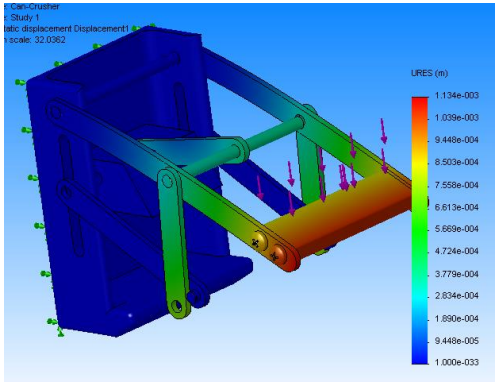


Basics of Finite Element Analysis (FEA)

- 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)

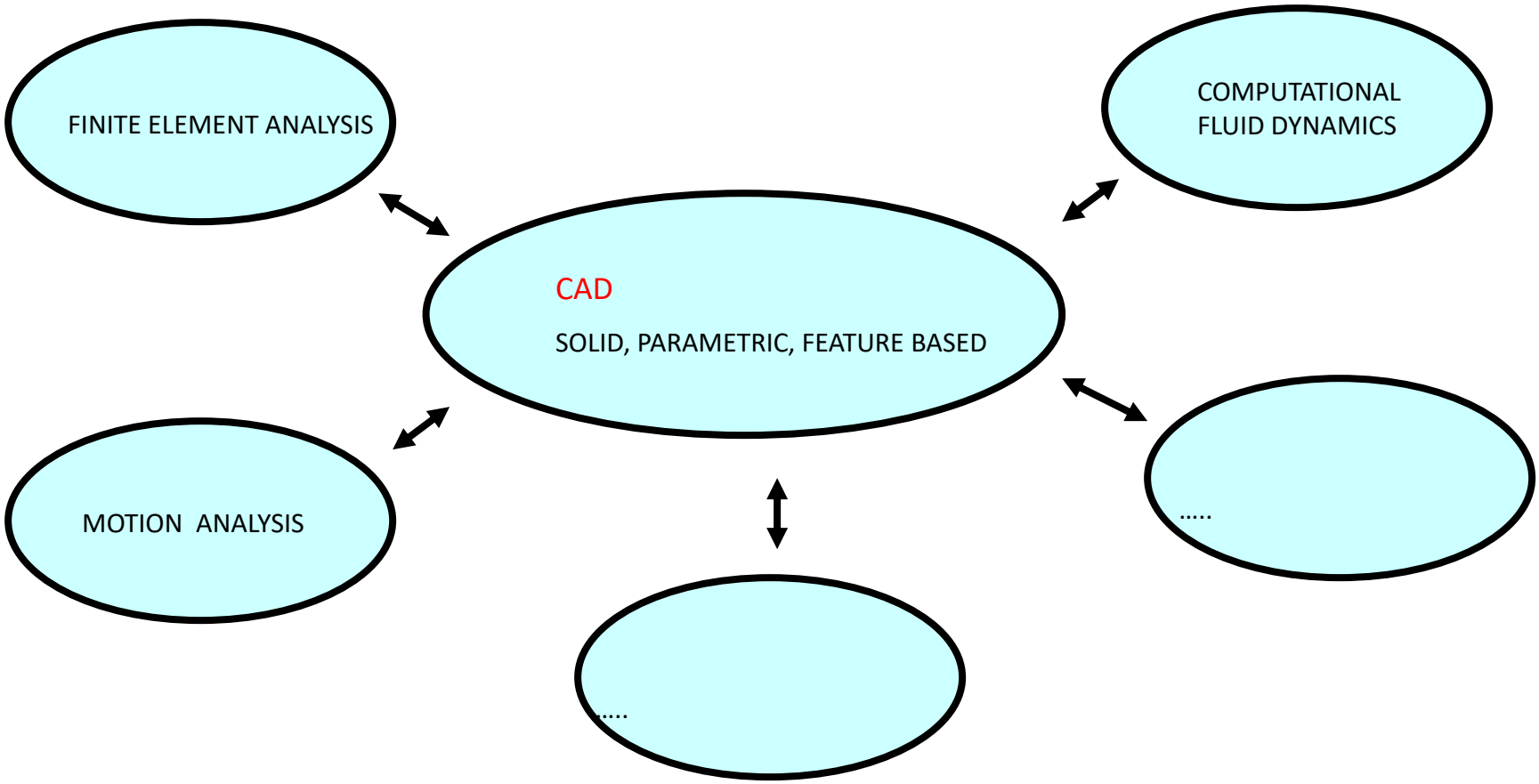
A CNC machine is an NC machine with the added feature of an on-board computer.

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



CAD (Computer Aided Design) is at the hub of other CAE (Computer Aided Engineering) tools

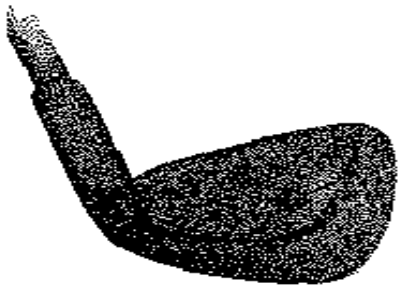
Solids

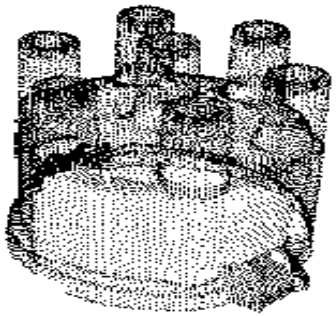
What is Solid?

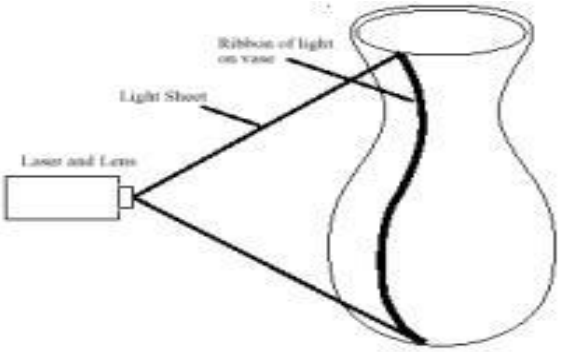
- Define Solid?
- How would you represent Solid in software (data model)?

Cloud of points

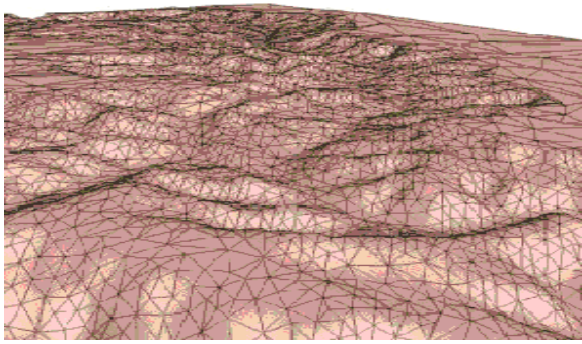
- The simplest form
- Unorganized / organized points
- Too many points to represent the desired shape
- Hard to handle → further processing is required
- Obtained by digitizing
  - CMM (coordinate measuring machine)
  - Laser range scanner
  - …







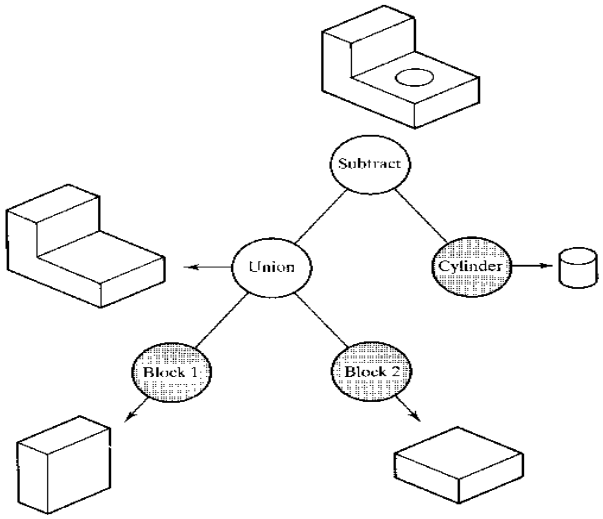
Mesh



- 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

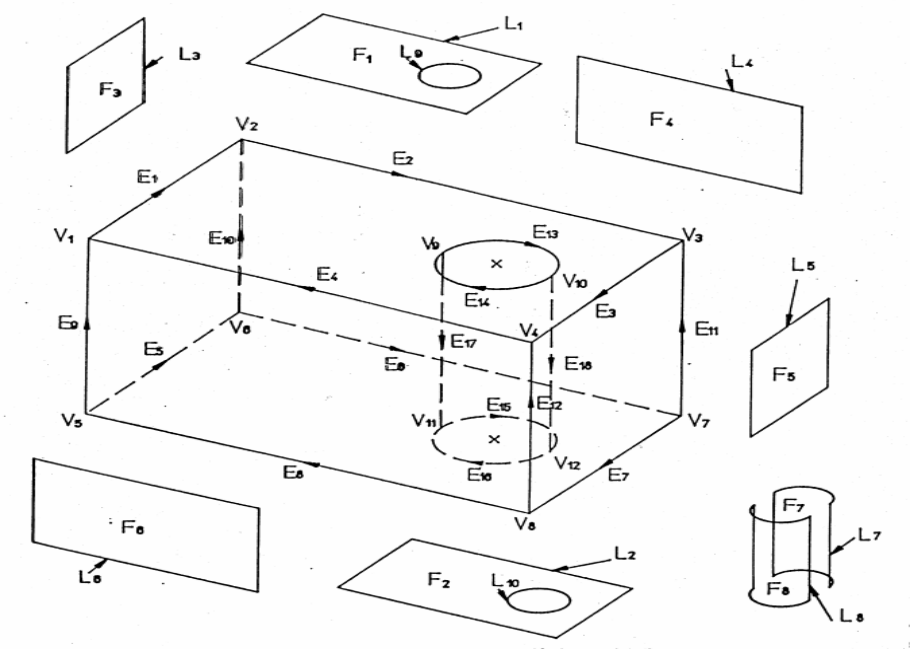
What to store : Modeling procedure

- 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

Example: A tetrahedron has four vertices, four faces, and six edges

4-6+4=2.

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

Extension of Euler-Poincare formula to 2-manifolds

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)

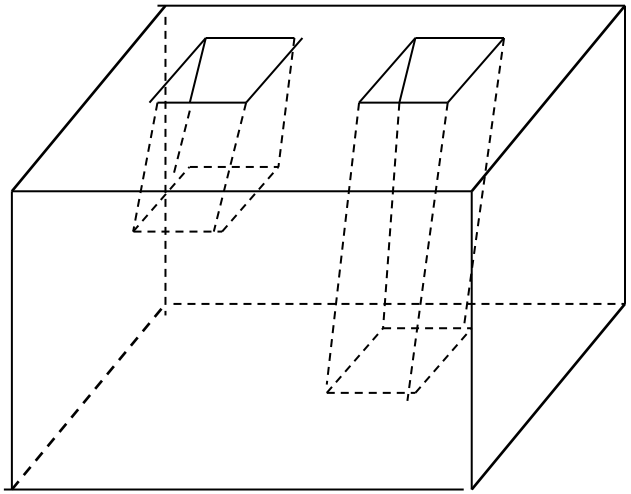
"Tweaking" (deformations, twistings, and stretchings but not tearing, or cutting) solids modifies the solid without changing the topology or the above numbers.

A solid with holes and loops

Example

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

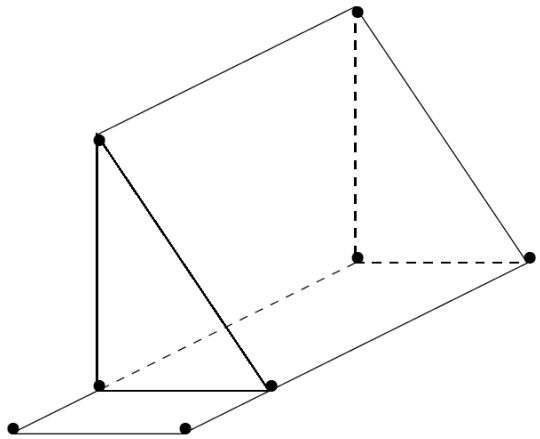
$$24 - 36 + 15 - 3 = 2(1 - 1)$$



Euler Poincare' Formula

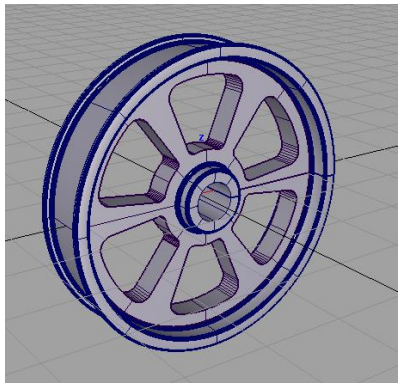
- Necessary but not sufficient condition for a valid representation.

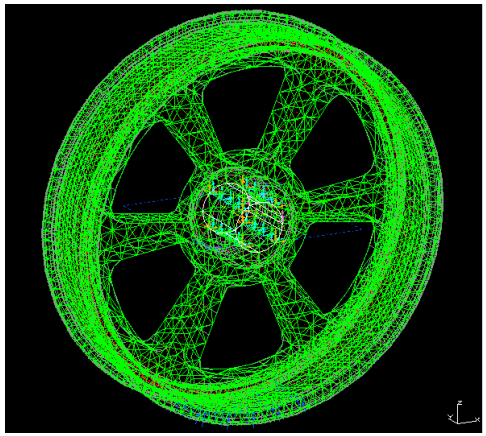
- Example: 8 vertices, 12 edges, 6 faces



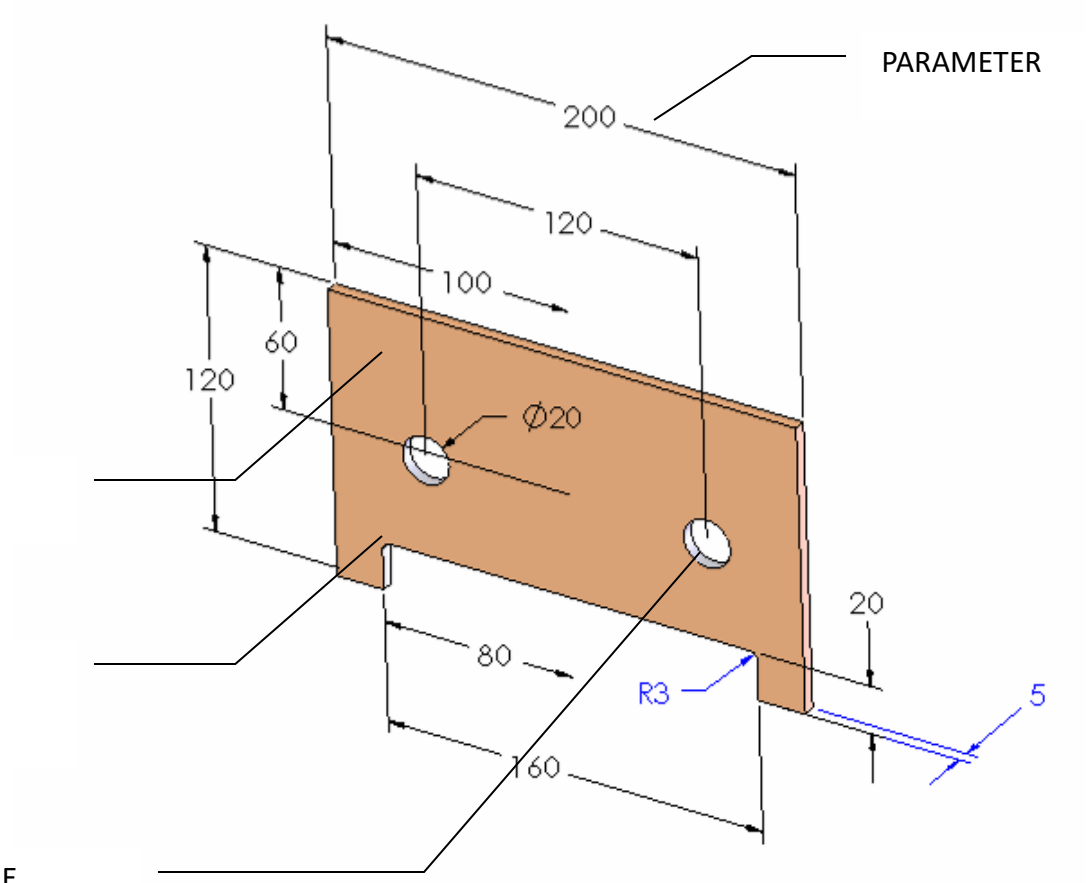
Brep vs Mesh (Design Desktop vs Catch)

- 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

References

- Ken Youssefi, “Introduction to Solid Modeling”
- Texas A & M, “Design Intent and Modeling Tools”
- Paul Kurowski, ‘Computer Aided Design (CAD)”