Introduction to Computer-Aided-Design

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Agenda

Introduction to CAD

Why CAD?

- 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 . . .

Why CAD?

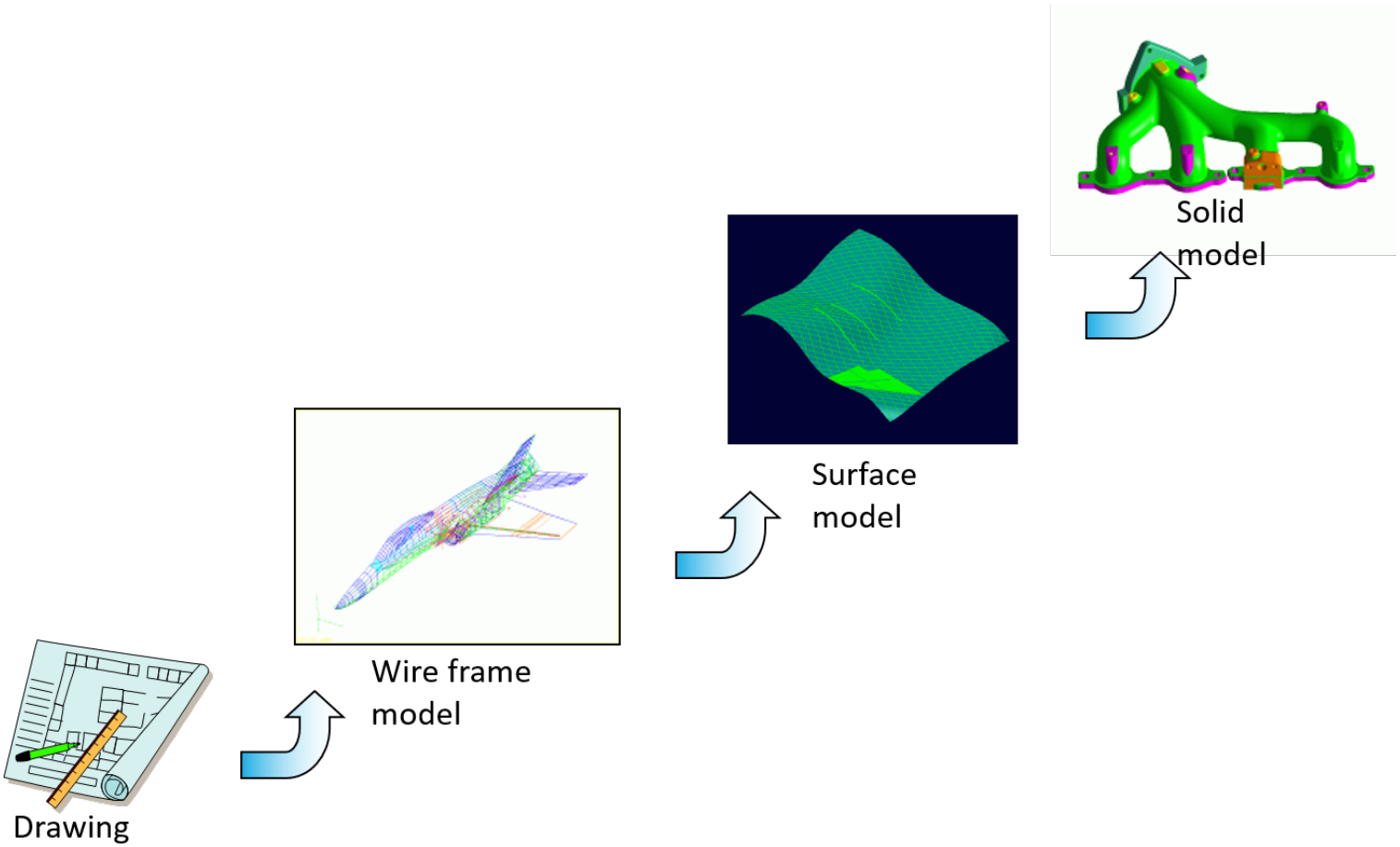
Better if assisted by Computers/Software
That's why : Computer Aided ... (CAx)

History

History

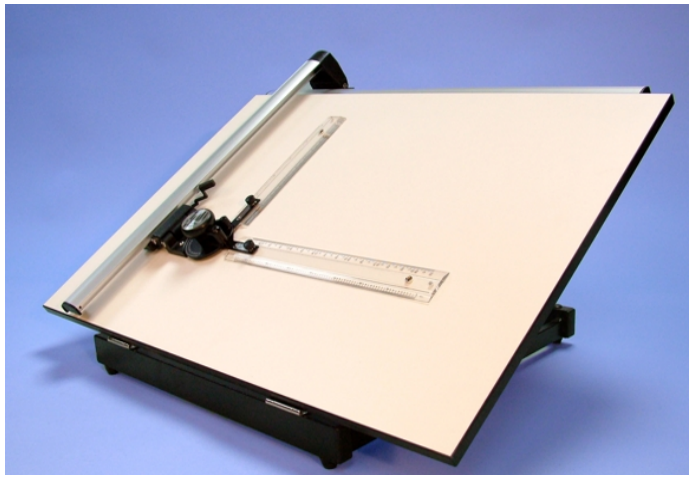
- The first source of CAD resulted from attempts to automate the drafting process.
- These developments were pioneered by the General Motors Research Laboratories in the early 1960s.
- CAD became more widely used after 1970 because of technological advancements.
- CAD allowed users to design products much quicker without the production of an actual product.

Evolution of CAD Technology



Manual drafting

- 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



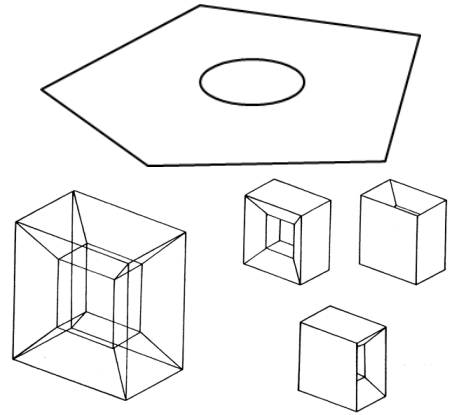
Modeling Approaches

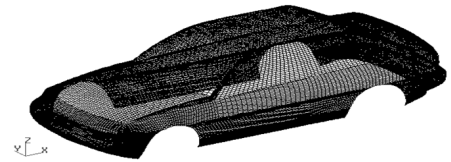
Modeling Approaches

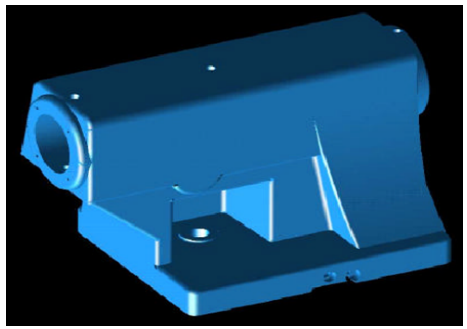
- By dimensionality: 2D/3D
- 2-Manifold vs Non-manifold
- Precision: Exact/Approximate
- What to store?
  - Procedure
  - Result
  - Hybrid

By dimensionality

- 2D model: Point, line, circular arc, planar curve
- 3D model
  - Wire frame
  - Surface
  - Solid



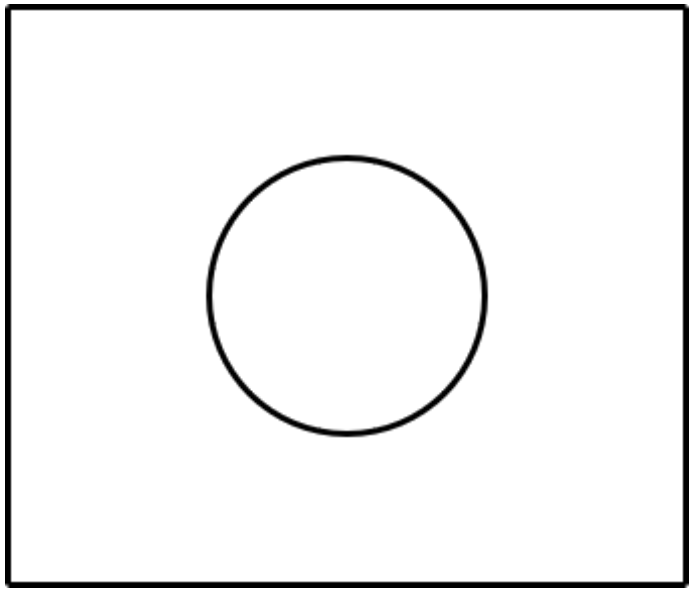




Advantages and Disadvantages of each?

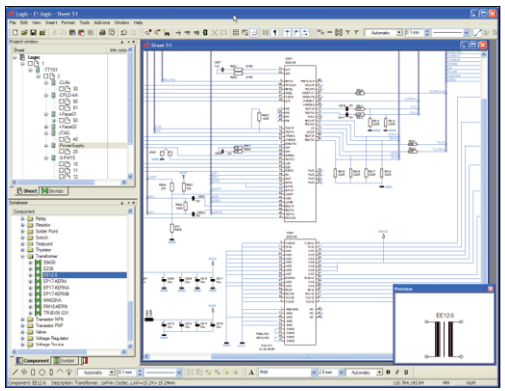
2D CAD

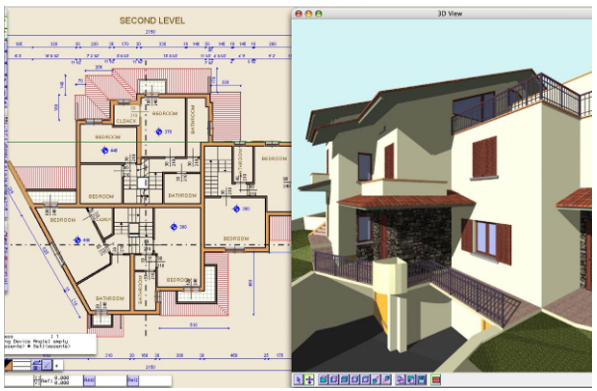
- Simply replaces manual drawing
- Provides a set of drawing tools to create 2D elements, like, Lines, circles, arcs, etc.
- More accurate, easier changes to drawings
- Still no 3D representation of the object
- Example: AutoCAD



2D Applications

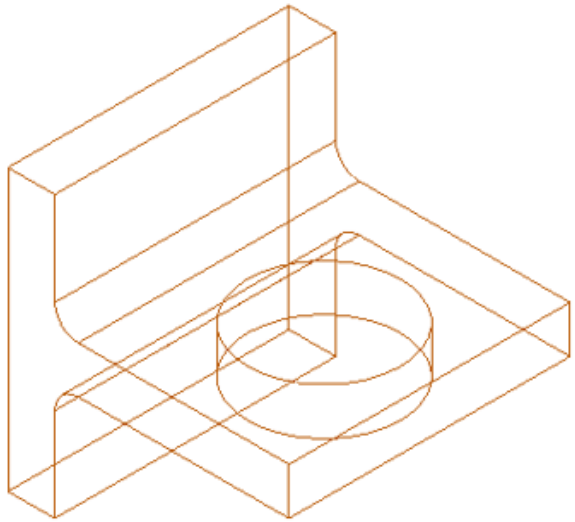
- Drafting – sketches, architectures, Drawings
- Art - Sketches, painting
- Electronic layouts, circuit design



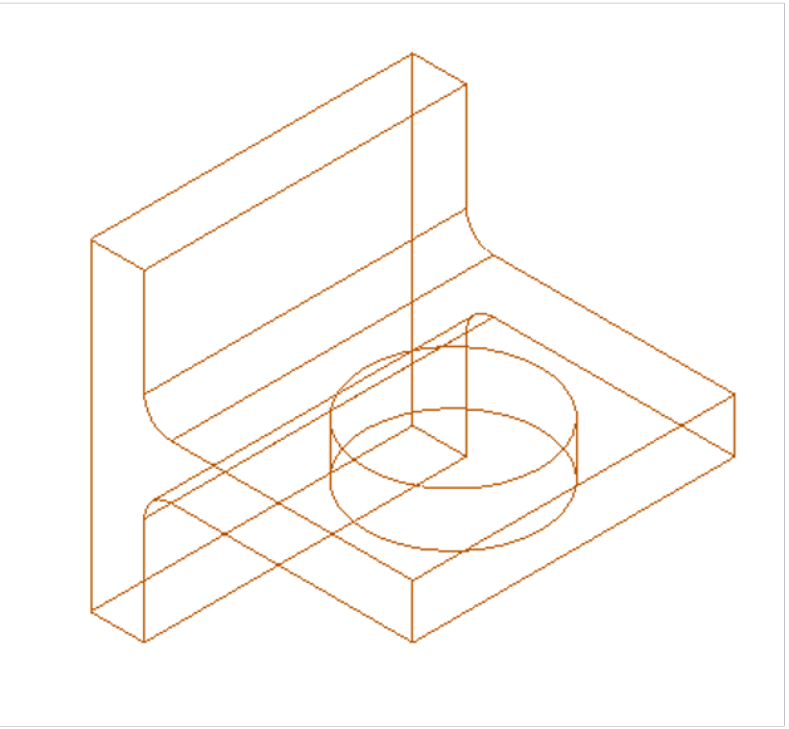


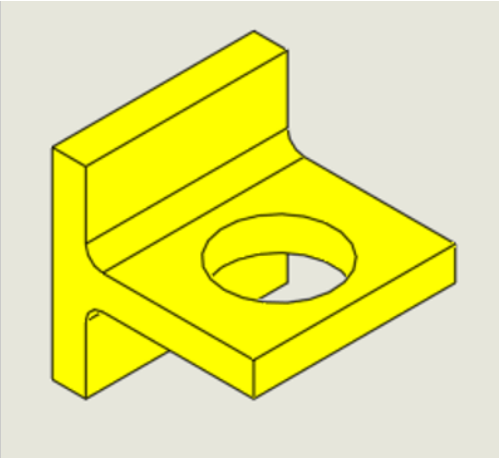
3D Wire frame Modeling

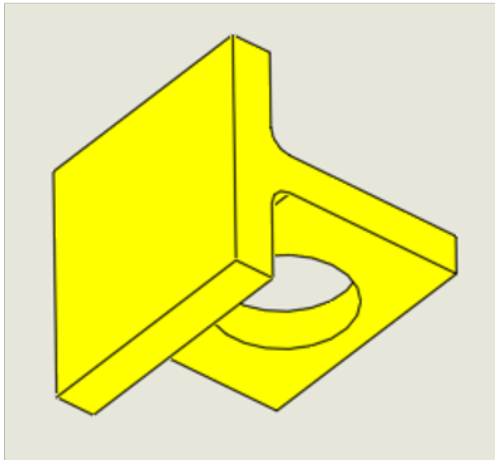
- Geometric entities are lines and curves in 3D
- Volume or surfaces of object not defined
- Easy to store and display
- Hard to interpret - ambiguous



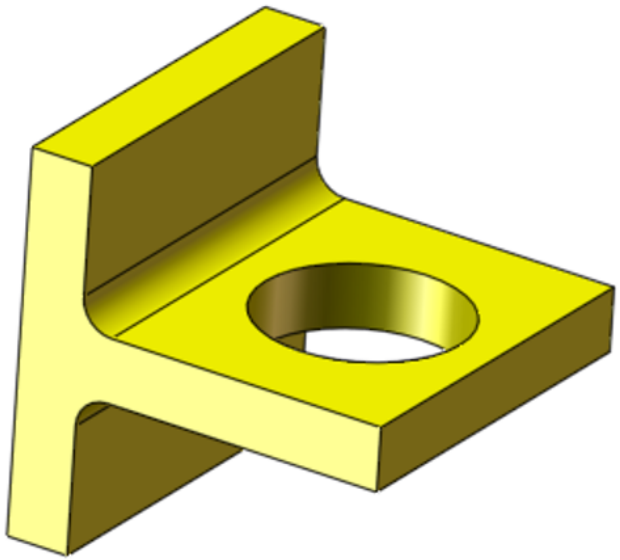
Problems with wire frame models

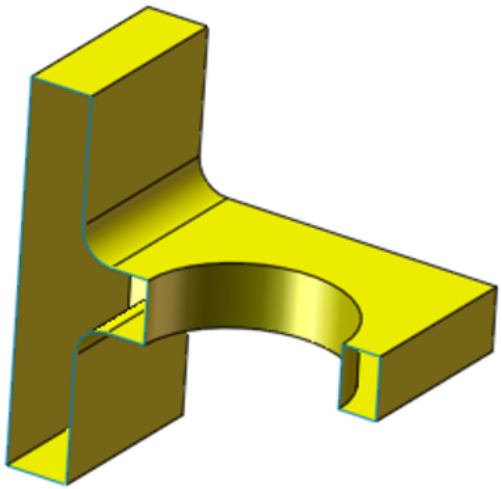






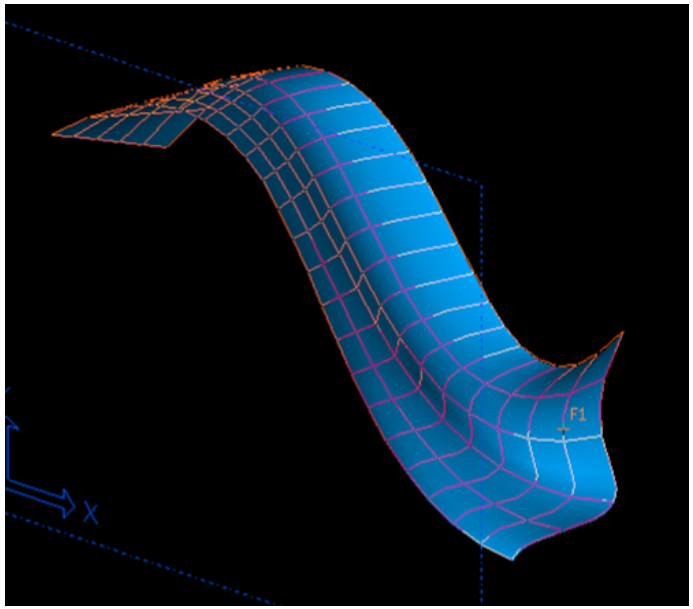
Surface Modeling





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



Surface Modeling

A Surface Model created using Alias Studio Tools

Surface Modeling

Surface Model created using Rhino

Why draw 3D Models?

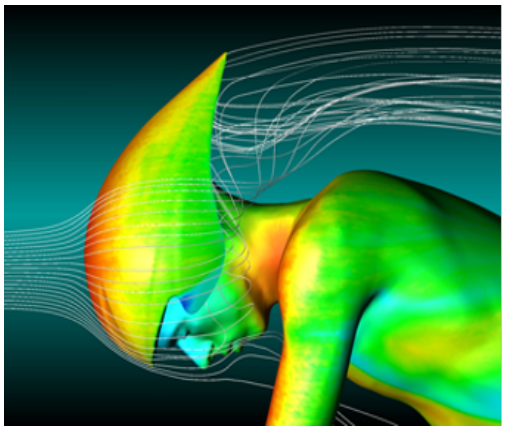
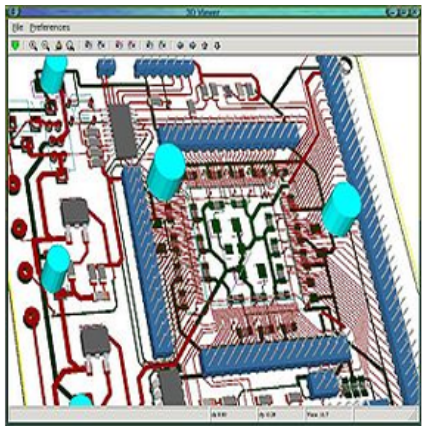
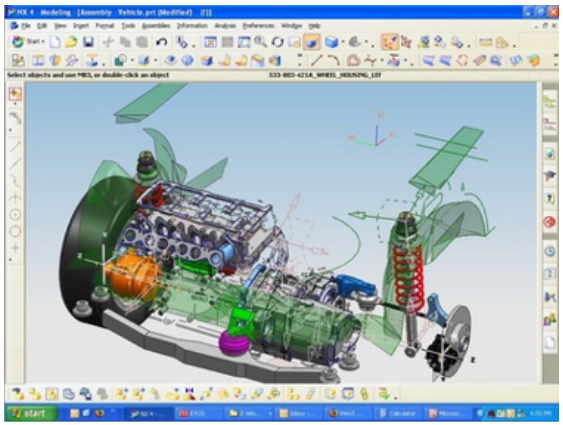
- 3D models are easier to interpret.
- Less expensive than building a physical model.
- 3D models can be altered easily, create more concepts.
- 3D models can be used to perform engineering analysis, finite element analysis (stress, deflection, thermal. . . ..) and motion analysis.
- 3D models can be used directly in manufacturing, Computer Numerical Control (CNC).

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

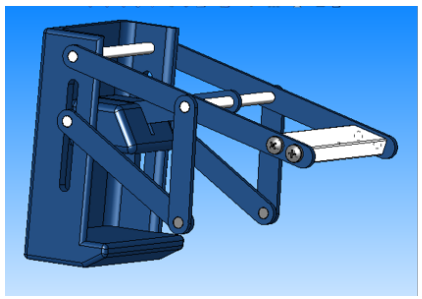
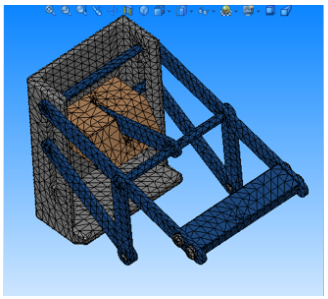
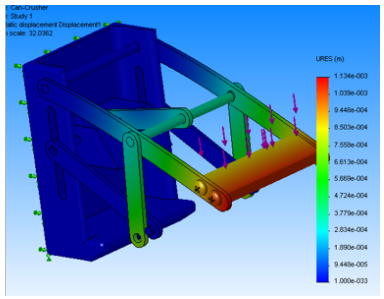
3D Applications

- 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.

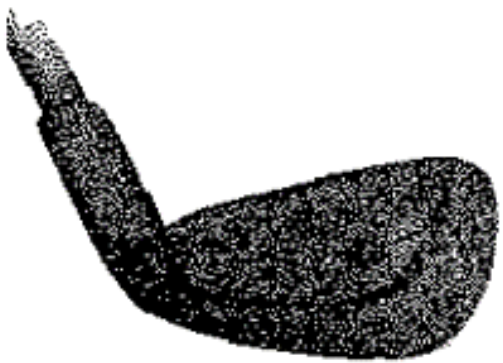
Solids

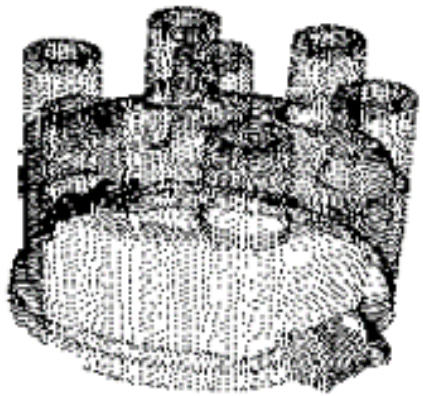
What is a Solid?

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

Cloud of points

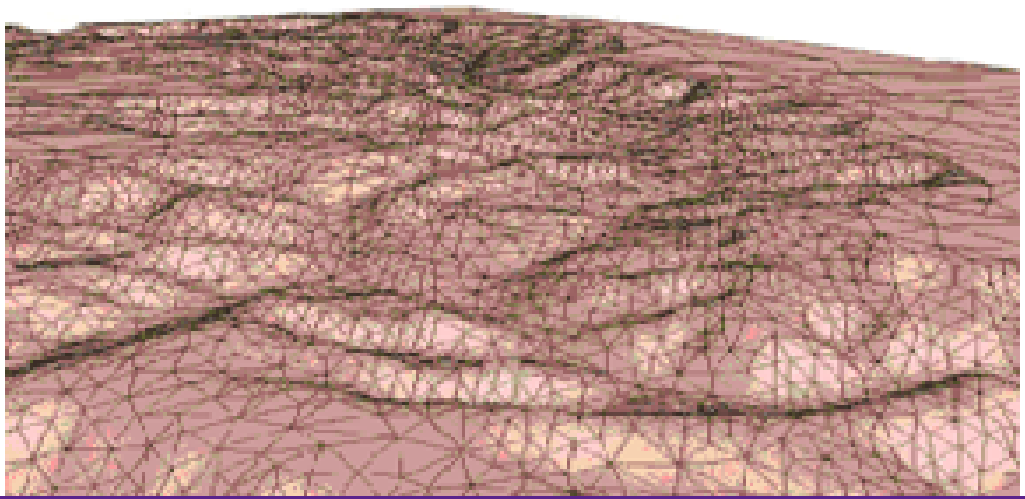
- The simplest form
- Unorganized / organized points
- Too many points to represent the desired shape
- Hard to handle $\rightarrow$ further processing is required
- Obtained by digitizing
  - CMM (coordinate measuring machine)
  - Laser range scanner
  - ...





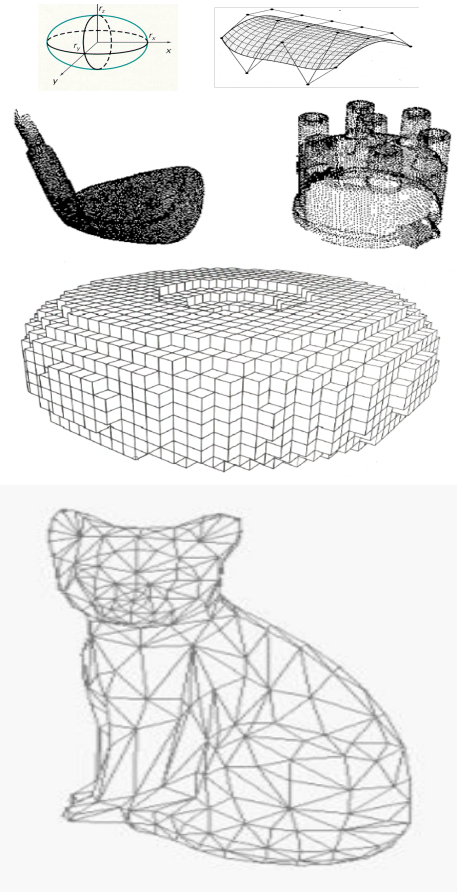
Mesh

- 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



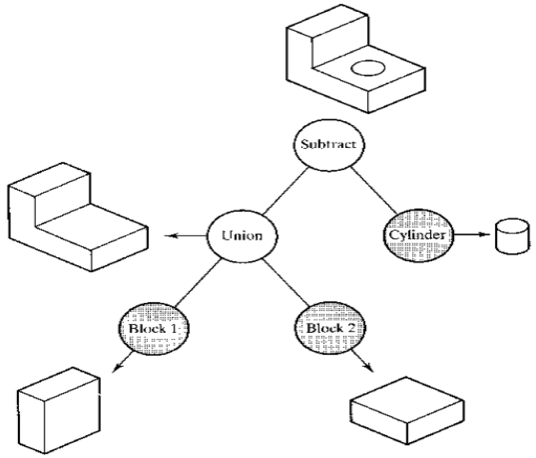
So, Classification By Precision

- Exact (?) model : Continuous/Smooth representation. Explicit / implicit / parametric curves / surfaces
- Approximate model
  - Cloud of points
  - Voxel
  - Mesh

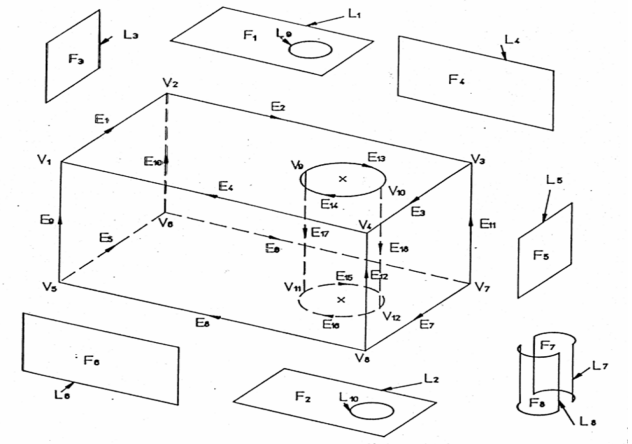


By Storage

- Procedural model : CSG (Constructive Solid Geometry)



- Result based model : B-Rep (Boundary representation)



B-Rep model

Topological element	Geometrical element
Vertex	Point
Edge	Curve
Loop (Edge list)	Composite curve
Face	Surface, trimmed surface
Lump	N/A
Body	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 to Euler-Poincare formula

- 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 to Euler-Poincare formula

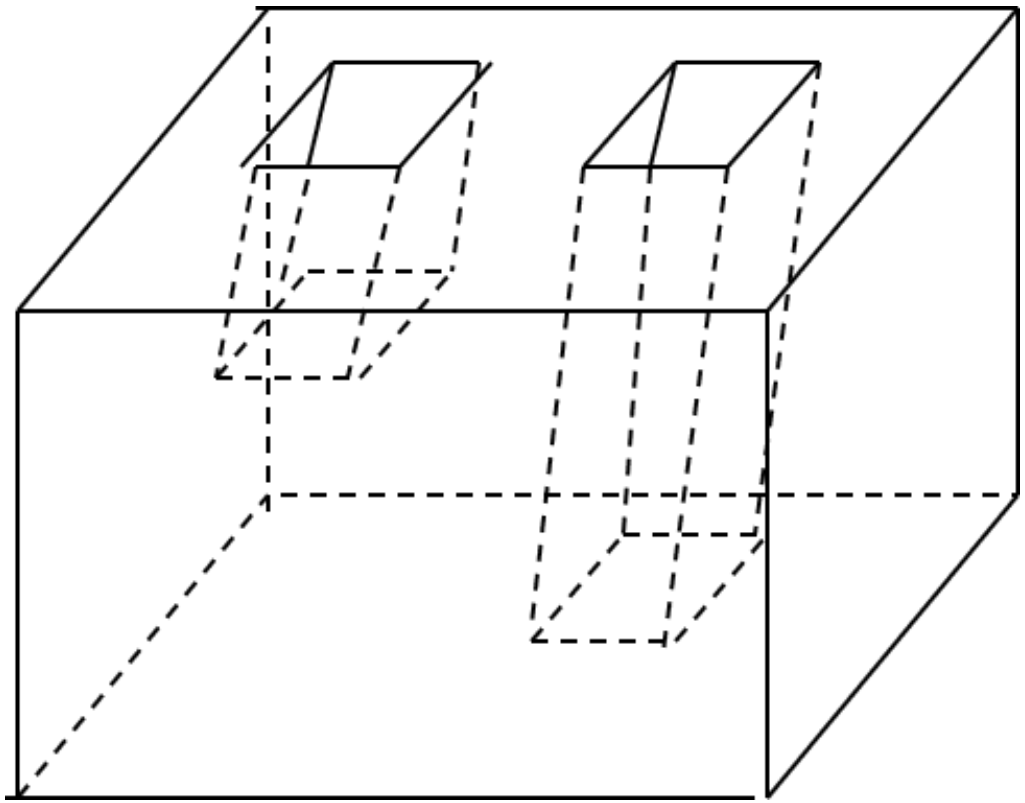
$V - E + F - H = 2(C - G)$

- V = Vertices
- E = Edges
- F = Faces
- H = Holes in faces
- C = Components (or shells)
- G = Genus (holes through solid)

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

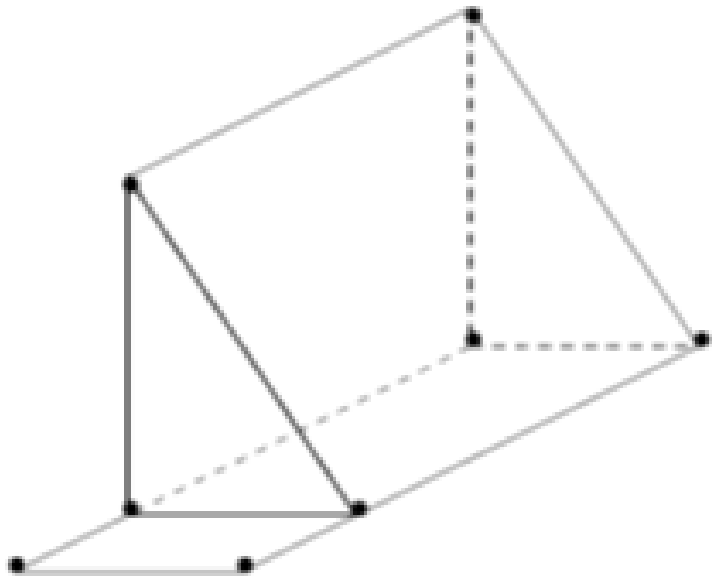
A solid with holes and loops

- $V - E + F - H = 2(C - G)$
- $24–36 + 15–3 = 2(1–1)$



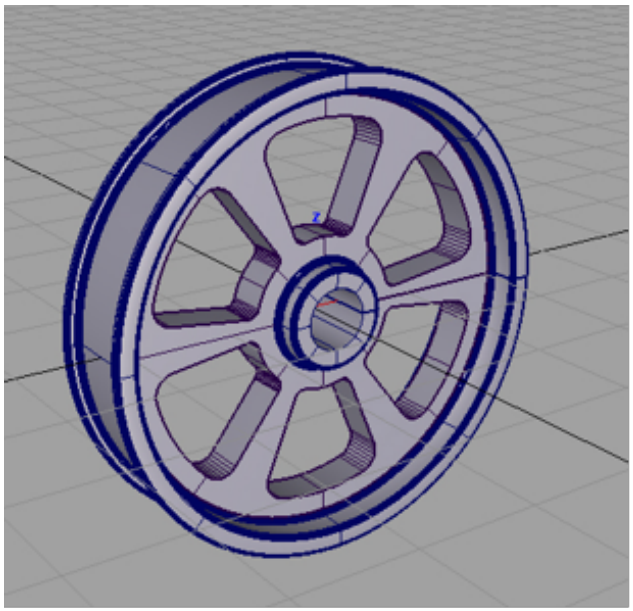
Limitations

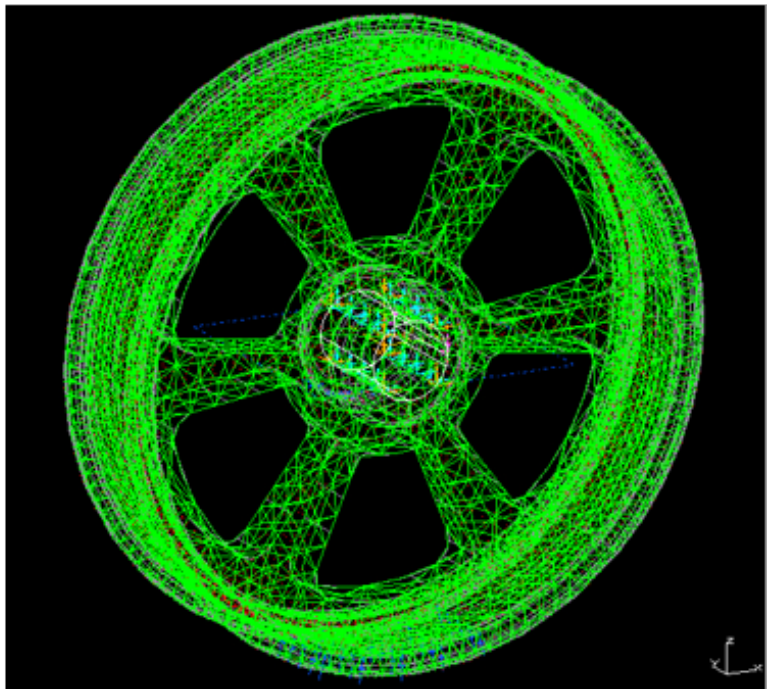
- Necessary but not sufficient condition for a valid representation.
- Example: 8 vertices, 12 edges, 6 faces



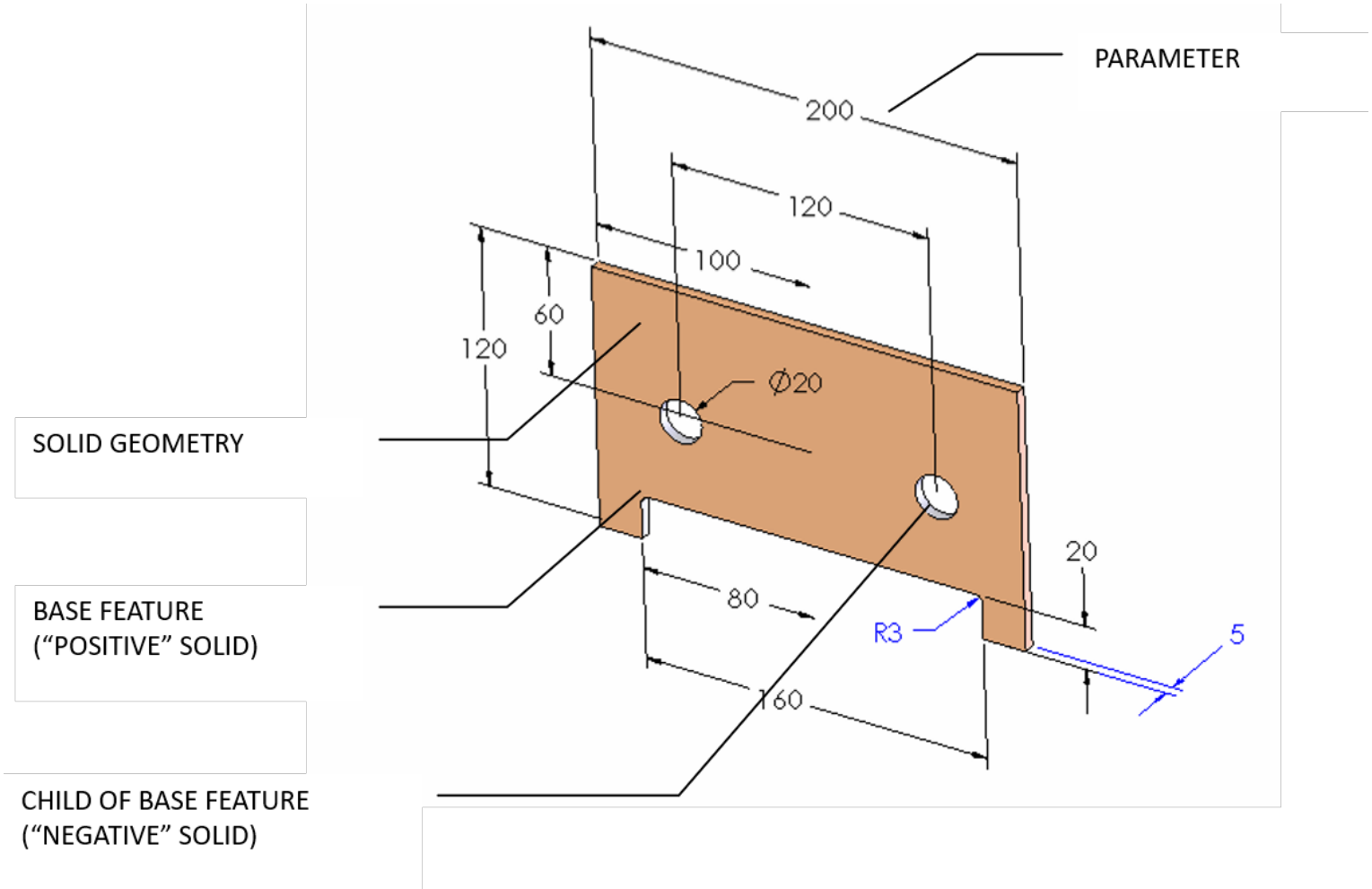
Brep vs Mesh

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





Parametric, Feature-based Solid Model



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, *somewhat*!!

Agenda

References

References

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

Thanks ... yogeshkulkarni@yahoo.com