

# INTRODUCTION TO COMPUTER-AIDED-DESIGN

Yogesh Kulkarni

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# Agenda

1 INTRODUCTION TO CAD

2 REFERENCES

# 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?

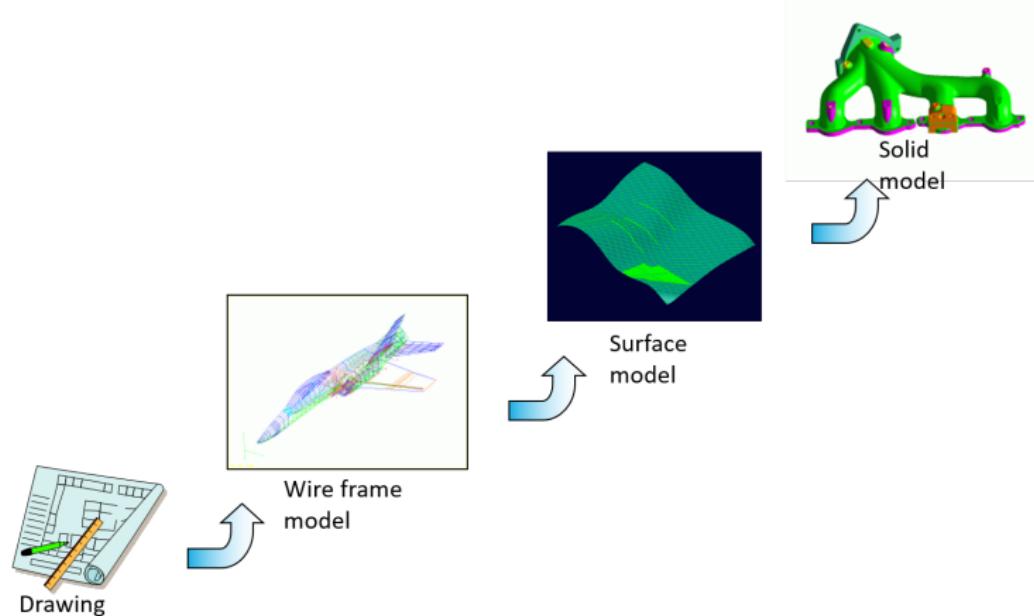
Better if assisted by Computers/Software  
That's why : Computer Aided ... (CAx)

# 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



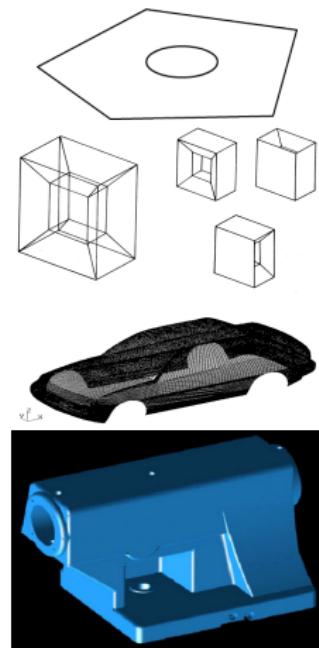
# Modeling Approaches

# Modeling Approaches

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

# By dimensionality

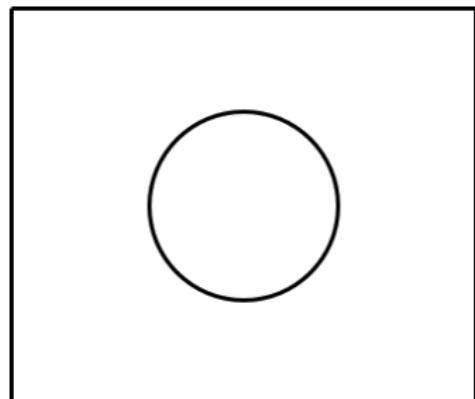
- ▶ 2D model: Point, line, circular arc, planar curve
- ▶ 3D model
  - ▶ Wire frame
  - ▶ Surface
  - ▶ Solid



Advantages and Disadvantages of each?

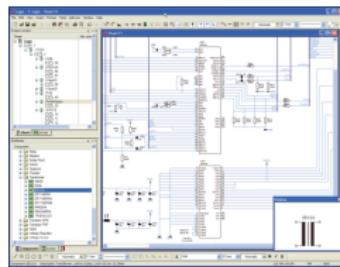
## 2D CAD

- ▶ 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



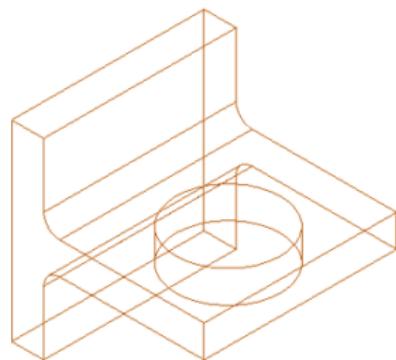
## 2D Applications

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

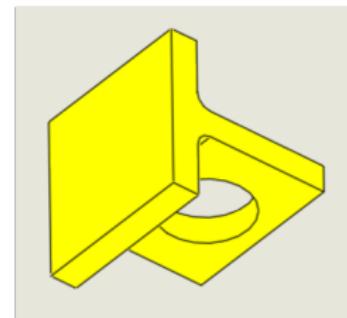
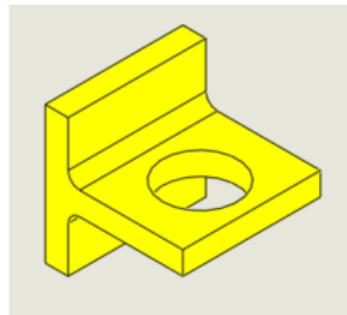
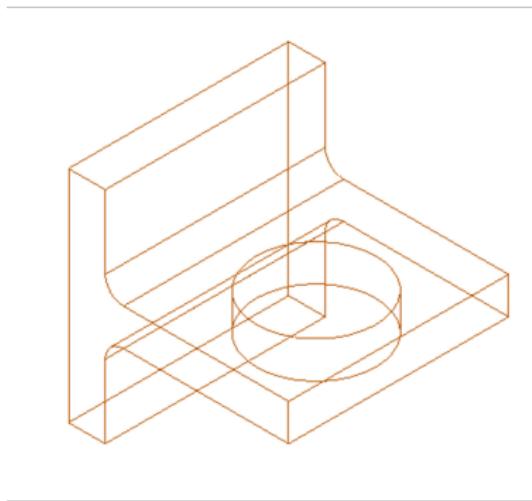


## 3D Wire frame Modeling

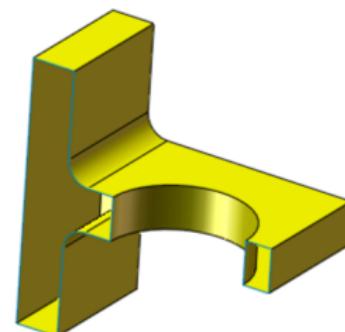
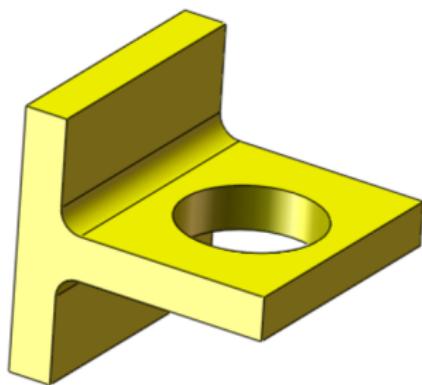
- ▶ Geometric entities are lines and curves in 3D
- ▶ Volume or surfaces of object not defined
- ▶ Easy to store and display
- ▶ Hard to interpret - ambiguous



# Problems with wire frame models

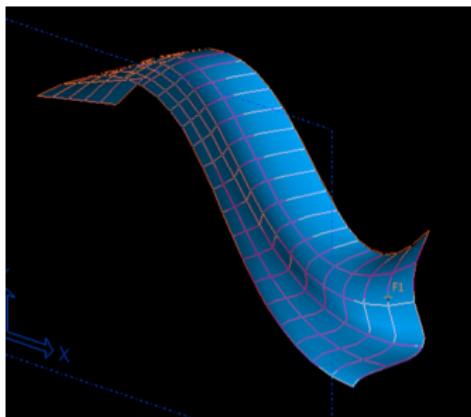


# Surface Modeling



# 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).

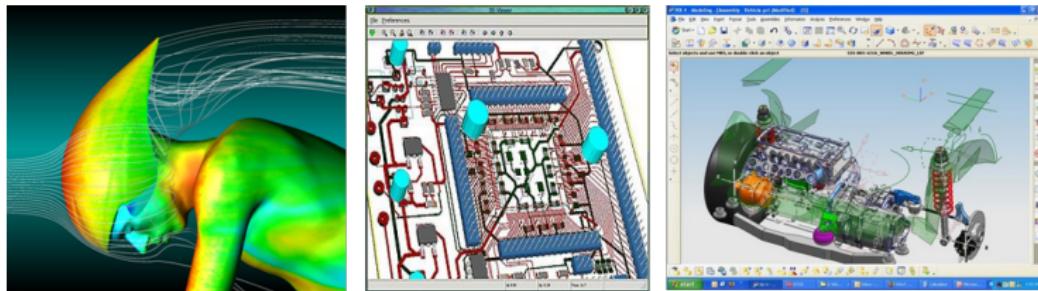
# Solid, parametric, feature based modeling

- ▶ 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



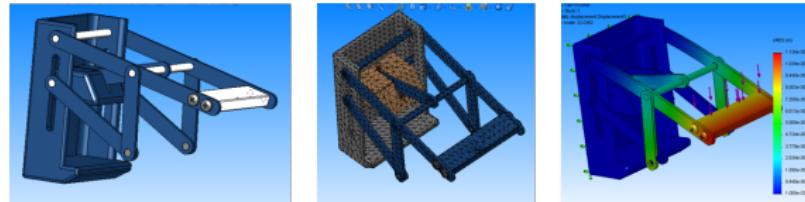
# 3D Applications

- ▶ 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.



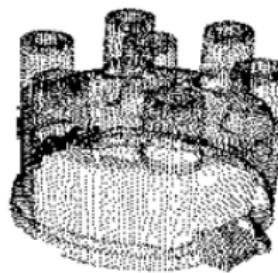
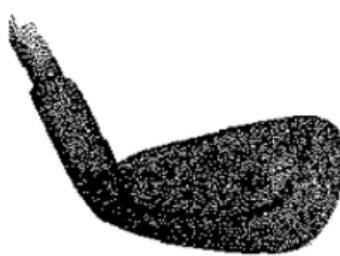
# Solids

## What is a Solid?

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

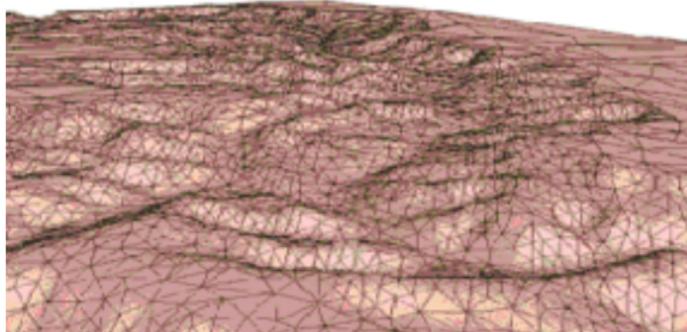
## Cloud of points

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



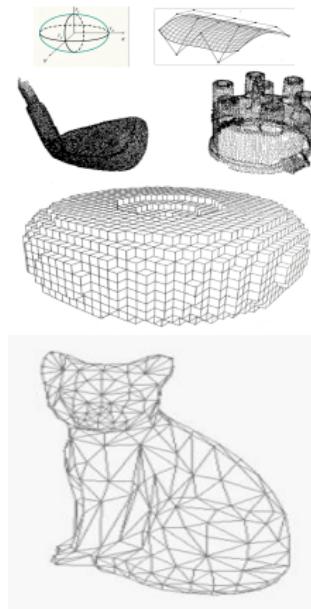
# Mesh

- ▶ 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
  - ▶ facetting exact surface model
- ▶ Example: 123D Catch



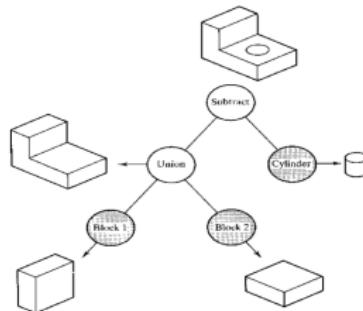
## So, Classification By Precision

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

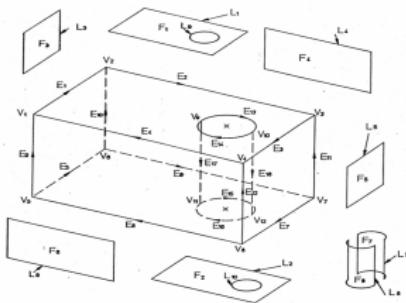


# By Storage

- ▶ Procedural model : CSG (Constructive Solid Geometry)



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



## B-Rep model

### Topological element

- ▶ 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 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

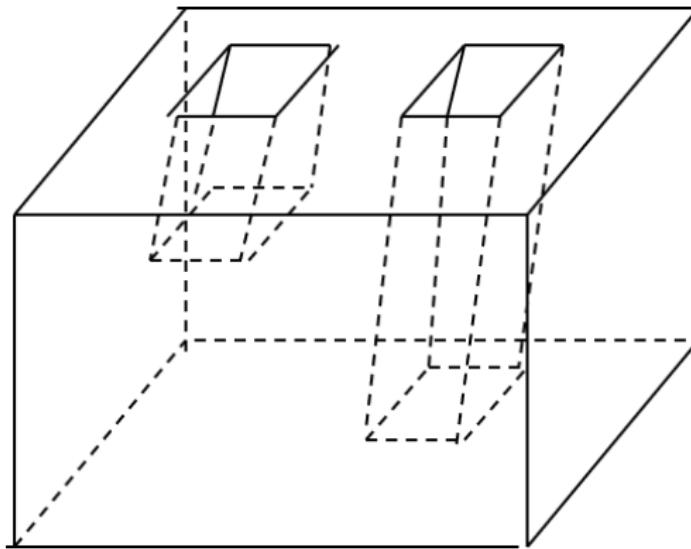
$$V - E + F - H = 2(C - G)$$

- ▶ 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.

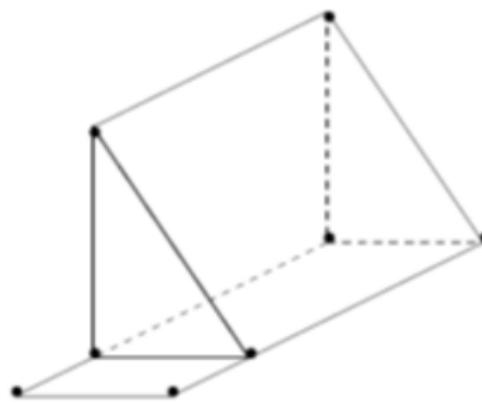
## A solid with holes and loops

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



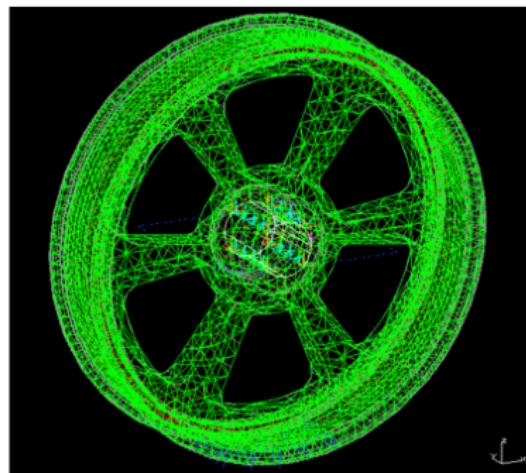
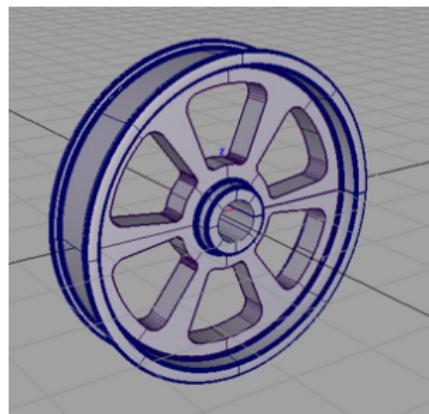
## Limitations

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

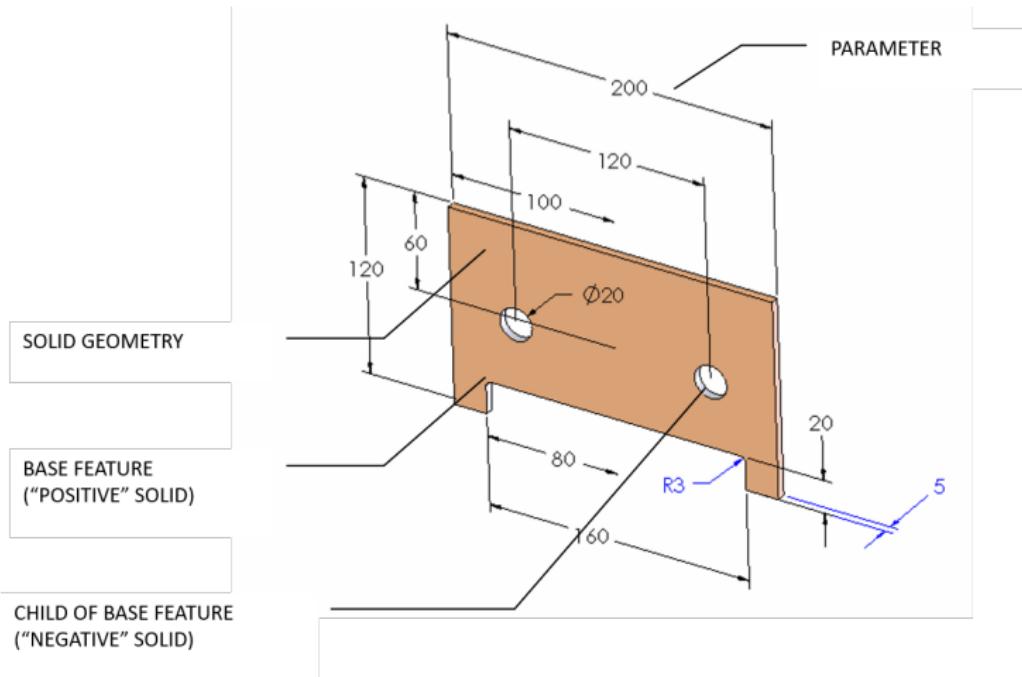


## Brep vs Mesh

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 Systèmes)
  - ▶ 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

① INTRODUCTION TO CAD

② REFERENCES

# 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