Geometric Modeling

25.353 Lecture Series

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and Industrial Engineering
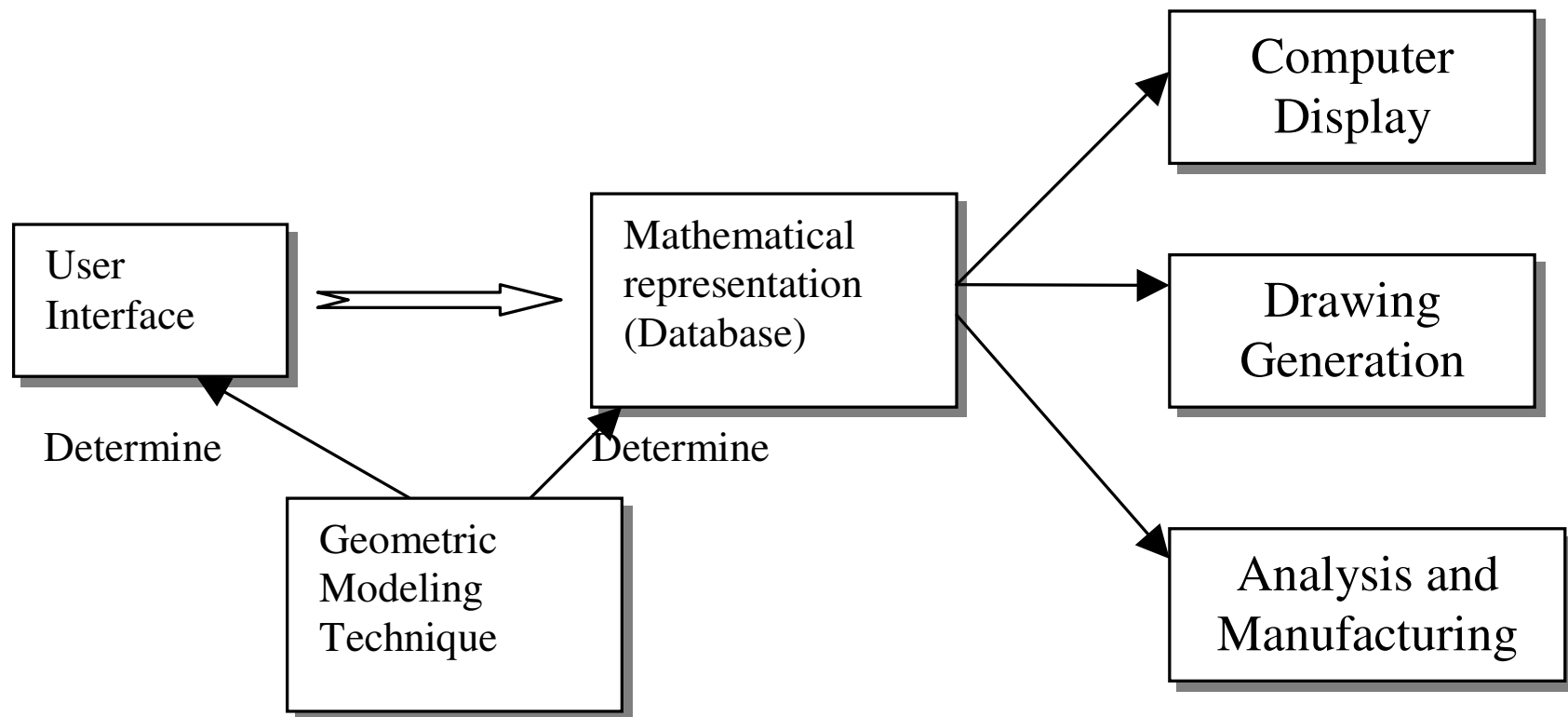
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Introduction

"Geometric modeling is as important to CAD as governing equilibrium equations to classical engineering fields as mechanics and thermal fluids."

- ✓intelligent decision on the types of entities necessary to use in a particular model to meet certain geometric requirements such as slopes and/or curvatures.
- ✓interpretation of unexpected results
- ✓evaluations of CAD/CAM systems
- ✓innovative use of the tools in particular applications.
- ✓creation of new attributes, or modify the obtained models to benefit new engineering applications.
- ✓understanding of terminology

The Role of Geometric Modeling in a CAD System

User Interface

Mathematical representation (Database)

Computer Display

Drawing Generation

Analysis and Manufacturing
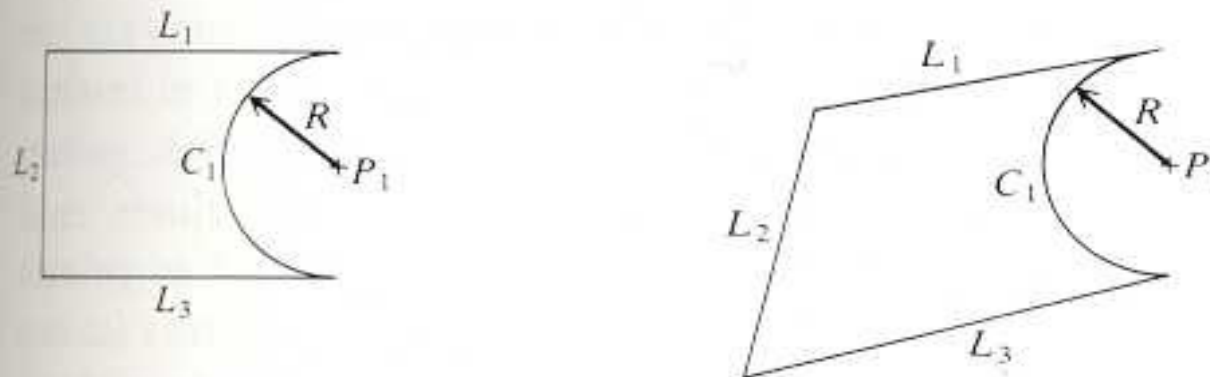
Geometric Modeling Technique

Determine

Determine

General Requirements

- Complete part representation including topological and geometrical data
  - Topology: the connectivity and associativity of the object entities; it determines the relational information between object entities
- Able to transfer data directly from CAD to CAE and CAM.
- Support various engineering applications, such as mass properties, mechanism analysis, FEM and tool path creation for CNC, and so on.

Topology and Geometry
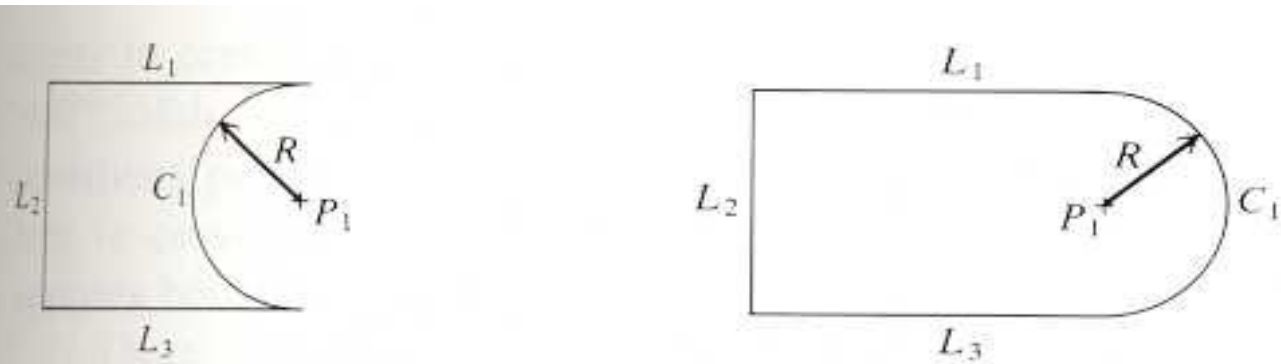
(a) Same geometry but different topology

(b) Same topology but different geometry

Comments on Geometric Modeling

- Geometric modeling is only a means not the goal in engineering.
- Engineering analysis needs product geometry; the degree of detail depends on the analysis procedure that utilizes the geometry.
- There is no model that is sufficient to study all behavioral aspects of an engineering component or a system.
- Attributes facilitate analysis and grow with applications

Basic Geometric Modeling Techniques

- 2-D Projection (Drawings)

- Wireframe Modeling

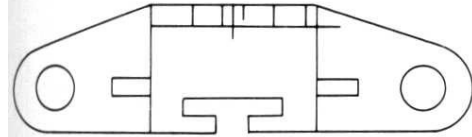- Surface Modeling

- Solid Modeling

2-D Projection
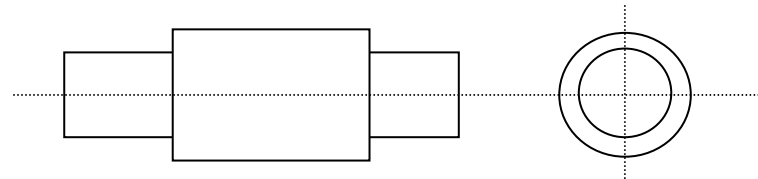
Problems:
- Training is necessary to understand the drawing
- Mistakes often occur
- Does not support subsequent applications such as finite element analysis (FEA) or NC part programming

Wireframe Modeling

- Developed in 1960s and referred as "a stick figure" or "an edge representation"

- The word "wireframe" is related to the fact that one may imagine a wire that is bent to follow the object edges to generate a model.

- Model consists entirely of points, lines, arcs and circles, conics, and curves.

- In 3D wireframe model, an object is not recorded as a solid. Instead the vertices that define the boundary of the object, or the intersections of the edges of the object boundary are recorded as a collection of points and their connectivity.
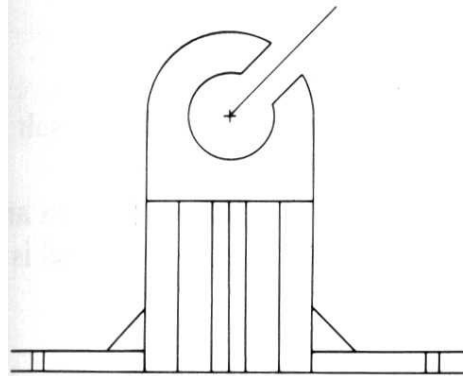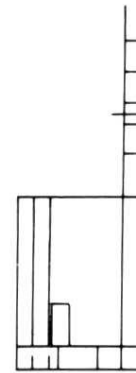
Wireframe Modeling



Top view
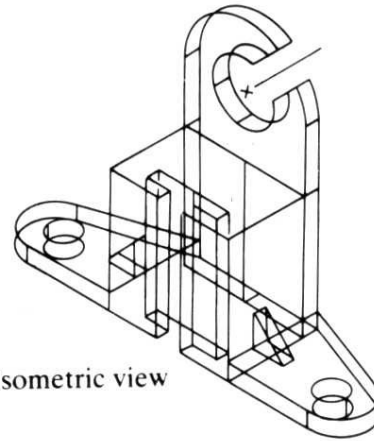
Isometric view

Front view

Right view

Advantages of Wireframe Modeling

- Simple to construct
- Does not require as much as computer time and memory as does surface or solid modeling
- As a natural extension of drafting, it does not require extensive training of users.
- Form the basis for surface modeling as most surface algorithms require wireframe entities (such as points, lines and curves)

Disadvantages

- The input time is substantial and increases rapidly with the complexity of the object

- Both detailed topological and geometric data need to be user-input;

- Unless the object is two-and-a-half dimensional, volume and mass properties, NC tool path generation, cross-sectioning, and interference cannot be calculated.

- Models are usually ambiguous (figures) and "nonsense" object may result.
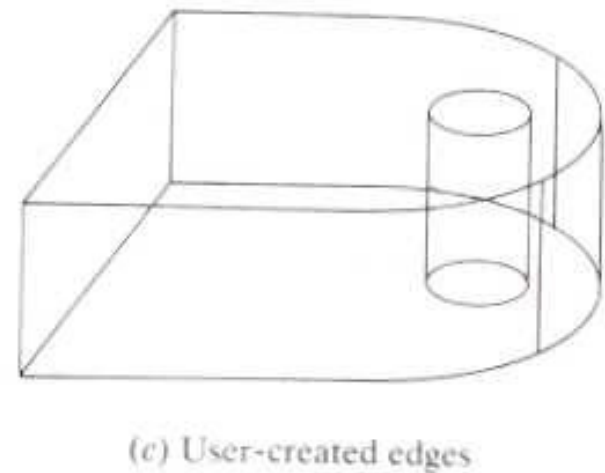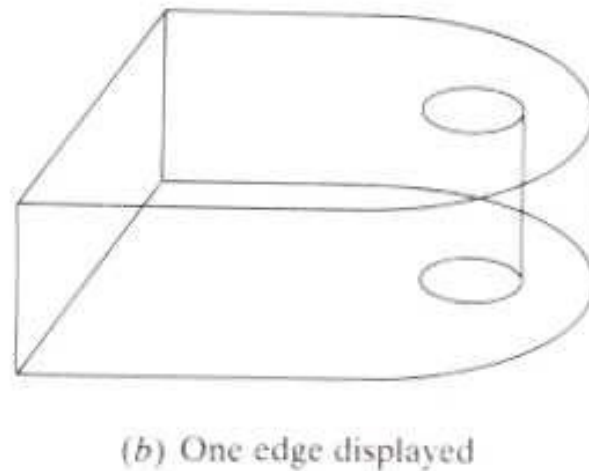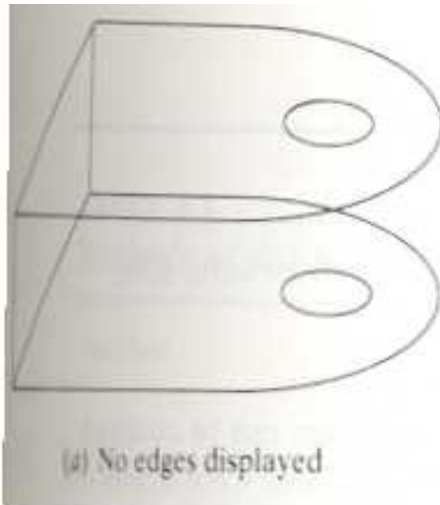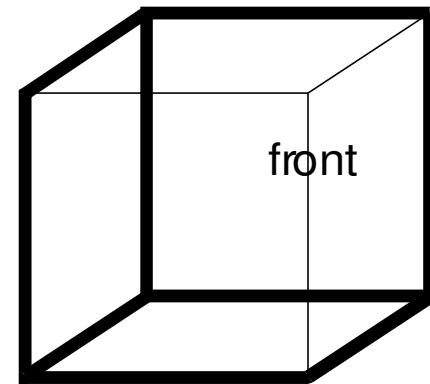

(a)   (b)   (c)
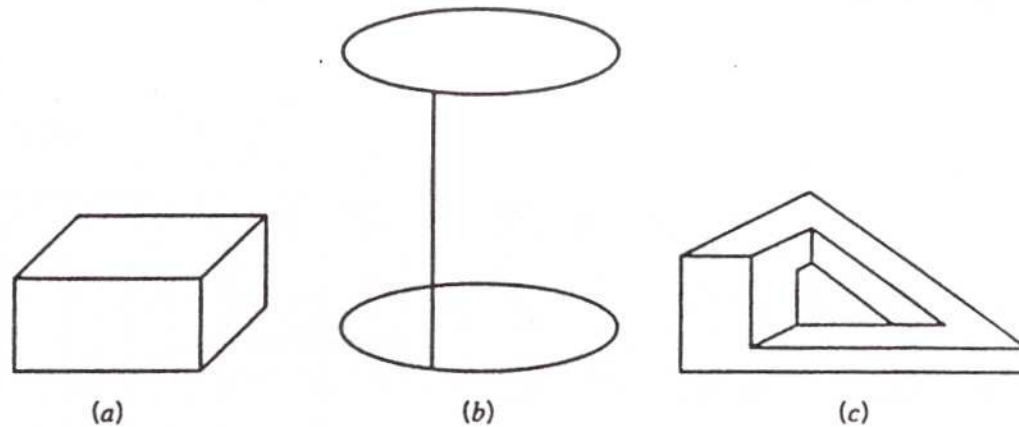
Ambiguous
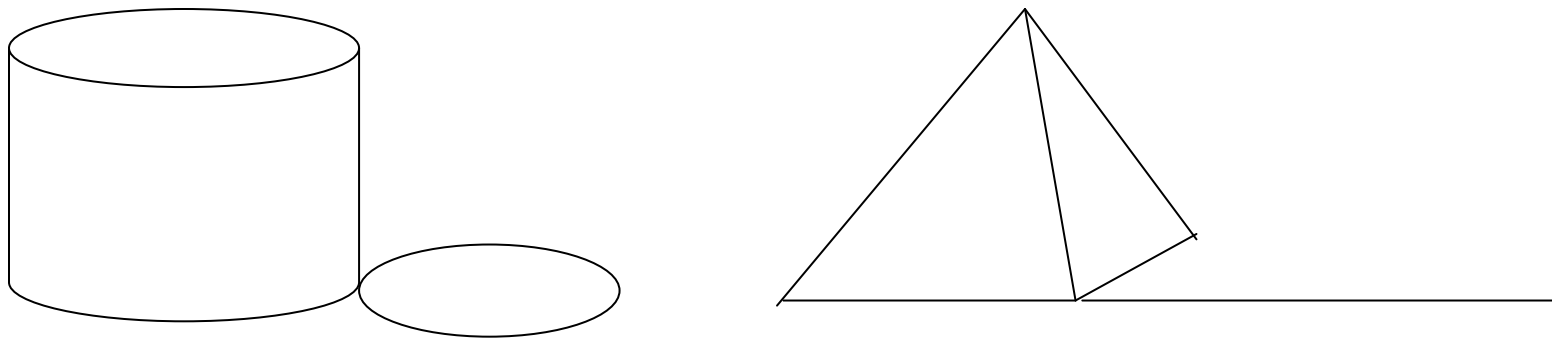
Nonsense

- Lack of visual coherence and information to determine the object profile

(a) No edges displayed   (b) One edge displayed   (c) User-created edges

- it is very difficult to remove the hidden lines based upon a wireframe model.
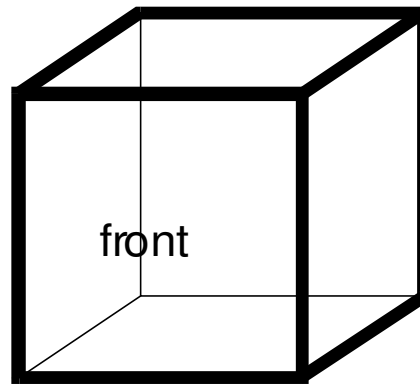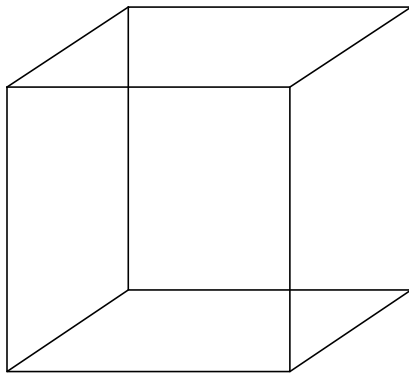
Today's Situation of Wireframe Modeling

- Simple enough for early design sketches
- May be sufficient for basic design and manufacturing needs (simple geometry, simple work, architecture drawings)
- Many companies have large amounts of wireframe databases that are worth millions of dollars and man-hours.
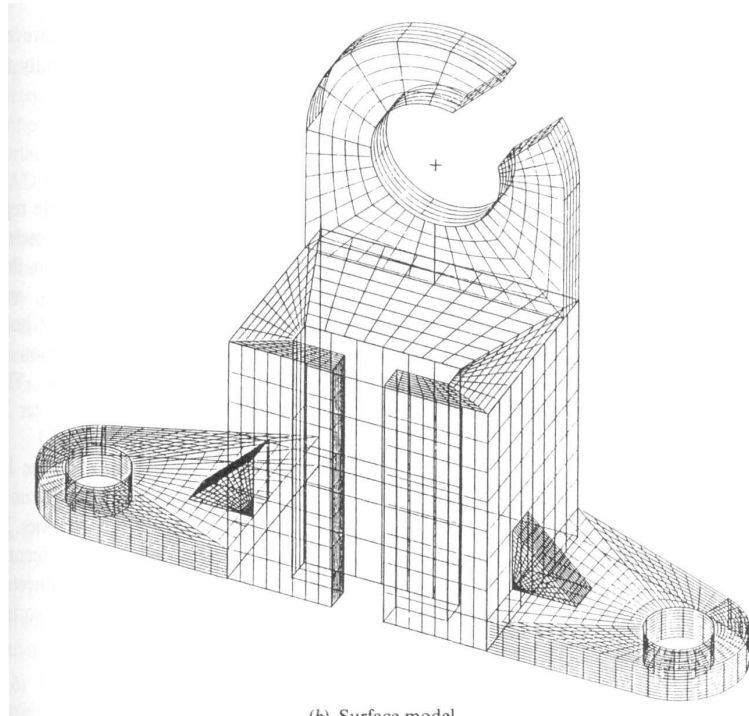
Surface Modeling

- A surface model is a set of faces.

- A surface model consists of wireframe entities that form the basis to create surface entities.

- In general, a wireframe model can be extracted from a surface model by deleting or blanking all surface entities

- Shape design and representation of complex objects such as car, ship, and airplane bodies as well as castings

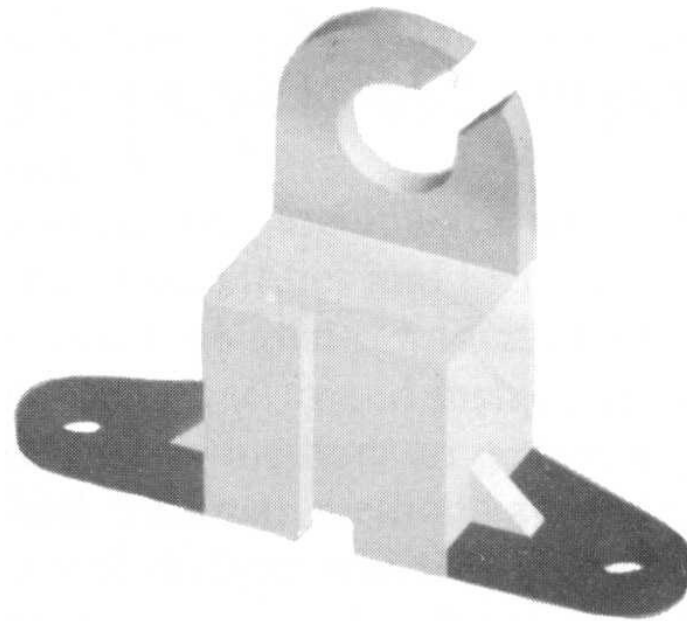# Examples of Surface Models
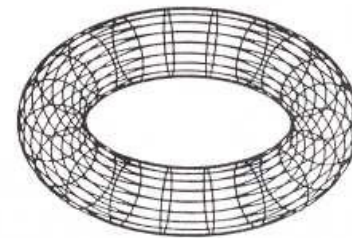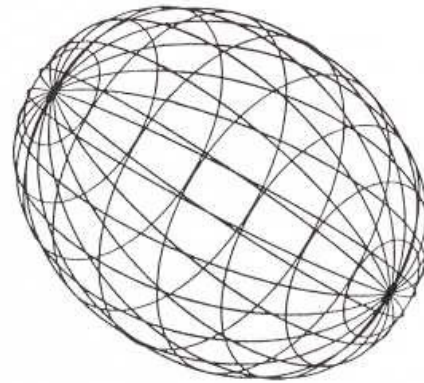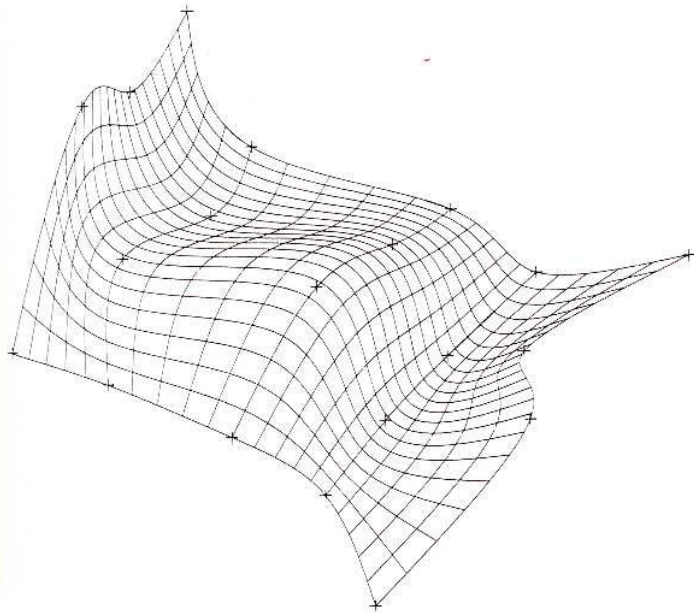
Examples of Surface Models

- Surface models define only the geometry, no topology.
- Shading is possible

(b) Surface model

Advantages of Surface Modeling

- Less ambiguous
- Provide hidden line and surface algorithms to add realism to the displayed geometry
- Support shading
- Support volume and mass calculation, finite element modeling, NC path generation, cross sectioning, and interference detection.

Disadvantages

- Require more training and mathematical background of the users
- Require more CPU time and memory
- Still ambiguous; no topological information
- Awkward to construct
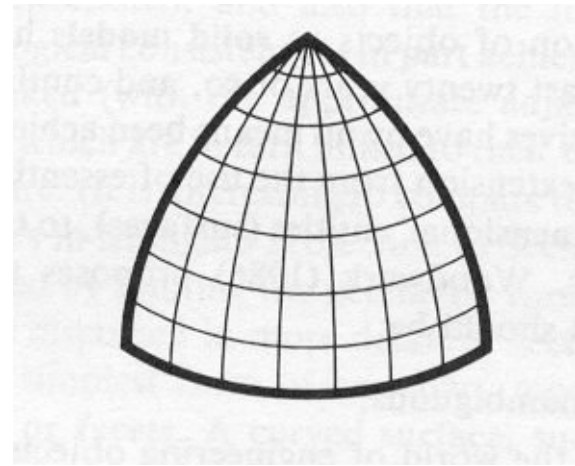
Solid Modeling

- informationally complete, valid, and unambiguous representation (Spatial addressability)
  - points in space to be classified relative to the object, if it is inside, outside, or on the object
- store **both geometric and topological** information; can verify whether two objects occupy the same space.
- improves the quality of design, improves visualization, and has potential for functional automation and integration.
- Support
  - weight or volume calculation, centroids, moments of inertia calculation,
  - stress analysis (finite elements analysis), heat conduction calculations, dynamic analysis,
  - generation of CNC codes, and robotic and assembly simulation

Isometric view
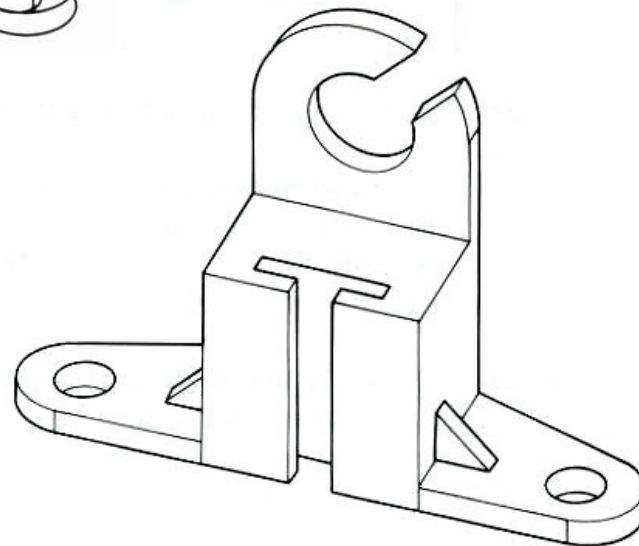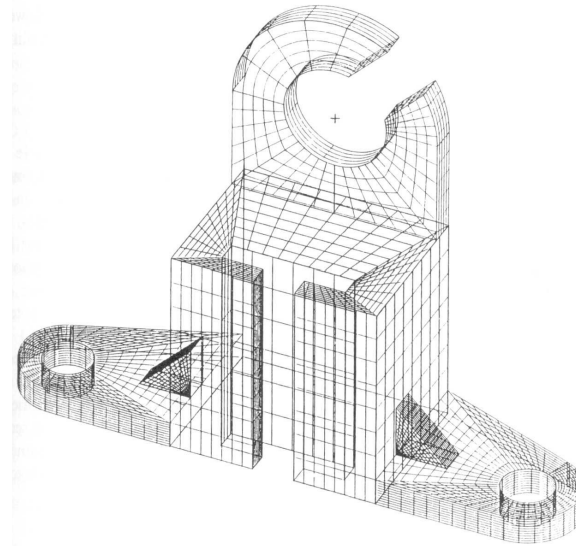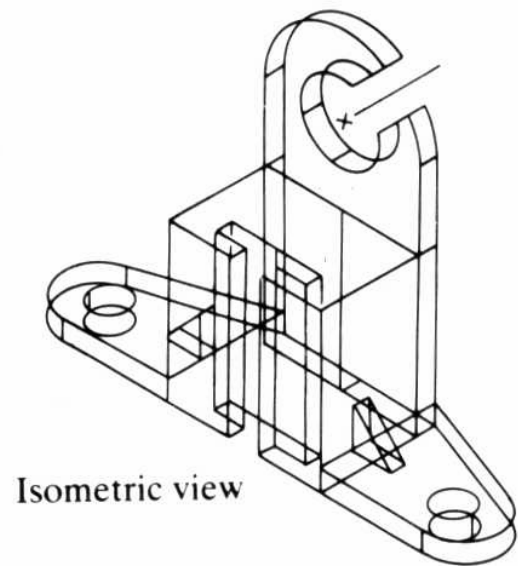
Information complete, unambiguous, accurate solid model

Quick Questions

- Geometric Modeling is a fundamental CAD technique.
- The capability of various CAD tools in geometric modeling is usually used as a crucial factor in tool selection.
- Wireframe models consist entirely of points, lines, and curves.
- Since wireframe models do not have "body knowledge", topological data are not needed in construction.
- Surface models store topological information of their corresponding objects.
- Both surface models and solid models support shading.
- Surface models is still ambiguous and thus cannot support a full range of engineering activities such as stress analysis.
- Solid models have complete, valid and unambiguous spatial addressability.
- In general, a wireframe model can be extracted from a surface or a solid model.

Summary

- Tedious, ambiguous, -- wireframe models
- A covered wireframe entities -- surface models
- Geometric and topologic, application oriented -- Solid models