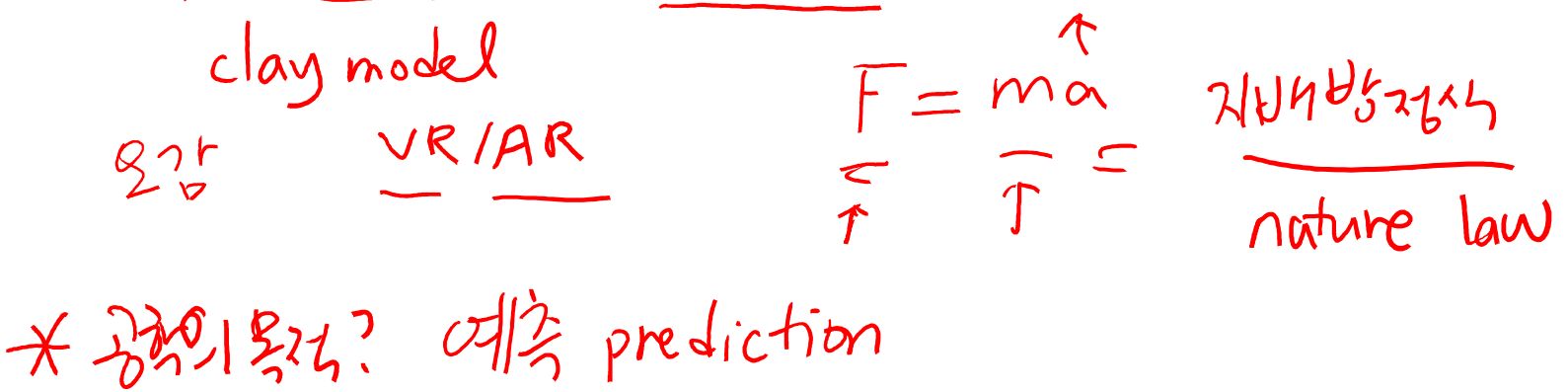
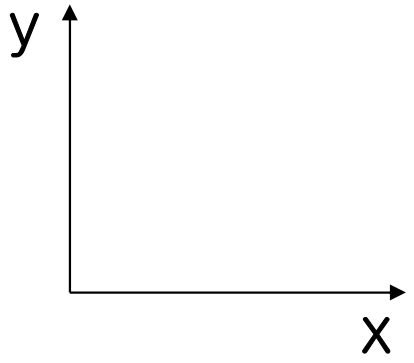
Geometric Modeling

- 기하학적 형상을 만드는 행위
- Modeling
- Model
  - 물체의 특성을 완전하고 정확하게 표현해야 함
  - Physical Model vs. Mathematical Model

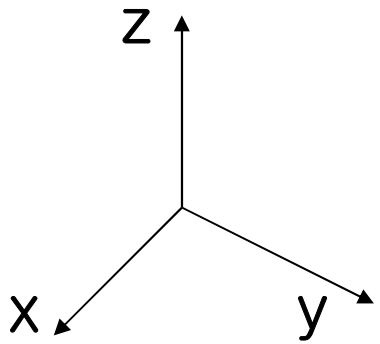


Modeling Space

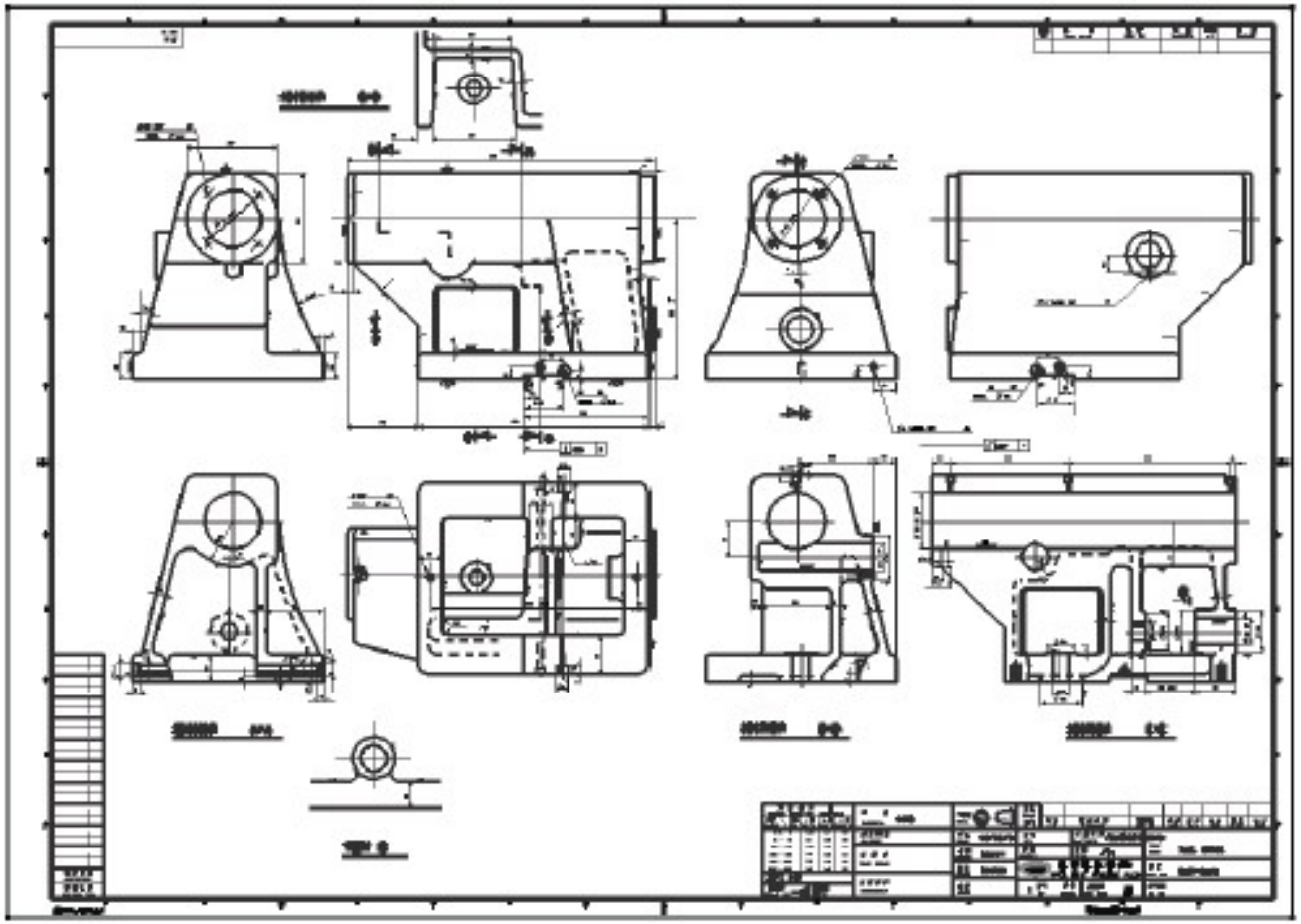
- 2D space (x,y)
  - Computer aided drafting



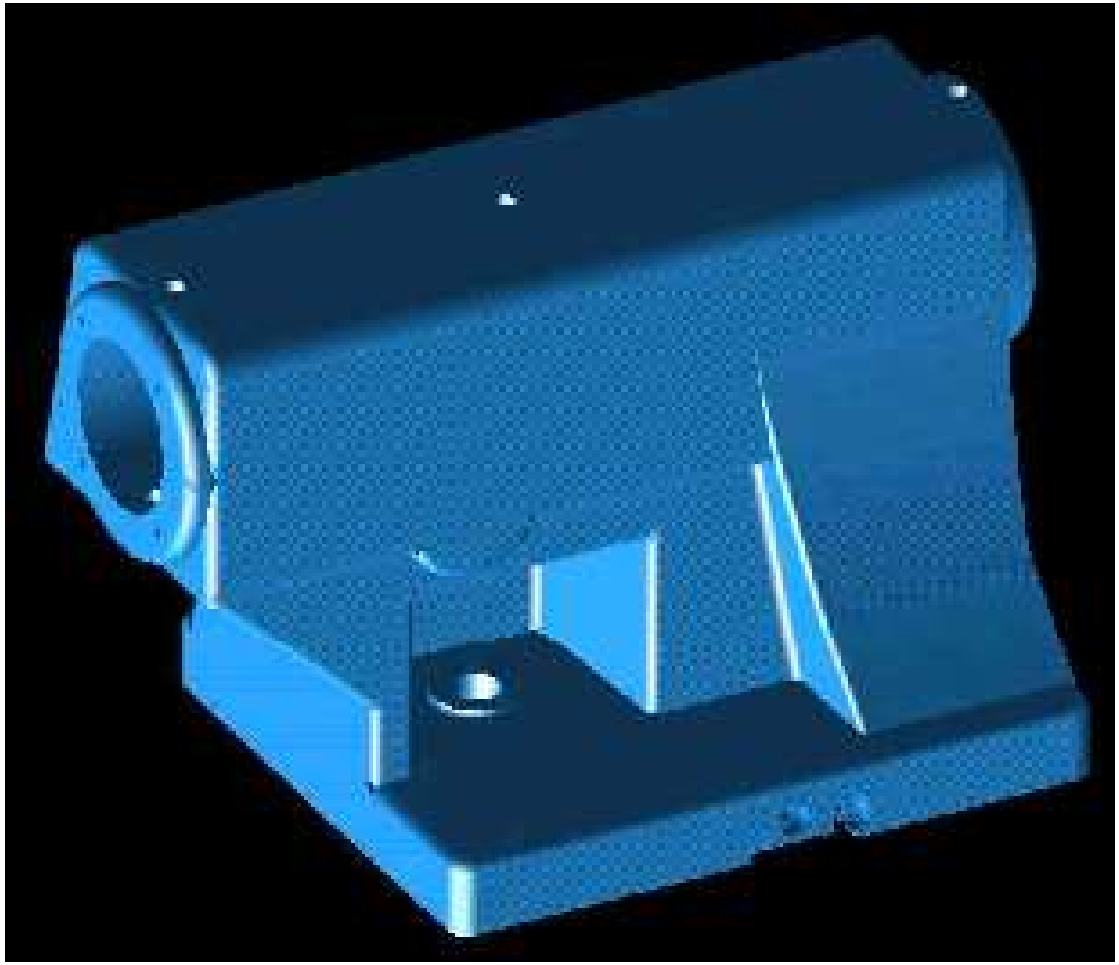
- 3D space (x,y,z)



Why 3D Model? (1)



Why 3D Model? (2)



Geometric Entity

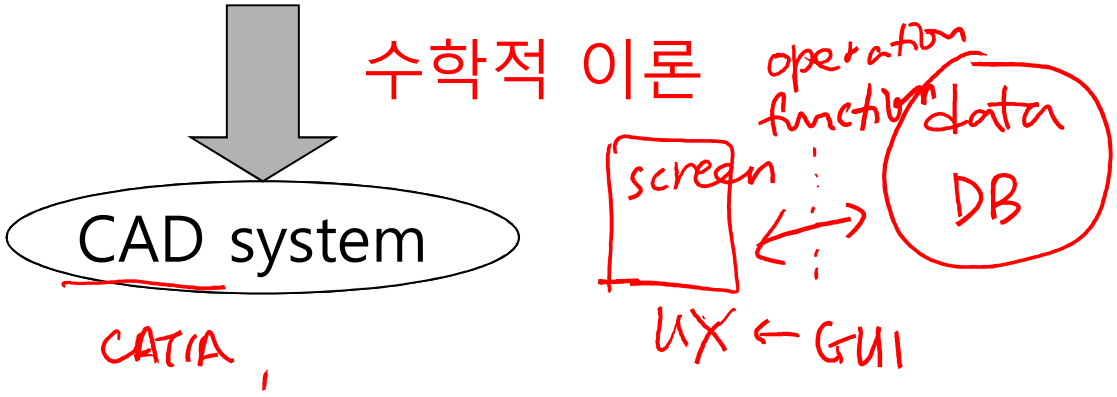
- Point : 좌표값
- Curve : 곡선의 방정식 (planar/space/freeform)
- Surface : 곡면의 방정식 (plane/sculptured)
- Solid : 부피를 둘러싸고 있는 곡면들의 방정식

Geometric modeling

↓

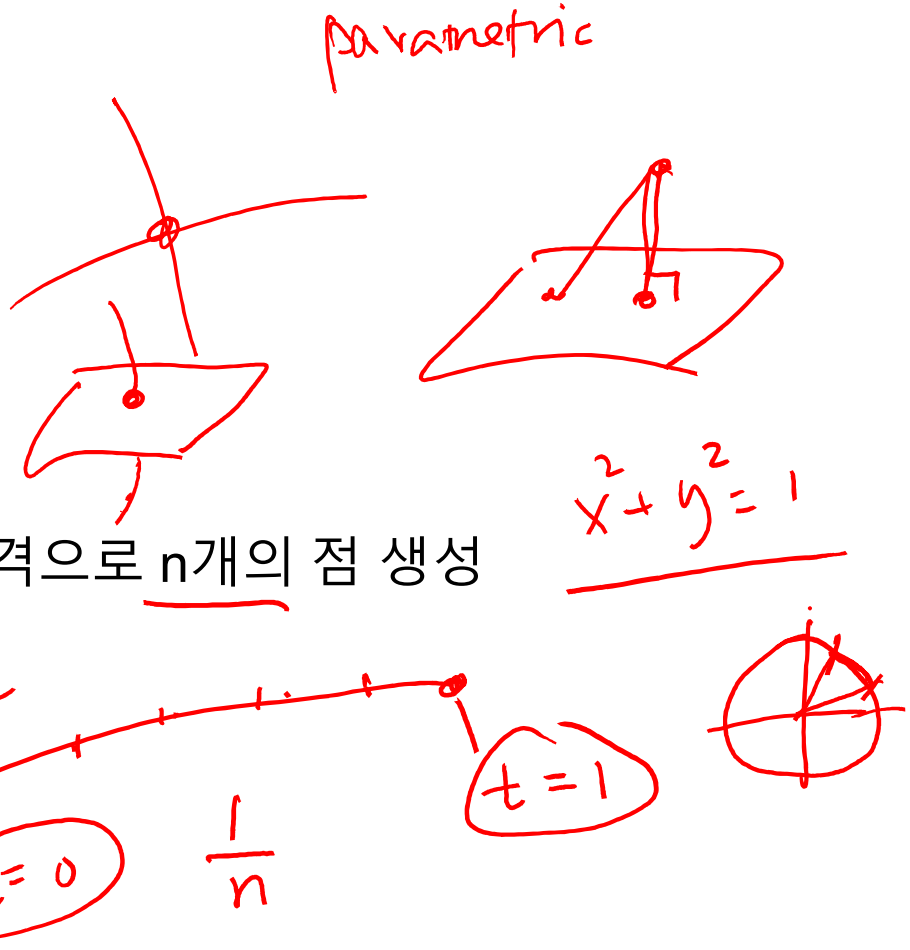
Solid modeling

Geometric entity를 편리하게 정의하는 기능
해당좌표나 방정식을 유도하고 저장하는 기능



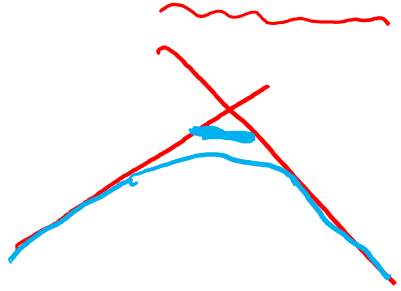
점(point) 정의

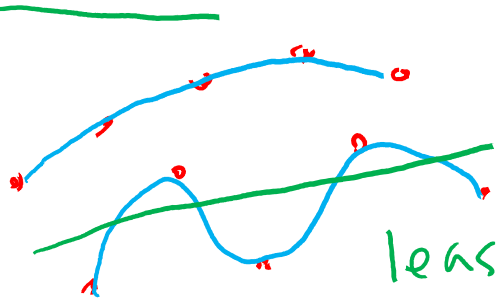
- 직접입력
  - 좌표값 입력
- 간접입력
  - 두 곡선의 교점 이용
  - 점을 곡면 위에 투영
  - 곡선과 곡면의 교점 이용
  - 주어진 곡선 위에 일정한 간격으로 n개의 점 생성



2D 곡선(curve) 정의

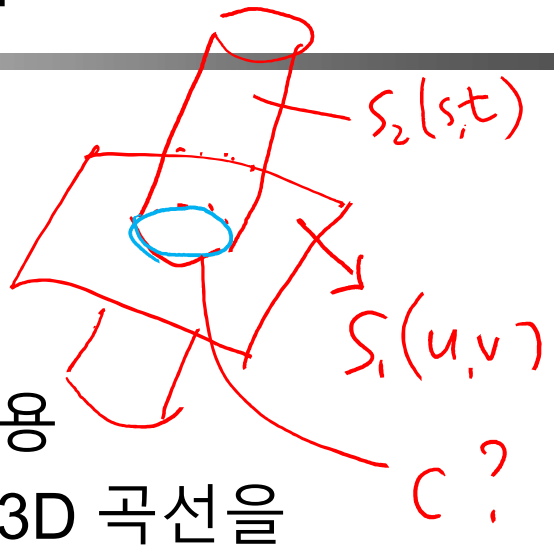
- 기본 2D 곡선 이용
  - 직선(line), 원(circle), 타원(ellipse), 포물선(parabola), 쌍곡선(hyperbola)
  - 몇 개의 파라미터값으로 간단하고 정확하게 표현
- 두 곡선 사이를 Blending
  - Rounding/Chamfer
- 순서가 정해진 여러 개의 2D 점 이용
  - 자유곡선을 정의
  - Interpolation/Approximation

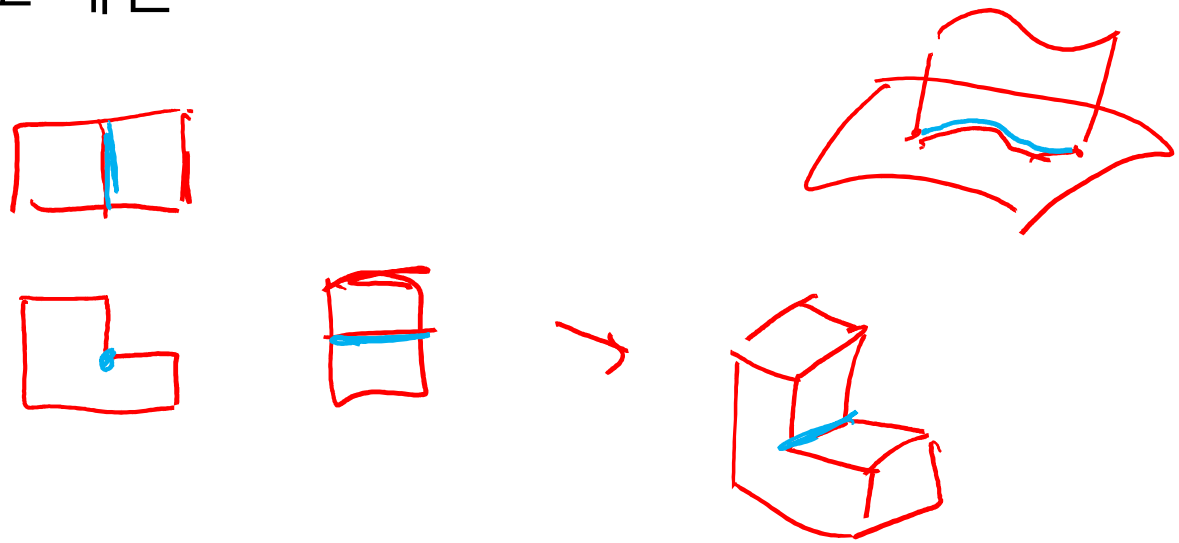




3D 곡선(curve) 정의

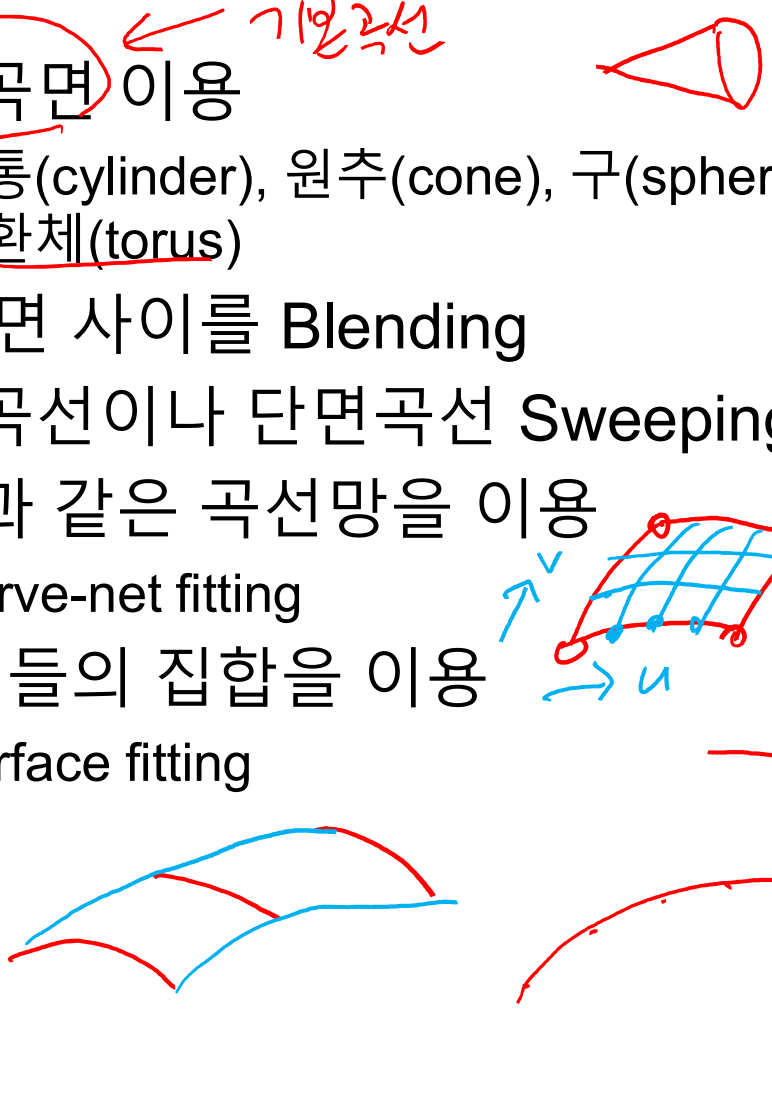
- 순서가 정해진 여러 개의 3D 점 이용
  - Interpolation/Approximation
- 두 곡면의 교선 이용
- 3D 곡선을 곡면 위에 투영시킨 곡선 이용
- 여러 view에 그려진 2D 곡선들로 부터 3D 곡선을 역으로 계산





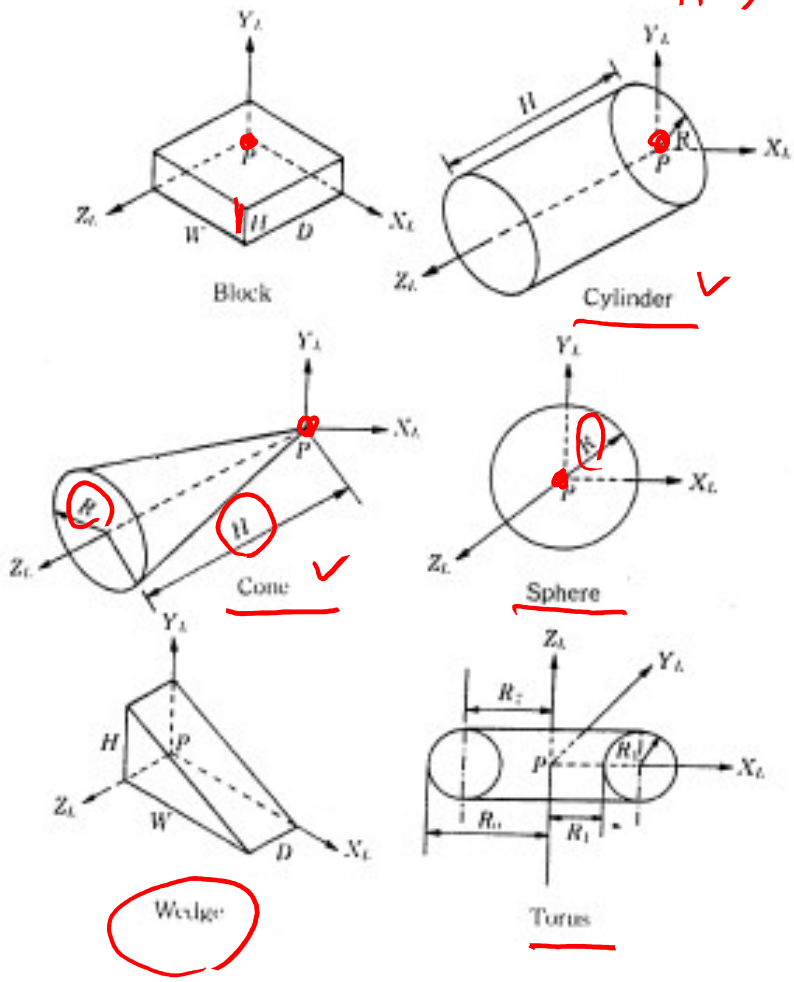
곡면(surface) 정의

- 기본곡면 이용
  - 원통(cylinder), 원추(cone), 구(sphere), 타원체(ellipsoid), 원환체(torus)
- 두 곡면 사이를 Blending
- 윤곽곡선이나 단면곡선 Sweeping
- 그물과 같은 곡선망을 이용
  - Curve-net fitting
- 3D 점들의 집합을 이용
  - Surface fitting

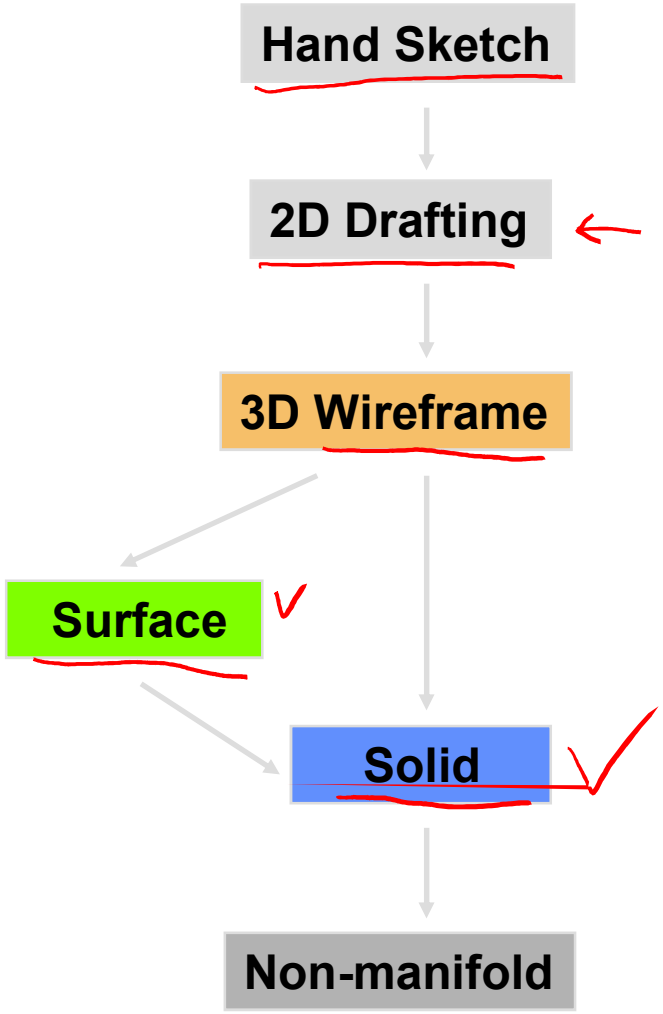


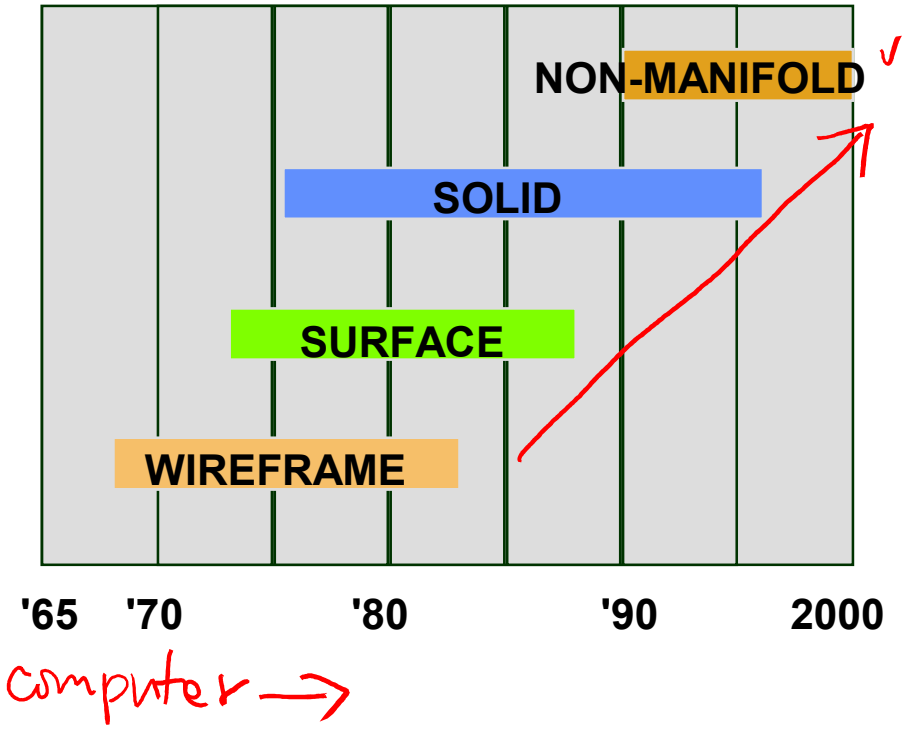
솔리드(solid) 정의

- 곡면 + 부피(닫힌 형태)
- Primitives
- Complex Solids
  - Boolean operations of primitives



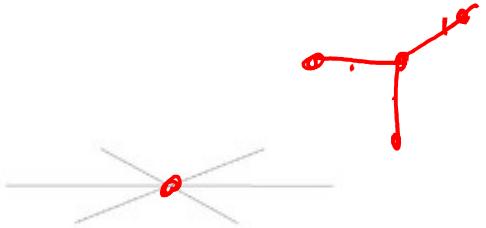
Evolution of Geometric Modeling Systems



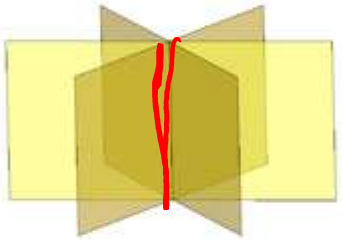


Manifold vs. Non-manifold

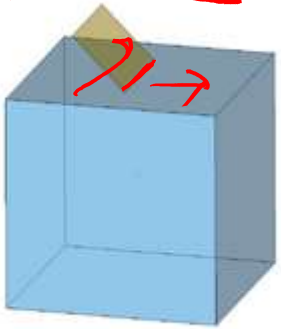
- Manufacturable vs. Non-manufacturable
- In manifold model,
  - Every point on a surface is two-dimensional
  - Every point has a neighborhood that is homeomorphic to 2D disk



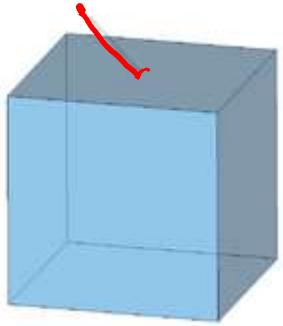
Vertex in a wire body



Edge in a sheet body



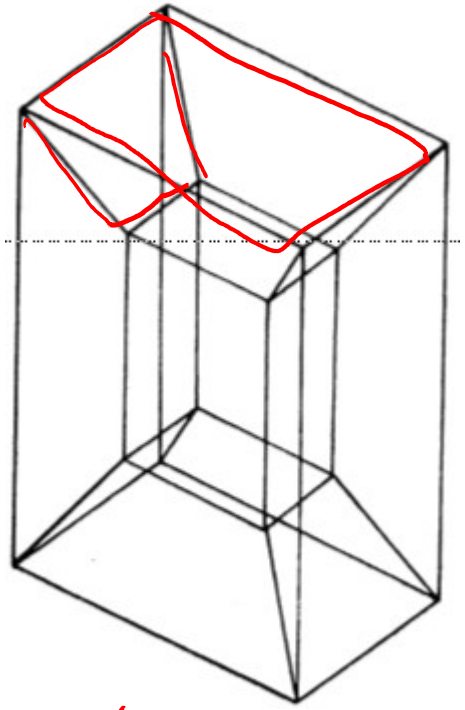
Edge

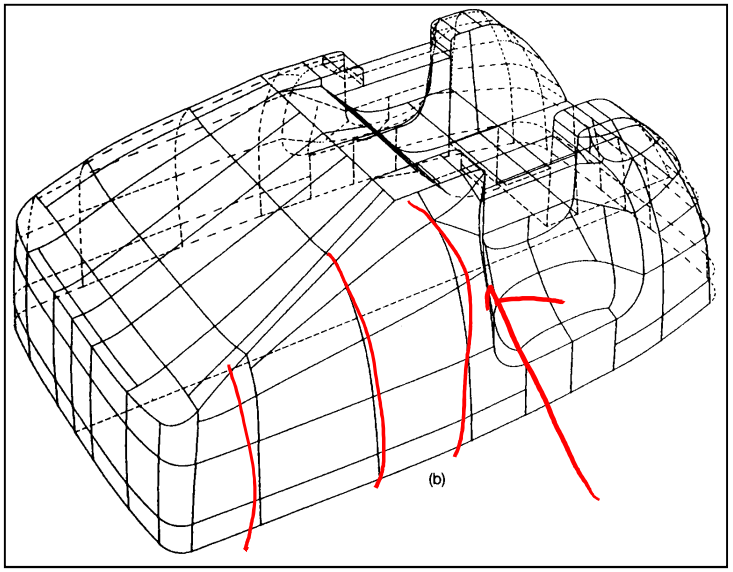


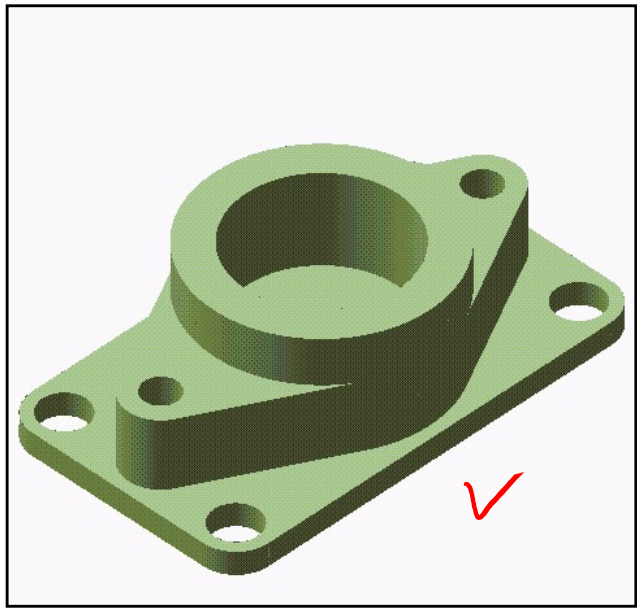
Vertex

Geometric Model

- Wireframe/ Surface/ Solid Model







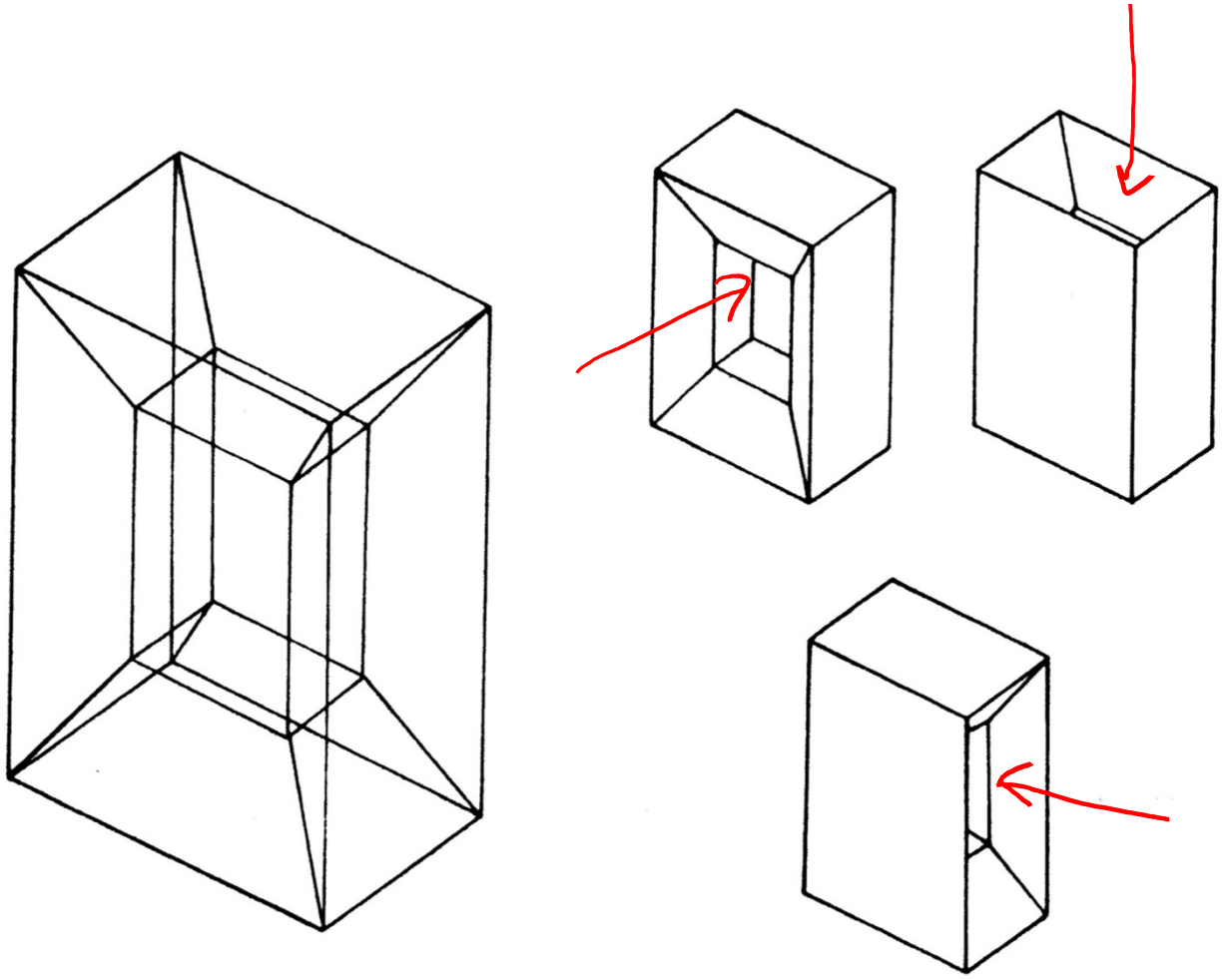
Contents

- Wireframe Modeling Systems
- Surface Modeling Systems
- Solid Modeling Systems
  - Modeling Functions
  - Data Structure
  - Euler Operators
  - Boolean Operations
  - Calculation of Volumetric Properties
- Nonmanifold Modeling Systems

Wireframe Model

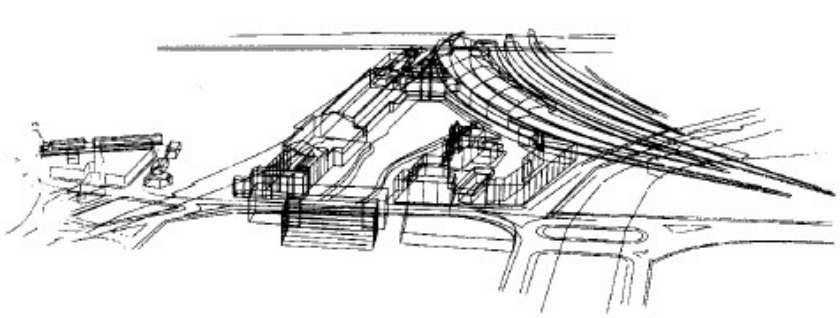
- Database
  - Represent a shape by its characteristic lines and end points
- Advantages
  - Require simple user input to create a shape
  - Easy to develop systems
- Disadvantages
  - Models can be ambiguous
  - No boundary surfaces and volume information
  - Impossible to calculate mass properties, drive NC tool paths, generate FEM meshes
- Products
  - Sketchpad, Steerbear

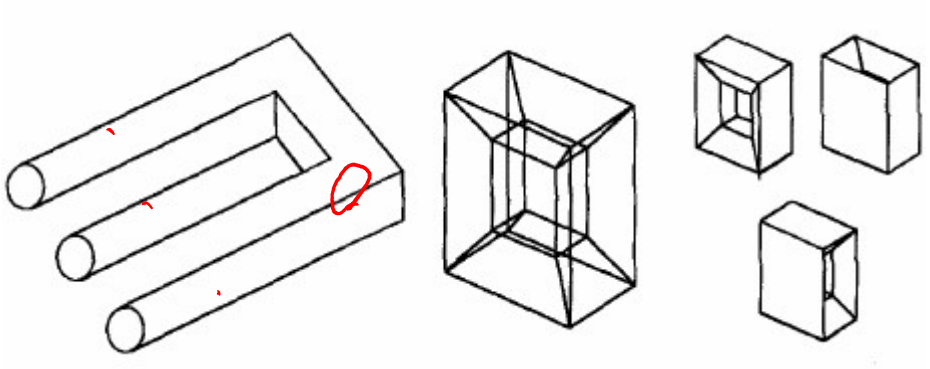
Ambiguous Wireframe Model

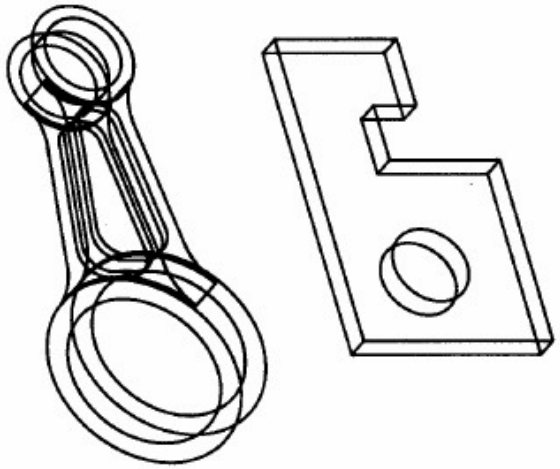


Basic 3D Models: Wireframe (1)

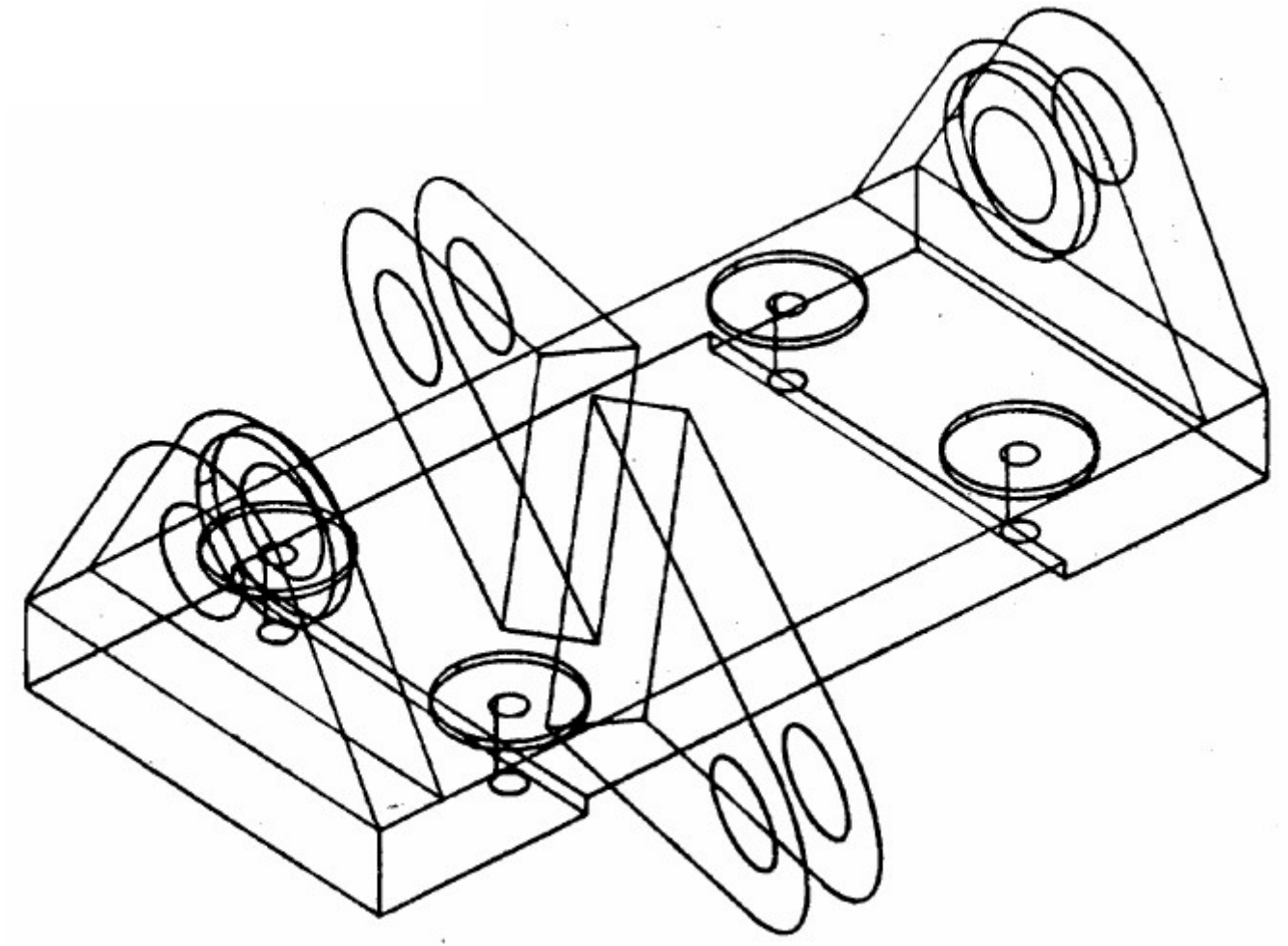
- Wireframes
  - easiest of all to create
  - nothing hidden
  - visually ambiguous
  - topological problems?





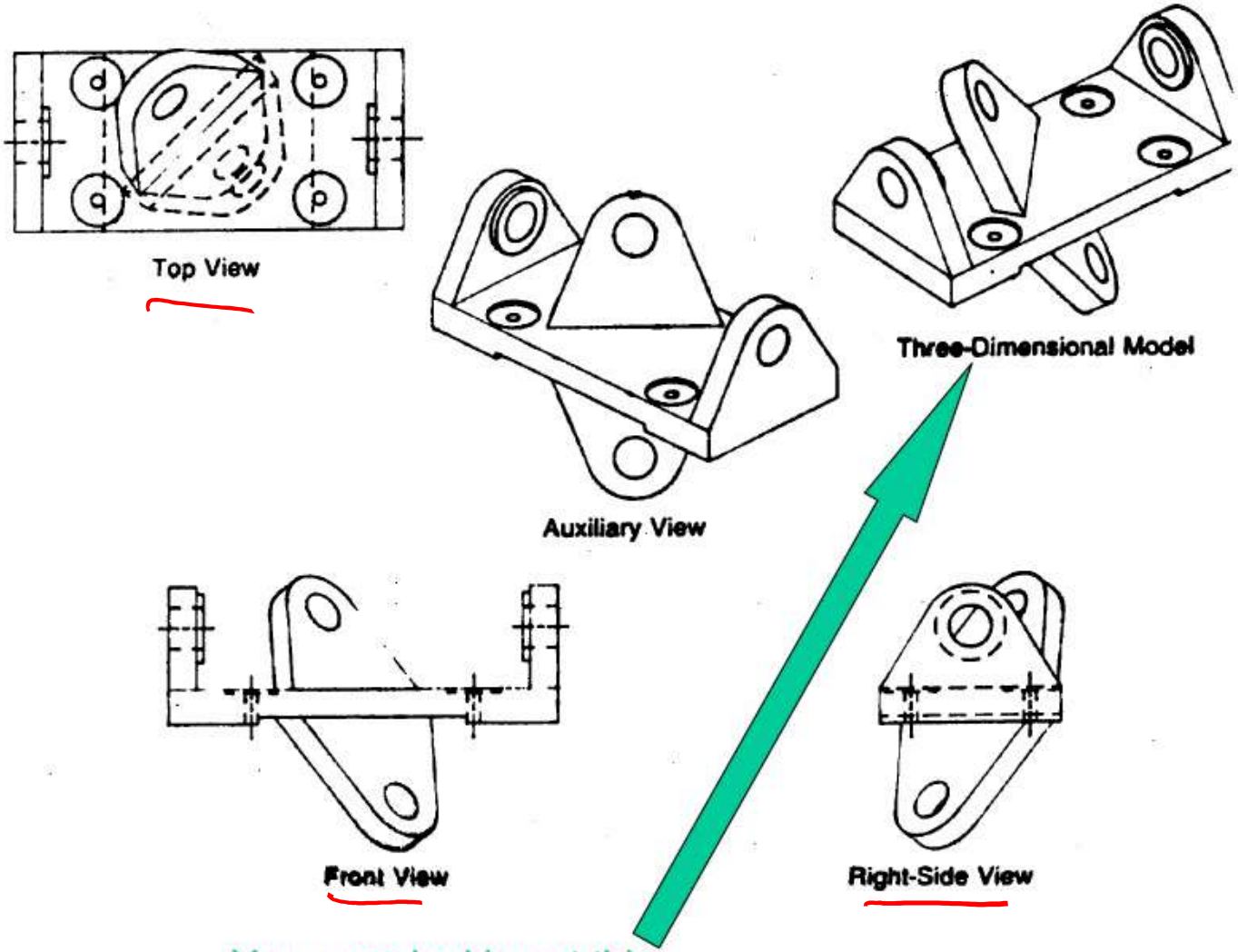


Basic 3D Models: Wireframe (2)



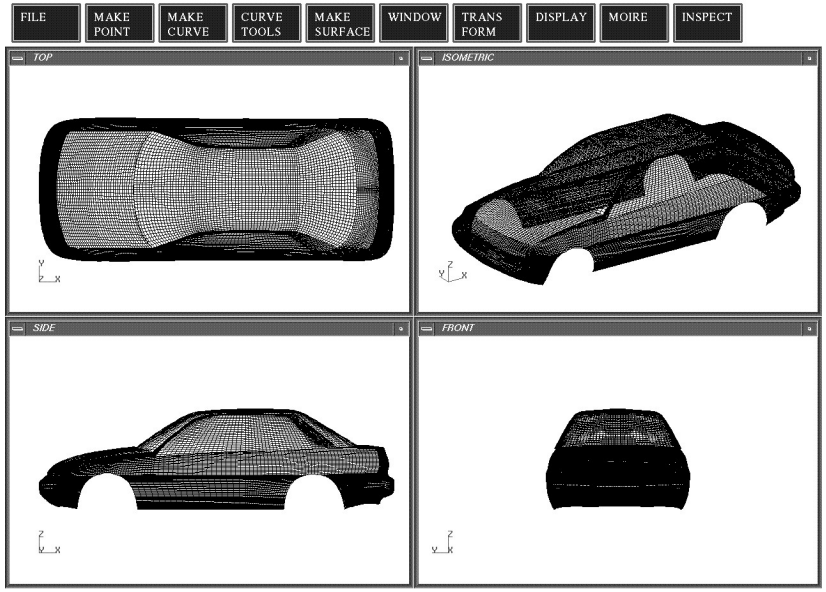
Can you figure out what this is? (It's really a valid wireframe model…)

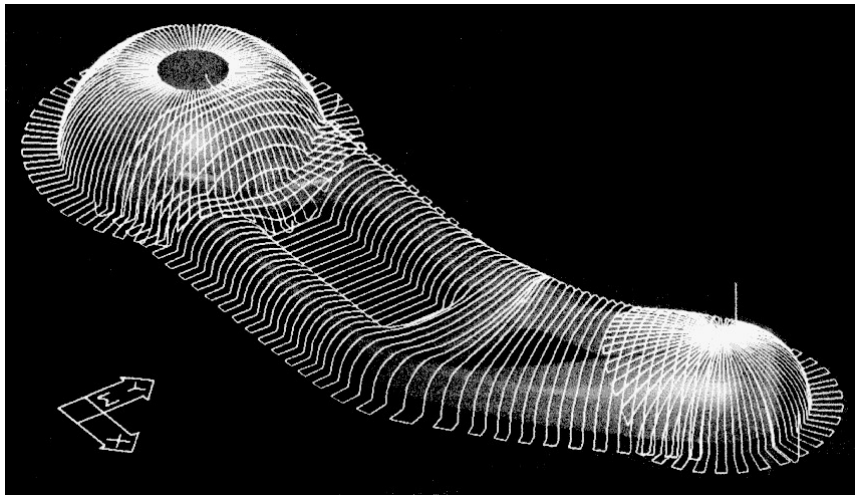
Basic 3D Models: Wireframe (3)



Surface Model (1)

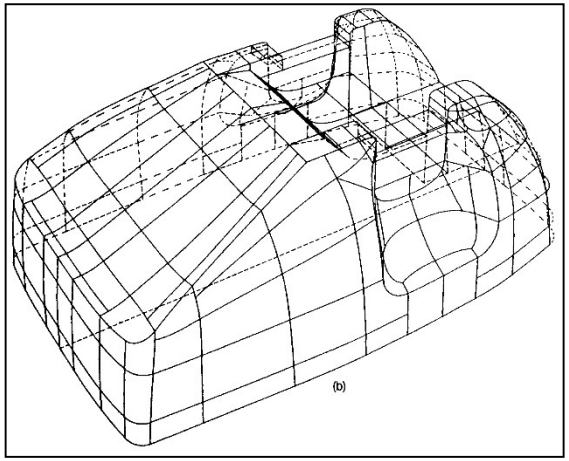
- Purpose
  - Visual model for aesthetical evaluation
  - Mathematical description to generate the NC Tool Paths

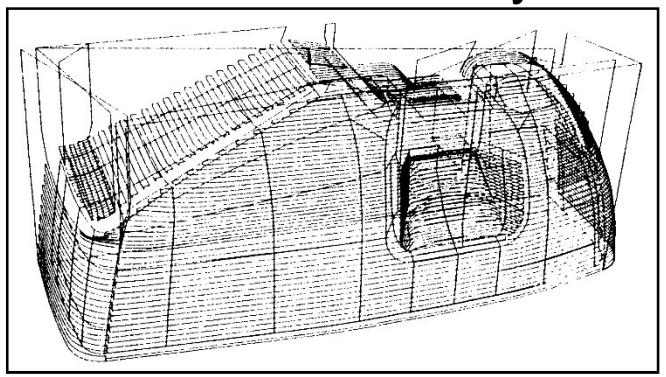




Surface Model (2)

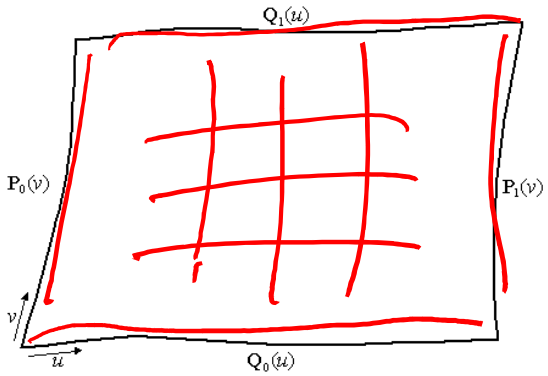
- Database
  - Characteristic lines and end points + surface (+surface connectivity) information
  - surface connectivity information
    - Useful for checking gouging of a surface adjacent to the surface being machined
    - If the system includes only a list of surface equations of infinite surfaces without connectivity information, the application should derive the surface boundaries and their connectivity information
  - NC Tool Path Generation with Surface Connectivity Information

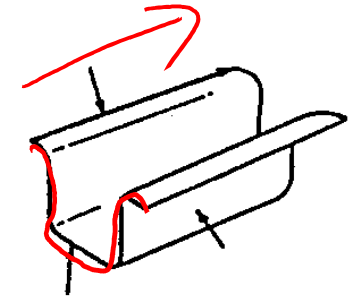




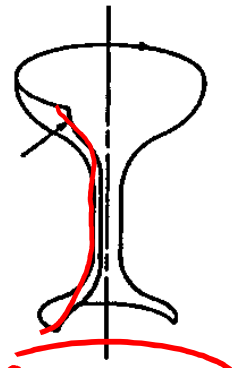
Surface Model (3)

- Creating methods
  - Interpolating the input points
  - Interpolating the curve nets
  - Translating or Revolving a specified curve





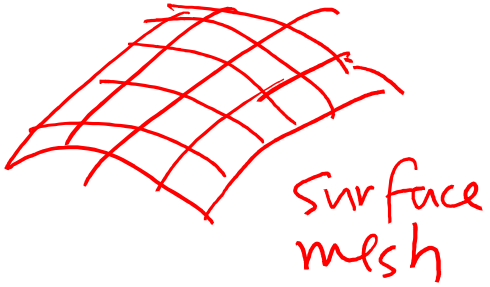
PAD
(translate)

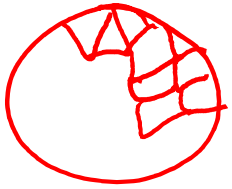


SHAFT
(revolve)

Surface Model (4)

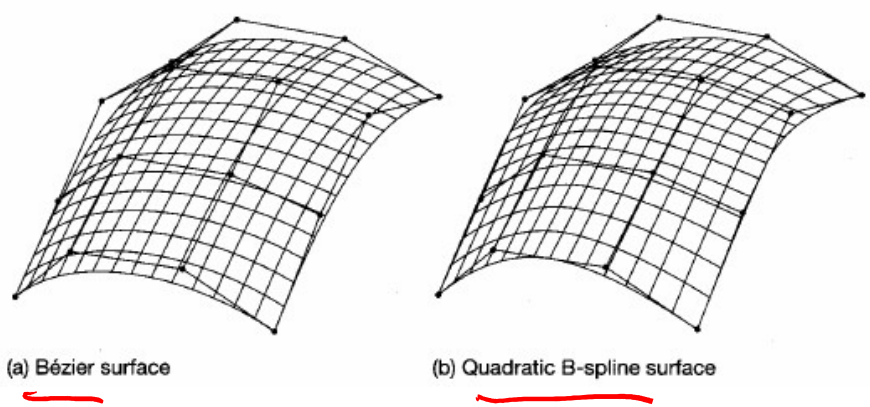
- Advantages
  - Automatic NC tool path generation
  - Visual model colored and shaded
- Disadvantages
  - Cannot calculate mass properties
  - Cannot generate FEM meshes
- Products
  - CATIA, ALIAS, OMEGA, SPEED+
  - Applications for CAM and CG

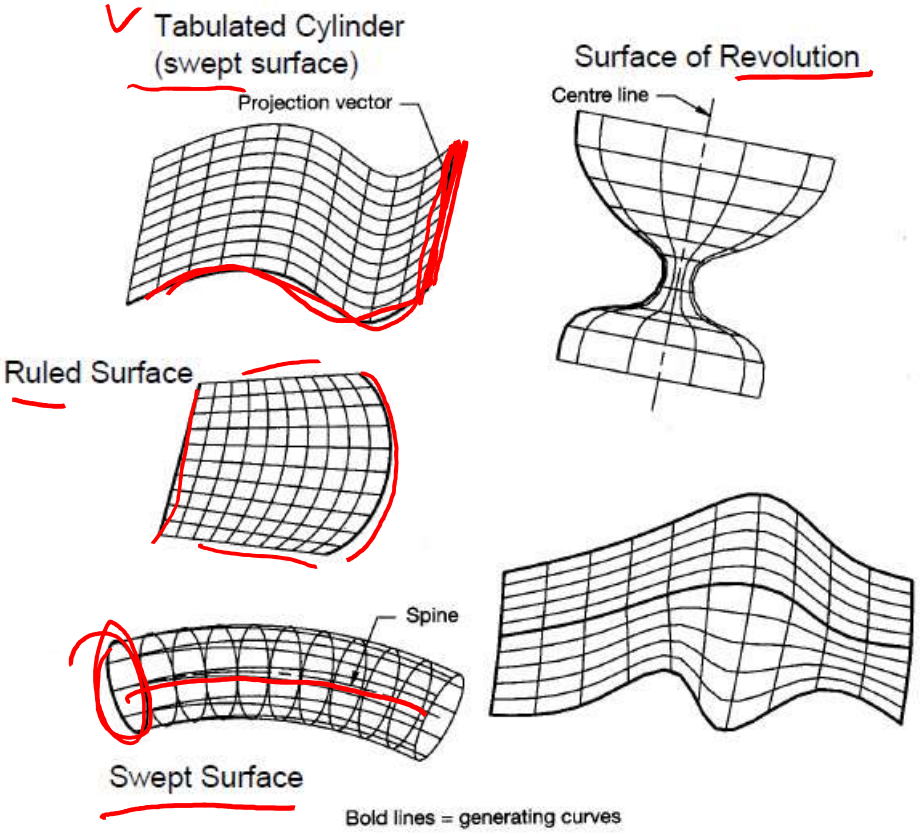




Basic 3D Models: Surface (1)

- Surface models
  - accurate surface definition
  - enclose a volume
  - topologically difficult to handle…

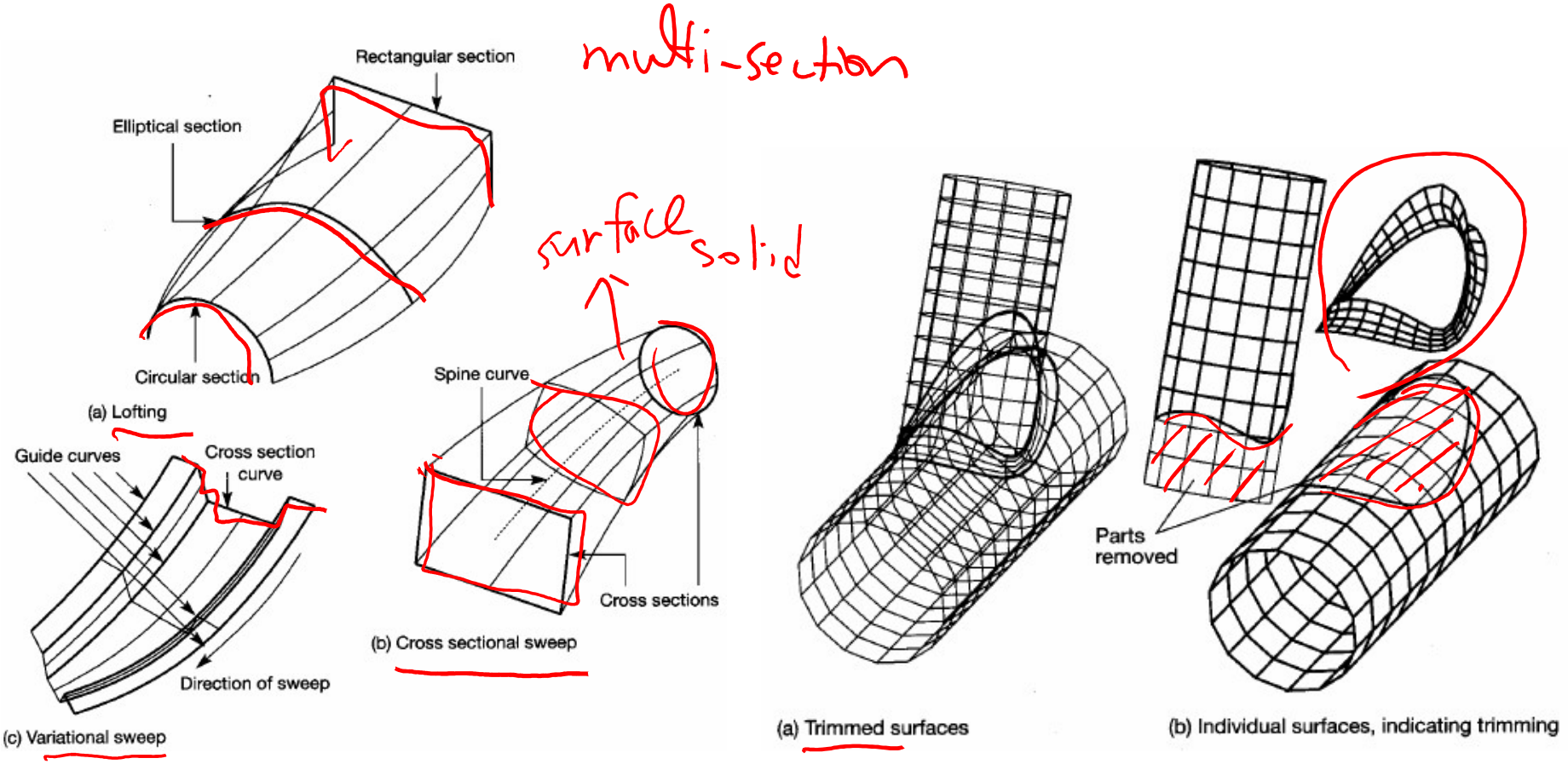




NOTE: control points define shape of surface

Basic 3D Models: Surface (2)

- More complex surfaces



Solid Model (1)

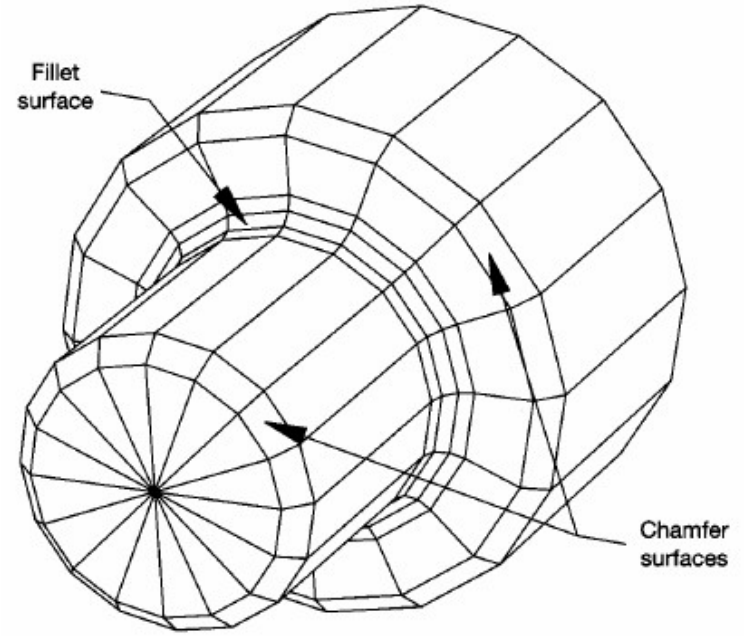
- Database
  - Store a closed volume
  - Surface information + In/out information
  - Not allow a simple set of surfaces or characteristic lines if it can not form a closed volume
- Products
  - TIPS, PADL-2, BUILD2, ROMULUS, DESIGNBASE, Pro/Engineer, SolidWorks, SolidEdge, CATIA, ParaSolid

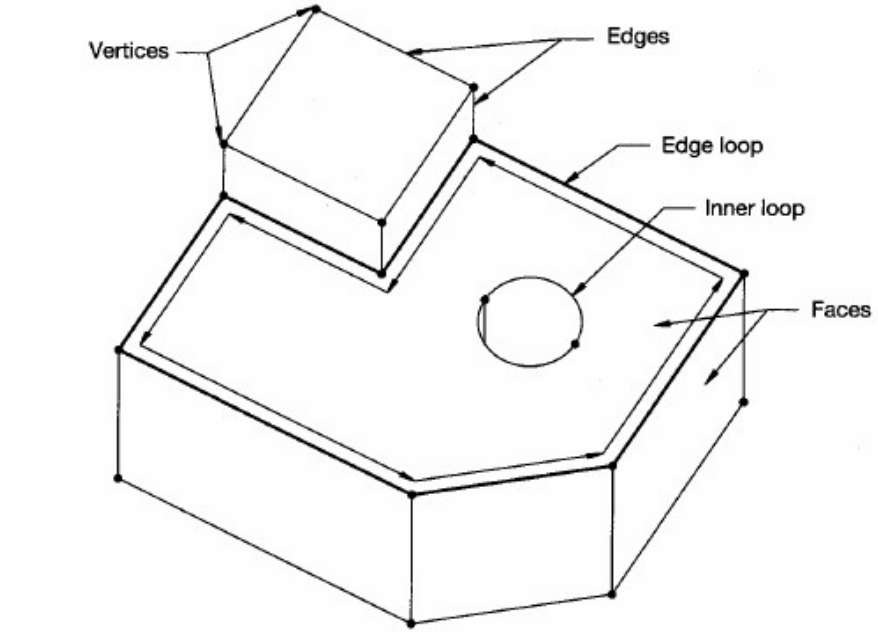
Solid Model (2)

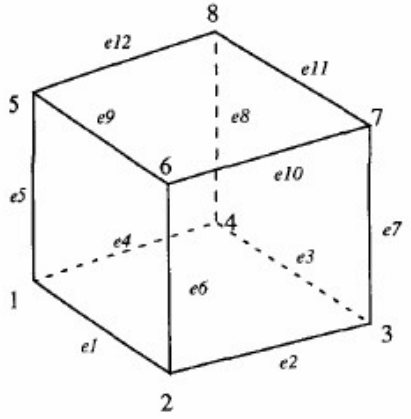
- Advantages
  - Calculate mass properties
  - Generate FEM solid meshes
  - Interference checking between objects
  - 3D visual model colored and shaded
  - NC tool path generation and simulation
- Disadvantages
  - Permit only a complete solid model
  - Require a large amount of input data (complicated and difficult)
  - Large amount of data storage

Basic 3D Models: Solid (1)

- Volumes
  - combine surfaces together
  - topology is a problem
  - boundary representation models (B-rep)





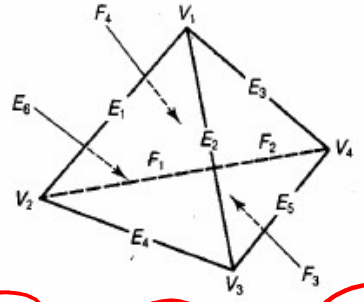



```
v1 x1 y1 z1     f1 v1 v2 v3 v4
v2 x2 y2 z2     f2 v6 v2 v1 v5
v3 x3 y3 z3     f3 v7 v3 v2 v6
v4 x4 y4 z4     f4 v8 v4 v3 v7
v5 x5 y5 z5     f5 v5 v1 v4 v8
v6 x6 y6 z6     f6 v8 v7 v6 v5
v7 x7 y7 z7
v8 x8 y8 z8
```

A vertex-based boundary model

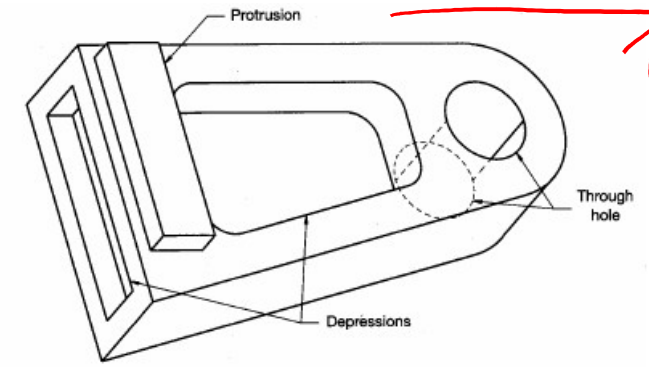
Basic 3D Models: Solid (2)

- Boundary models (b-rep)
  - aka: graph-based models
  - graph nodes & edges



Vertices	Edges	Faces
V_1	E_1	F_1
V_2, V_3, V_4 E_1, E_2, E_3 F_1, F_2, F_4	V_1, V_2 E_2, E_3, E_4, E_6 F_1, F_4	V_1, V_2, V_3 E_1, E_4, E_2 F_2, F_3, F_4
V_2	E_2	F_2
V_1, V_3, V_4 E_1, E_4, E_6 F_1, F_3, F_4	V_1, V_3 E_1, E_3, E_4, E_5 F_1, F_2	V_1, V_3, V_4 E_2, E_5, E_3 F_1, F_3, F_4
V_3	E_3	F_3
V_1, V_2, V_4 $E_2, \ldots$	V_1, V_4 $E_1, E_2, \ldots$	V_4, V_3, V_2 $E_4, \ldots$

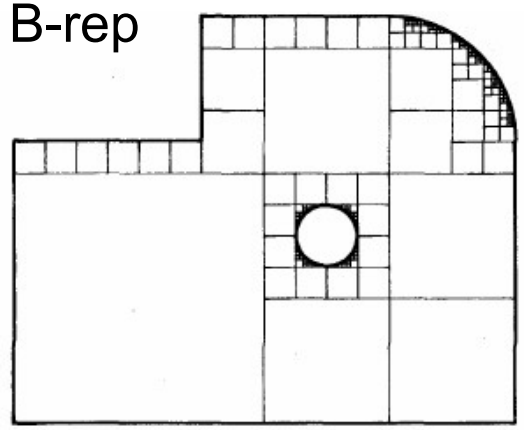
- Rules
  - faces bounded by single loop or ring of edges
  - edge joins exactly 2 faces and is terminated by vertices
  - at least 3 edges meet at each vertex
  - Euler's Rule applies: V-E+F=2 (extended: V-E+F-H=2(S-P))



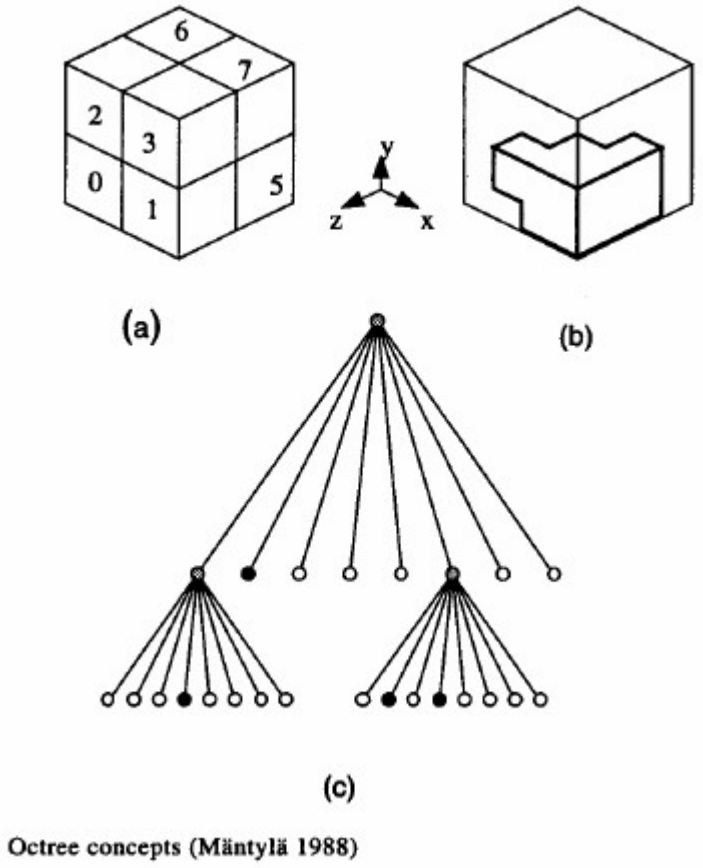
	Vertices	Edges	Faces	Holes	Passages
Basic shape	8	12	6		
Protrusion adds	8	12	5	1	
Depression with sharp corners adds	8	12	5	1	
Depression with filleted corners adds	16	24	9	1	
Through hole adds	4	6	2	2	1

Basic 3D Models: Solid (3)

- Solid models
  - Notion of inside vs. outside
  - Analytical models (extend surface to 3-parameters)
  - Spatial decomposition or cell enumeration
  - Constructive solid geometry (CSG)
  - B-rep

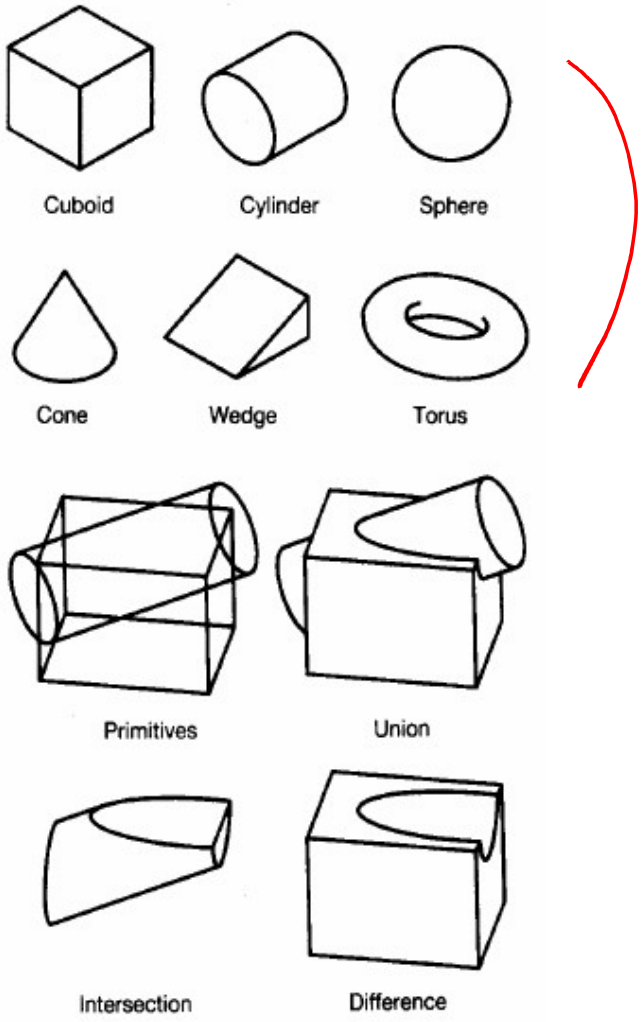


Quadtree (2D)

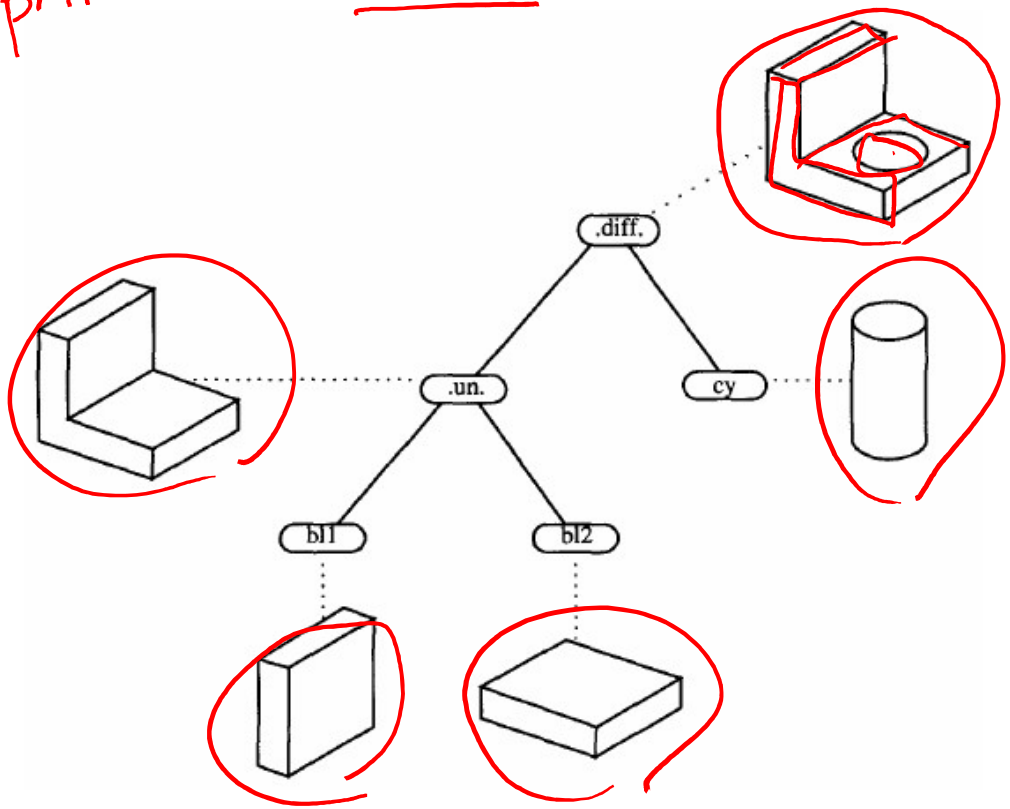


Octree (3D)

Basic 3D Models: Solid (4)



primitive + boolean operation

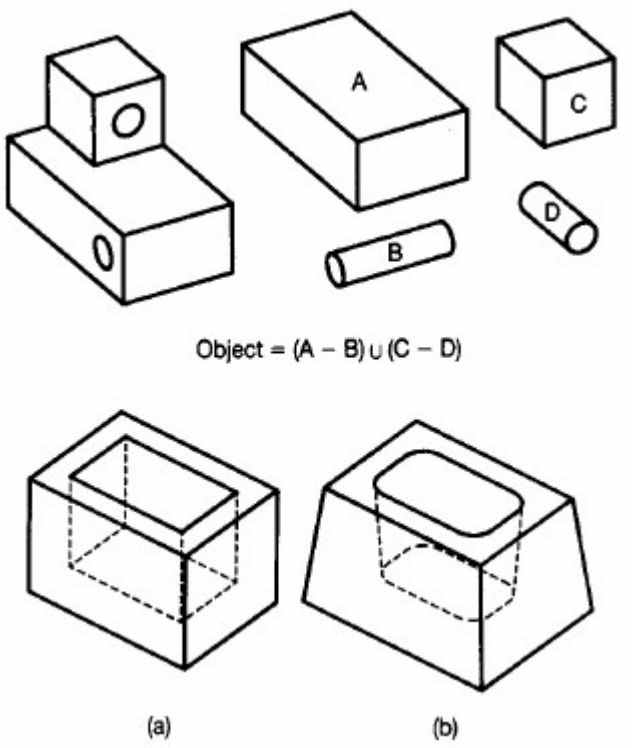


CSG Primitives and Boolean Operations

Graph-based CSG representation

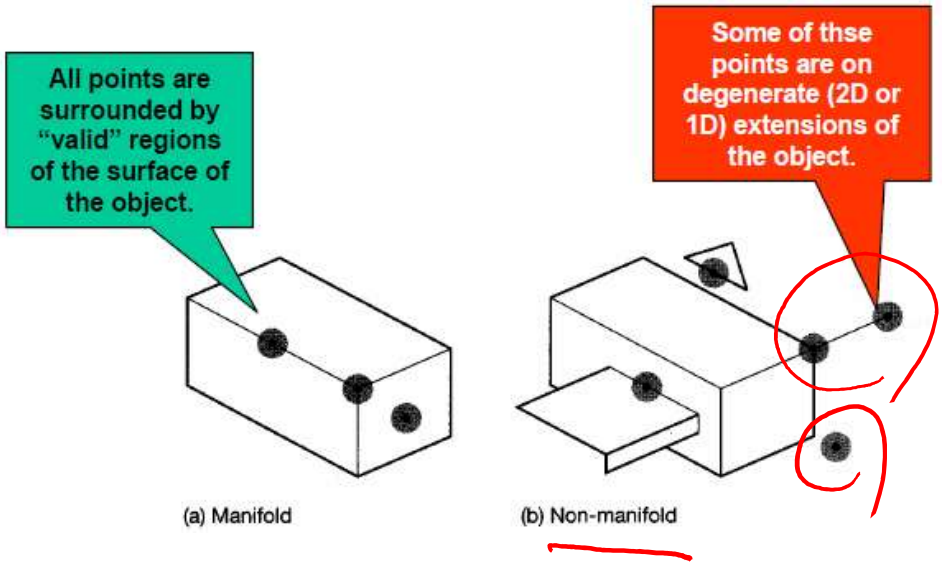
Basic 3D Models: Solid (5)

This is a “simple” CSG object...



This is a much more complex CSG object!
(can you see why this is so?)

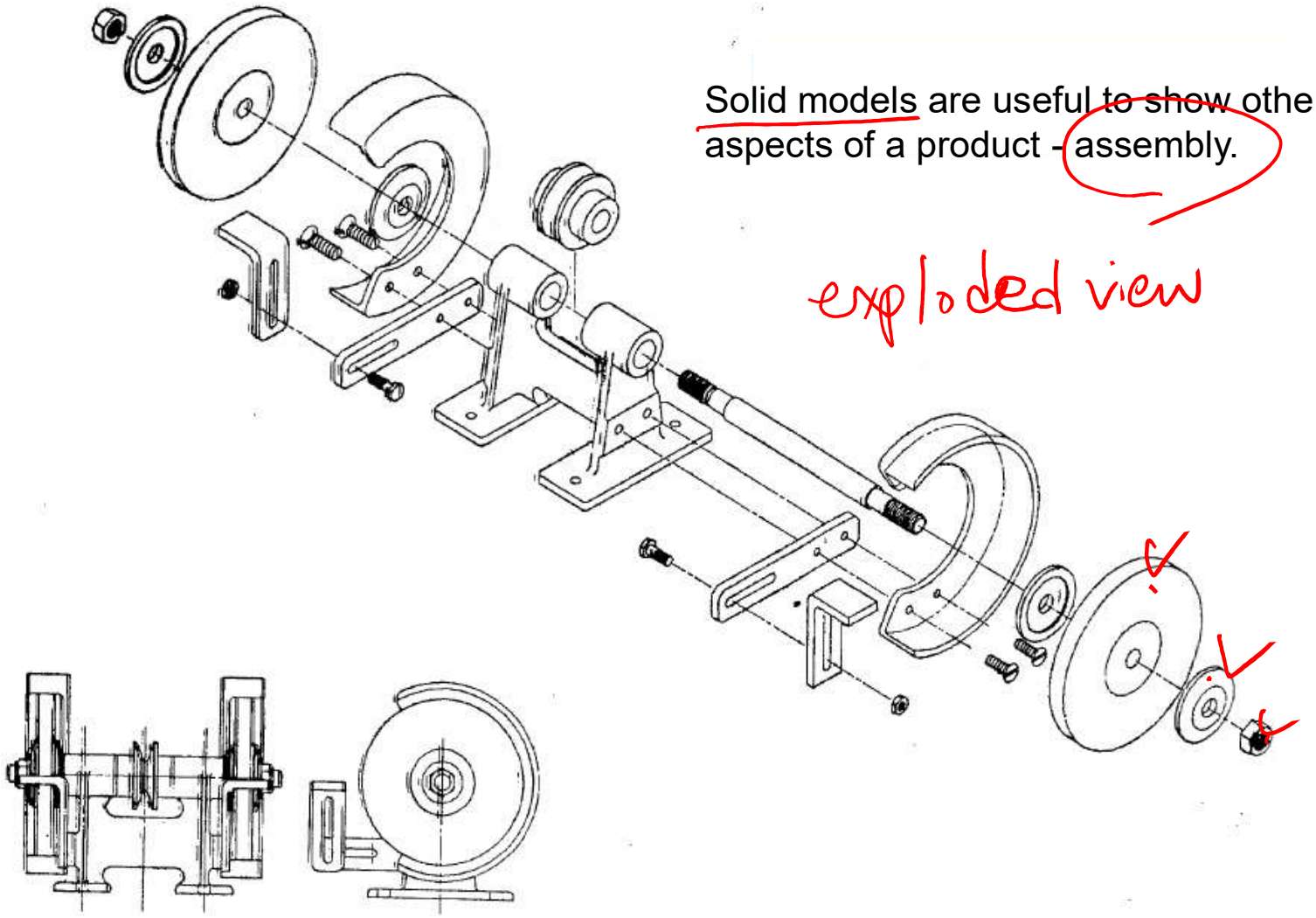
Solid models can have problems...



NOTE: By restricting the types of Boolean operations that are allowed, we can avoid most of these degeneracies.

Solid models are useful to show other aspects of a product - assembly.

exploded view

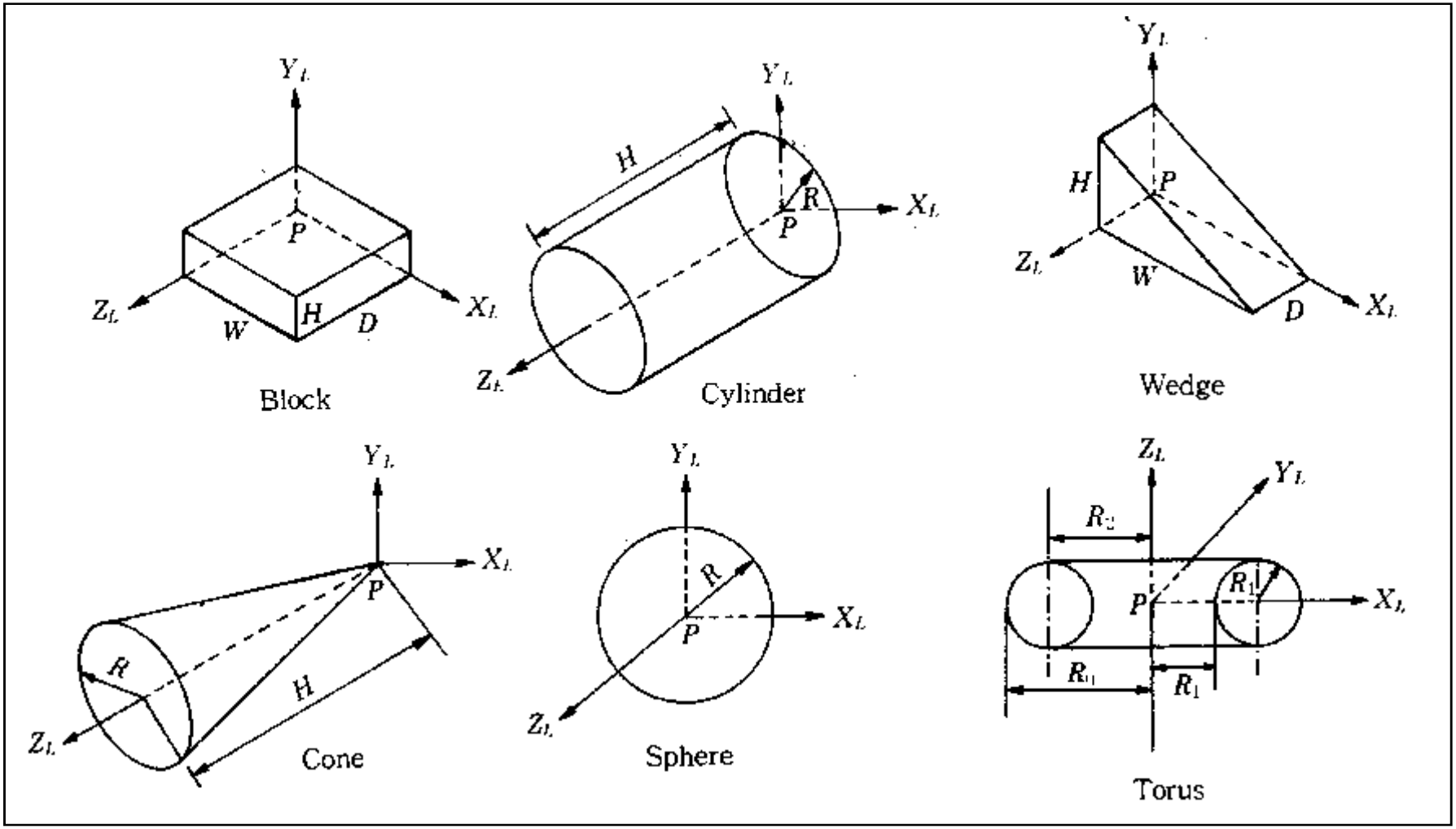


Solid Modeling Functions

- Primitive Creation Functions + Boolean Operations
- Surface Moving Functions
  - Sweeping, Swinging (used for Parametric Modeling)
  - Skinning
- Local Modification Functions
  - Rounding(or Blending, or Filleting), Lifting
- Boundary Modeling
- Feature-Based Modeling
- Parametric Modeling

CATIA
Dressed-up

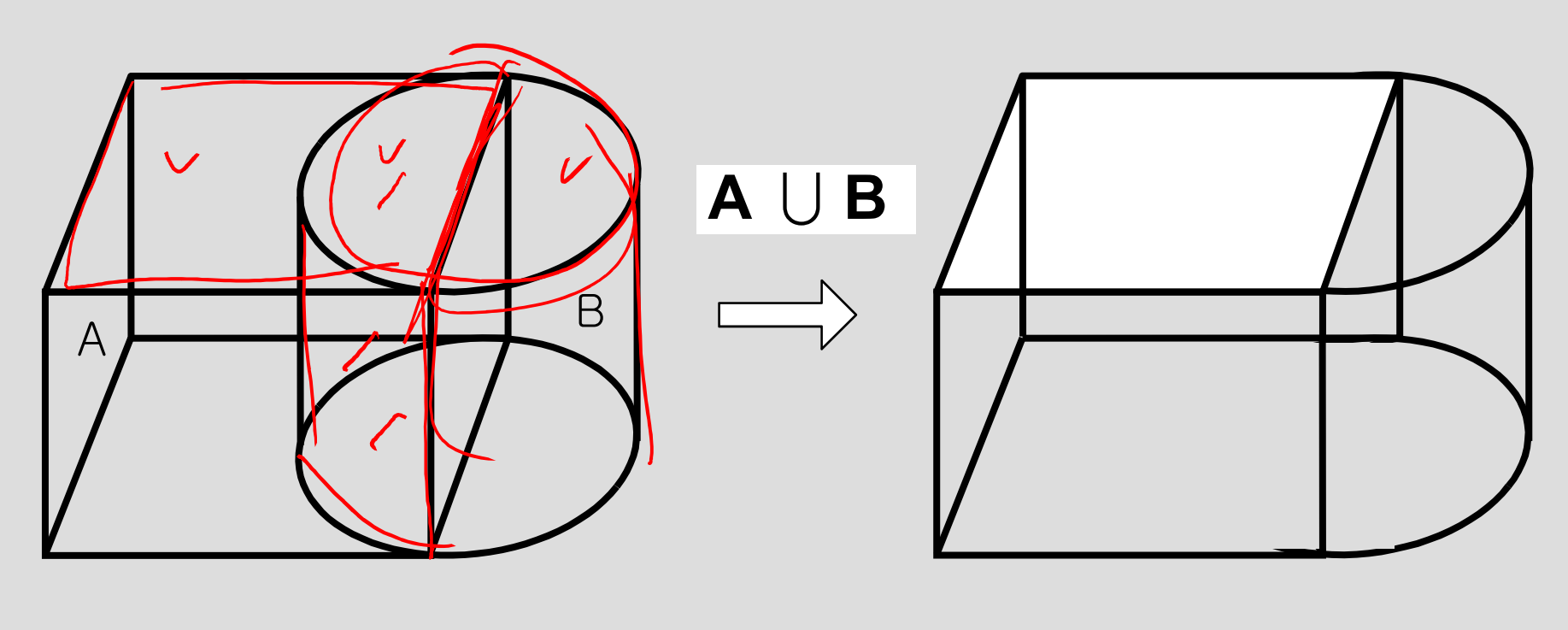
Primitive Creation Functions



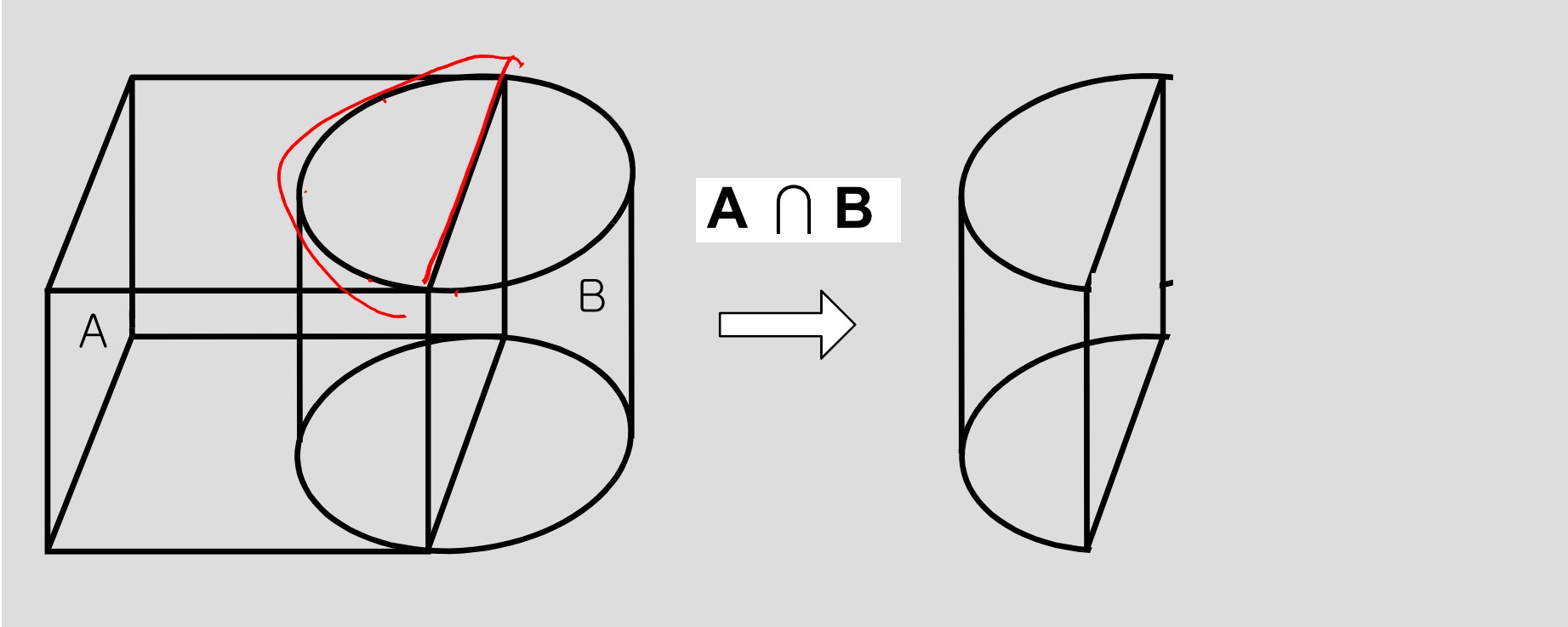
Boolean Operations

- Basic Idea:
  - Each primitive solid is assumed to be a set of points, a Boolean operation is performed on point sets, and the result is a solid composed of the points resulting from the operation.
- Boolean Operations
  - Union
  - Intersection
  - Difference
  - (Similar Operations: Sectioning and Gluing)

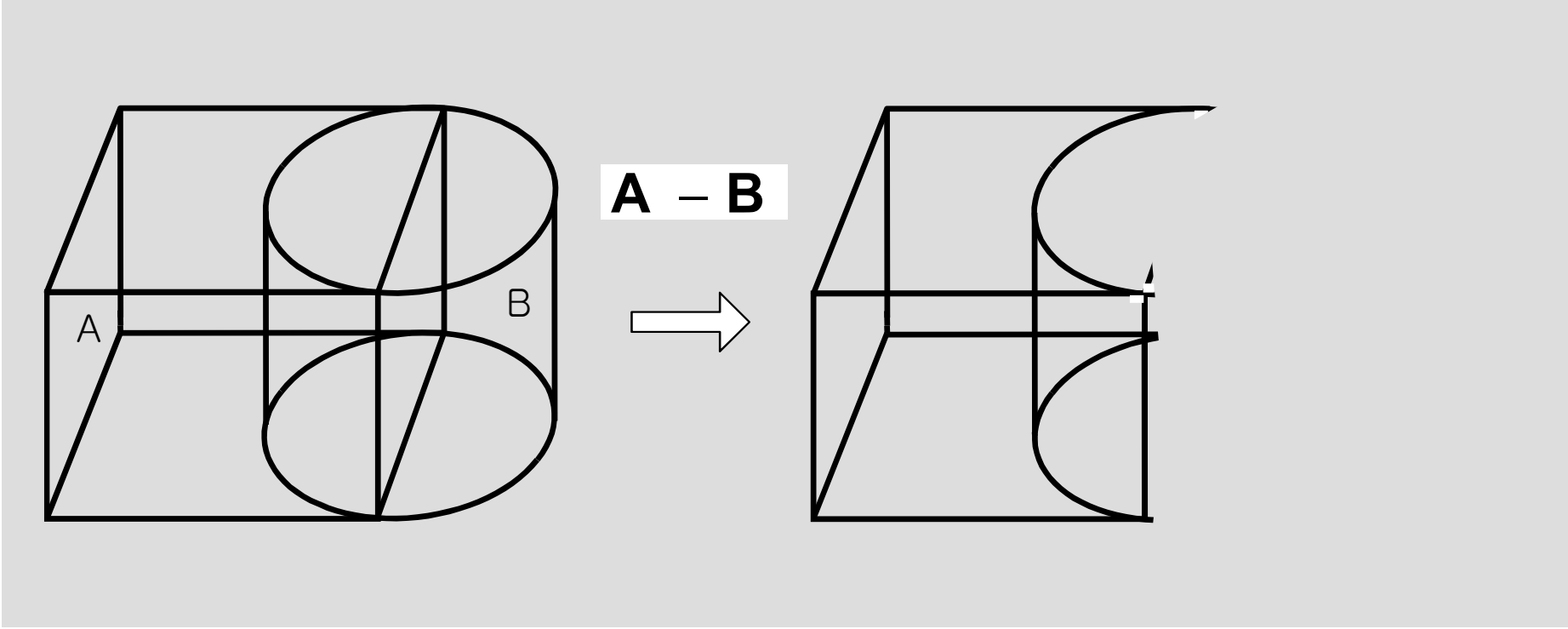
Union Operation



Intersection Operation

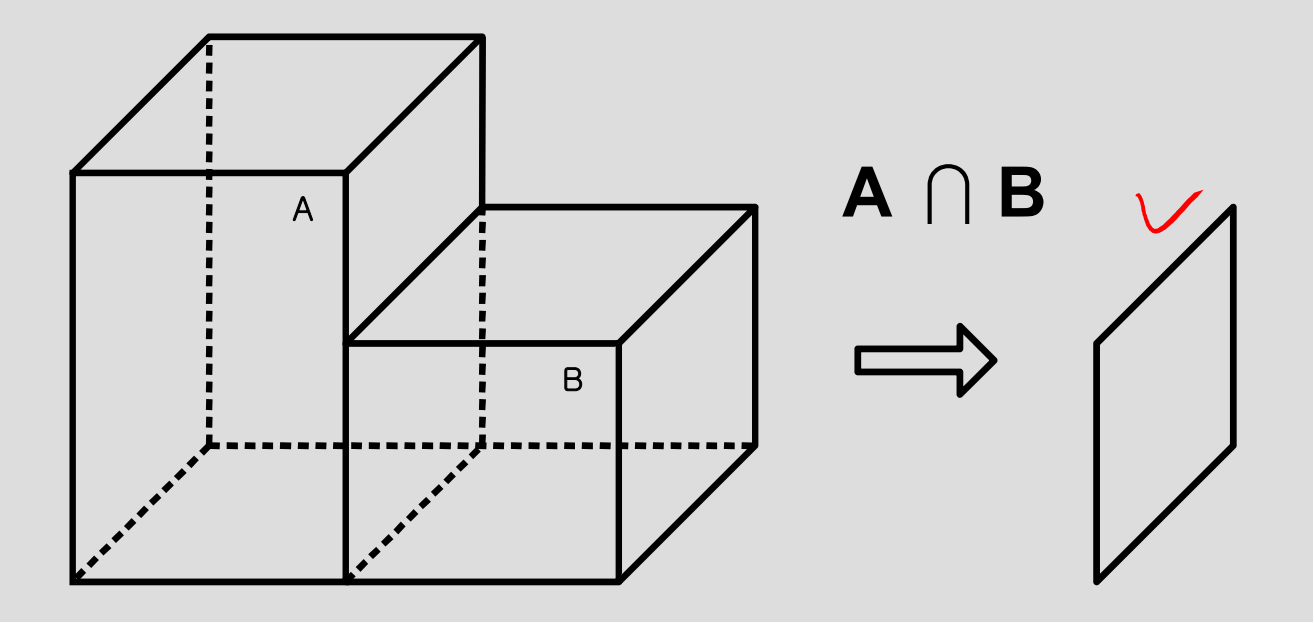


Difference Operations



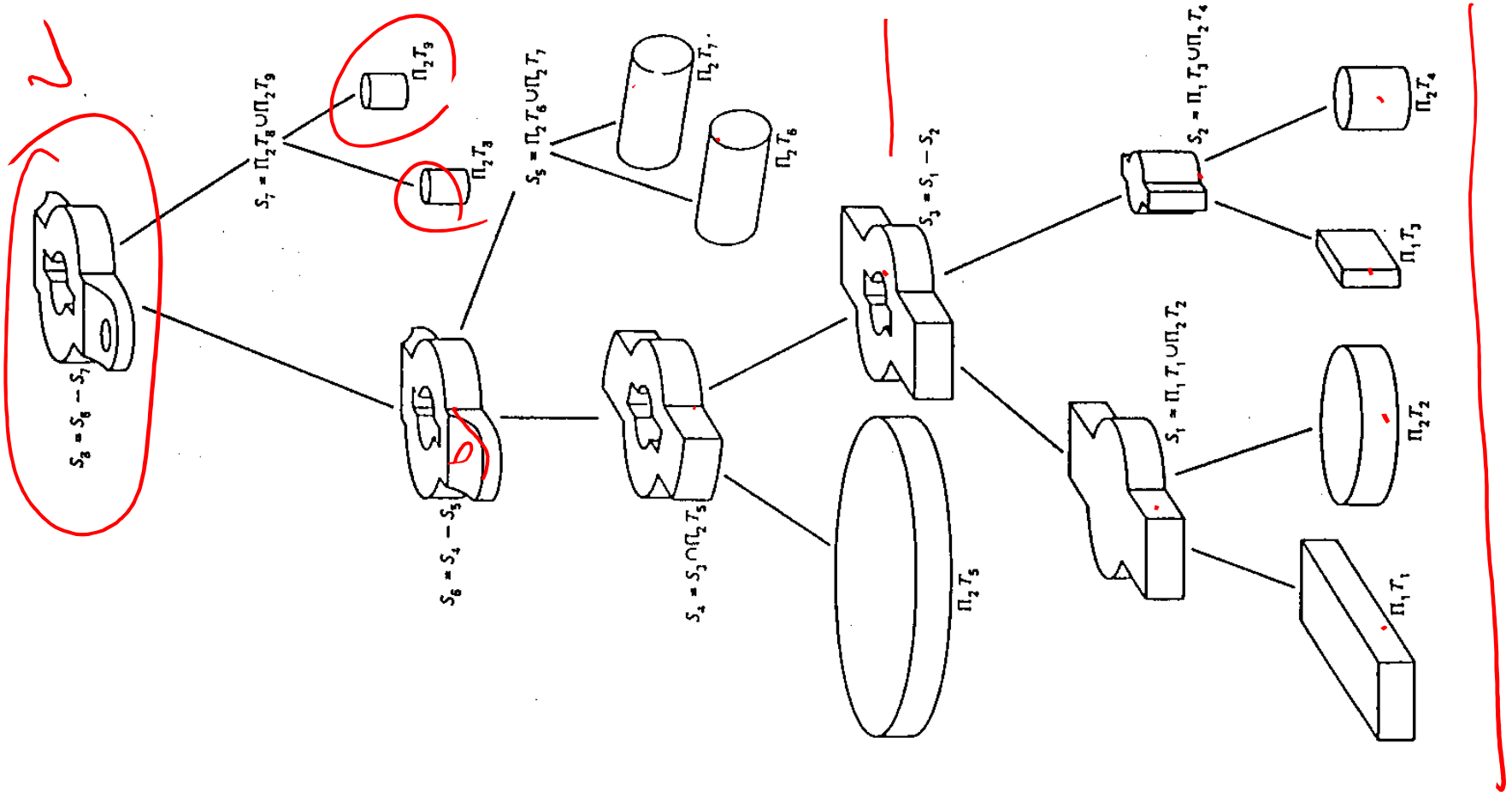
Limitation of Solid Models in Boolean Operations

- Solid models are not closed to Boolean operations

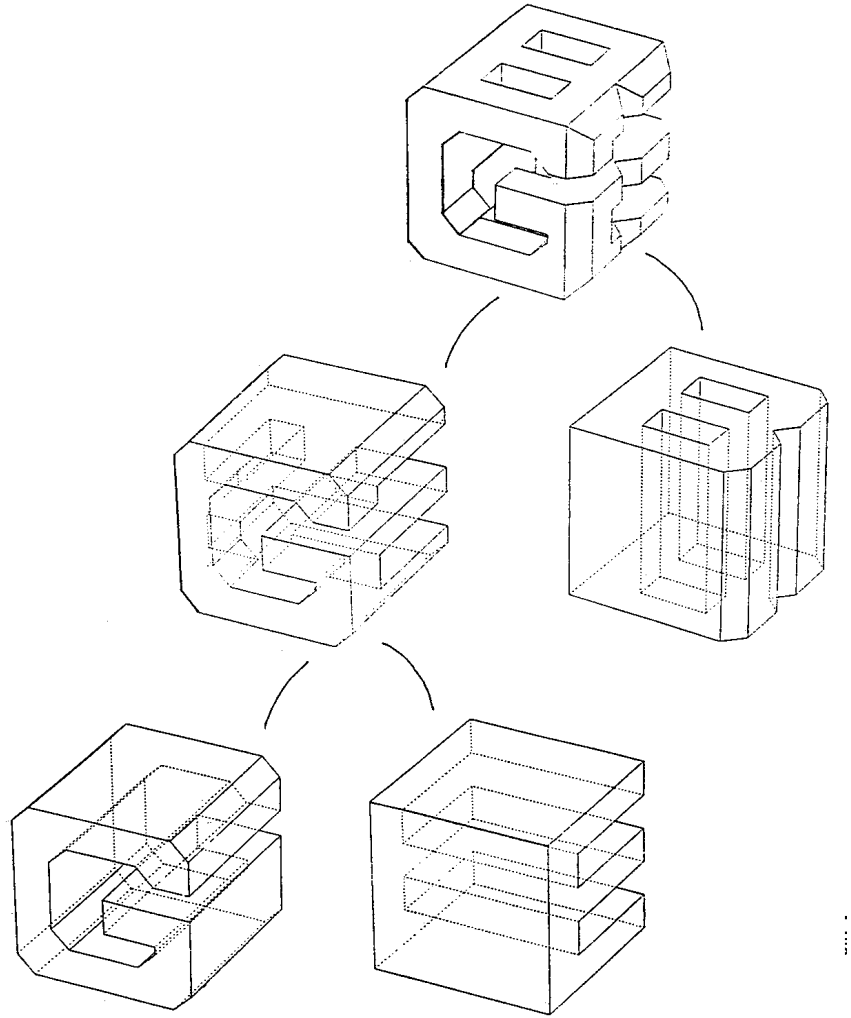


Result is $\varnothing$ in Solid Modeler

Example of Boolean Operations (1)

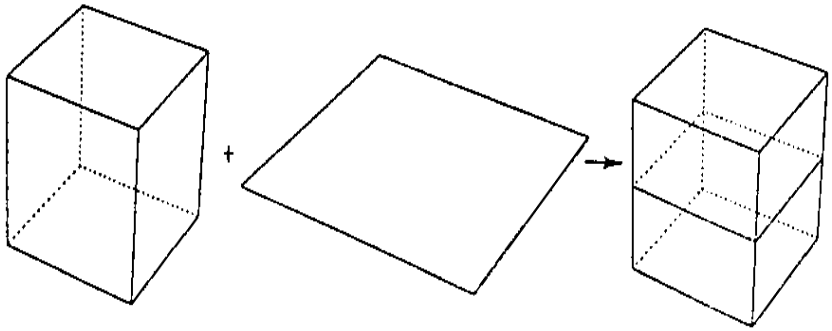


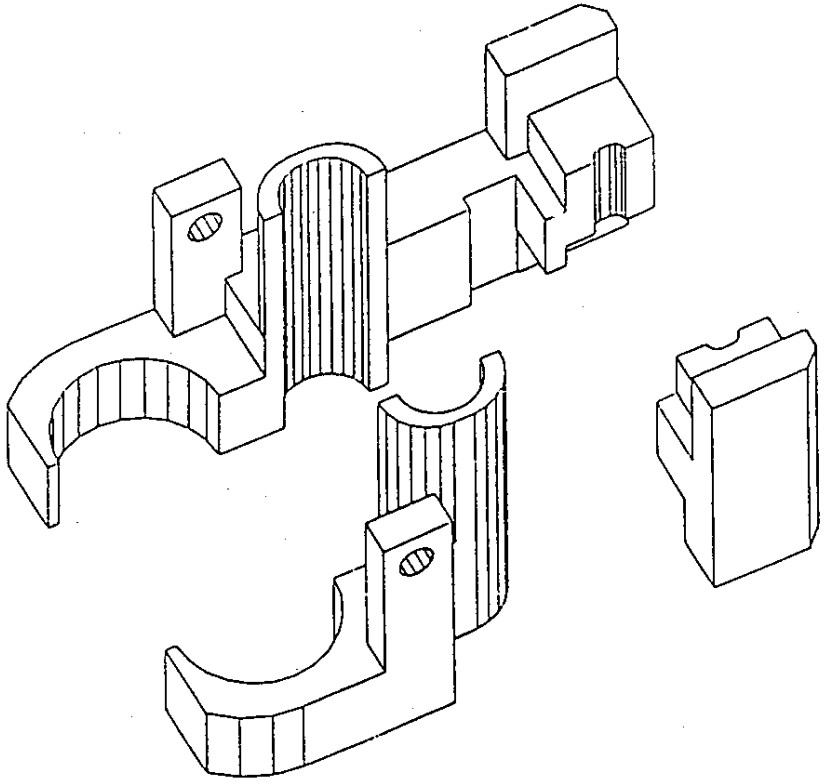
Example of Boolean Operations (2)



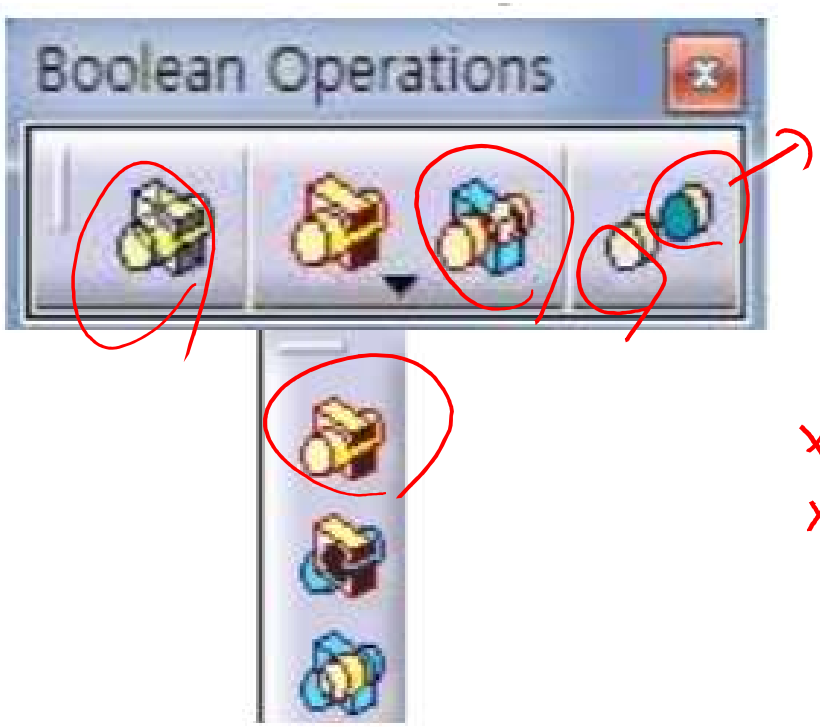
Sectioning (or Cutting)

- Useful for Cross-Sectional View



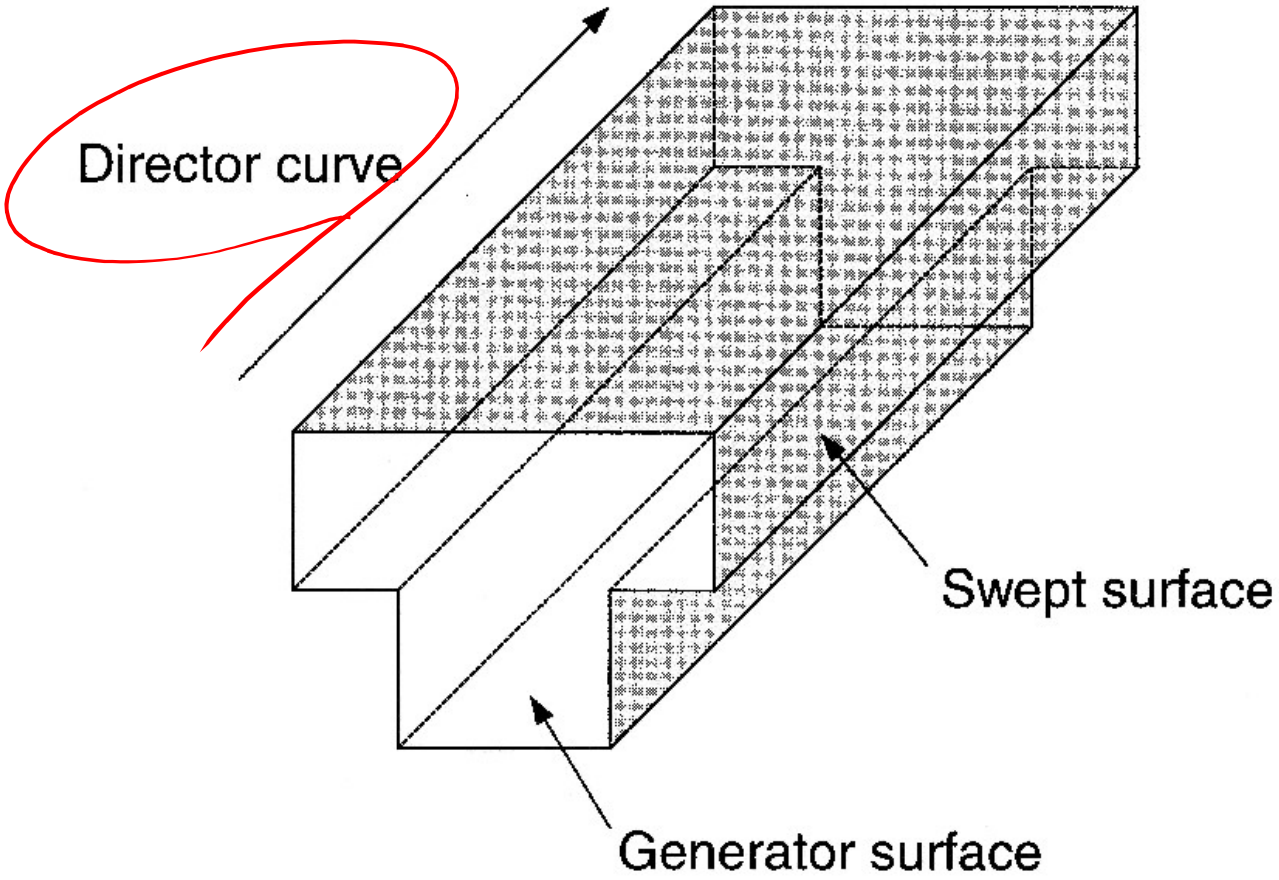


CATIA: Part Design

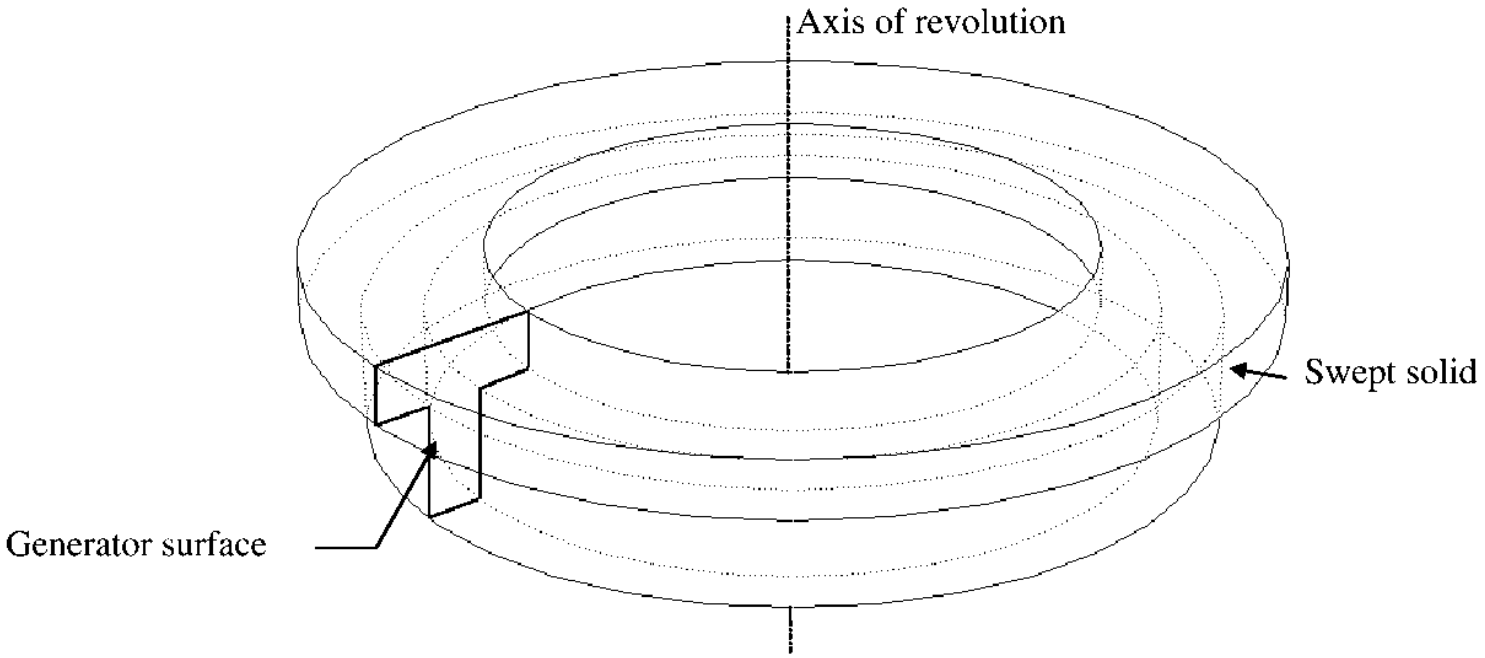


- Assemble (body속성 유지)
- Add
- Remove
- Intersect
- ✓ Union Trim
- ✗ Remove Lump

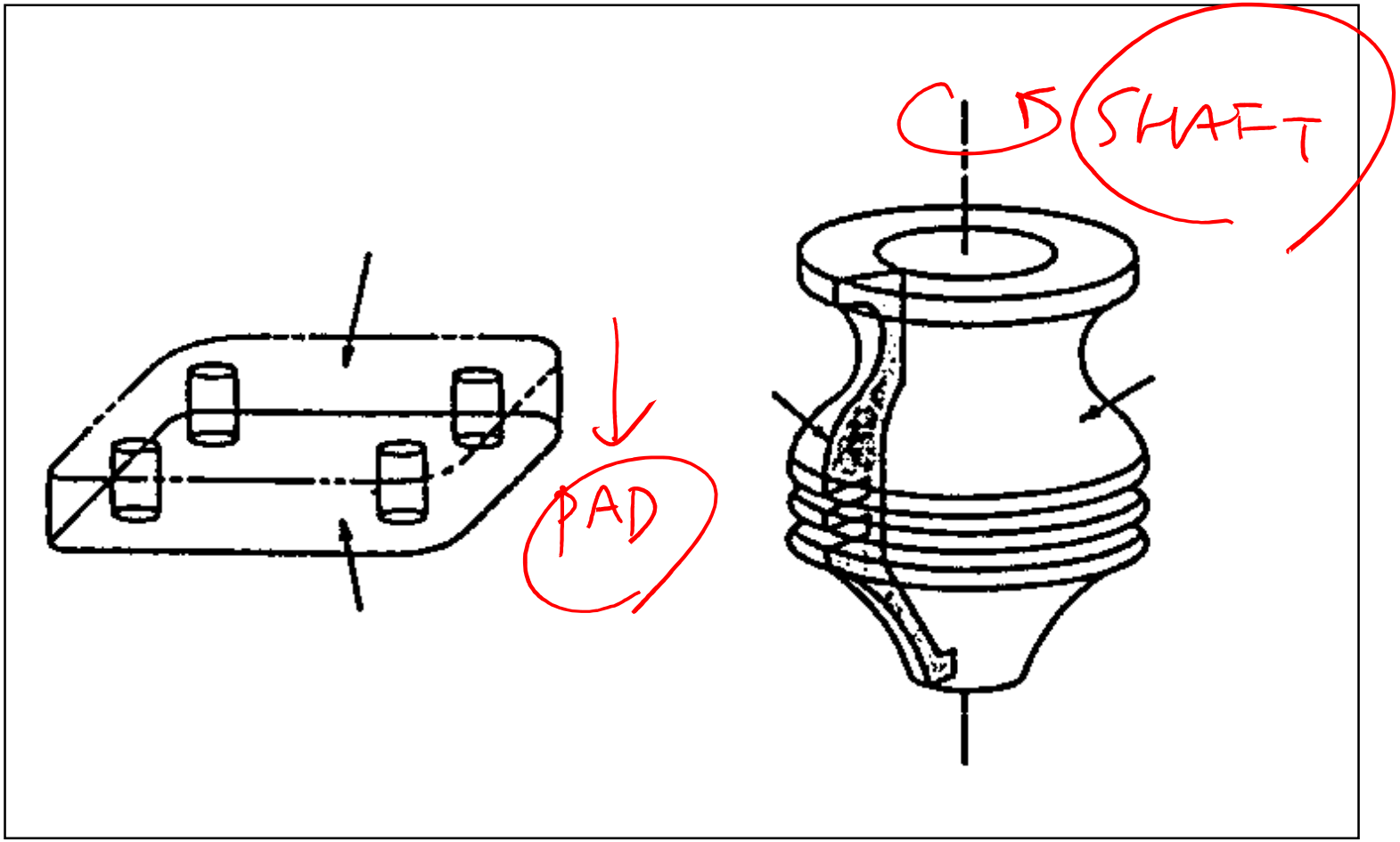
Translational Sweeping



Rotational Sweeping (Swing)

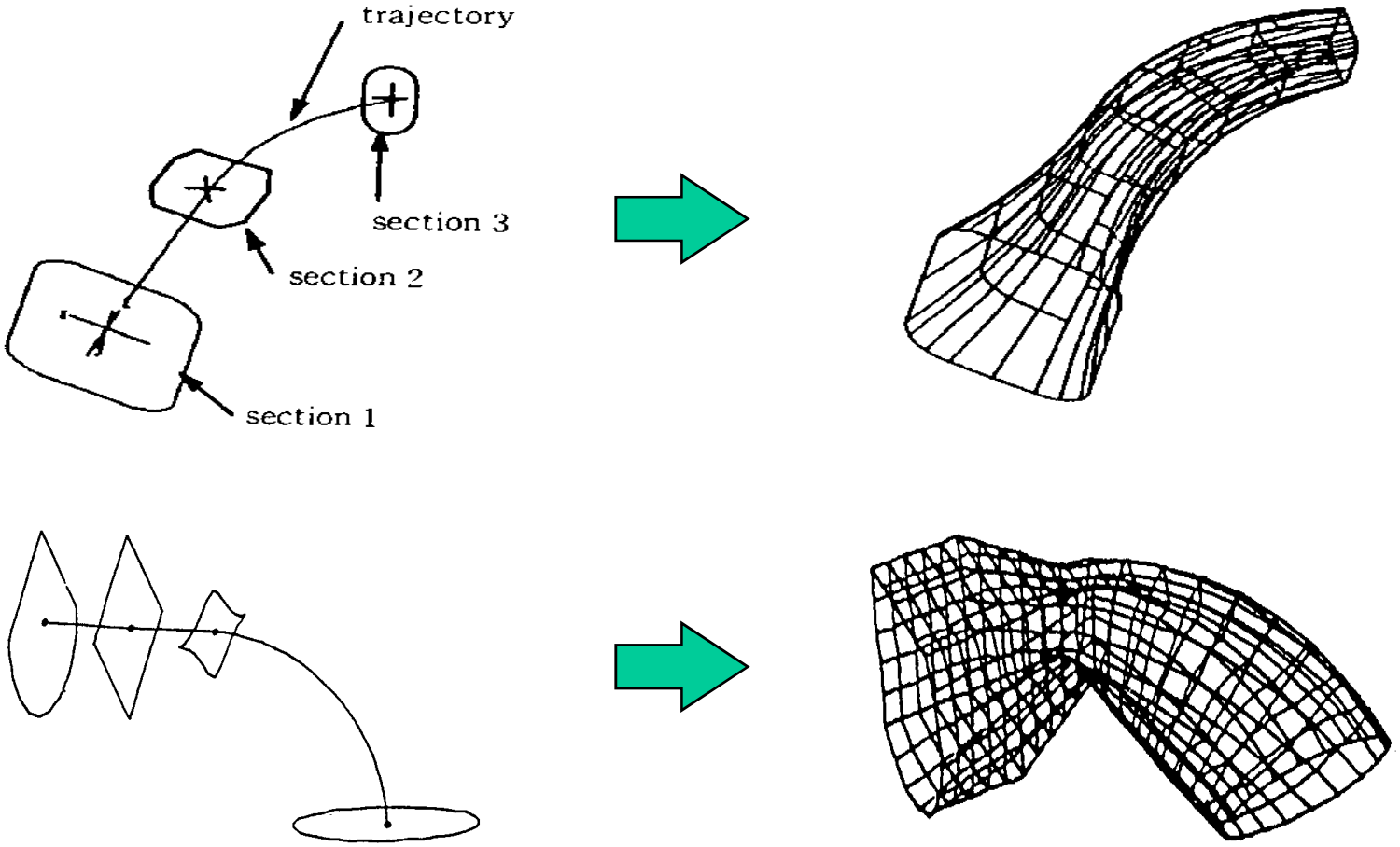


Examples of Sweeping Operations

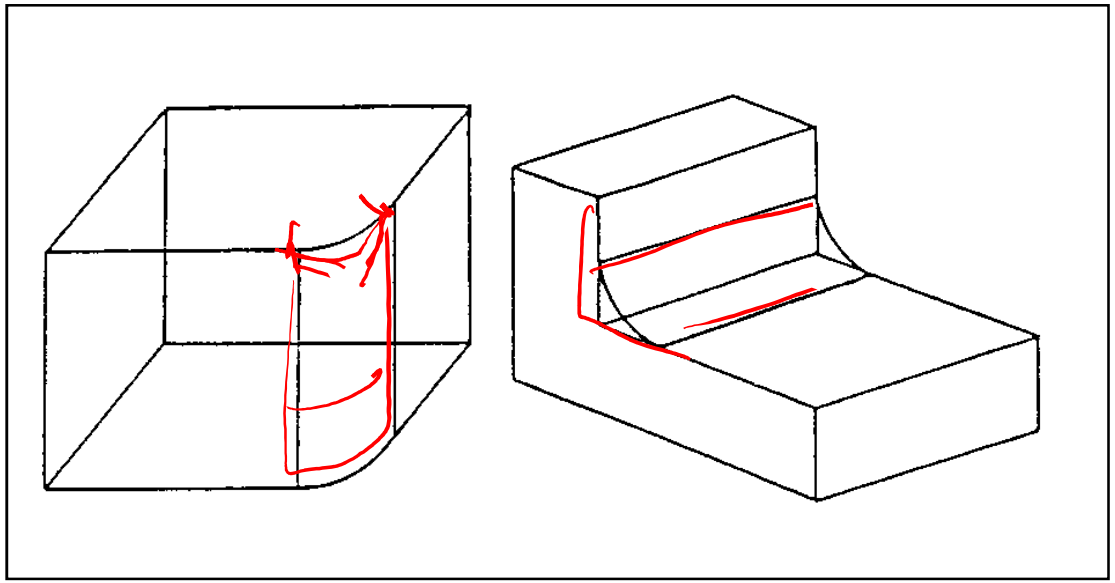


Skinning

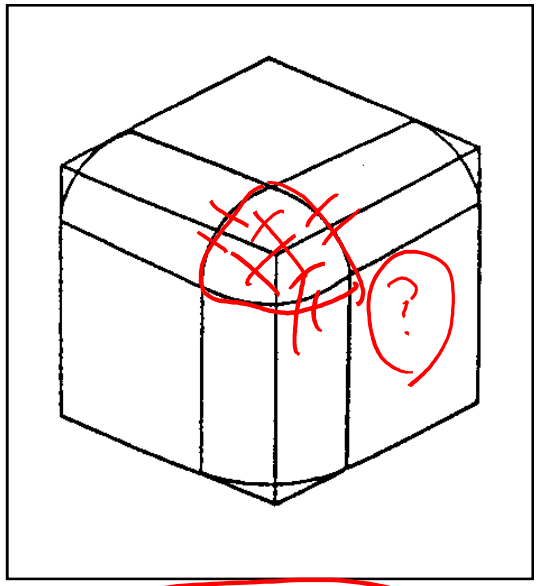
multi-section Sweeping



Rounding

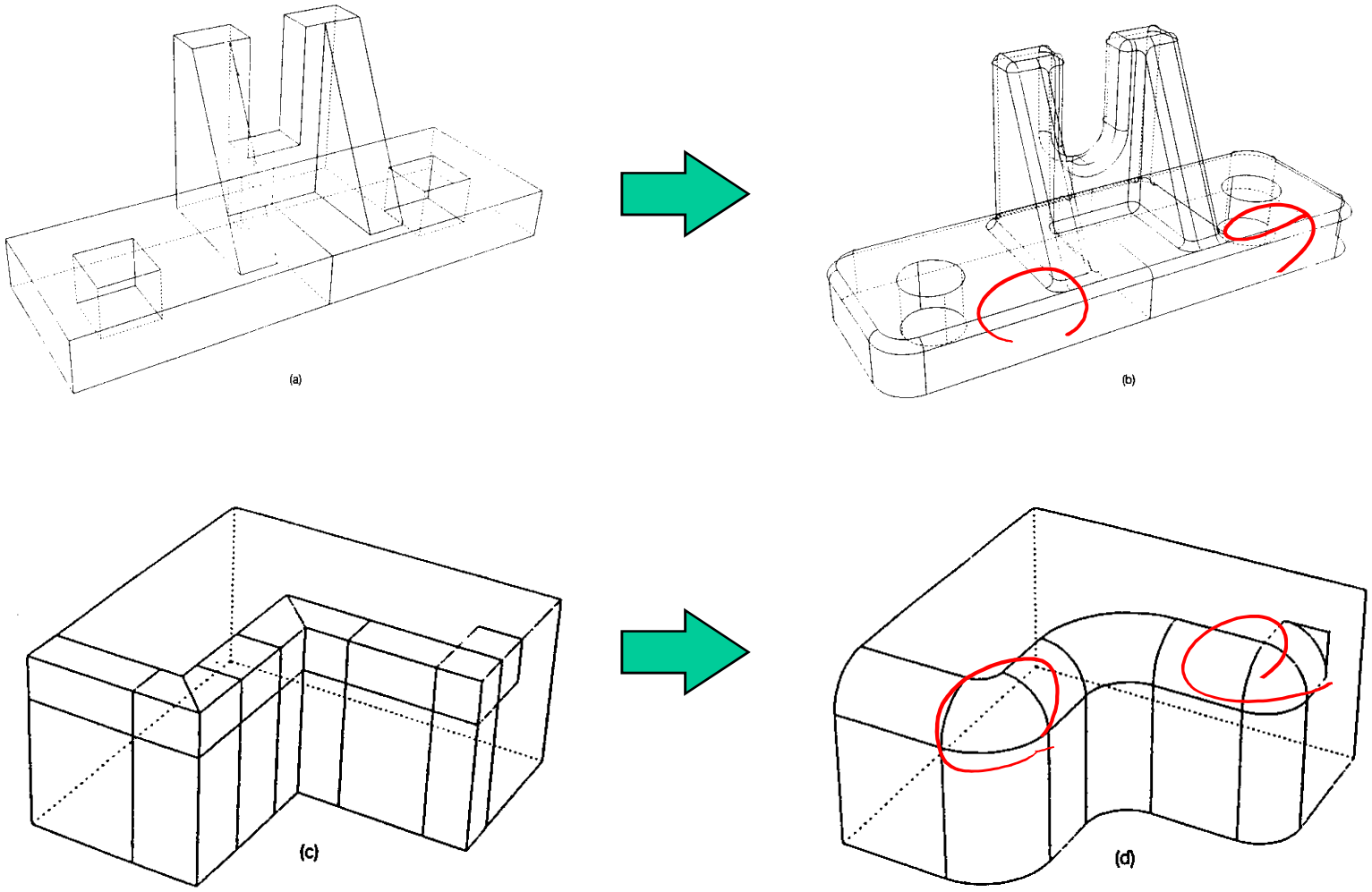


Edge Rounding

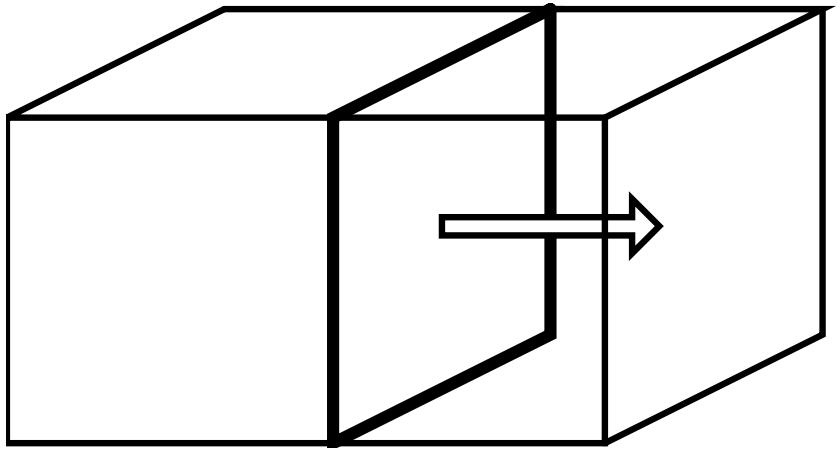


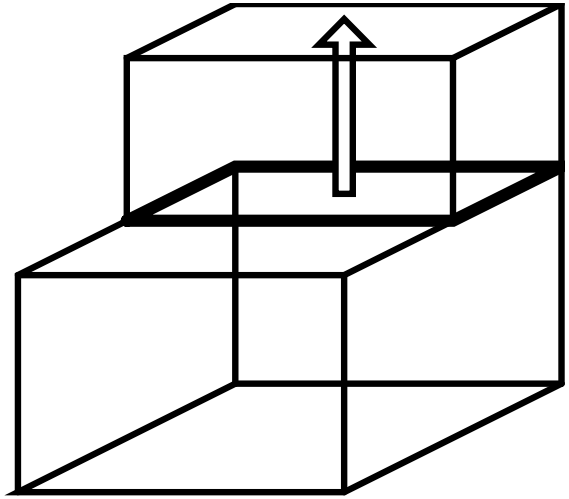
Vertex Rounding

Examples of Rounding Operation

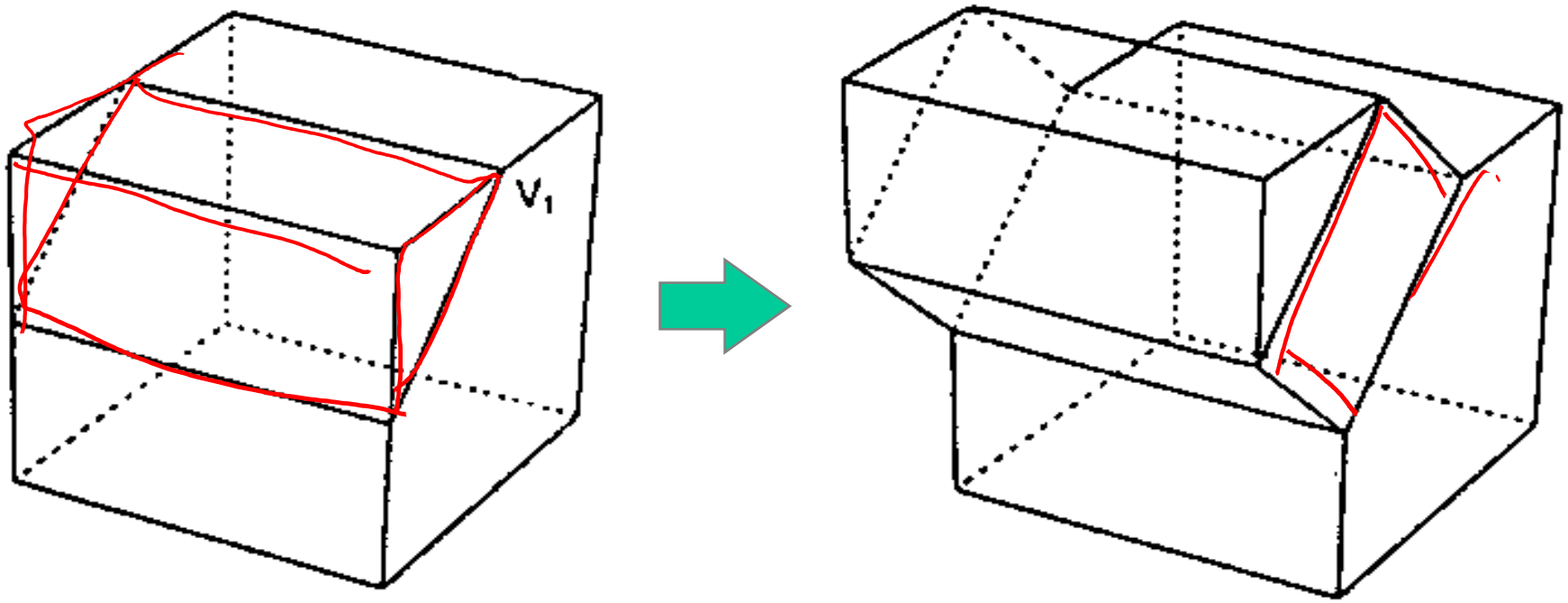


Lifting

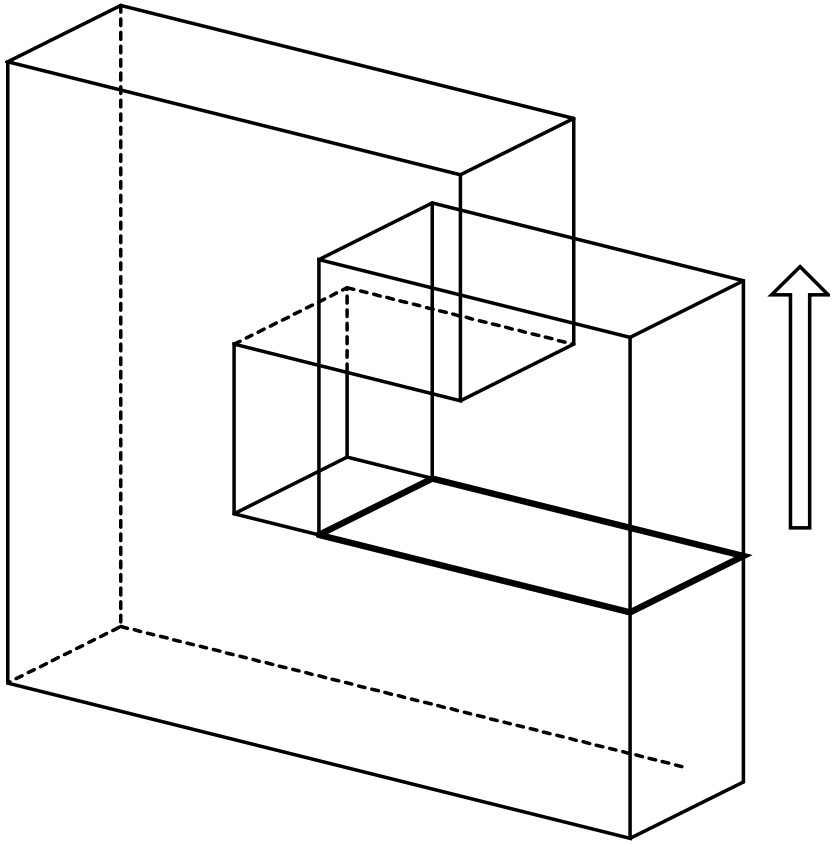




Lifting a Face Group

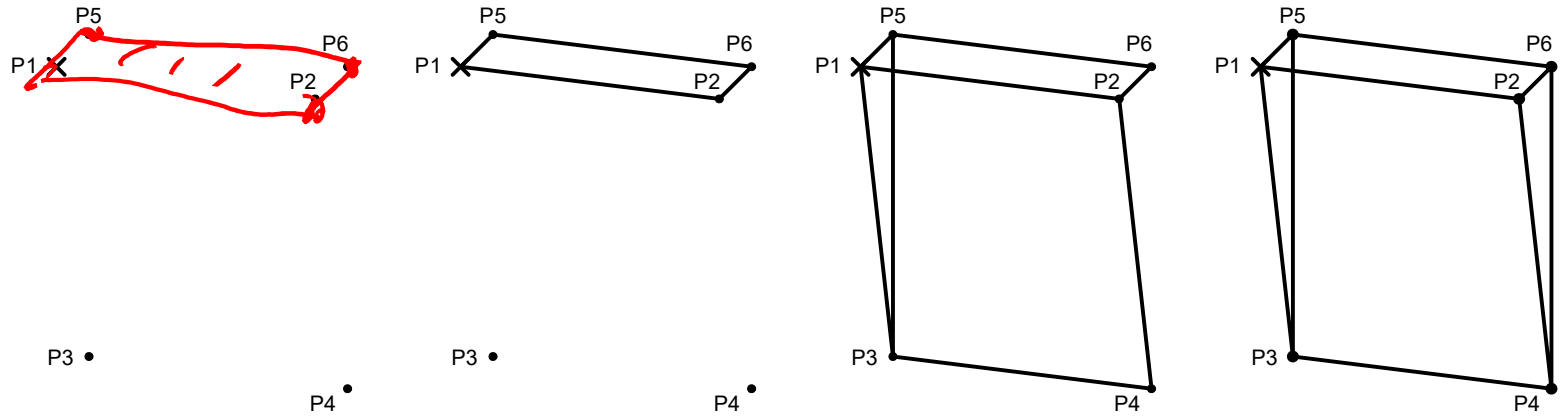


Self-Intersection Caused by Lifting



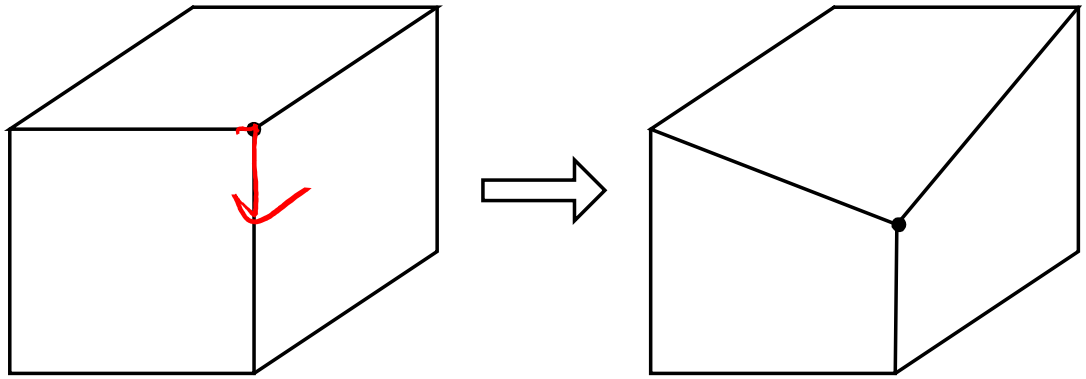
Boundary Modeling Functions

- Add, delete, or modify the lower entities of a solid, such as vertices, edges, and faces directly



Tweaking

- Vertex Moving



- Surface Replacement