COMPUTER AIDED ENGINEERING DESIGN (BFF2612)

GEOMETRIC MODELLING

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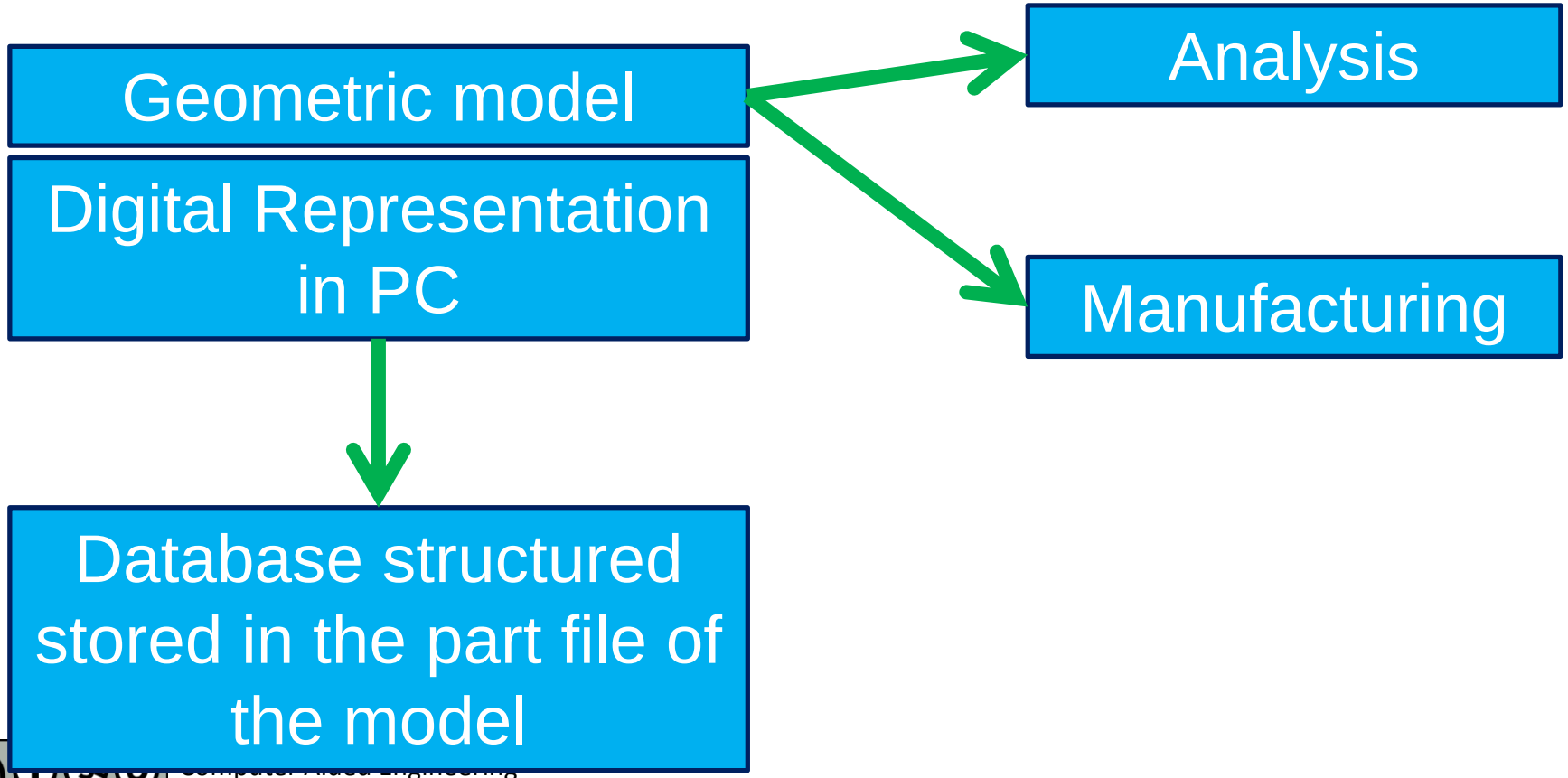
OVERVIEW

- Aims
  - Introduction of Geometric Modelling
- Expected Outcomes
  - Students should be able to understand the geometric models 1D, 2D and 3D and modelling method
- References

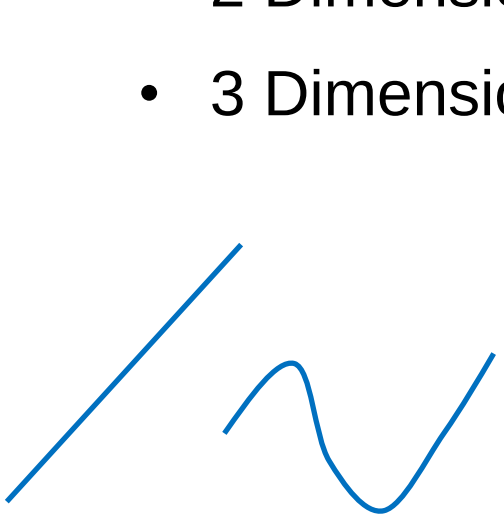
1. Ibrahim Zeid, 2005. Mastering CAD/CAM, McGraw Hill
2. Chris Mc Mohan, Jimmie Browne CAD CAM from principle to practice, Addison Wesley Publishing

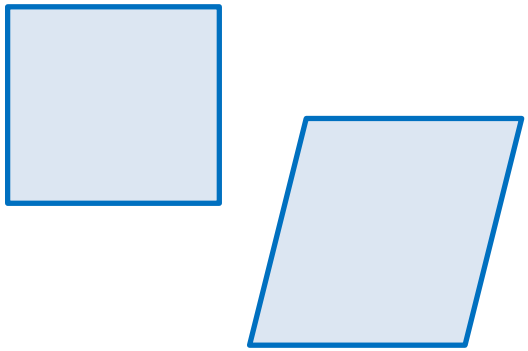
GEOMETRIC MODEL

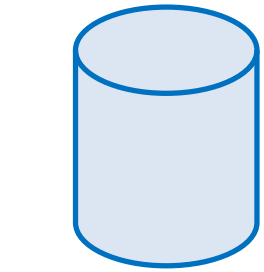


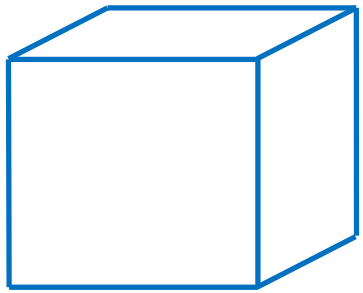
GEOMETRIC MODELS

- 1 Dimension: Line, Curve, Spline
- 2 Dimensions: Surface, Plane, Face
- 3 Dimensions: Solid

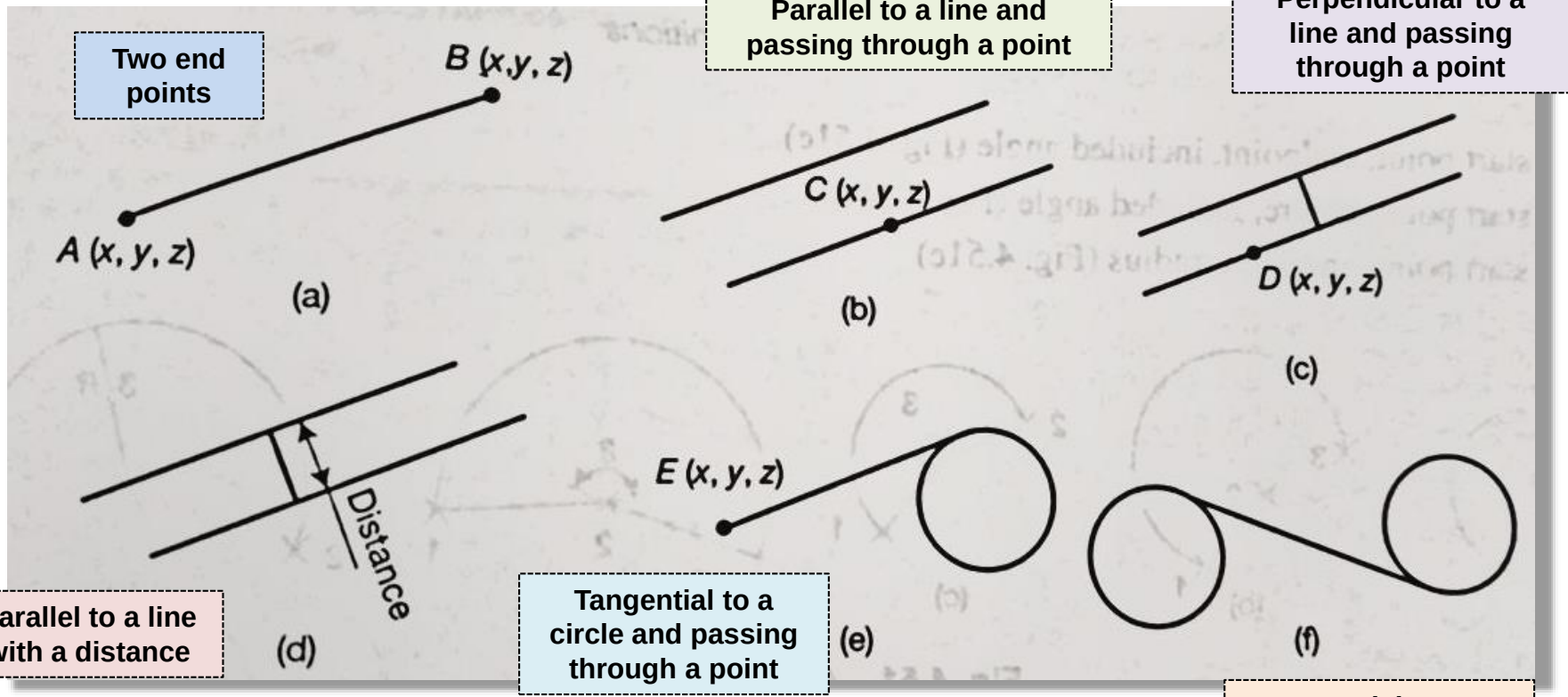








LINE DEFINITIONS

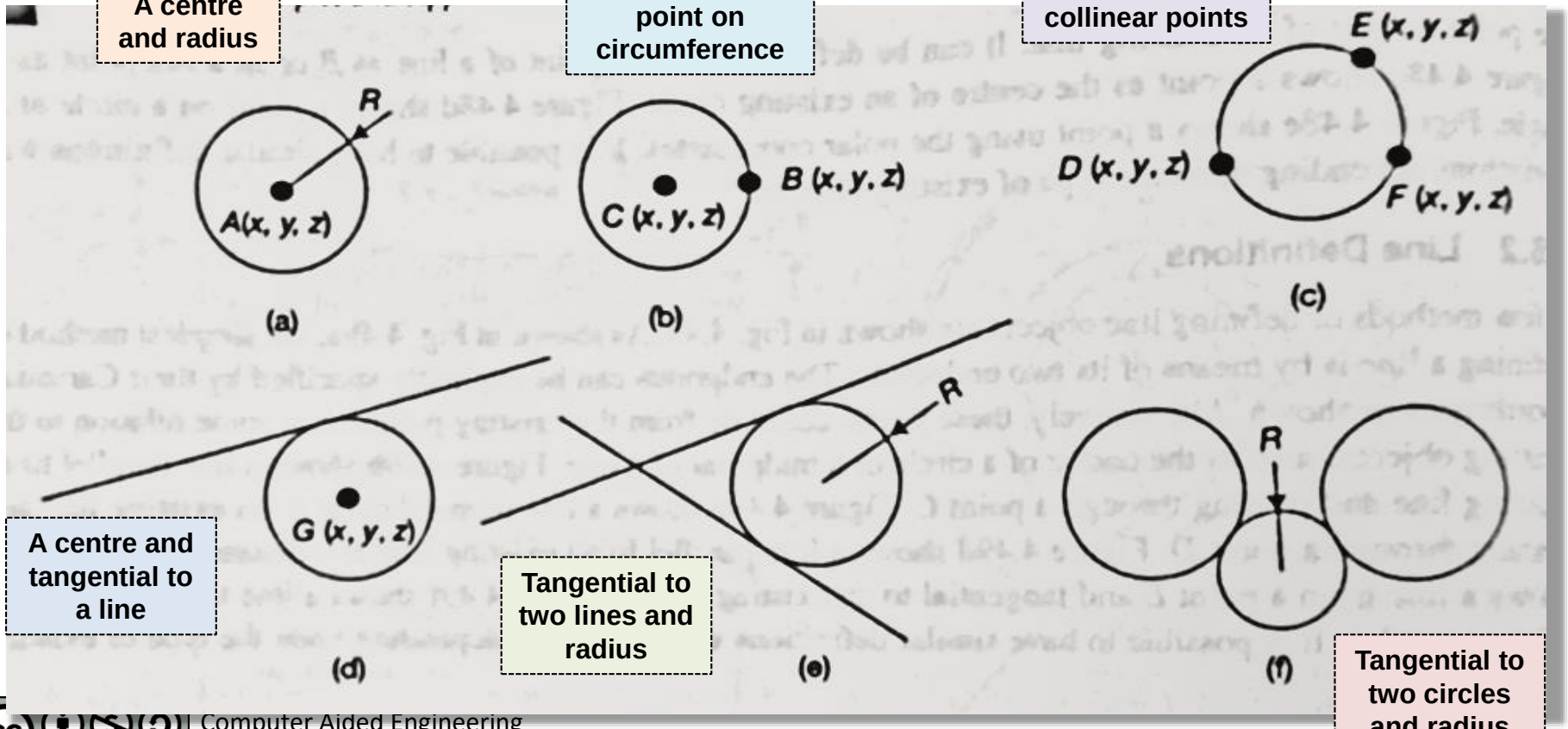


CIRCLE DEFINITIONS

A centre and radius

A centre and a point on circumference

Passing through three collinear points

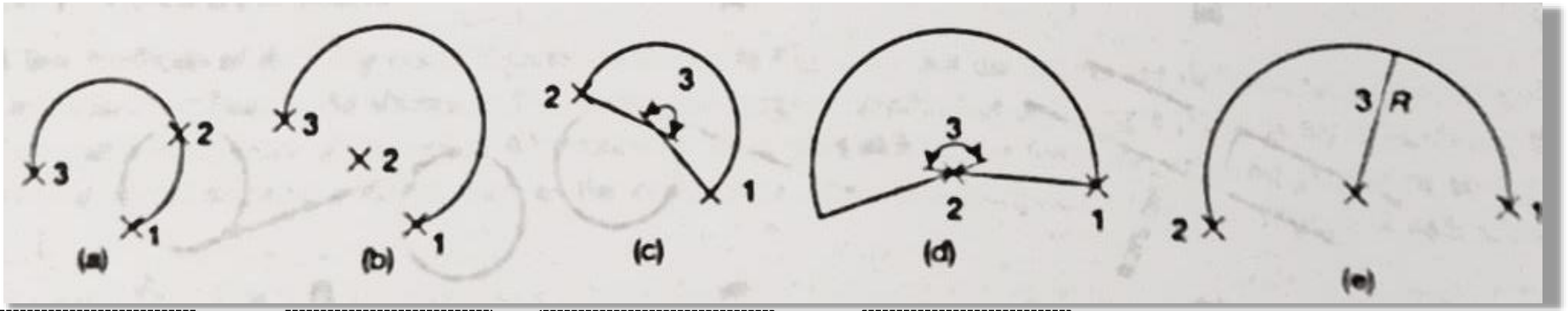


A centre and tangential to a line

Tangential to two lines and radius

Tangential to two circles and radius

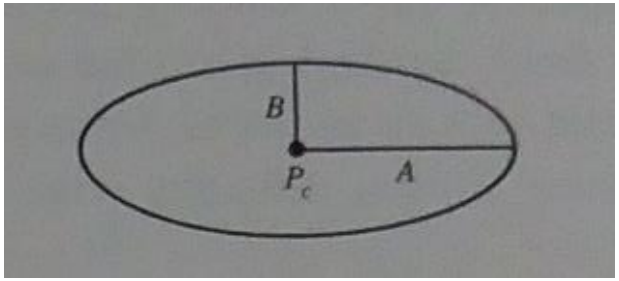
ARC DEFINITIONS



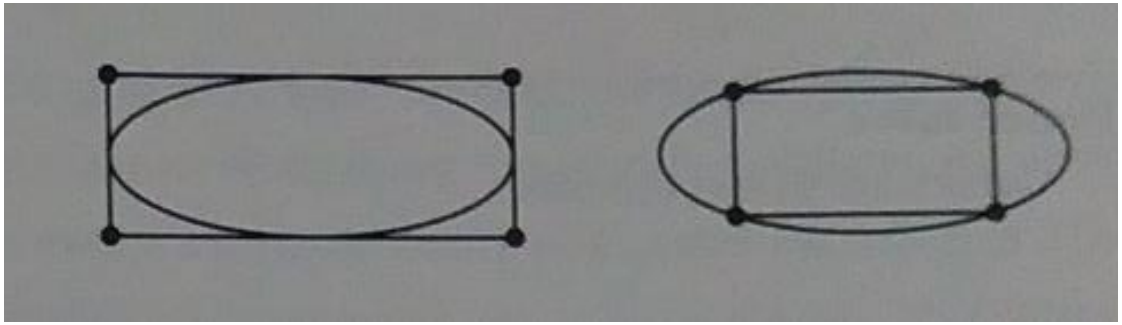
Three points on the arc	Start point, centre, endpoint	Start point, endpoint, included angle	Start point, centre, included angle	Start point, endpoint, radius

ELLIPSES DEFINITIONS

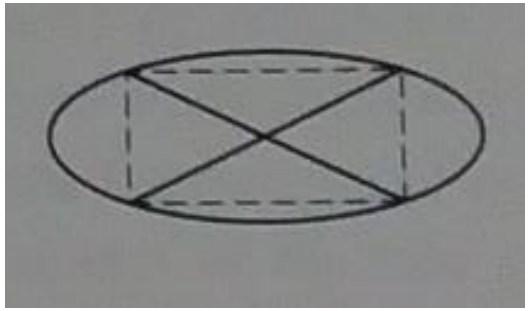
Centre and axes lengths



Four points

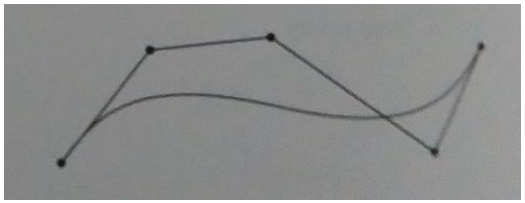


Two conjugate diameters

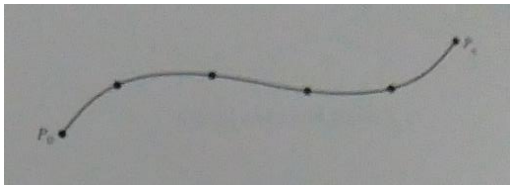


METHODS OF DEFINING SYNTHETIC CURVES

Bezier curves: curve extrapolates (does not pass through) data points



B-spline curves: curve interpolates (passes through) data points



3D GEOMETRIC MODELS

- **Wire-frame (line model):** simples to create, but contain only information about part edges and corners. Represents an object by its bounding edges. No explicit face (surface) or volume information in the model.
- **Surface:** precisely define the outside envelop of part geometry, but contain no data on interior properties.
- **Solid:** overcomes these limitations by representing the solid nature of the object in the computer.

WIREFRAME GEOMETRY

- Earliest CAD systems used 2D, for simple parts and more economical.
- Created by drawing lines, arcs, circles, and curves on a plane in the computer.
- The geometry of the parts is still not fully defined. The surfaces between the wireframes edges are not known, the computer is unable to determine what is inside and outside of the part being designed.
- Ambiguity in representation, and possible nonsense objects.
- Limitation to calculate mechanical properties, or geometric intersections.
- Complex model is difficult to interpret.

WIREFRAME GEOMETRY

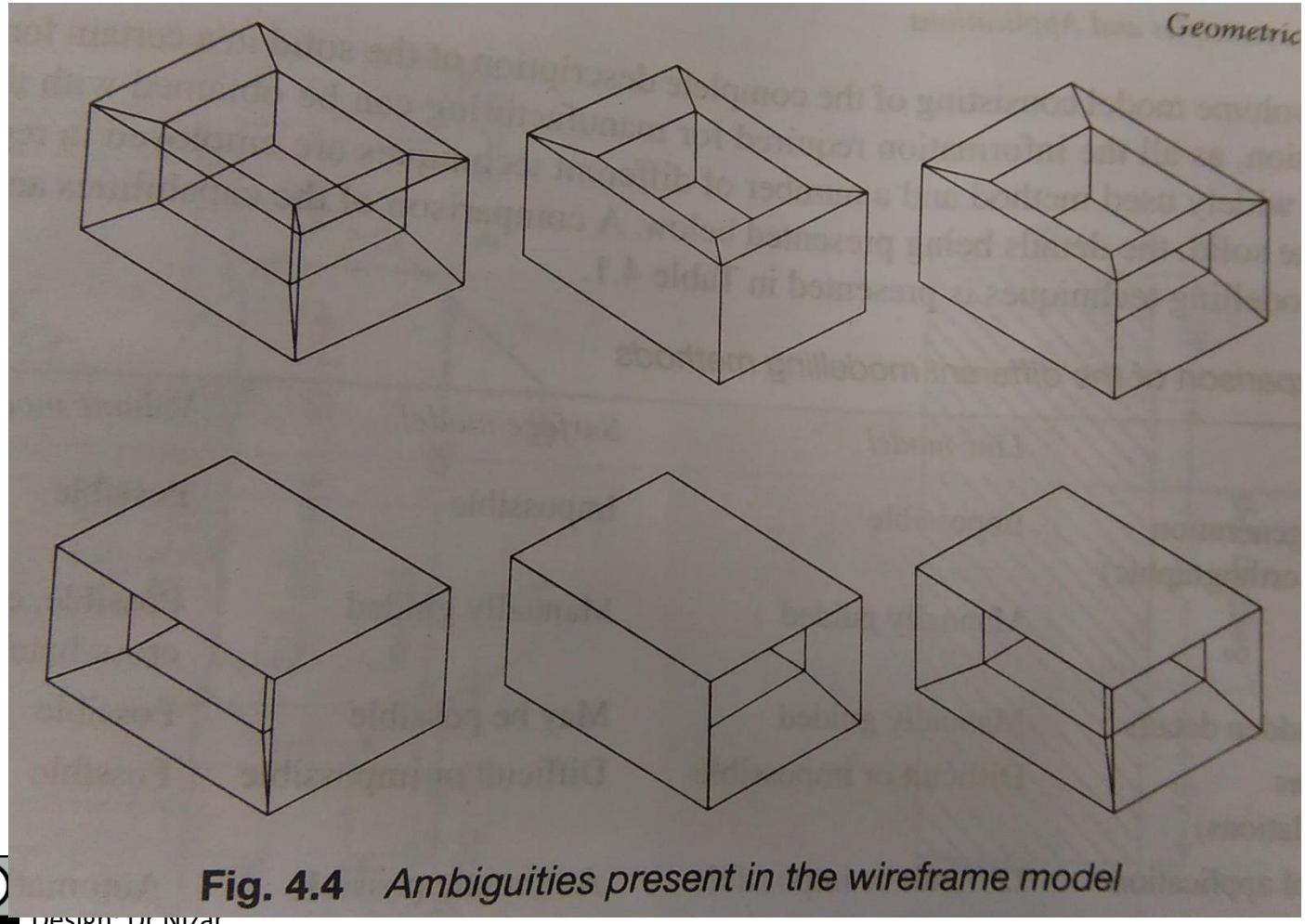


Fig. 4.4 *Ambiguities present in the wireframe model*

WIREFRAME GEOMETRY

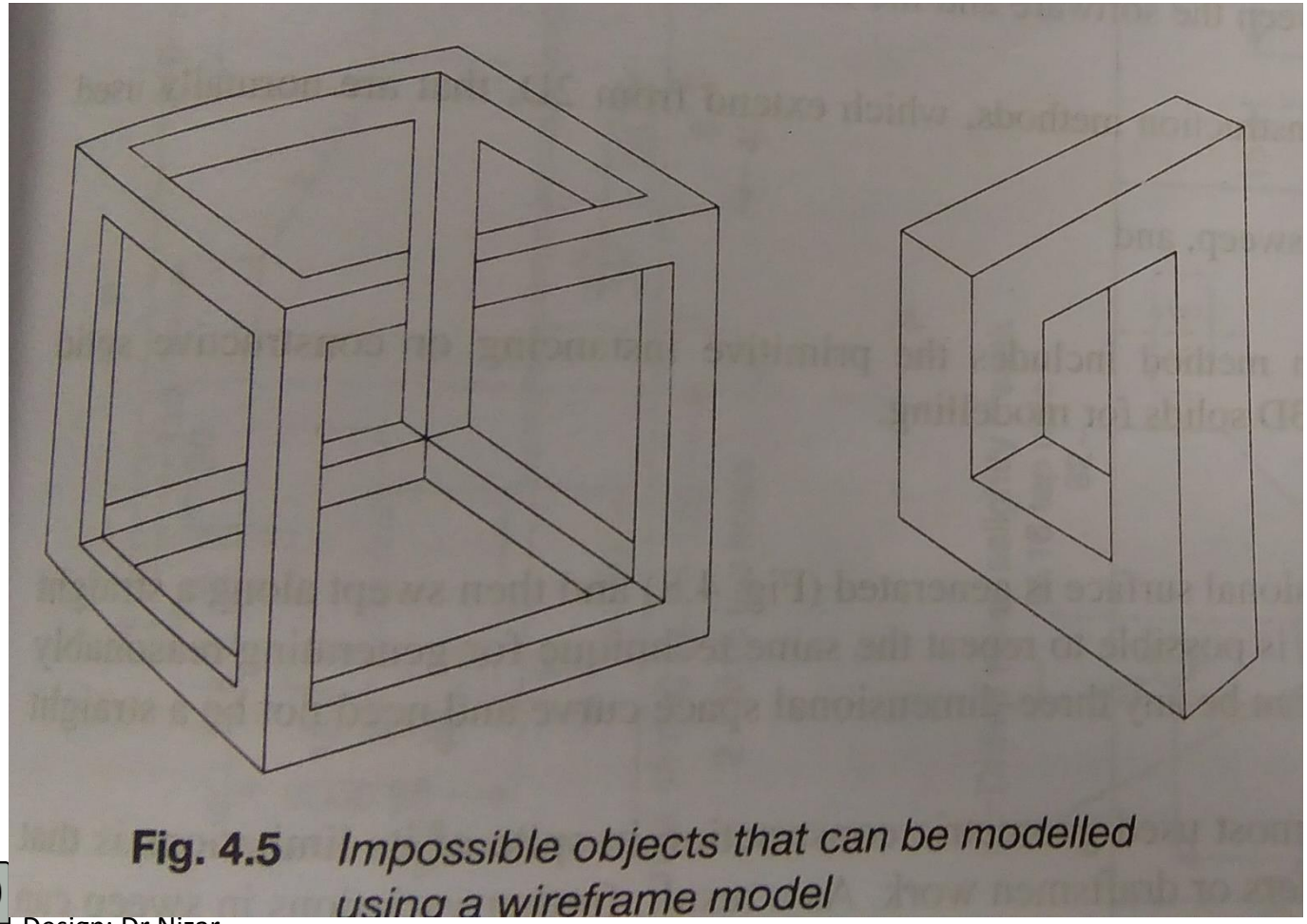


Fig. 4.5 *Impossible objects that can be modelled using a wireframe model*

SURFACE GEOMETRY

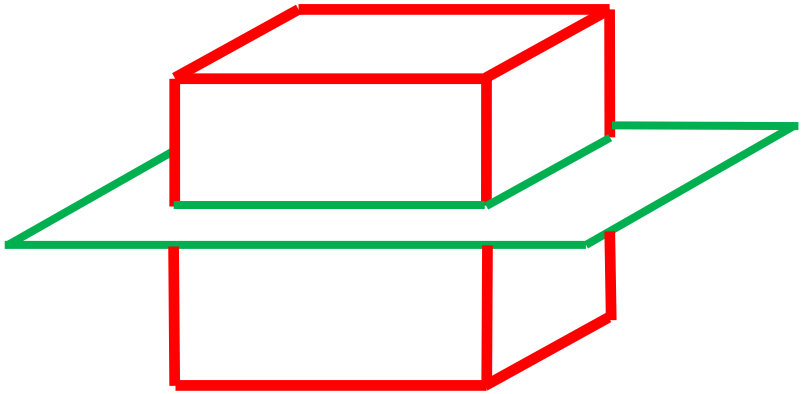
- Constructed from surfaces such as planes, rotated curve surfaces and complex surfaces.
- No information regarding the interior of the solid model is available which can be relevant for generating the NC cutter data.
- Calculation of properties such as mass and inertia is difficult.
- Use when a surface is present in the product for design.
- Mathematical techniques for handling surfaces are: Bezier and B-splines.

Example:
Making sculptured surfaces such as car body and ship hull.

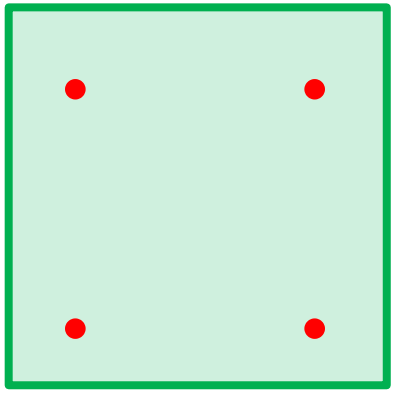
SOLID GEOMETRY

- Consist of complete description of the solid in a certain form.
- All information required for manufacturing can be obtained with this technique.
- Needs to make sure the sequence of design is correct.
- Advantage: It is possible to modify the geometry by picking up the individual feature and changing the attributes.

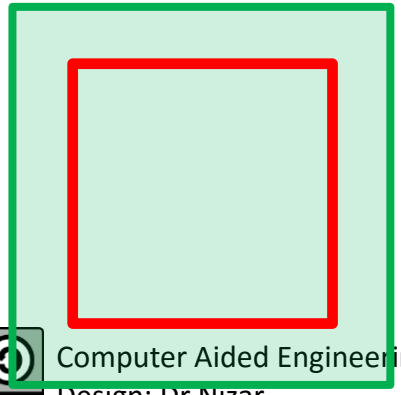
3D GEOMETRY TECHNOLOGIES



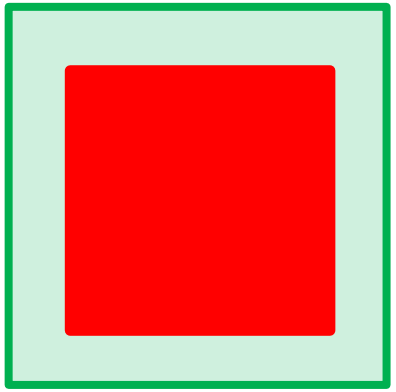
Slice of a cube



WIREFRAME

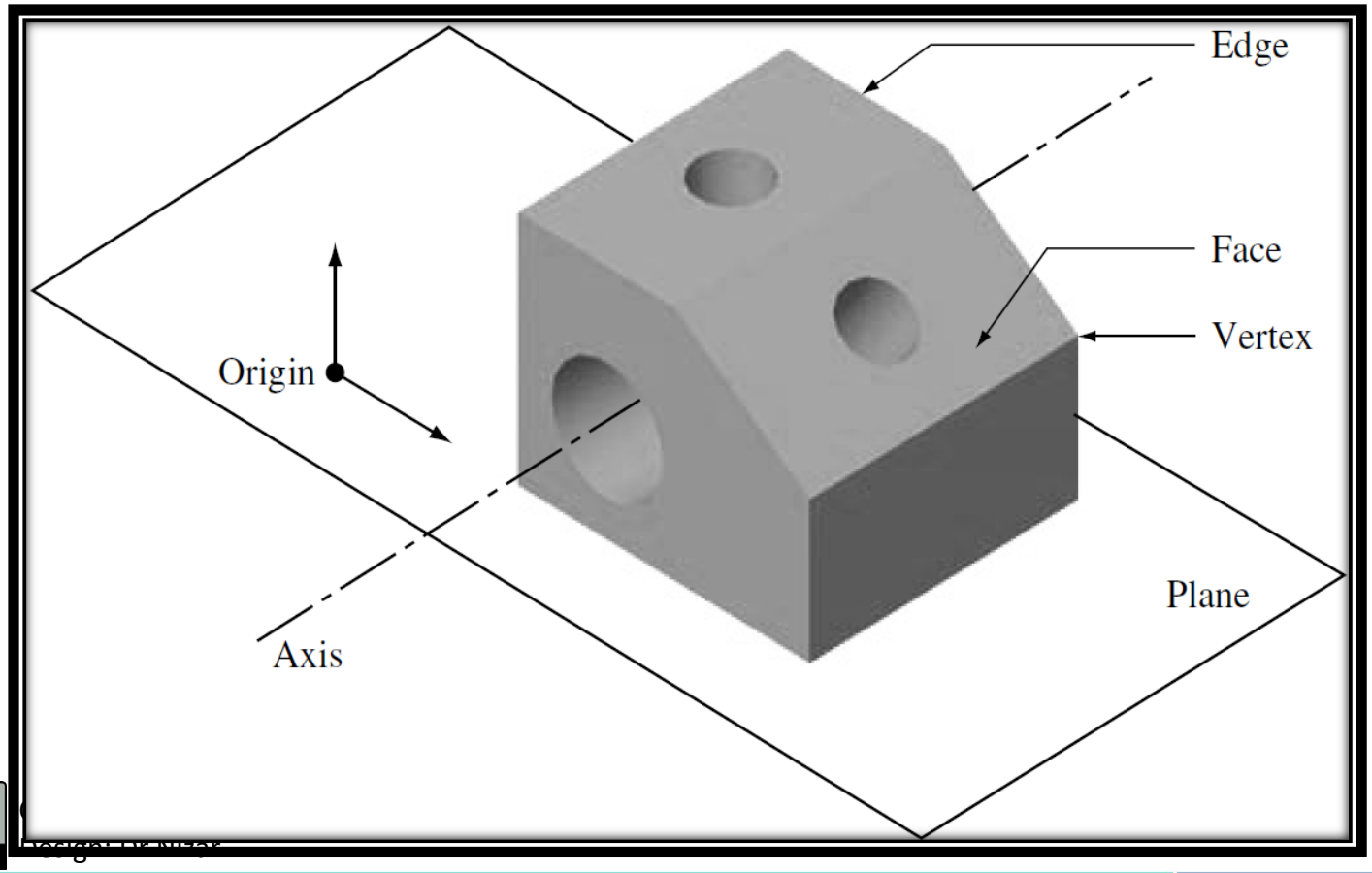


SURFACE



SOLID MODEL

TERMINOLOGY OF A SOLID MODEL



SOLID MODEL

Solid model is a complete, unique and unambiguous representation of an object.

FACES **EDGES** **VERTICES**

SOLID MODELLING

- Add an ordering to the surfaces and curves found in surface models.
- This ordering, called *topology*, allows the computer to determine the volume that is enclosed by the object's bounding surfaces, as opposed to the volume that is outside those surfaces.
- The solid model is able to determine the relationship of any point in space to the solid model: whether it is inside, outside, or lies on the surface of the solid.
- Solid modelling allows to automatically perform Boolean operations between two solid models. Boolean operations are used to combine two solid models into a more complex part.

THREE SOLID MODELING APPROACHES

1. **Primitives**

   Build based on a combination of simple, generic and standard shapes via Boolean operations union, subtraction, and intersection.

2. **Features**

   Similar to the primitives approach, replaces primitives solid with features and embeds Boolean operations in the feature definition.

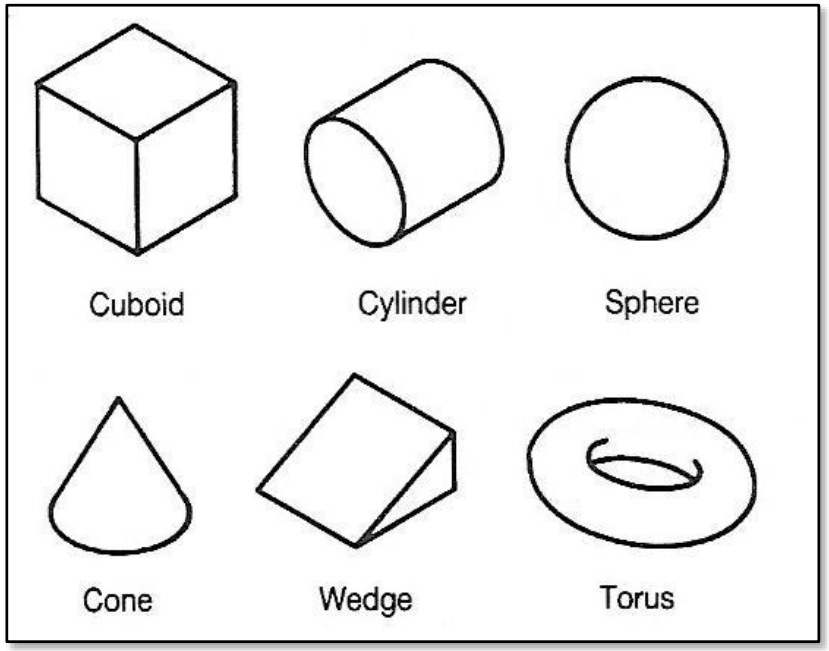
3. **Sketching (Commonly use)**

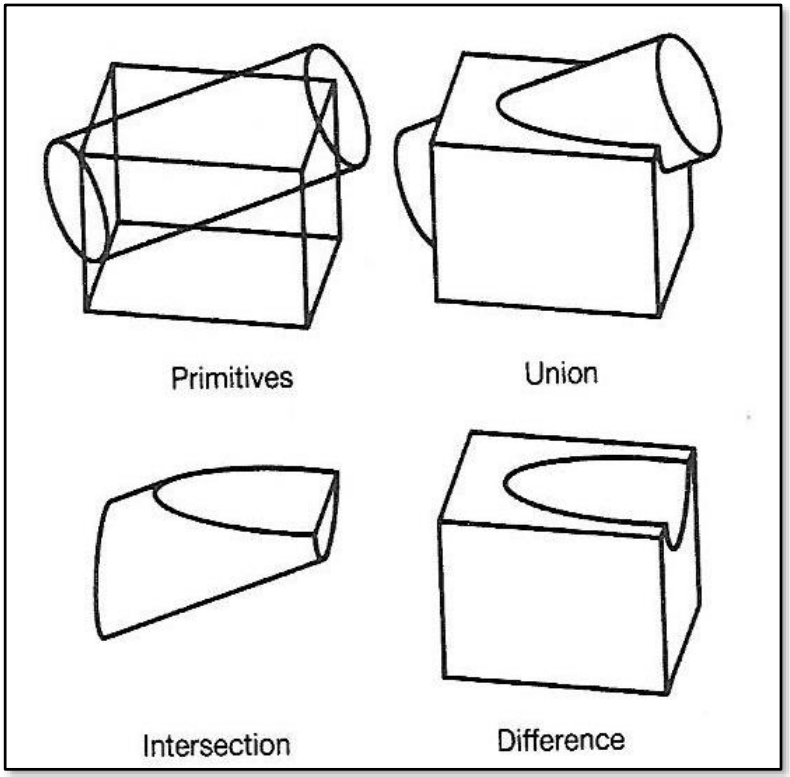
   Similar to feature approach. Instead of using predefined shapes only, such as holes and ribs, it allows CAD designers to create much elaborate and more general features starting from a sketch.

SOLID MODELLING
Boolean Operations

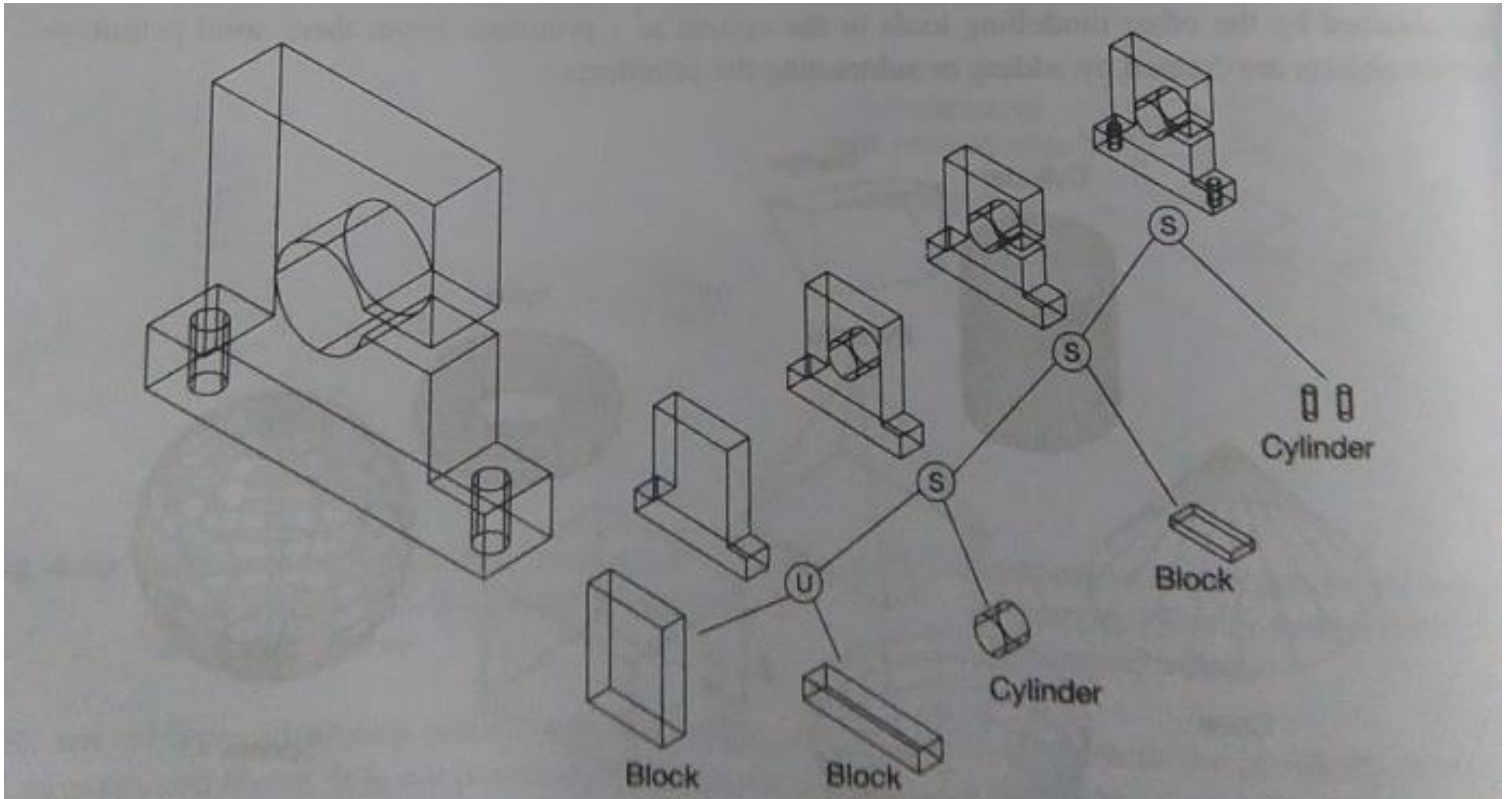
- Boolean operations can be used to add material to or remove material from a solid. These operations provide the basis for creating complete and unambiguous descriptions of physical objects within CAD/CAM systems.
- The problem with solid modelling has been that Boolean operations are rather difficult to use in many situations. Many designers have found them to be unintuitive and difficult to control.
- Form features combined with constraint parameters have greatly simplified how designers work with solid modellers to design parts and assemblies.

SOLID MODELLING
Boolean Operations





SOLID MODELLING
Boolean Operations

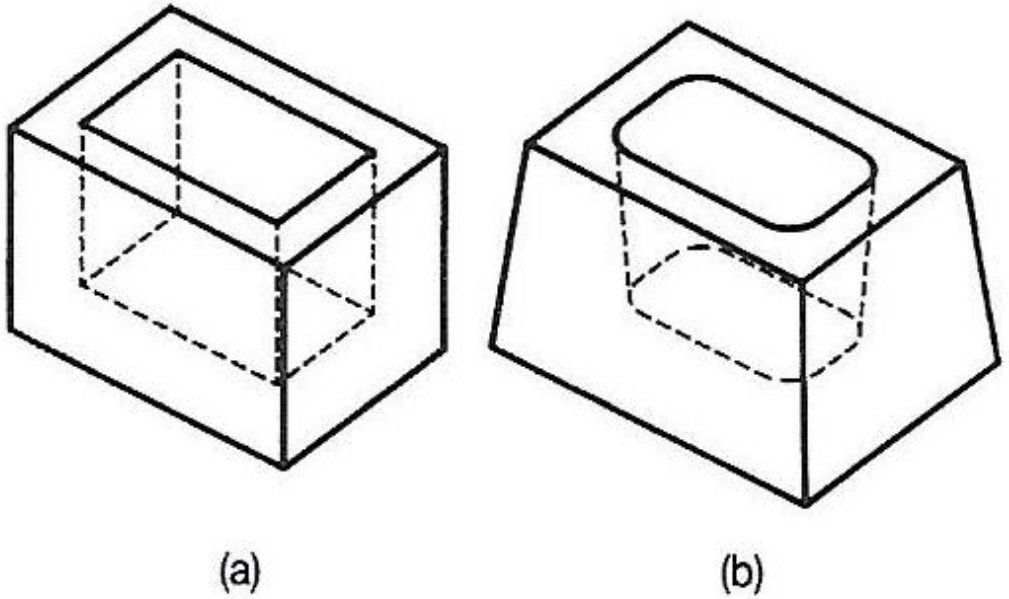


4.16 *Creating a solid with 3D primitives in solid modelling and the model shown in the of Constructive Solid Geometry (CSG)*

SOLID MODELLING
Limitations of Boolean Operations

Limitations:

- Range of geometric primitives is limited to planar or quadric surfaces (straight forward line/surface or surface/surface intersection algorithms).
- Complex geometric leads to performance degradations.



SAMPLE CASE:
Creating a hole in a block

Primitives:

1. Create the block using a block primitive.
2. Create a cylinder in the right location and orientation relative to the block.
3. Subtract the cylinder from the block.

Features:

1. Create the block using a block feature.
2. Create the hole in the block by creating a hole feature in the right location and orientation relative to the block.

Sketching:

1. Select or define a sketch plane.
2. Sketch 2D profile (of a rectangle with the hole feature).
3. Modify sketch dimensions and update sketch.
4. Create 3D feature by extrusion.

SOLID MODEL OPERATIONS

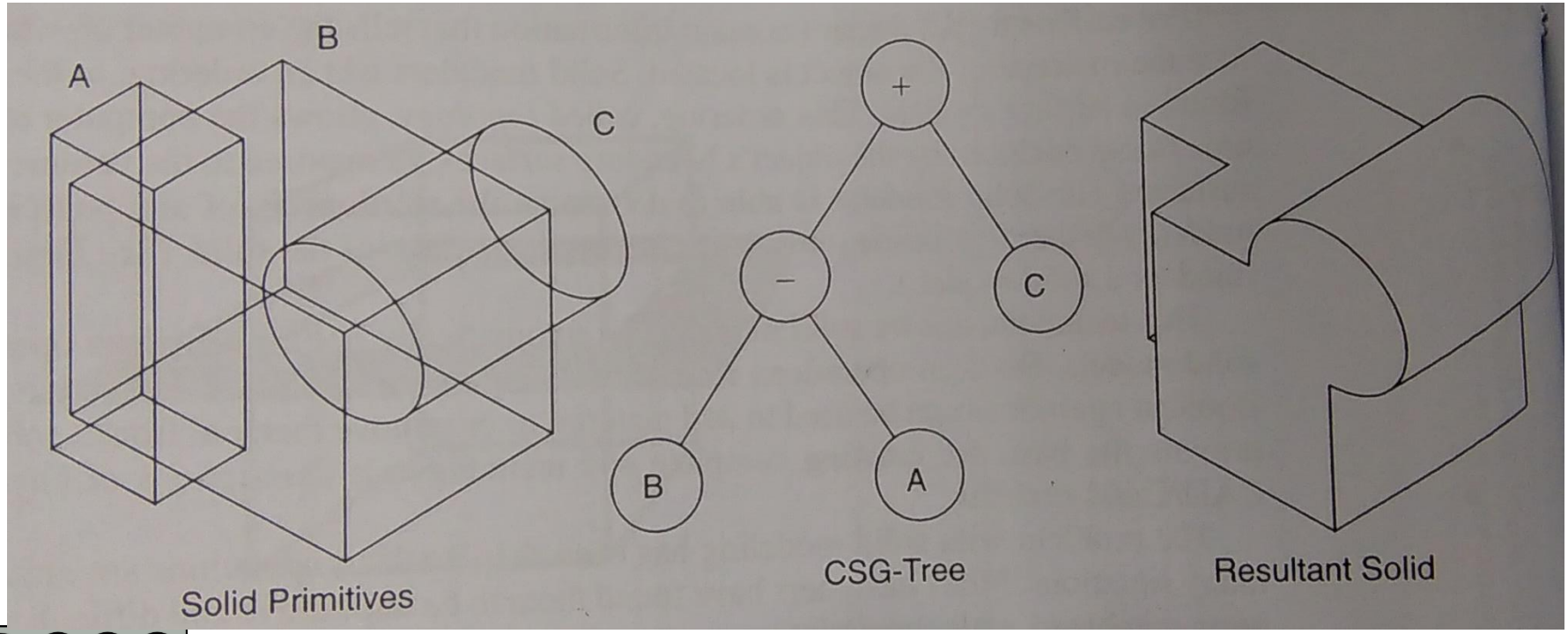
1. Constructive solid geometry (CSG)
2. Boundary representation (B-rep)
3. Hybrid (B-rep combined with CSG tree)
4. Sweeping / extrusion
5. Tweaking
6. Sewing

SOLID MODEL OPERATIONS

Constructive solid geometry (CSG)

- The geometry of the final object is defined by the building block solids (primitives) and operators (union, difference, intersection).
- Technique that uses Boolean operators on solid primitives to build desired solid.
- The solid is stored in a complex data structure consisting of shells, faces, edges and vertices.
- Primitives include blocks, cylinders, cones, spheres, and other relatively simple solid shapes.

Constructive Solid Geometry (CSG)

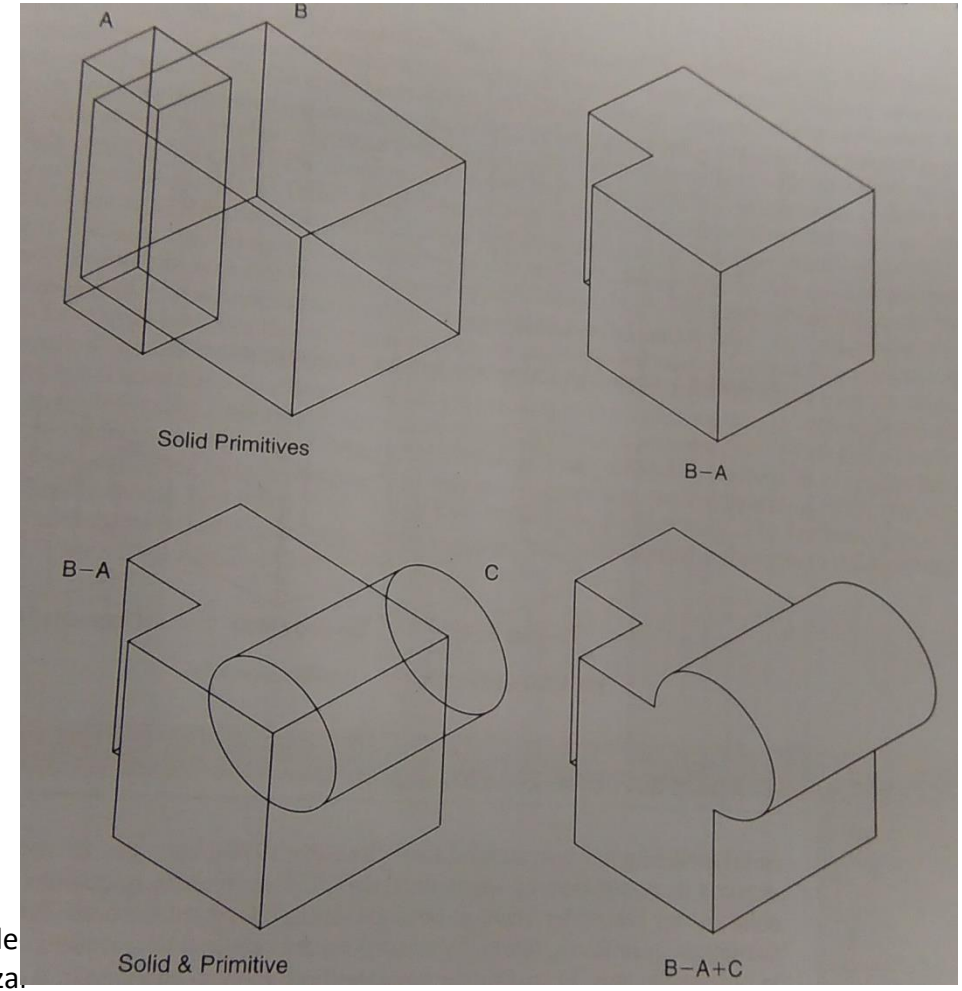


SOLID MODEL OPERATIONS

Boundary representation (B-rep)

- A solid is represented as a collection of connected surface elements, the boundary between solid and non-solid.
- Use Boolean combinations of primitive solids. The primitives and complex solids resulting from their combination, are defined as a collection of faces, edges and vertices.
- At each Boolean operation is completed, the existing solid is extended to include new faces, edges, vertices, etc., so that it can be used in the next operation. Each preceding Boolean operation need to be re-done when a change is made to the model.
- The B-rep model is always fully evaluated, no extra steps are needed to find its edges, and up-to-date edge and face information are always available.

Boundary Representation (B-rep)



SOLID MODEL OPERATIONS

Hybrid (B-rep combined with CSG tree)

Hybrid provides flexibility of easily changing the CSG-tree, as well as direct access to all of the model's faces and edges.

SOLID MODEL OPERATIONS

Sweeping/extrusion

- Operation that creates complex solids by projecting a profile in a third dimension. The profile is usually (but not always) 2D and may be extruded along a vector or curved or rotated about an axis. Complex sweep operations can combine basic translation or rotation with twist, taper, skew, etc. used in CSG and B rep modellers.
- Varied facilities available normally in the two-dimensional modellers, they can also be utilised for modelling three dimensional solids.

SOLID MODEL OPERATIONS

Tweaking

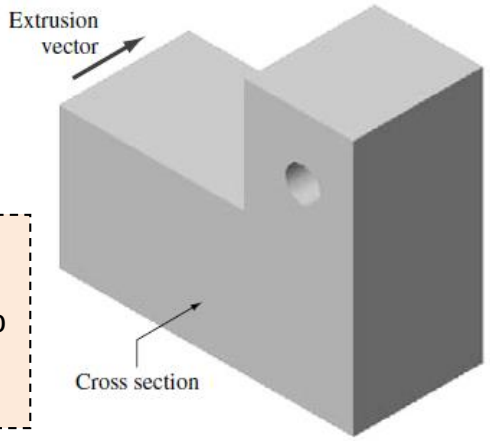
- A group of operations used to make local modifications to a solid model.
- Tweaking operations include stretching, moving holes, bosses, or other features of a face; splitting a face into two faces; and dragging an edge or vertex.

Sewing

- A solid-model construction technique that allows a group of surfaces in a surface model to be joined (sewn) along common edges (adding topographical information) into a solid model.

TYPES OF GEOMETRIC MODELS

Constant cross section and thickness in a direction perpendicular to the plane of the cross section

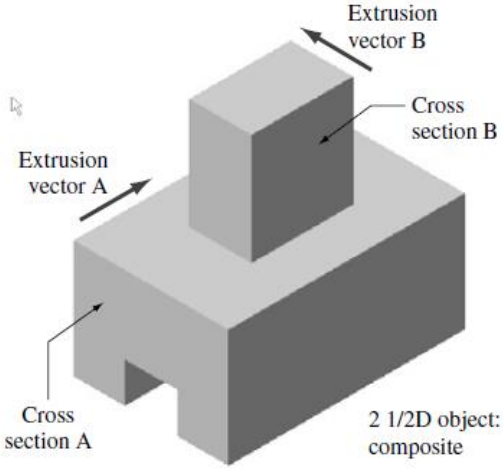


2 1/2D object: extrusion

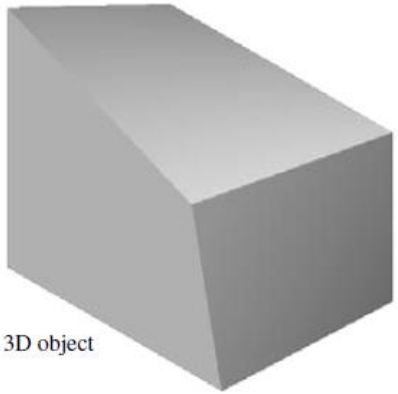
2 1/2D object: axisymmetric

Constant cross section that revolved about an axis of revolution through an angle $0 < \theta \leq 360$

Combination of multiple 2 1/2D objects



2 1/2D object: composite



3D object

Does not have any geometric uniformity in any direction

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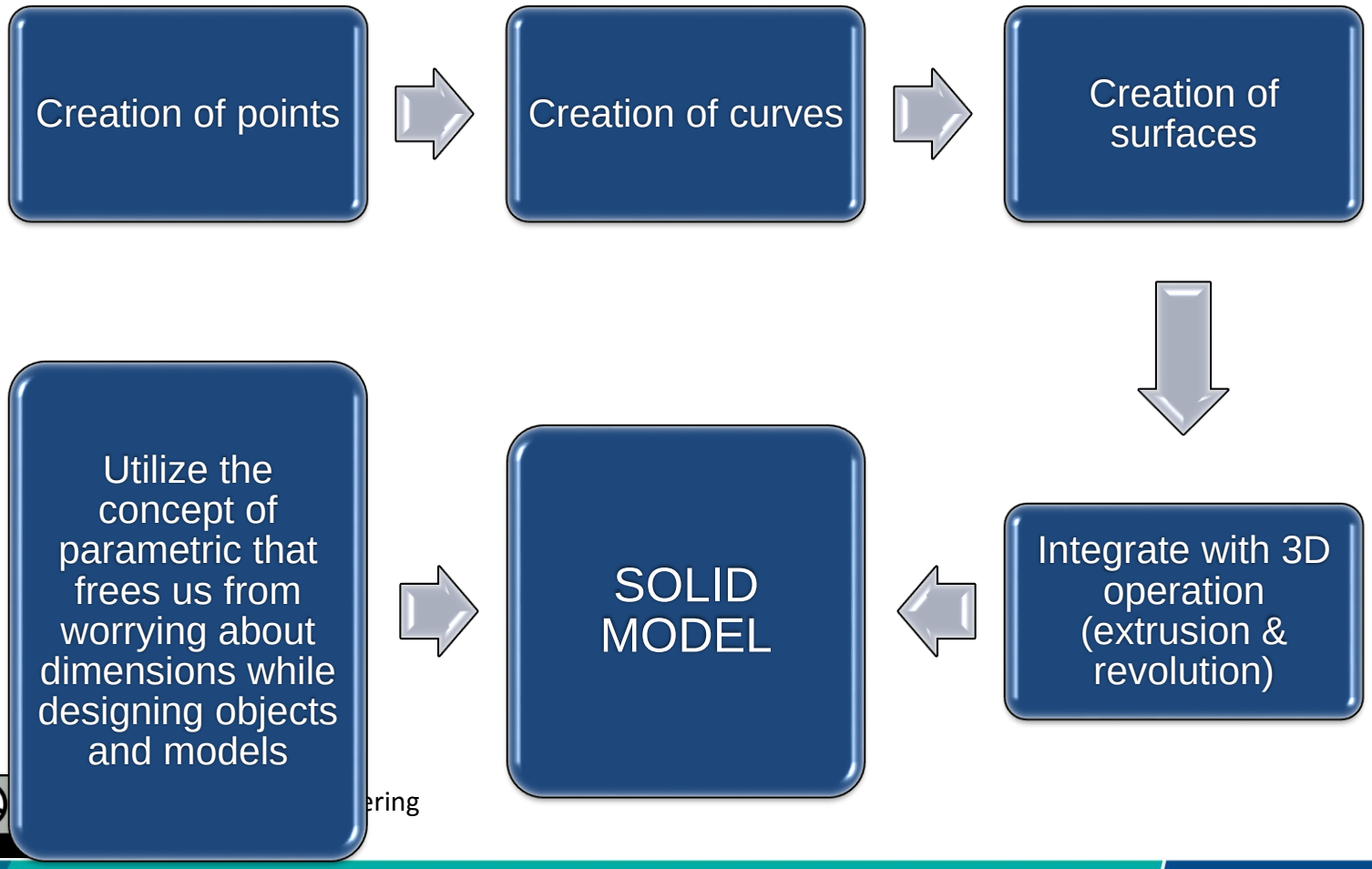
CONSTRUCTION OF SOLID MODEL



Have any questions?

Thank you
and Have a nice day!

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