SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
An Autonomous Institution

Accredited by NBA – AICTE and Accredited by NAAC – UGC with 'A+' Grade
Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai

DEPARTMENT OF AUTOMOBILE ENGINEERING

19AUT303 – Additive Manufacturing and its applications

III YEAR / V SEM

UNIT – 1 INTRODUCTION TO 3D PRINTING & CAD FOR ADDITIVE MANUFACTURING

Manufacturing

Manufacturing is the creation or production of goods with the help of equipment, labor, machines, tools, and chemical or biological processing or formulation. It is the essence of secondary sector of the economy.

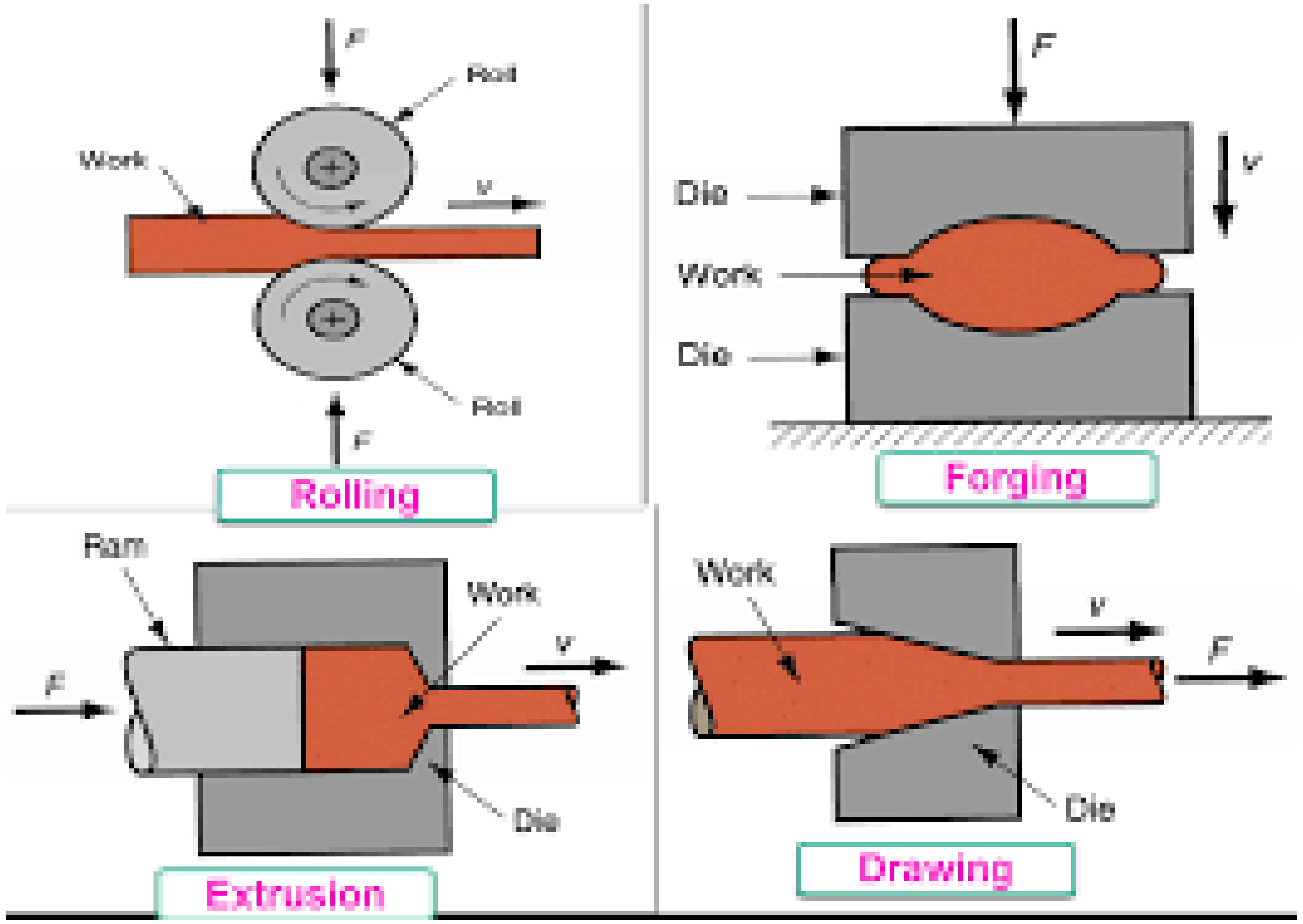
Classification

Manufacturing processes are classified into six broad categories:

- **forming,**
- **casting, moulding,**
- **joining,**
- **machining, and**
- **additive manufacturing**.

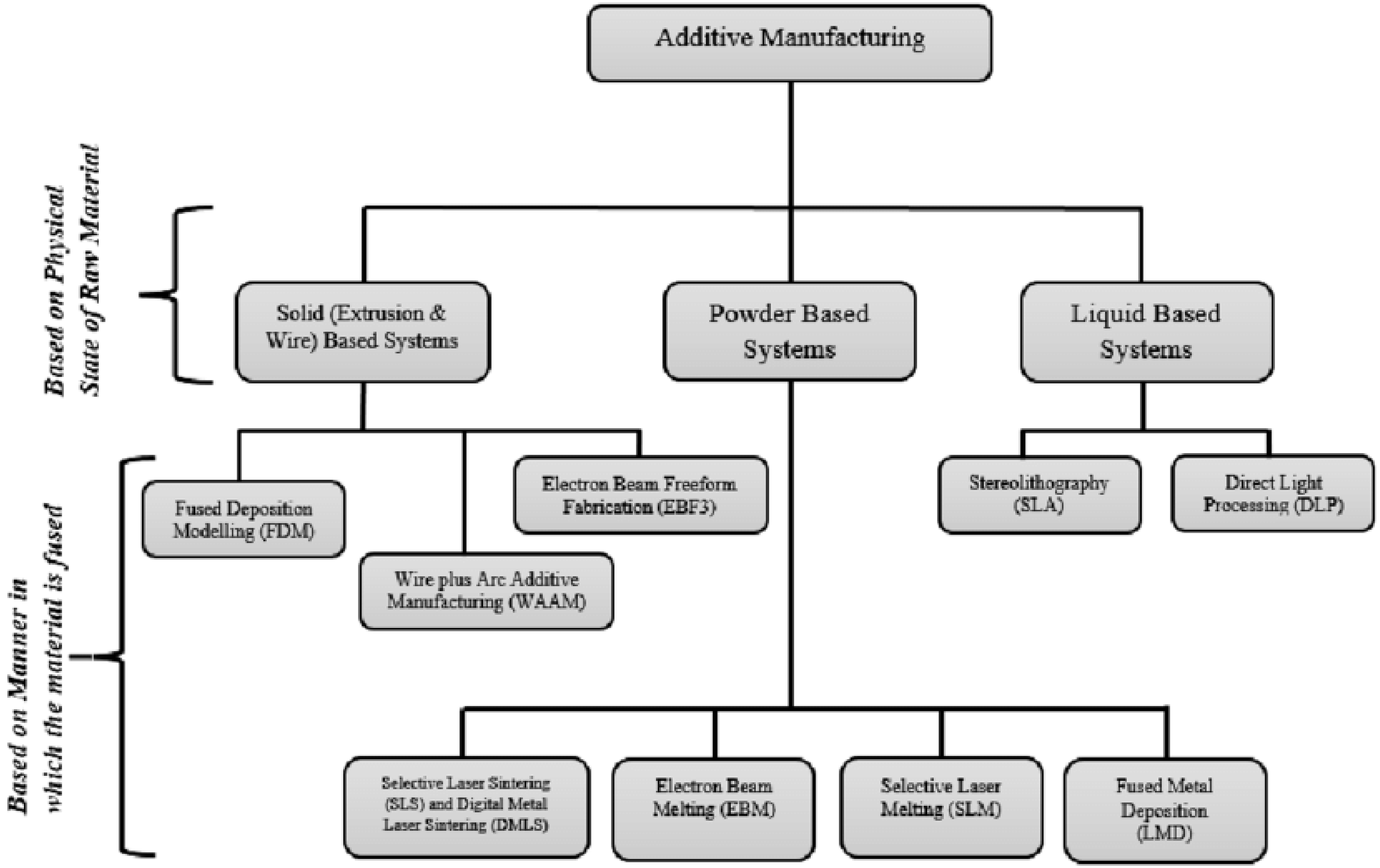
Forming

Forming is **a process in which the shape of a partly finished product, for example sheet metal, is changed using plastic deformation**

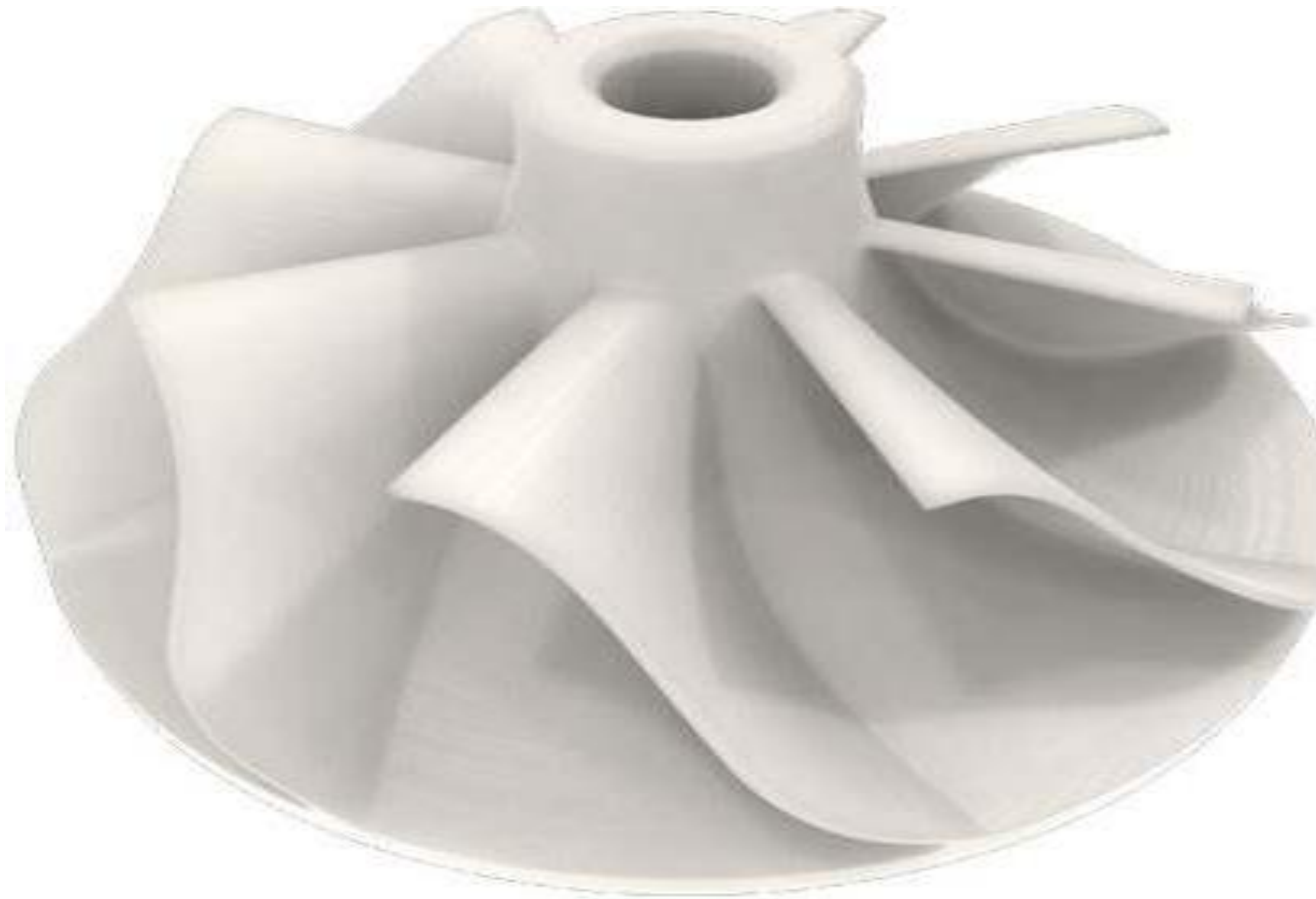


Additive Manufacturing

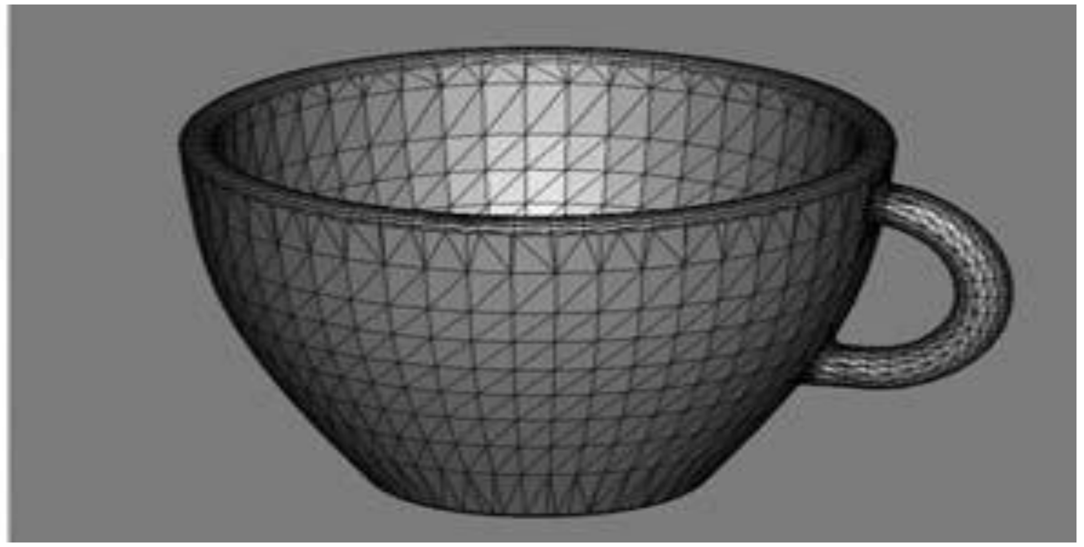
Additive manufacturing is **the process of creating an object by building it one layer at a time**



Additive Manufacturing
Based on Physical State of Raw Material
Solid (Extrusion & Wire) Based Systems
Powder Based Systems
Liquid Based Systems
Based on Manner in which the material is fused
Fused Deposition Modelling (FDM)
Wire plus Arc Additive Manufacturing (WAAM)
Electron Beam Freeform Fabrication (EBF3)
Stereolithography (SLA)
Direct Light Processing (DLP)
Selective Laser Sintering (SLS) and Digital Metal Laser Sintering (DMLS)
Electron Beam Melting (EBM)
Selective Laser Melting (SLM)
Fused Metal Deposition (LMD)



CAD MODEL INTO STL FORMAT



STL uses triangles to describe the surfaces to be built. Each triangle is described as three points and a facet normal vector indicating the outward side of the triangle, in a manner similar to the following:

facet normal 4.470293E02 7.003503E01 7.123981E-01
outer loop
vertex 2.812284E+00 2.298693E+01 0.000000E+00
vertex 2.812284E+00 2.296699E+01 1.960784E02
vertex 3.124760E+00 2.296699E+01 0.000000E+00
endloop endfacet

GENERIC AM

Effects of building using different layer thicknesses

OTHER RELATED TECHNOLOGIES

1. Reverse engineering technology
2. Computer aided engineering (CAE):

   3D CAD model + Engineering analysis software packages
3. Haptic

Source: Gibson, Additive Manufacturing

Difference between various AM techniques?

- ✓ Techniques used for creating layers;
- ✓ Techniques of bonding the layers together;
- ✓ Speed;
- ✓ Layer thickness;
- ✓ Range of materials;
- ✓ Accuracy;
- ✓ Cost.

Evolution

AM applications timeline

This timeline lays out past, present and potential future AM developments and applications.
(courtesy of Graham Tromans)

1988-1994	rapid prototyping
1994	rapid casting
1995	rapid tooling
2001	AM for automotive
2004	aerospace (polymers)
2005	medical (polymer jigs and guides)
2009	medical implants (metals)
2011	aerospace (metals)
2013-2016	nano-manufacturing
2013-2017	architecture
2013-2018	biomedical implants
2013-2022	in situ bio-manufacturing
2013-2032	full body organs

CASE STUDY

GE AND MORRIS TECHNOLOGY
Graham Tromans

The automotive and aerospace industries are two of the main beneficiaries of AM. In 2012, GE Aviation bought AM Morris Technologies, one of the biggest metal additive manufacturers in the world. GE is ramping up AM manufacturing of aero engine fuel nozzles. The conventional method of making fuel nozzles requires making 20 separate parts and welding them together, "which is extremely labour-intensive and has a high scrap rate," said Graham Tromans, Principal and President of AM consultancy GP Tromans Associates. AM allows the creation of pre-assembled nozzles. GE predicts that, by late 2015/16, it will make 10-20 fuel nozzles for each engine using AM, or 25,000 a year. The company also envisages that 50% of a jet engine will be additive manufactured within current lifetimes.

Pros and Cons

Pros	Cons
Freedom to design and innovate without penalties	Unexpected pre- and post-processing requirements
Rapid iteration through design permutations	High process cost
Excellent for mass customization	Lack of industry standards
Elimination of tooling	Low speed, not suitable for mass production
Green manufacturing	Inconsistent Materials
Minimal material waste	Limited number of materials
Energy efficient	High equipment cost for high-end manufacturing
Enables personalized manufacturing	

Benefits

AM benefits: Weight reduction

TRADITIONAL DESIGN

Source: SAVING project

> A conventional steel buckle weights 155 g[1)]

> Weight should be reduced on a like-for-like basis within the SAVING project

> Project partners are Plunkett Associates, Crucible Industrial Design, EOS, 3T PRD, Simpleware, Delcam, University of Exeter

AM OPTIMIZED DESIGN

Source: SAVING project

> Titanium buckle designed with AM weighs 70 g – reduction of 55%

> For an Airbus 380 with all economy seating (853 seats), this would mean a reduction of 72.5 kg

> Over the airplane's lifetime, 3.3 million liters of fuel or approx. EUR 2 m could be saved, assuming a saving of 45,000 liters per kg and airplane lifetime

1) 120 g when made of aluminum

Source: SAVING project/Crucible Industrial Design Ltd.; Roland Berger

MATERIAL CLASSIFICATION

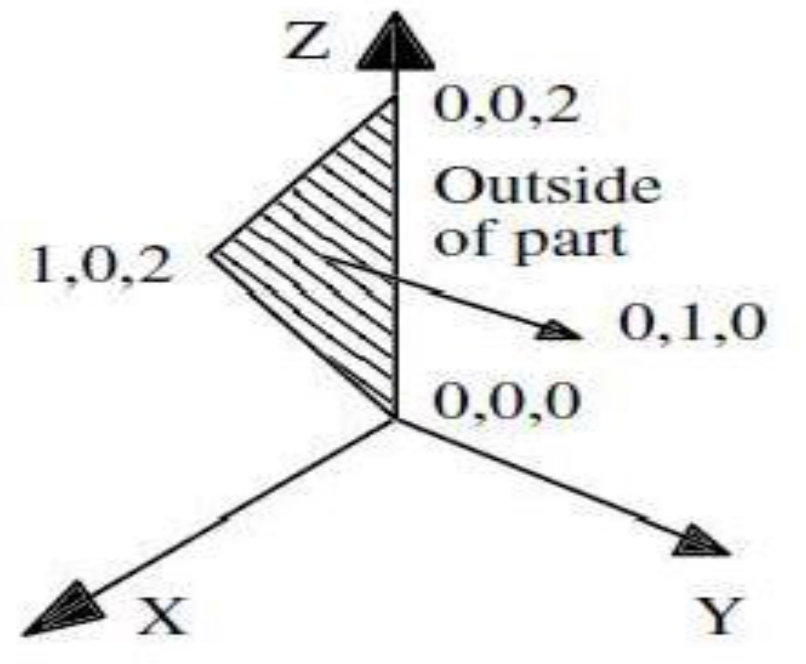
1. Polymers
2. Metals
3. Ceramics
4. Composites

Polymers

a) ABS polymer
b) Acrylics
c) Cellulose
d) Nylon
e) Polycarbonate
f) Thermoplastic polyester
g) Polyethylene
h) Polypropylene
i) Polyvinylchloride

SAMPLE STL FILE

```
solid print
 facet normal 0.00000e+00  1.00000e+00  0.00000e+00
  outer loop
   vertex  0.00000e+00  0.00000e+00  2.00000e+01
   vertex  0.00000e+00  0.00000e+00  0.00000e+00
   vertex  1.00000e+01  0.00000e+00  2.00000e+01
  endloop
 endfacet
 facet normal 0.00000e+00  1.00000e+00  0.00000e+00
  outer loop
   vertex  1.00000e+01  0.00000e+00  2.00000e+01
   vertex  0.00000e+00  0.00000e+00  0.00000e+00
   vertex  1.00000e+01  0.00000e+00  0.00000e+00
  endloop
 endfacet
.......
```



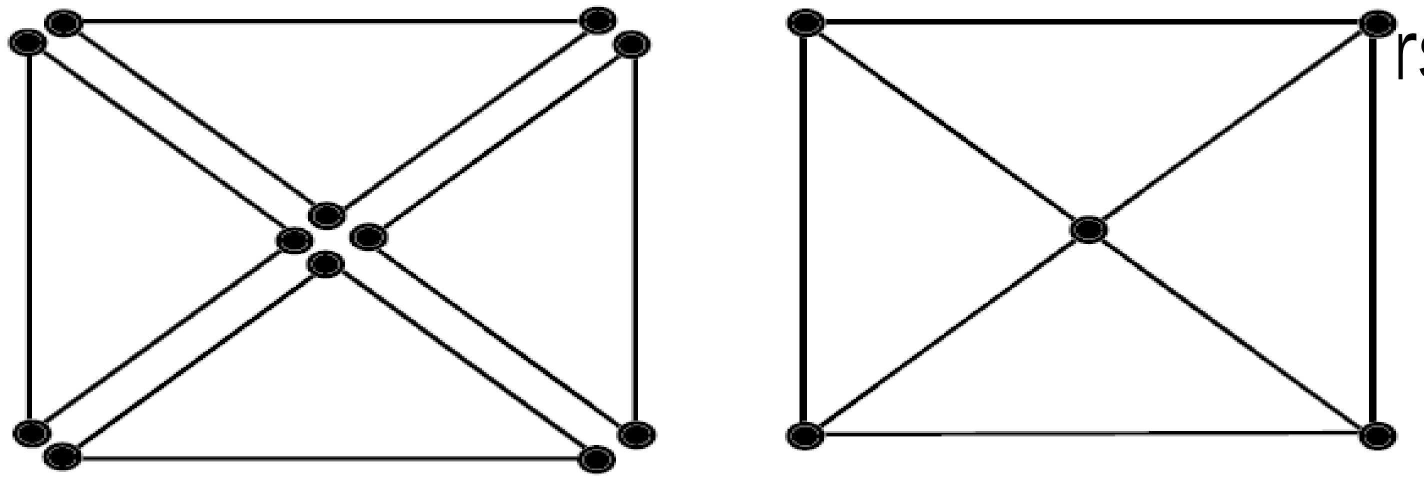
STL FILE

Advantages

- (i) Provides a simple method of representing 3D CAD data
- (ii) A *de facto* standard and has been used by most CAD systems and RP systems
- (iii) It can provide small and accurate files for data transfer for certain shapes

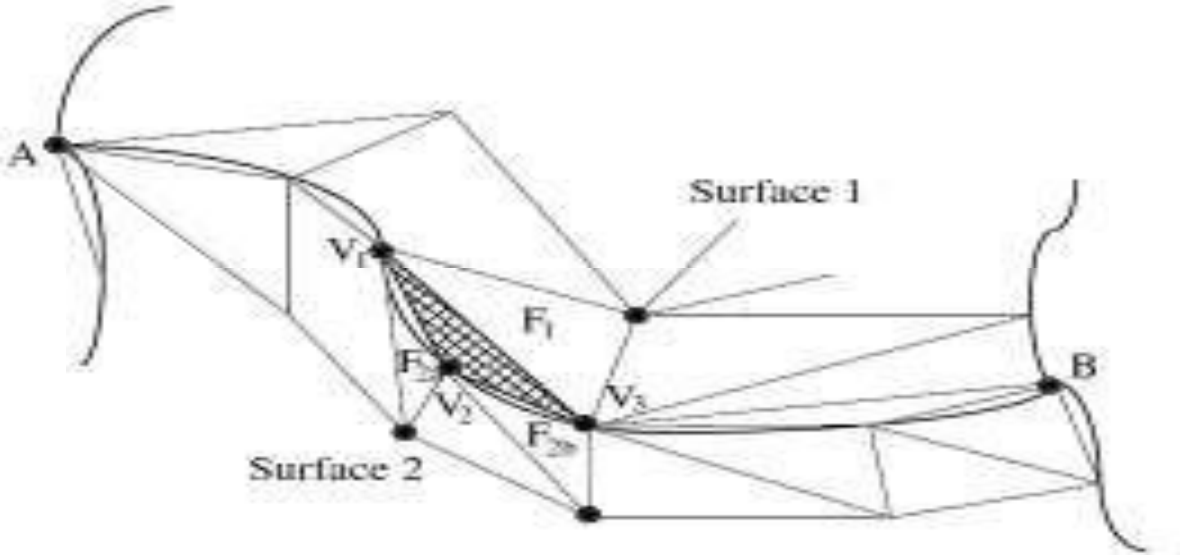
Disadvantages

- (i) The STL file is many times larger than the original CAD data file
- (ii) The geometry flaws exist in the STL file
- (iii) The subsequent slicing ... rs



STL File Problems

(1) Gaps (cracks, holes, punctures) that is, missing facets.
(2) Degenerate facets (where all its edges are collinear).
(3) Overlapping facets.
(4) Non-manifold topology conditions.



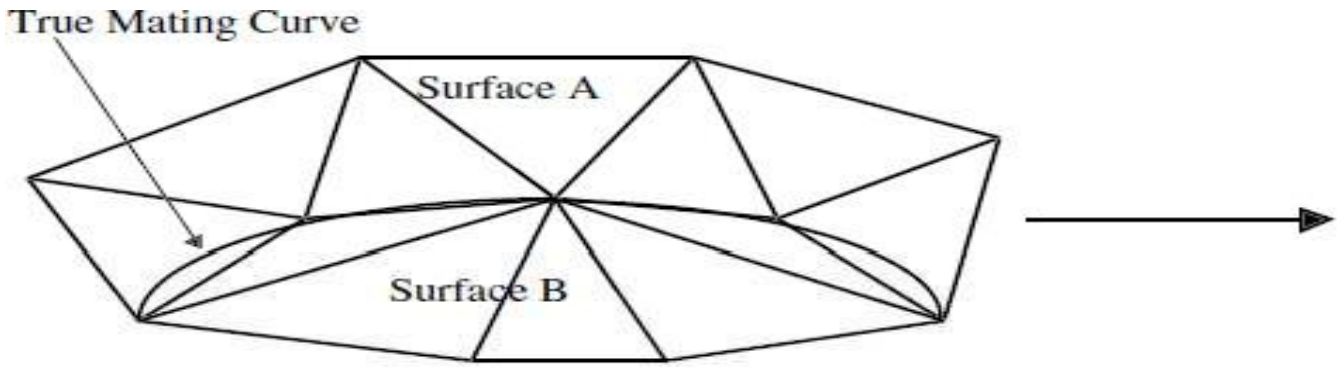


Figure 6.4(a): Shell punctures created by unequal tessellation of two adjacent surface patches along their common mating curve

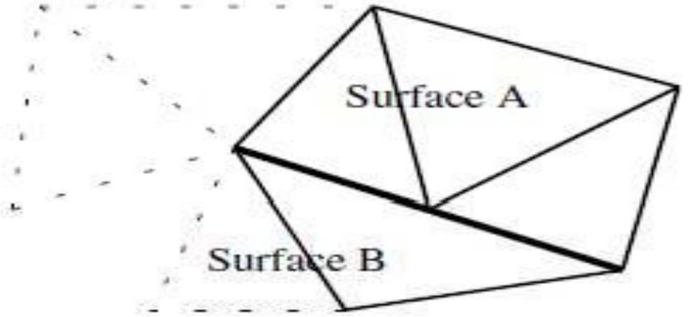
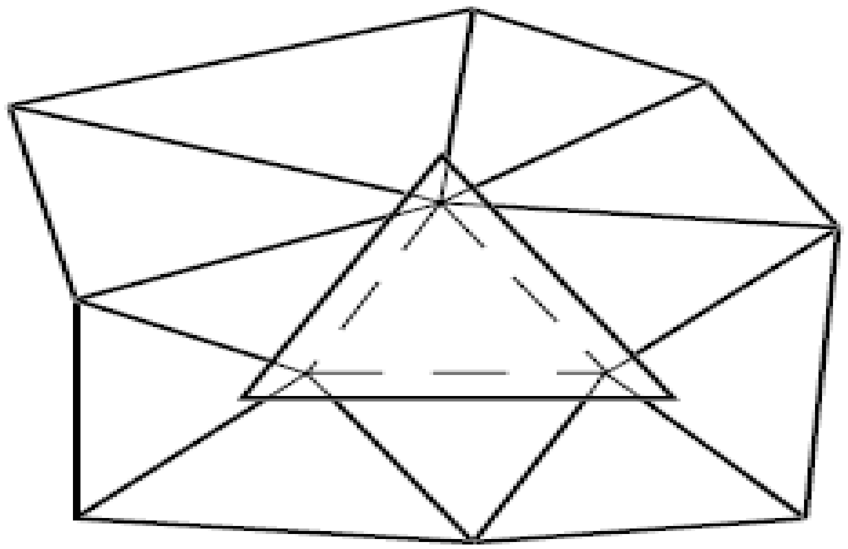
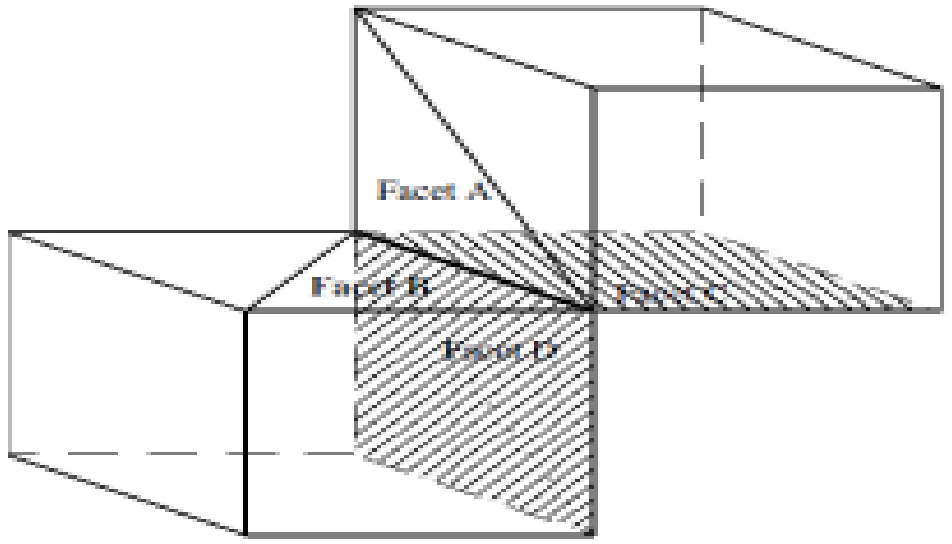


Figure 6.4(b): Shell punctures eliminated at the expense of adding degenerate facet





Valid vs. Invalid Tessellated Models

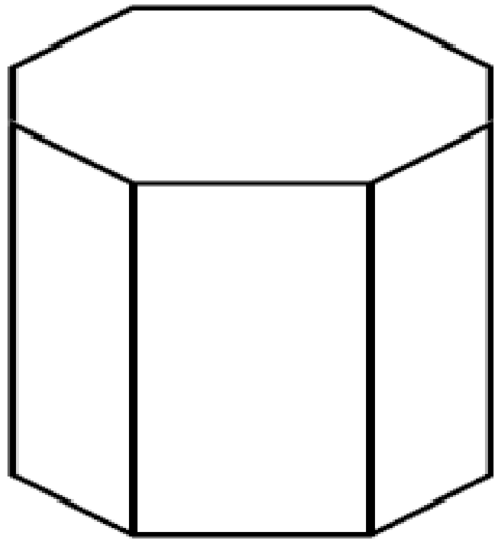


Figure 6.7(a): A valid 3D model

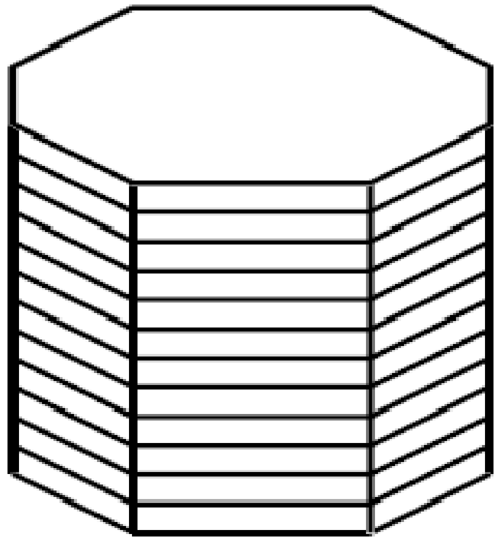


Figure 6.7(b): A 3D model sliced into 2D planar layers

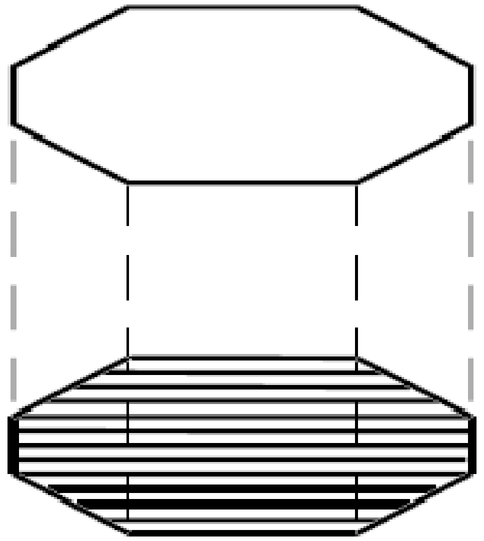


Figure 6.7(c): Conversion of 2D layers into 1D scan lines

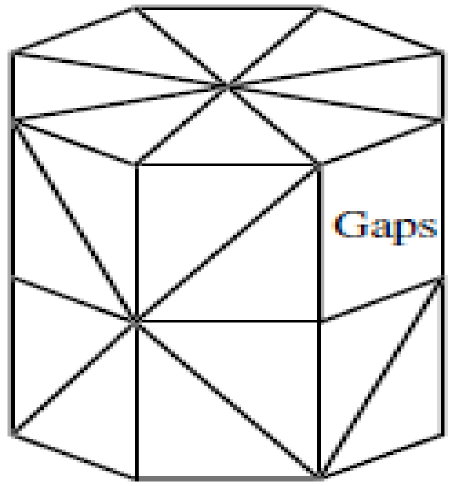


Figure 6.8(a): An invalid tessellated model

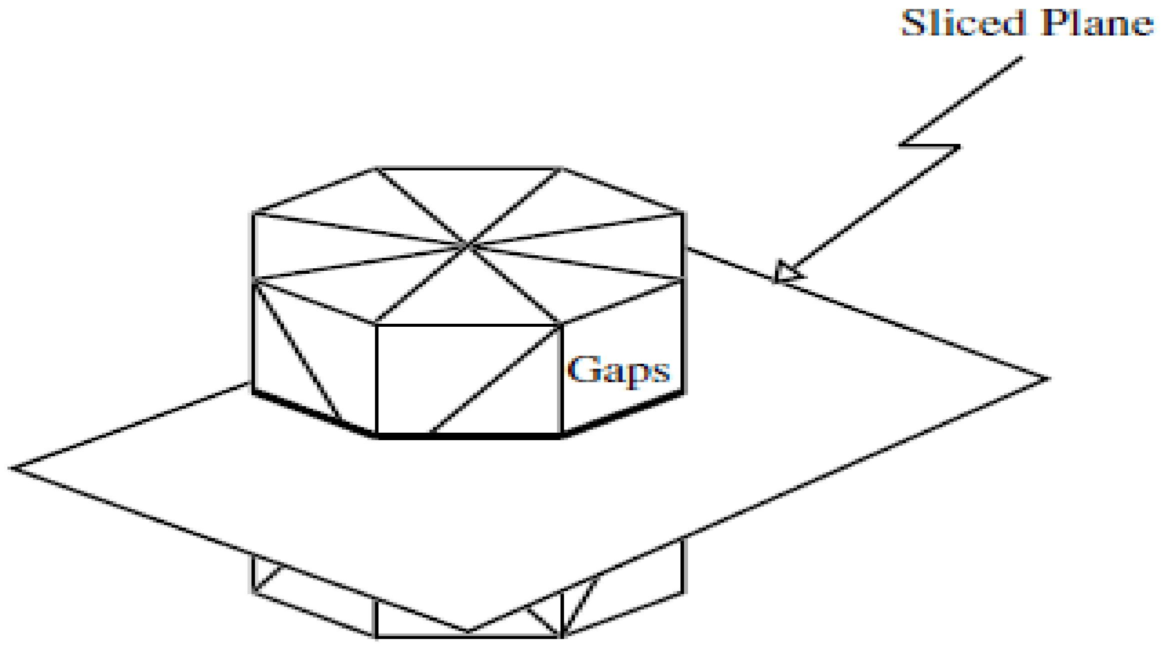


Figure 6.8(b): An invalid model being sliced

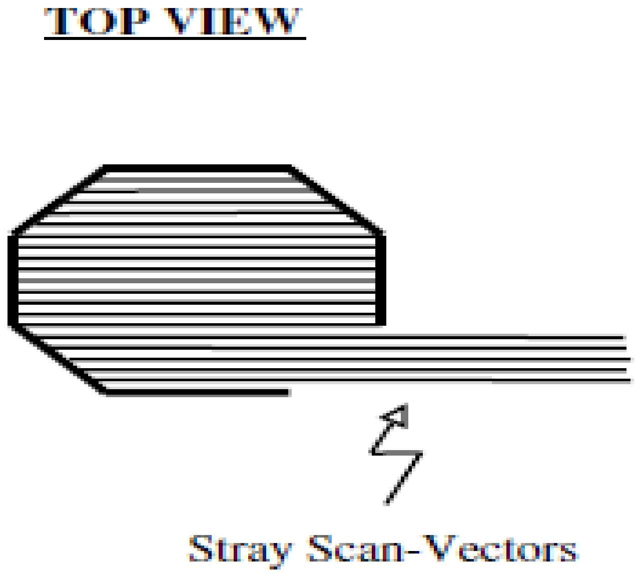
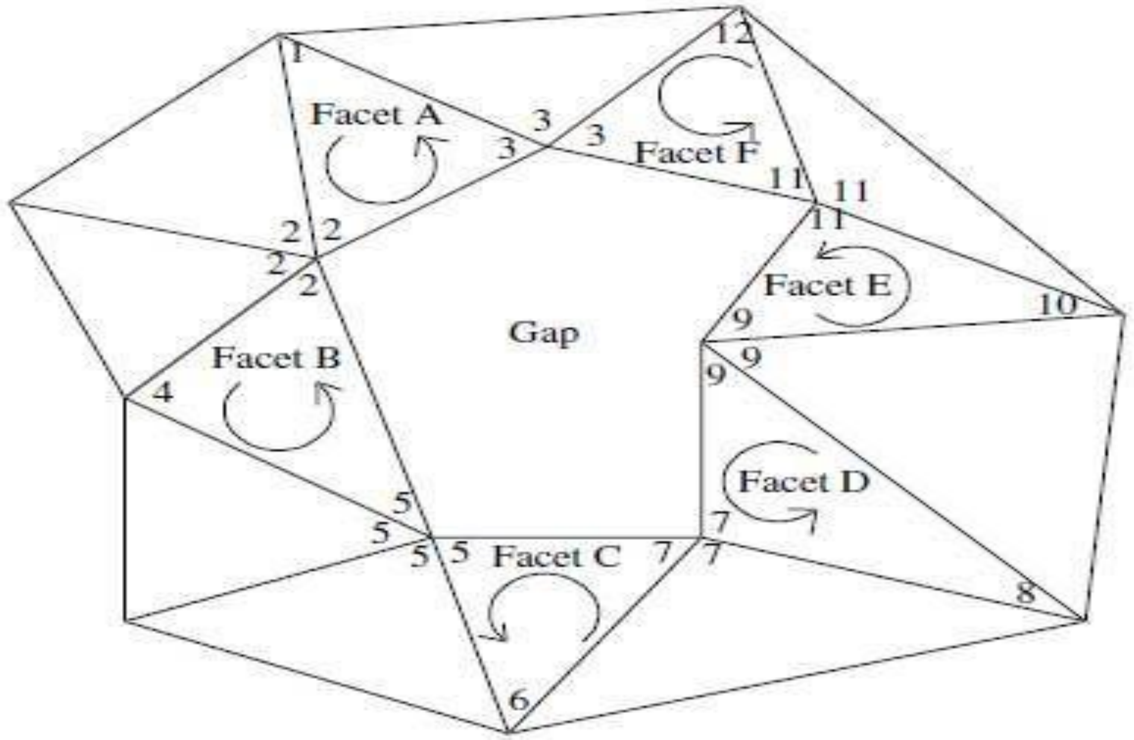
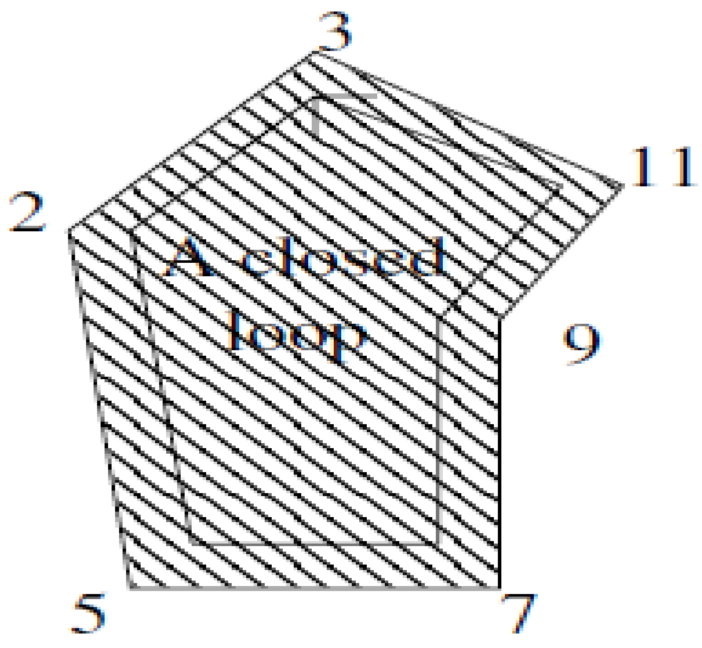


Figure 6.8(c): A layer of an invalid model being scanned

STL File Repair





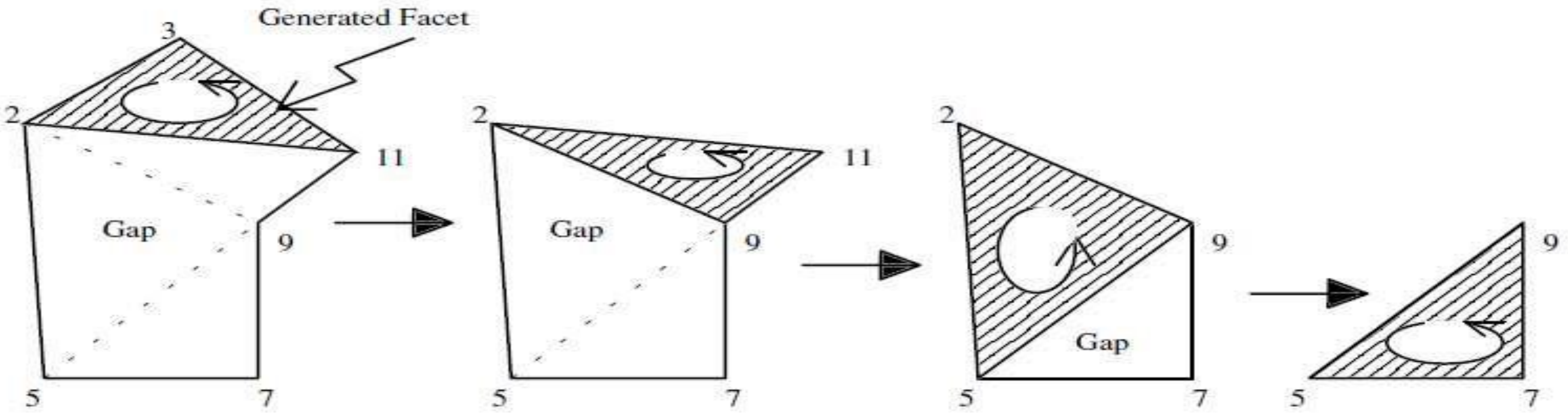
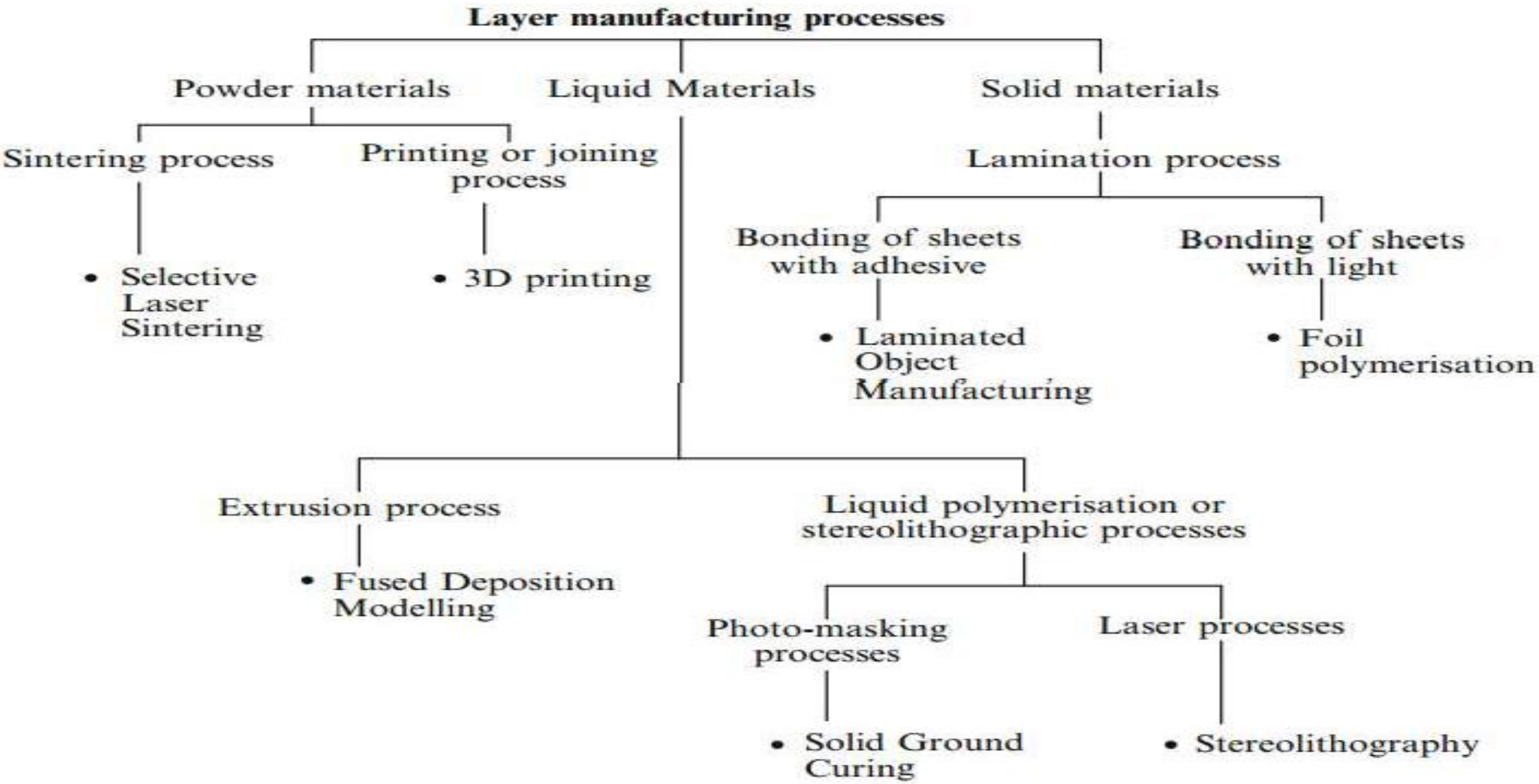


Figure 6.12(a): First facet generated

Figure 6.12(b): Second facet generated

Figure 6.12(c): Third facet generated

Figure 6.12(d): Fourth facet generated


Layer manufacturing processes
Powder materials
Liquid Materials
Solid materials
Sintering process
Printing or joining process
• Selective Laser Sintering
• 3D printing
Lamination process
Bonding of sheets with adhesive
Bonding of sheets with light
• Laminated Object Manufacturing
• Foil polymerisation
Extrusion process
Liquid polymerisation or stereolithographic processes
• Fused Deposition Modelling
Photo-masking processes
Laser processes
• Solid Ground Curing
• Stereolithography

2D Vs 3D Modelling

Aspects of 2D and 3D

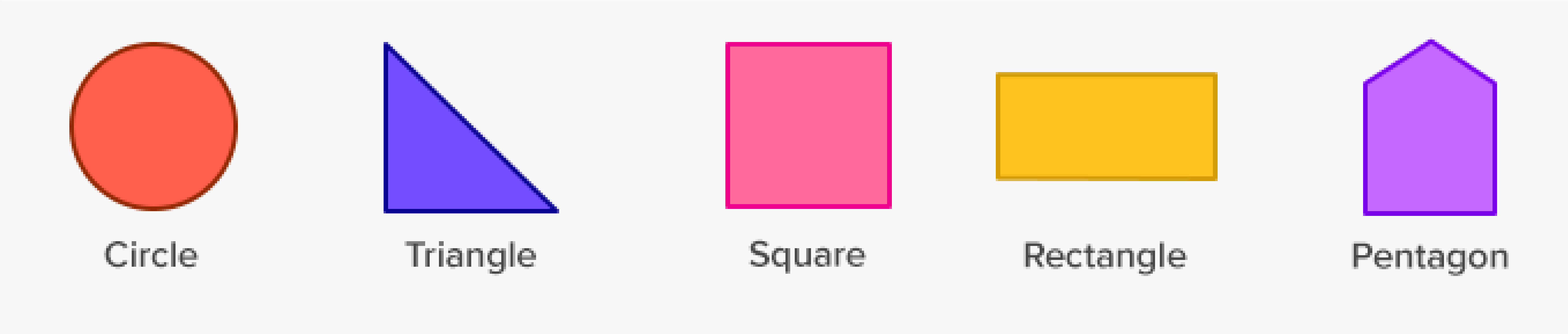
A 2D shape is a figure that has only length and height as its dimensions. Because 2D shapes lie on a flat surface, they are also known as plane figures or plane shapes. While they have areas, 2D shapes have no volume.

Apart from length and height, a 3D shape also has width or depth as its third dimension.

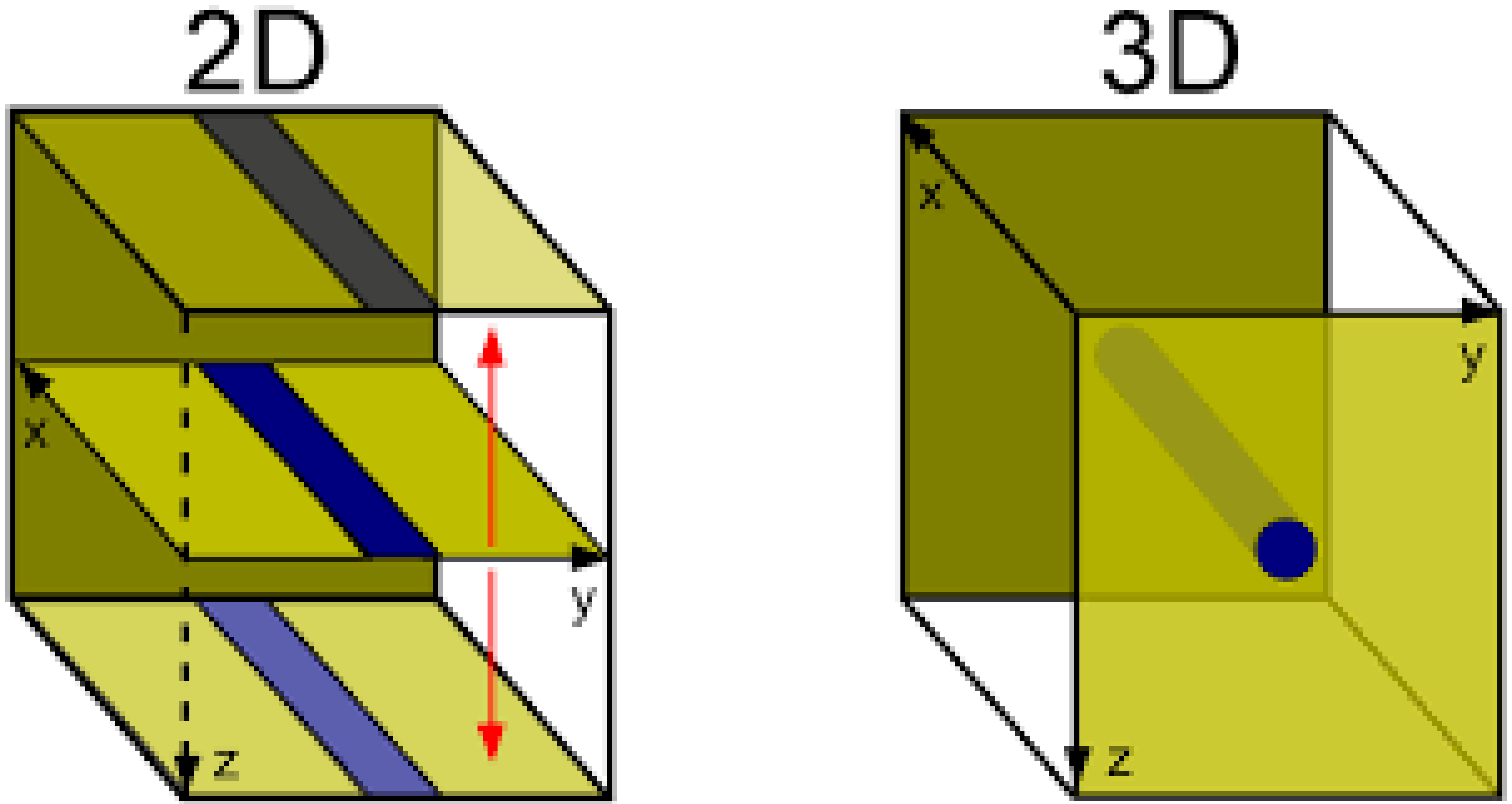
2D Vs 3D Modelling

	2D	3D
Definition	Two-dimensional	Three-dimensional
Dimensions	Length and height	Length, height, and width
Mathematical Definition	x- and y-axes	x-, y-, and z-axes
Examples	Circle, triangle, square, rectangle, and pentagon	Cylinder, pyramid, cube, and prism

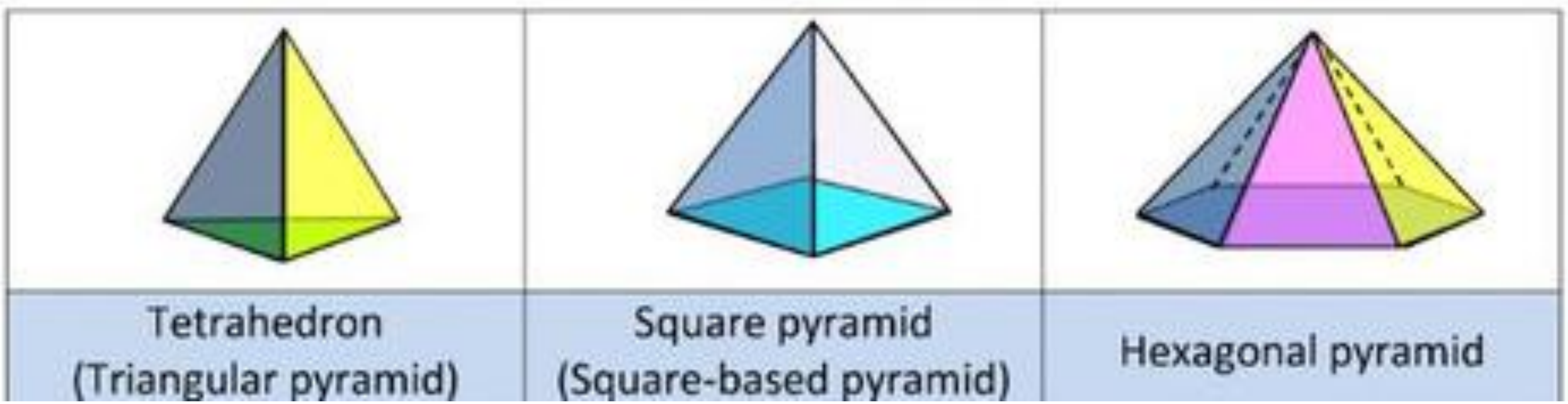
2D Examples

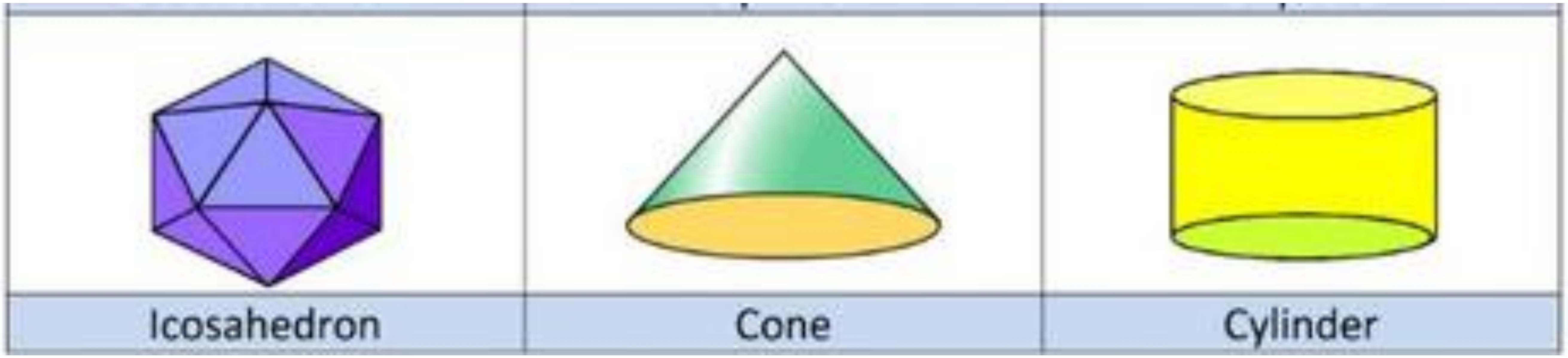


2D Examples

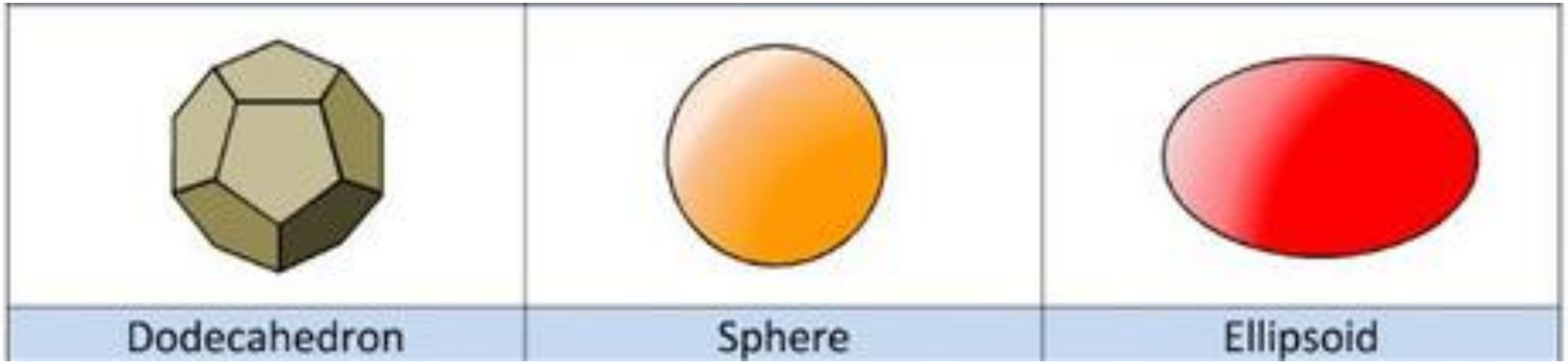


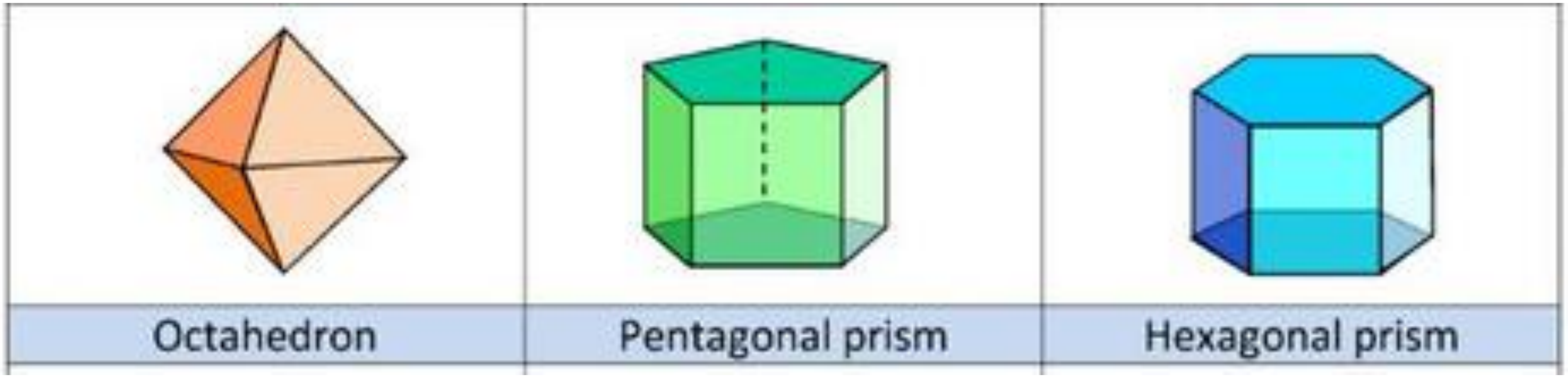
3D Examples


Tetrahedron
(Triangular pyramid)
Square pyramid
(Square-based pyramid)
Hexagonal pyramid

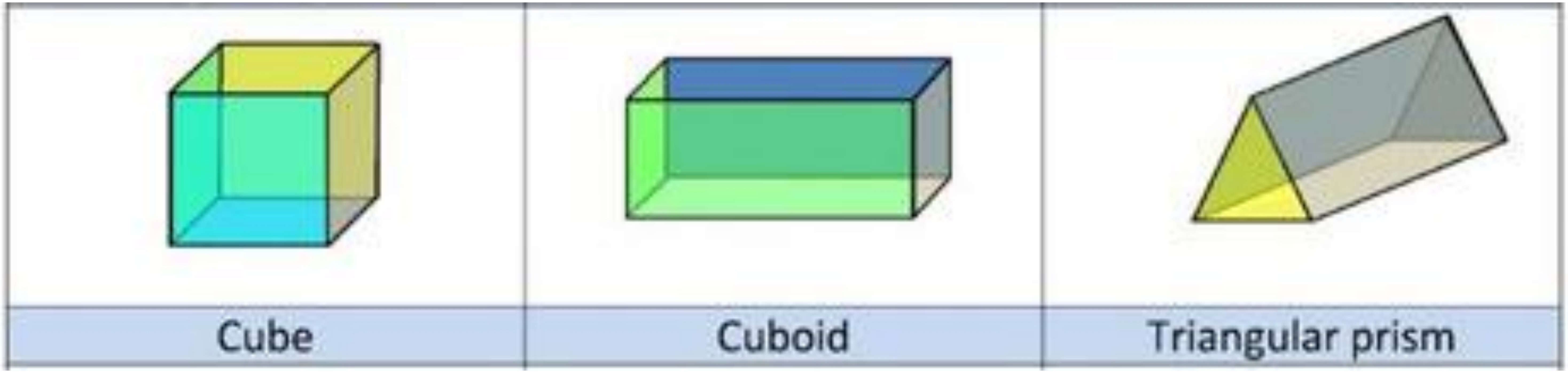

Icosahedron
Cone
Cylinder

3D Examples


Dodecahedron
Sphere
Ellipsoid


Octahedron
Pentagonal prism
Hexagonal prism

3D Examples



3D Modelling Softwares

- Inventor
- Solid Edge
- Solidworks
- CATIA
- ProE.Houdini
- Cinema 4D
- Modo
- Autodesk 3Ds Max
- Autodesk Maya
- Autodesk Mudbox
- ZBrush
- Rhinoceros

2D Modelling Softwares

- AutoCAD.
- LibreCAD.
- nanoCAD.
- QCAD.
- DraftSight.
- Draft IT.
- ActCAD 2019 Professional.
- BricsCAD.

Thank You