Course Title: Computer Graphics
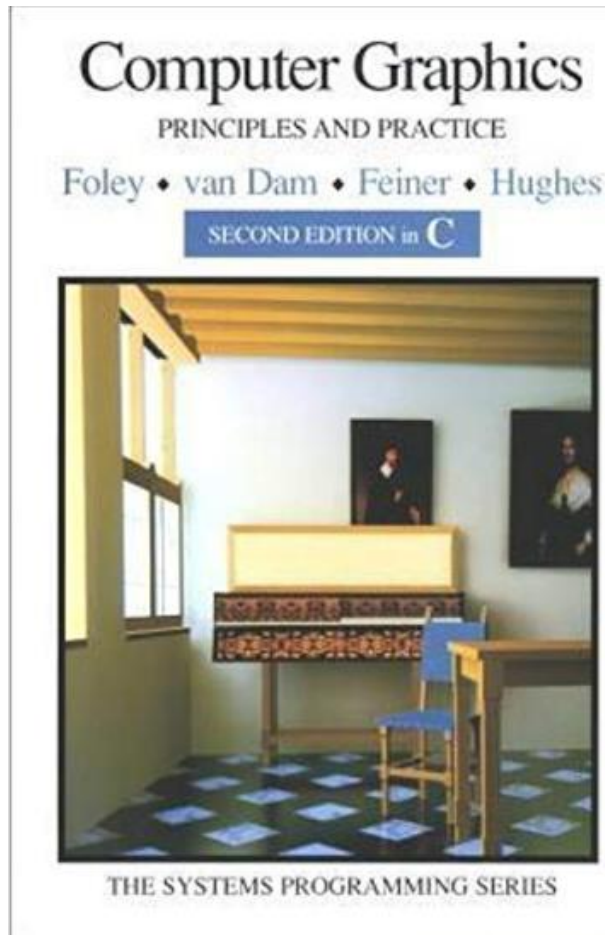
Course Instructor: Dr. Prerana Mukherjee (PhD, IIT Delhi)
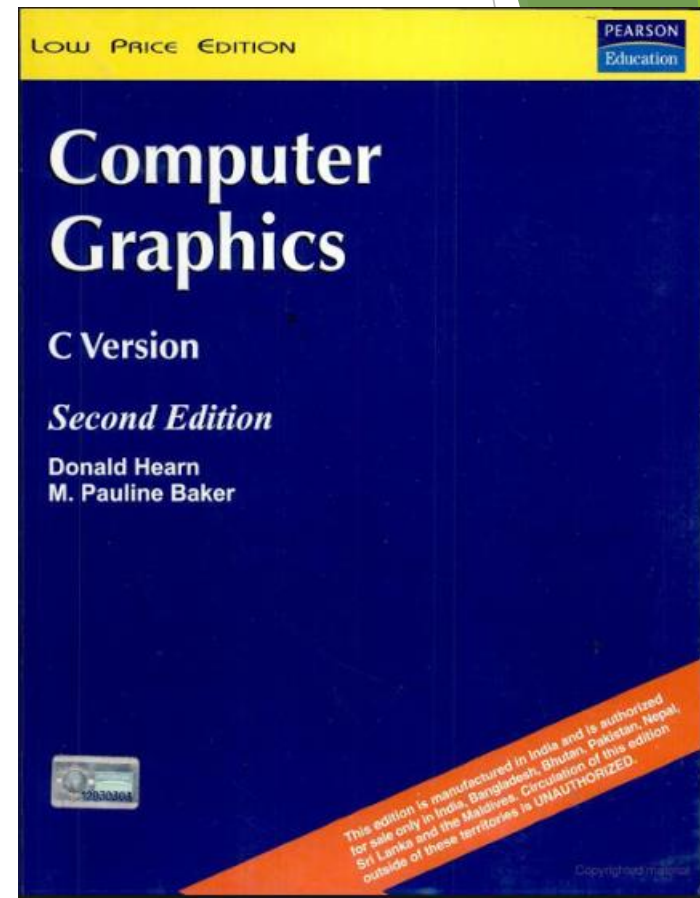**Course Webpage: TBD**

Teaching Assistants (TAs):

Textbooks

Computer Graphics (2nd Edition) by Foley

Computer Graphics (2nd Edition) by Hearn and Baker

CHAPTER 1

Introduction to Computer Graphics

Outline

▶ Basic Definitions

▶ Applications

▶ GUI – Graphical User Interface

▶ Various application packages and standards are available

▶ Tools used

▶ Active vs Passive CG systems

▶ Geometric Primitives

▶ Geometric Modelling: 2-D Projection

▶ Geometric Modelling: Wireframe

Outline

▶ Geometric Modelling: Solid Modelling

▶ Geometric Modelling: CSG

▶ Boolean Operators

▶ CSG Tree

Basic Definitions

▶ Computer Graphics involves display, manipulation and storage of pictures and experimental data for proper visualization using a computer.

▶ Typical graphics system comprises of a host computer with support of fast processor, large memory, frame buffer and

• Display devices (color monitors),

• Input devices (mouse, keyboard, joystick, touch screen, trackball)

• Output devices (LCD panels, laser printers, color printers. Plotters etc.)

• Interfacing devices such as, video I/O, TV interface etc.
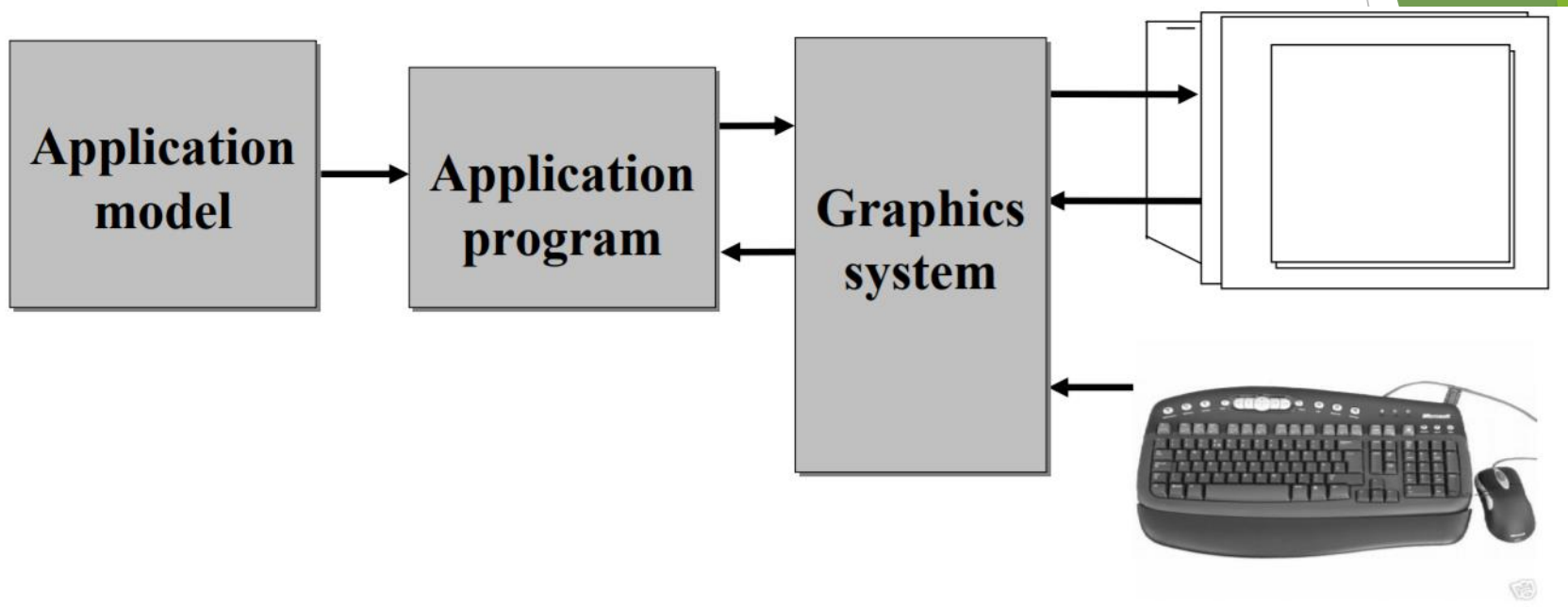
Conceptual framework for interactive graphics

Applications

- **GUI**

- **Office automation**

- **Plotting in business**

- **Desktop publishing**

- **Plotting in science and technology**

- **Web/business/commercial publishing and advertisements**

- **CAD/CAM design (VLSI, Construction, Circuits)**

- **Scientific Visualization**

Applications

- **Entertainment**
  (movie, TV Advt., Games etc.)

- **Simulation studies**
- **Simulators**

- **Cartography**
- **Multimedia**

- **Virtual reality**

- **Process Monitoring**

- **Digital Image Processing**

- **Education and Training**

GUI – Graphical User Interface

Typical Components Used:

- **Menus**
- **Icons**
- **Cursors**
- **Dialog Boxes**
- **Scroll Bars**

- **Buttons**
- **Valuators**
- **Grids**
- **Sketching**
- **3-D Interface**

Various application packages and standards are available:

- **Core graphics**

- **GKS**

- **SRGP**

- **PHIGS, SPHIGS and PEX 3D**

- **OpenGL (with ActiveX and Direct3D)**

- **X11-based systems.**

Various application packages and standards are available:

- **Core graphics**

- **GKS** — Graphics Kernel System by ISO (International Standards Organization) & ANSI (American National Standards Institute)

- **SRGP** — Simple Raster Graphics Package

- **PHIGS, SPHIGS and PEX 3D** — Programmers Hierarchical Interactive Graphics System

- **OpenGL (with ActiveX and Direct3D)**

- **X11-based systems.**

Various platforms used:

DOS,	Windows,
Linux,	OS/2,
SGI,	SunOS,
Solaris,	HP-UX,
Mac,	DEC-OSF.

Tools used:

Various utilities and tools available for web-based design include: Java, XML, VRML and GIF animators.

Certain compilers, such as, Visual C/C++, Visual Basic, Borland C/C++, Borland Pascal, Turbo C, Turbo Pascal, Gnu C/C++, Java provide their own graphical libraries, API, support and help for programming 2- D/3-D graphics.

Some these systems are
❑ device-independent (X11, OpenGL)
❑ device-dependent (Solaris, HP-AGP).

Active vs Passive CG systems

- Computer Graphics systems could be active or passive.

- In both cases, the input to the system is the scene description and output is a static or animated scene to be displayed.

- In case of active systems, the user controls the display with the help of a GUI, using an input device.

- Computer Graphics is now-a-days, a significant component of almost all systems and applications of computers in every field of life.

Geometric Primitives

Four basic output primitives (or elements) for drawing pictures:

- **POLYLINE**
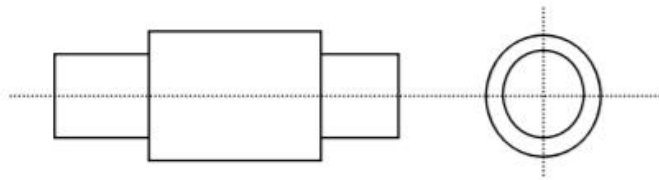
- **Filled POLYGONS (regions)**

- **ELLIPSE (ARC)**

- **TEXT**

- **Raster IMAGE**

Four major areas of Computer Graphics are:

- **Display of information,**

- **Design/Modeling,**

- **Simulation and**

- **User Interface.**

# Geometric Modelling: 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
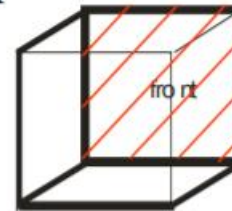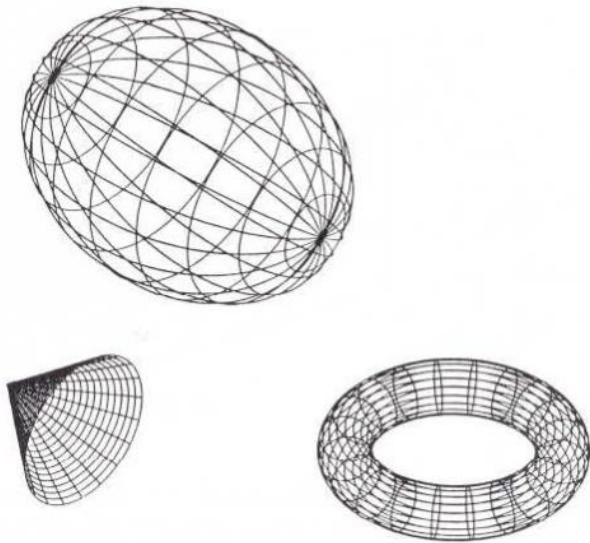
Geometric Modelling: Wireframe

- 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 <u>points, lines, arcs and circles, conics, and curves</u>.
- 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.
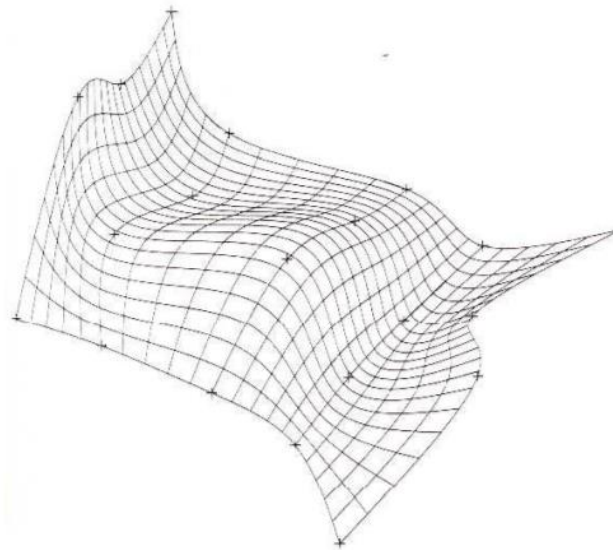
or

front

front
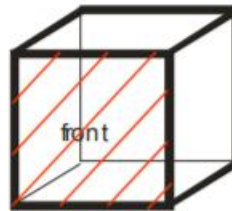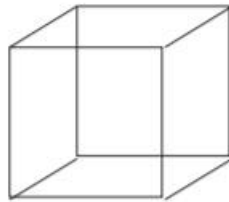
ambiguous

Analytical Surfaces

Free-form, Curved, or
Sculptured Surface

Geometric Modelling: Surface

- 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

- Used to be separated, shape model are now incorporated into solid models (e.g. Pro/E)
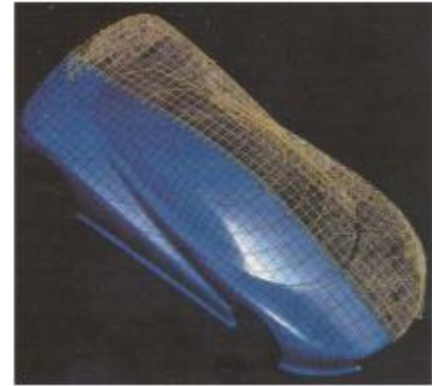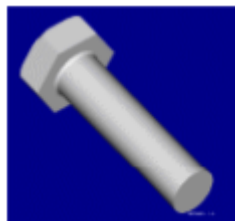
Example: Surface Modelling

- Surface models define only the geometry, no topology.
- Shading is possible
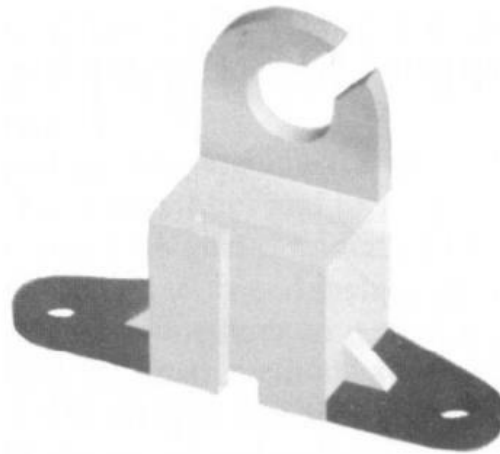
Shading - by interpreting the polygons'
- Direction (normal)
- Spatial order

Why Solid Modeling?
Using volume information
– weight or volume calculation, centroids, moments of inertia calculation,
– stress analysis (finite elements analysis), heat conduction calculations, dynamic analysis,
– system dynamics analysis
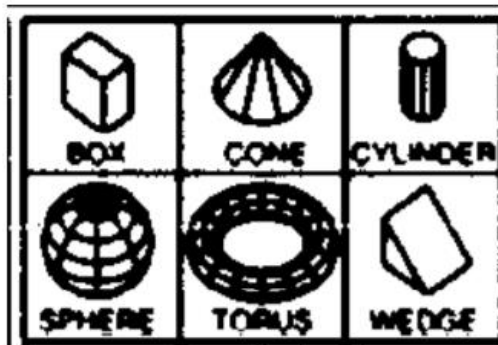- store both geometric and topological information

Constructive Solid Geometry (CSG)

- Pre -defined geometric defined geometric primitives primitives
- Boolean operations
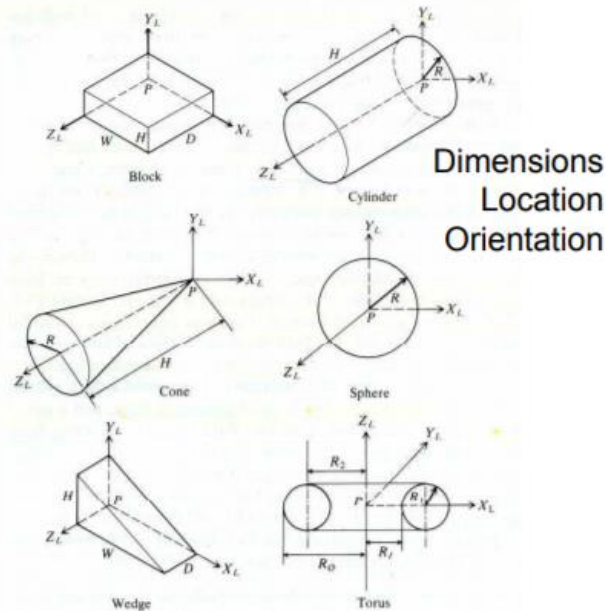- CSG tree structure (building process/approach)

Geometric Primitives - CSG

- A collection of pre-defined (low level) geometric primitives
- Sweeping of a 2D cross-section in the form of extrusion and revolving are used to define the 3D shape (for uncommon shapes).
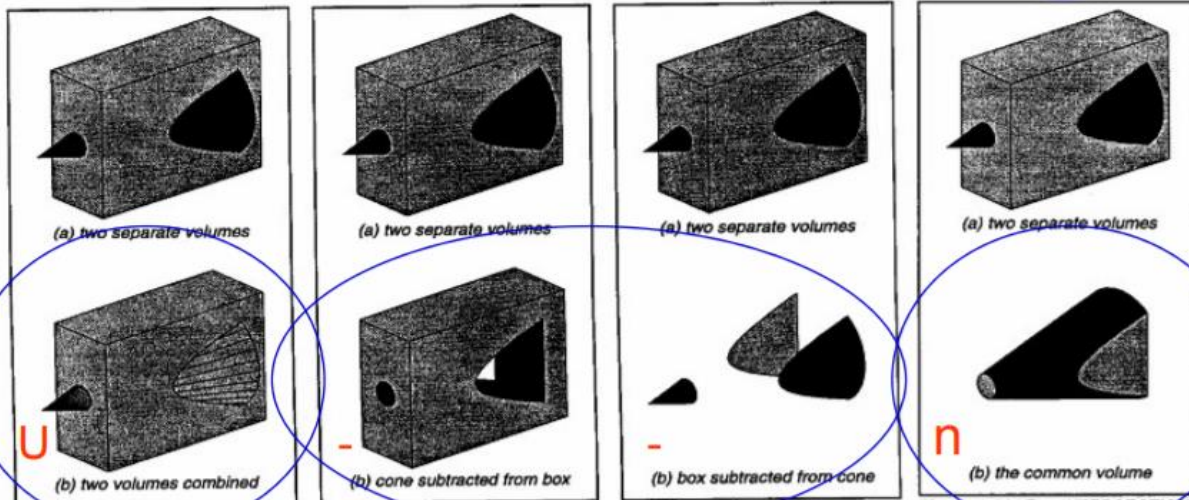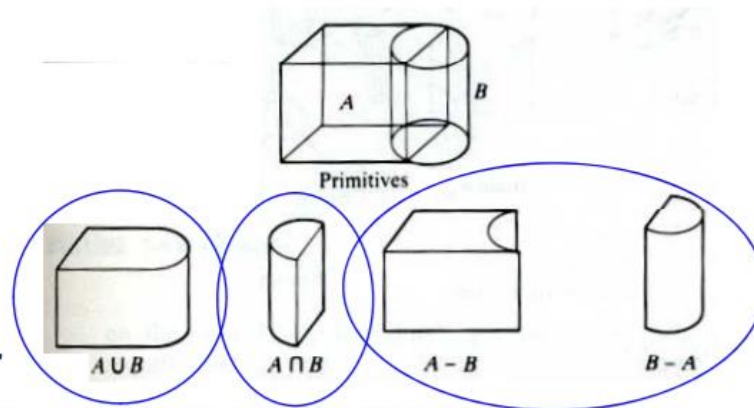

Low Level Geometric Primitives

Defined Geometric Features

Dimensions
Location
Orientation

Boolean Operations in CSG

- Union, **U**
- Intersection, **n**
- Difference, or Subtraction, **-**

Primitives

$A \cup B$ $A \cap B$ $A - B$ $B - A$

(a) two separate volumes   (a) two separate volumes   (a) two separate volumes   (a) two separate volumes

(b) two volumes combined   (b) cone subtracted from box   (b) box subtracted from cone   (b) the common volume
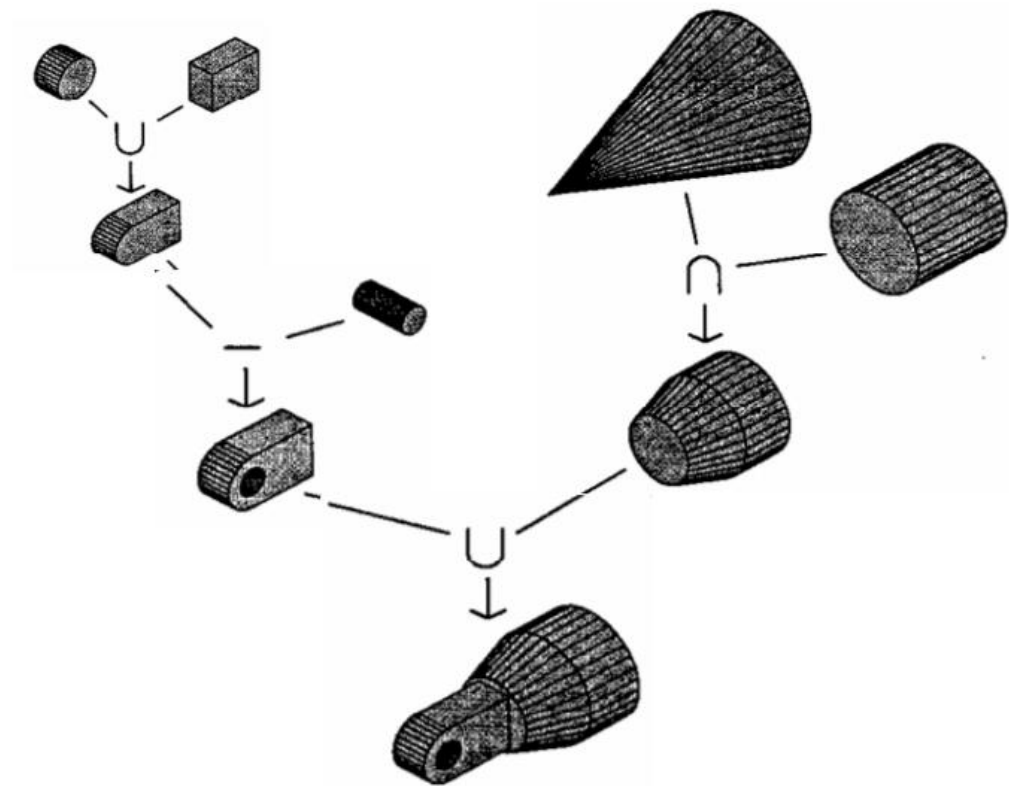
CSG Tree

CSG Tree
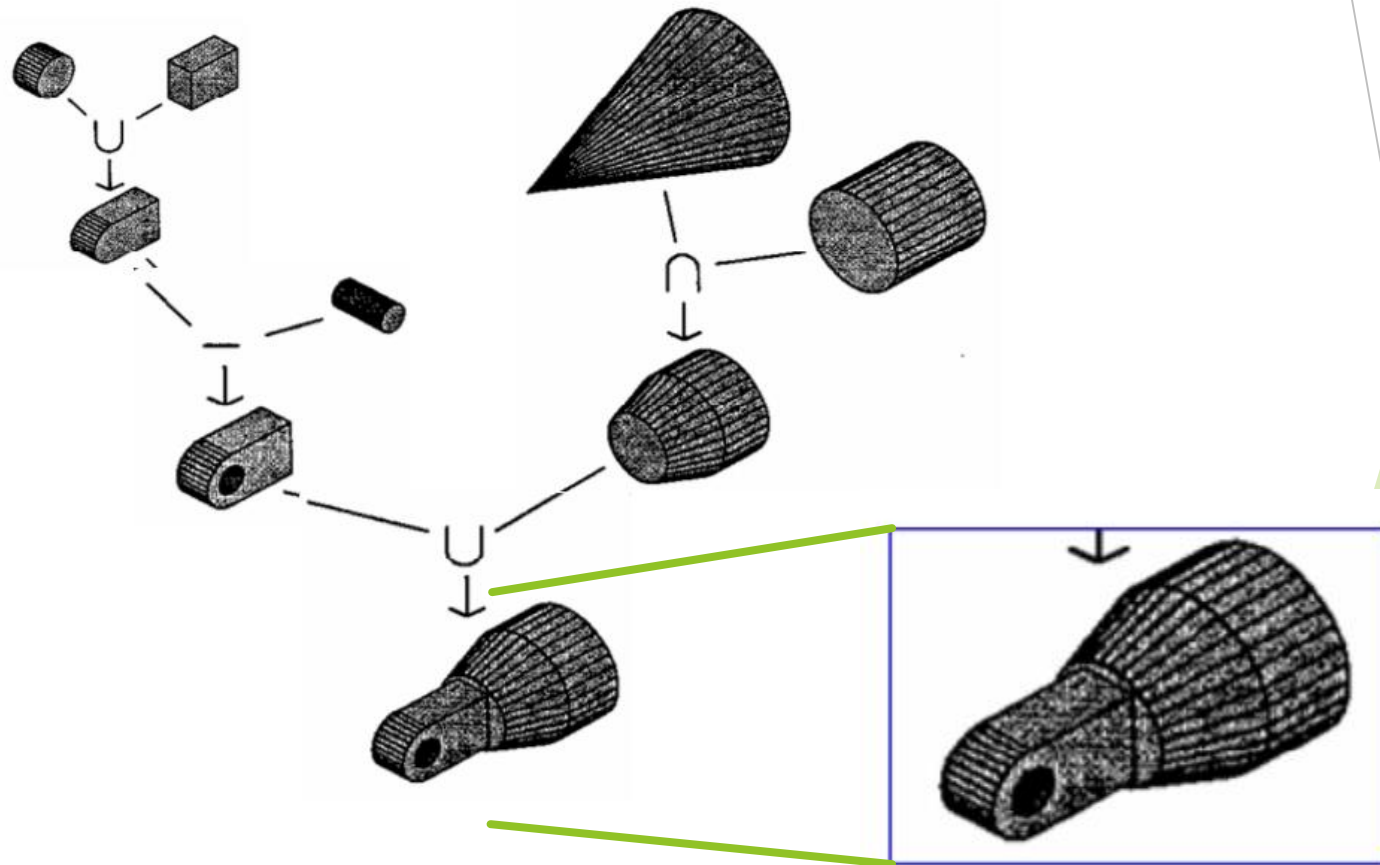
Concepts (1)

▶ Various fundamental concepts and principles in Computer Graphics are

▶ Display Systems Storage displays, Random scan, Raster refresh displays, CRT basics, video basics, Flat panel displays.

▶ Transformations Affine (2-D and 3-D): Rotation, Translation, Scale, Reflection and Shear. Viewing: The Camera Transformations - perspective, orthographic, isometric and stereographic views, Quaternion.

Concepts (2)

▶ Scan Conversion and Clipping Drawing of Points, Lines, Markers, Curves, Circles, Ellipse, Polyline, Polygon. Area filling, fill-style, fill pattern, clipping algorithms, anti-aliasing etc.

▶ Hidden Surface Removal Back face culling, Painter's algorithm, scan-line algorithm, BSP-trees, Z-buffer/sorting, Ray tracing etc.

▶ Shading & Illumination Phong's shading model, texture mapping, bump mapping, Gouraud shading, Shadows and background, Color models etc.

Concepts (3)

▶ Solid Modeling Wire-frame, Octrees, Sweep, Boundary representations. Regularized Boolean set operations, Constructive Solid Geometry.

▶ Curves and Surfaces Bezier (Bernstein Polynomials) Curves, BSplines, Cubic-Splines, Quadratic surfaces, parametric and non-parametric forms, Hermite Curves etc.

Concepts (4)

- Miscellaneous Animation, Fractals, Projection and Viewing, Geometry, Modeling, Image File formats, Image Morphing, Interaction (sample and event-driven) etc.

- Advanced Raster Graphics Architecture Display Processors, Pipeline and parallel architectures, multi-processor systems, hybrid architectures.

References

1. Computer Graphics; Principles and practice; 2nd edn. in C; J. Foley, A. Van Dam, Feiner and Hughes; Addison Wesley, 1997.
2. Mathematical elements for Computer Graphics; 2nd edn.; D. F. Rogers and J. A. Adams; McGraw-Hill International. Edn., 1990.
3. Computer Graphics - C version; D. Hearn and M. P. Baker; Pearson Education, 2004.
4. Computer Graphics using OpenGL; 2nd edn.; F. S. Hill Jr.; Pearson Education, 2003.
5. Procedural Elements for Computer Graphics; 2nd Edn., D. F. Rogers, Tata McGraw-Hill, 2002.