Computer Graphics Summary - Ankit Pangeni

- Computer Graphics: Field related to the creation, storage and manipulation of images of objects.
- Applications of CG: GUI, education, Computer animation & art, virtual reality, simulation and modelling
- Pixel: One dot or a picture element.
- Scan line: A row of pixel
- Raster: A rectangular array of pixels.
- Resolution: Maximum number of pixels that can be displayed horizontally and vertically on a display device.
- Refresh rate: Number of times per sec the image is redrawn.
- Raster Graphics: Composed of pixels, increase or decrease in image quality depending upon size, requires scan conversion
- Vector Graphics: Composed of paths, more expensive, no inc or dec.
- Aspect ratio: Ratio of vertical to horizontal points of the screen
- Frame Buffer: Memory where picture definition is stored. Also called refresh buffer.
- Raster scan display: Poor or less resolution, less expensive. Stores picture defn in frame buffer. produces realistic images due to shadow & hidden surface techniques
- Random (vector) scan display: High resolution, more expensive, Stores picture definition in refresh display file, Produces less realistic image.
- Input devices: Mouse, keyboard, light pen, track ball, etc.
- Beam penetration:- used with Random Scan system to display color, can display four colors: red, green, orange & yellow. picture quality is poor but gives high resolution.
- Shadow mask: Used with raster scan system. Can display millions of color, more expensive, picture quality is high & gives low resolution.
- Graphics software: a) General programming packages: used in C, JAVA Ex: open GL
  b) special-purpose: CAD, paint, adobe draw

o Software standards: a) Graphics kernal system (GKS)
→ 1st graphics software adopted by ISO
→ originally designed as 2D graphics package
→ Rewriting code is not required.

b) PHIGS (programmers Hierarchical interactive Graphics standard)
→ extension of GKS that provides 3D package
→ provides additional functions for object modeling, surface rendering

c) PHIGS+
→ extension of PHIGS
→ 3D surface shading capabilities

o Scan conversion: Procedure used to digitize or rasterize the pixel data available on frame buffer.

o Line drawing algorithms: (Line: set of points defined by its width & endpoints)

1) Digital Differential Analyser (DDA)
→ Simple, easy to understand, requires no special skills
→ faster than direct use of line equation
→ slope is stored in floating point (ie real arithmetic)
→ Round-off errors may occur, & time consuming

2) Bresenham's Line drawing Algorithm (BSA)
→ uses fixed points (ie. Integer arithmetic)
→ More efficient and accurate than DDA

o Circle: set of points that lie at equal distance (radius) from a fixed point called centre.

o Ellipse: Extension of circle

o Area filling: Process of filling image or region. Filling can be boundary or interior region.

o Scan line polygon fill ~~alg~~ algorithms: Used for solid color filling in polygons. Intersection of scan line with edges of polygon are found & then sorted. Then make pair of intersections & fill in the color

o Inside-outside Test: Simple way of finding whether a point is inside or outside a polygon is to test how many times a ray intersects the edges of polygon. If ray outside, then even number of intersections, if inside then odd no. of intersections

o Boundary fill: Filling the color in closed area by starting a point inside a region & paint the interior ~~the~~ outward towards boundary. Boundary should have single color.

o Flood fill: Used when boundry has multiple colors. Instead of filling color till we encounter a specific boundary color, we just fill the pixels with default color.

- **Transformation**: The operations that are applied to change the position, shape, size and orientation of object is called transform

- **Basic transformations**:
  1) Translation:- The change in position of an object along a straight line.

  $p(x,y) \xrightarrow[t(tx,ty)]{} p(x',y')$ $\quad x' = x + tx$ $\quad y' = y + ty$

  2) Rotation:- Process of changing the angle of an object. It can be done clockwise and anticlockwise.

  $p(x,y) \xrightarrow[R\theta]{} p'(x',y')$ $\quad p' = \underbrace{\begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix}}_{R\theta} P$

  3) Scaling: It is the transformation that alters the size of an object. The size may increase or decrease depending upon scaling factors.

  $p(x,y) \xrightarrow[S(Sx,Sy)]{} p'(x',y')$ $\quad x' = x \cdot Sx$ $\quad y' = y \cdot Sy$ $\quad p' = \begin{bmatrix} Sx & 0 \\ 0 & Sy \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$

- **Reflection**: Transformation that produces mirror image of an object. The mirror image can be about either x-axis or y-axis.
- **Shearing**: Transformation that distorts the shape of an object.
- **Homogeneous coordinates**: Used to express any 2D transformation as matrix multiplication
- **Window**: A world coordinate area selected for display.
- **Viewport**: A device coordinate area to which a window is mapped
- **Viewing transformation**:- Mapping of world coordinate scene to device coordinat.
- **Clipping**: Process of discarding (cutting off) those parts of a picture which are outside the clipping window.
- **Types of clipping**: point clipping, line clipping, text clipping
- **Line clipping algorithms**: Cohen-Sutherland & Liang-Brasky Line clippin
- **Polygon clipping algorithm**: Sutherland-Hodgeman polygon clipping
- **Projection**: Process of representing n-dimensional object into a n-1 dimension. Ex: converting 3D object to a 2D object.
- **Parallel projection**:- It is used to display picture in true shape. Here, we specify a direction of projection instead of centre of projection
- **Orthographic projection**: The direction of projection is normal to the projection of the plane.
- **Oblique projection**: The direction of projection is not normal to the projection of the plane. we can view the object better than orthographic projection.

- Center of projection:- The projectors (ie. light rays reflecting from 3D object onto 2D plane) convergence point is COP.
- Perspective projection:- The distance from center of projection to project plane is finite & size of object varies inversely with distance which looks more realistic.
- Representing Surfaces:- Two categories — Boundary representations (B-rep), Space-partitioning representation
- B-rep: Describes 3D objects as a set of surfaces that separate the object interior from the environment
- Space-partitioning: Describes interior properties by partitioning the spatial region containing an object into a set of small solids.
- Polygon Surfaces: Most commonly used B-rep for 3D graphics objects. It is a set of surface polygons that enclose the objects interior.
  - → polygon tables: Stores information about vertex, edges & polygons.
  - → polygon Mesh: collection of edges, vertices, & polygons connected such that each edge is shared by atmost two polygons. can be used to model almost any object.
  - → Plane Eqn: Another method for representation of the polygon surface for 3D obj. Eqn of plane: $Ax+By+Cz+D=0$
- Wireframe representation: If the object is defined only by a set of nodes & set of connecting the nodes, then resulting representation is wireframe. 3D object is represented as a set of straight lines
- Blobby objects: Object that do not maintain a fixed shape. Their shape show certain degree of fluidity. ex: droplets, human muscles, cloth, etc.
- Solid modeling: Representation of solid parts of an object in our computer.
- Sweep representation:- Used to construct 3D object from 2D shapes that have some kind of symmetry. We can represent such objects by specifying a 2 dimensional shape & a sweep that moves the shape through a region of space.
- Boundary represantion: Geometrical & topological description of the object's boundary. Consists of 3 primitive topological entities: faces (2-D entities), edges (1-D) & vertices (0-D).
- Spatial partitioning representation: Describes objects as collection of adjoining non-intersection solids. Used in ray tracing.

- Binary Space partition Tree (BSP): Here, we subdivide a scene into two sections at each step with a plane that can be at any position & orientation. It is a way of grouping data so that it can be processed faster.

- Octree representation: Hierarchical tree structure where each internal node has exactly eight children are octree. These are used to represent solid objects in those graphics systems that require displays of object. Octree are most often used to partition a 3D space by recursively subdividing it into eight octants.

Hermite cubic Spline curve	Bezier curve	B-spline curve
→ It is 3rd degree polynomial with 4 data points and 4 coefficients	→ It is curve of nth degree polynomial with n+1 no. of data points	→ It is a bezier curve with varying degree
Advantage → Easy for computation	→ It is smooth due to high degree continuity	→ Degree of curve is independent of data points
→ It cannot have control over more than 4 data points, less smooth than Bezier and B-spline curve.	→ Computation required is more due to higher degree.	→ Computational time increases with complexity of curve.

- Illumination model: Mathematical model to determine color calculation or intensity calculation of a pixel.

- Illumination models:
  1) Ambient light: Light seen on object surface due to some distant light source like Sun, moon.
  2) Diffuse reflection:- Reflection due to rough regular surface. Reflection of light is equal in all directions. It is the background light reflected from walls & ceilings.
  3) Specular reflection:- It is the white highlights seen on shiny surfaces. It occurs due to total internal reflection of incident light.

- Intensity Attenuation:- Rate of decrease of intensity of light with respect to the distance between light source & objects.

- Color consideration:- Most of the illumination models use monochromatic light. To solve this, we write intensity equation as a function of color properties of light source & object surfaces.

- Transparency: It means only a certain fraction of light can pass behind through the transparent surface, other ~~fraction~~ fraction are reflected.

- Shadows: Help create realism. Human can distinguish more clearly, movement and depth of objects.

- Polygon surface rendering/surface shading:- Process of calculating intensity and color considerations for polygon surface.

* Constant intensity shading:- illumination model is applied by selecting arbitrary pixel inside the surface & calculated. intensity is applied to all other pixels inside the surface

* Gouraud shading:- Firstly, average surface normal vector at each vertex is determined, illumination model are applied to each vertex to determine intensity value at that vertex, these calculated intensities are interpolated to determine intensity value of all other pixels.
It suffers from Mach Band effect (white & dark spots on ~~corner~~ corner).

* Phong shading: Improvement over Gouraud, that interpolate average surface normal vector to calculate color of the surface. It is the most efficient shading but requires more calculations

- Visible surface detection: Process of identifying those parts of a scene that are visible from a chosen viewing position

- OpenGL: Software interface that allows a programmer to communicate with graphics hardware. Designed for rendering 2D and 3D graphics. Provides a common set of commands, that can be used to manage graphics

- GLUT: provides a portable API for creating a window & interacting with I/O devices. Helps in development of more complicated graphics objects. like sphere, torus.

- Call back functions: User-defined functions which the GLUT calls when it needs to know how to process something.
Ex: glutMouseFunc, glutKeyboardFunc, glutIdleFunc()

- Color command: Two color models: RGBA & color index.
Ex: glColor3f(0.0f, 0.1f, 0.5f)