UNIT-I: Introduction to Computer Graphics

1. Definition of Computer Graphics

Computer graphics is the field of study and practice that involves the creation, manipulation, and representation of visual content using computers. It encompasses a wide range of techniques and technologies for generating and processing digital images.

Key aspects:

- Computer graphics involves both 2D and 3D visual content
- It includes the creation, storage, manipulation, and display of images
- The field combines elements of computer science, mathematics, and visual arts
- It deals with both vector and raster graphics
- Computer graphics is fundamental to modern user interfaces and visual computing

2. Application Areas of Computer Graphics

Computer graphics has permeated numerous fields, revolutionizing how we visualize and interact with information.

Detailed breakdown:

1. **Entertainment**:
    - Video games: 3D modeling, texturing, animation, and real-time rendering
    - Movies: Special effects, CGI (Computer-Generated Imagery), animated films
    - Virtual Reality (VR) and Augmented Reality (AR): Immersive experiences, 3D environments
2. **Education**:
    - Interactive learning tools: Visual simulations, 3D models of complex systems
    - Training simulators: Flight simulators, medical procedure training
    - Educational software: Engaging visuals for better understanding of concepts
3. **Science and Engineering**:
    - Data visualization: Turning complex datasets into understandable visual representations
    - CAD (Computer-Aided Design): Designing products, buildings, and mechanical parts

- Simulation: Modeling physical phenomena, testing designs virtually

4. **Medicine**:
   - Medical imaging: Processing and visualizing MRI, CT scans, and X-rays
   - Surgical planning: 3D modeling of organs for pre-operative planning
   - Prosthetics design: Custom-fit prosthetics using 3D scanning and modeling
5. **Business**:
   - Advertising: Creating eye-catching graphics and animations
   - Data presentation: Infographics, charts, and interactive dashboards
   - Product design: Conceptualizing and prototyping products virtually
6. **Art and Design**:
   - Digital art: Creating artwork directly on computers
   - Graphic design: Logos, layouts, and visual branding
   - Web design: Creating visually appealing and functional websites

3. Graphical User Interface (GUI)

A Graphical User Interface is a visual way of interacting with electronic devices through graphical elements rather than text-based interfaces.

Key points:

- **Definition**: A system of interactive visual components for computer software
- **WIMP paradigm**: Windows, Icons, Menus, Pointer - the core elements of most GUIs
- **Event-driven programming**: The GUI responds to user actions (events) like clicks or key presses
- **Widgets**: Reusable GUI components such as buttons, text boxes, sliders, and dropdown menus
- **Advantages**: More intuitive for users, easier to learn than command-line interfaces
- **Challenges**: Requires more system resources, can be slower than text-based interfaces for expert users

Historical context:

- Developed at Xerox PARC in the 1970s
- Popularized by Apple with the Macintosh in 1984

- Became widespread with Microsoft Windows in the 1990s

4. Display Technologies

4.1 Cathode Ray Tubes (CRT)

CRT is a vacuum tube containing electron guns and a fluorescent screen used to view images.

Detailed description:

- Electron guns emit beams of electrons
- Beams are focused and accelerated towards the screen
- Deflection coils direct the beam to scan across the screen
- Phosphor coating on the screen emits light when struck by electrons
- Images are formed by rapidly scanning the electron beam across the screen

Types of CRT displays:

4.1.1 Random Scan Displays (Vector Displays)

- Draw images using lines by directly controlling the electron beam
- High precision for line drawings
- Limited to wireframe images
- Used in early CAD systems and oscilloscopes

4.1.2 Raster Scan Displays

- Scan the electron beam in a fixed pattern (left to right, top to bottom)
- Create images using a matrix of pixels
- Can display complex images and colors
- Basis for modern TV and computer monitors

4.2 Color CRT Monitors

Detailed description:

- Use three electron guns, one each for Red, Green, and Blue
- Employ a shadow mask or aperture grille to direct electron beams
- Each pixel on the screen consists of red, green, and blue phosphor dots
- Combine RGB phosphors in varying intensities to create full-color images

- Offer high contrast ratios and good color reproduction

4.3 Flat Panel Displays

Modern display technologies that offer advantages over CRTs in terms of size, weight, and power consumption.

4.3.1 Plasma Panels

Key points:

- Contain cells filled with ionized gas (plasma)
- Each cell acts as a tiny fluorescent lamp
- Produces light through electrical stimulation of the gas
- Offers high contrast ratios and wide viewing angles
- Challenges include high power consumption and potential for screen burn-in

4.3.2 Liquid Crystal Displays (LCD)

Detailed description:

- Use liquid crystals to control light passage
- Backlight illuminates the display (usually LED in modern displays)
- Pixels consist of liquid crystal layers between polarizing filters
- Electric current alters crystal alignment to allow/block light
- Types include TN (fast, cheap), IPS (better color and viewing angles), and VA (high contrast)
- Advantages: Low power consumption, no geometric distortion
- Disadvantages: Limited viewing angles (improved in modern panels), potential for dead pixels

4.3.3 Electroluminescent Displays

Key aspects:

- Use phosphor materials that emit light when electric current is applied
- Very thin and energy-efficient
- High contrast and wide viewing angles
- Often used in small devices or as backlights
- Examples include OLED (Organic Light Emitting Diode) displays
- OLED advantages: Perfect blacks, vibrant colors, potential for flexible displays

5. Graphics Software

5.1 Graphical Kernel System (GKS)

Detailed description:

- First ISO standard for graphics programming
- Provides a set of drawing primitives for 2D graphics
- Aims for device-independent graphics output
- Key features:
  - Output primitives: lines, polygons, text
  - Input handling for various devices
  - Coordinate systems and transformations
  - Segmentation for grouping graphical elements
- Limitations: Primarily focused on 2D graphics, lacks advanced 3D capabilities

5.2 Programmer's Hierarchical Interactive Graphics System (PHIGS)

Key points:

- Extension of GKS to support 3D graphics
- Designed for interactive applications and complex scenes
- Supports hierarchical structure of graphical data
- Key concepts:
  - Structures and elements for organizing graphical data
  - Viewing and modeling transformations for 3D manipulation
  - Input handling and events for user interaction
  - Support for animation and dynamic scenes
- Advantages over GKS: Better suited for CAD/CAM applications, supports complex 3D scenes

6. Color Models

Mathematical systems for representing colors in digital systems.

6.1 RGB (Red, Green, Blue)

Detailed description:

- Additive color model based on light emission

- Primary colors: Red, Green, Blue
- Colors created by combining different intensities of these primaries
- Each color typically represented by 8 bits (0-255) per channel
- Used in displays, digital cameras, and image processing
- Represents a wide color gamut suitable for electronic displays
- Example: RGB(255, 0, 0) represents pure red

6.2 CMYK (Cyan, Magenta, Yellow, Key/Black)

Key aspects:

- Subtractive color model based on light absorption
- Used primarily in printing processes
- Primary colors: Cyan, Magenta, Yellow, with Black added for deeper shadows and text
- Colors created by absorbing light with different combinations of inks
- Each color represented as a percentage (0-100%) of ink coverage
- More suitable for reproducing colors on physical media
- Example: CMYK(0%, 100%, 100%, 0%) represents pure red in print

6.3 HSV (Hue, Saturation, Value)

Detailed description:

- Represents colors in a way that's closer to human perception
- Components:
  - Hue: Color type (0-360 degrees on the color wheel)
  - Saturation: Color intensity or purity (0-100%)
  - Value: Brightness (0-100%)
- Intuitive for color selection and manipulation in graphics software
- Easier for humans to reason about than RGB or CMYK
- Example: HSV(0°, 100%, 100%) represents pure red

7. Color Lookup Table

Detailed description:

A Color Lookup Table (CLUT) is a mechanism used in computer graphics to reduce memory requirements and speed up display processes.

Key characteristics:

- Stores a limited palette of colors (typically 256 in 8-bit color systems)
- Each entry contains RGB values for a specific color
- Pixels in the image store an index to the table instead of full color information

Functionality:

- When displaying an image, the system looks up the color values for each pixel
- Changing colors in the table affects all pixels referencing those entries

Benefits:

- Reduces memory usage for images
- Allows quick color changes by modifying the table
- Useful for creating visual effects (e.g., color cycling in old video games)
- Can optimize color usage for specific images or applications

Limitations:

- Restricts the number of colors that can be displayed simultaneously
- Not suitable for photorealistic images requiring millions of colors

Historical significance:

- Crucial in early computer graphics with limited memory and processing power
- Still used in some specialized applications and in color quantization algorithms

Example application: In a 256-color system, instead of storing 3 bytes (24 bits) of RGB data per pixel, only 1 byte (8 bits) is needed to reference the color in the CLUT, potentially reducing memory usage by 66%.