Computer Graphics

Computer Graphics [ETUCCS601T]

Introduction: Light sources, basic illumination models, halftone patterns and dithering techniques, raster-scan systems, random scan systems, graphics monitors and work stations and input devices, **Output primitives:** Points and lines, line drawing algorithms, mid-point circle and ellipse algorithms. Filled area primitives: Scan line polygon fill algorithm, boundary-fill and flood-fill algorithms

Introduction

The term 'Computer Graphics' was coined by **William Fetter (**a graphic designer at Boeing, in 1960**).** While Fetter is credited with using the term, he also acknowledged that the concept was initially developed by **Verne Hudson** another Boeing employee

Computer graphics is a dynamic and essential field within computing that involves the creation, manipulation, and rendering of visual content using computers.

Computer graphics is a dynamic field within computing, involves the creation, manipulation, and rendering of visual content using computers. It includes digital images, animations, and interactive graphics

Computer Graphics including digital images, animations, and interactive graphics used in various sectors such as entertainment, education, scientific visualization, and virtual reality. Computer Graphics can be used in UI design, rendering, geometric objects, animation, and many more

- Computer Graphics is the pictorial representation and manipulation of data by a computer
- It displays the information in the form of graphical objects such as pictures, charts, diagram and graphs.
- Graphical objects convey more information in less time and easily understandable formats for example statically graph shown in stock exchange.
- In computer graphics picture or graphics objects are presented as a collection of discrete pixels.
- We can control intensity and color of pixel which decide how picture look like.
- The special procedure determines which pixel will provide the best approximation to the desired picture or graphics object this process is known as **Rasterization**.
- The process of representing continuous picture or graphics object as a collection of discrete pixels is called **Scan Conversion**.

Types of Computer Graphics

Computer graphics can be broadly categorized based on their applications, nature, or the way they are generated. Here are the main types of computer graphics −

- **Raster Graphics (Bitmap Graphics)** − Bitmap graphics are the images made up of tiny dots called pixels (picture elements).
- **Vector Graphics** − Images are created using mathematical equations to represent geometric shapes such as lines, circles, and polygons.
- **3D Graphics** − Graphics that represent three-dimensional objects and scenes, often used for simulations, video games, and movies.
- **Interactive Graphics** − Graphics that allow users to interact with them, typically through a user interface (UI).
- **Real-Time Graphics** − Graphics that are rendered in real-time, meaning they are created and displayed instantly as the user interacts with them.

Advantages of computer graphics

- Computer graphics is one of the most effective and commonly used ways of communication with computer.
- It provides tools for producing picture of “real-world” as well as synthetic objects such as mathematical surfaces in 4D and of data that have no inherent geometry such as survey result.
- It has ability to show moving pictures thus possible to produce animations with computer graphics.
- With the use of computer graphics we can control the animation by adjusting the speed, portion of picture in view the amount of detail shown and so on.
- It provides tools called motion dynamics. In which user can move objects as well as observes as per requirement for example walk throw made by builder to show flat interior and surrounding.
- It provides facility called update dynamics. With this we can change the shape color and other properties of object.
- Now in recent development of digital signal processing and audio synthesis chip the interactive graphics can now provide audio feedback along with the graphical feed backs.

Applications of Computer Graphics

- Data Visualization – Charts and Graphs
- Computer Aided Design (CAD). Now a days we use in different sectors that are
- Virtual Reality
  - VR: User interacts and views with a 3D world using “more natural” means
  - Best VR
- Data Visualization
  - Scientific, Engineering, Medical data
  - Visualizing millions to billions of data points
  - See trends
  - Different schemes

- Education and Training
  - Models of physical, financial, social systems
  - Comprehension of complex systems

- Computer Art
  - Fine and commercial art
  - Performance Art
  - Aesthetic Computing
  - SIGGRAPH (Special Interest Group on Graphics and Interactive Techniques)
- Games/Movies
- Image Processing :- Manipulating images using efficient algorithm.
- Graphical User Interfaces (GUIs)
  - WIMP interface (Windows,Icons,Menus,pointers)
  - HCI

Basic Illumination Models

Illumination model, also known as Shading model or Lighting model, is used to calculate the intensity of light that is reflected at a given point on surface. it simulate how light interacts with objects to determine their appearance

1. Ambient Illumination

Assume you are standing on a road, facing a building with glass exterior and sun rays are falling on that building reflecting back from it and the falling on the object under observation. Ambient Illumination is the one where source of light is indirect. The reflected intensity I_{amb} of any point on the surface is:

$$I_{amb} = K_a I_a$$

Where, I_a : ambient light intensity
K_a : surface ambient reflectivity, value of K_a varies from 0 to 1

2. Diffuse Reflection:- Diffuse reflection occurs on the surfaces which are rough or grainy. In this reflection the brightness of a point depends upon the angle made by the light source and the surface. The reflected intensity I_{diff} of a point on the surface is:

$$I_{diff} = K_d I_p \cos(\theta) = K_d I_p (N \cdot L)$$

Where, I_p : the point light intensity
K_d : the surface diffuse reflectivity, value of K_d varies from 0 to 1
N : the surface normal
L : the light direction

3. Specular Reflection:- When light falls on any shiny or glossy surface most of it is reflected back, such reflection is known as Specular Reflection. **Phong Model** is an empirical model for Specular Reflection which provides us with the formula for calculation the reflected intensity $I_{spec.}$

$$I_{spec} = W(\theta)\, I_l \cos^n(\Phi)$$

where, $W(\theta) : K_s$

L : direction of light source

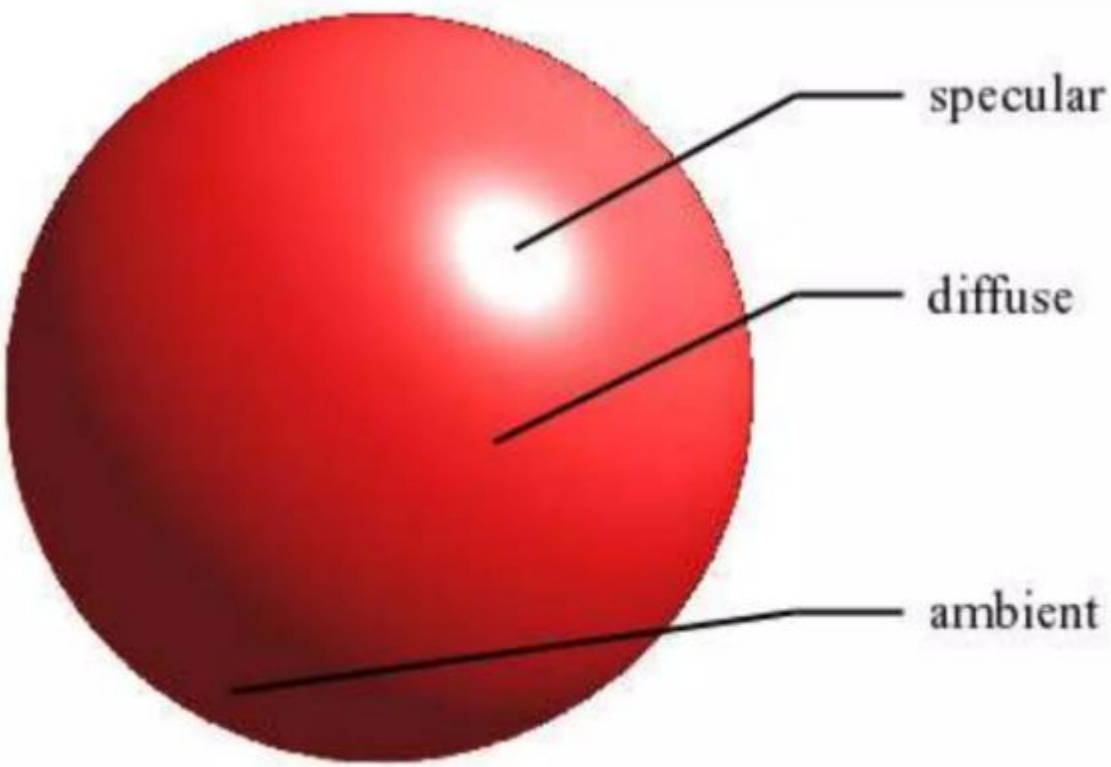
N : normal to the surface

R : direction of reflected ray

V : direction of observer

Θ : Angle between L and R

Φ : angle between R and V


specular
diffuse
ambient

There are three factors on which lighting effect depends on:

1.Light Source : Light source is the light emitting source. There are three types of light sources: Their position, electromagnetic spectrum and shape determine the lighting effect.

1. **Point Sources -** The source that emit rays in all directions (A bulb in a room).
2. **Parallel Sources -** Can be considered as a point source which is far from the surface (The sun).
3. **Distributed Sources -** Rays originate from a finite area (A tube light).

2.Surface : When light falls on a surface part of it is reflected and part of it is absorbed. Now the surface structure decides the amount of reflection and absorption of light. The position of the surface and positions of all the nearby surfaces also determine the lighting effect.

3.Observer : The observer's position and sensor spectrum sensitivities also affect the lighting effect

Halftone patterns and dithering are techniques used to represent continuous-tone images (like photographs) using only a limited number of colors, typically just black and white, or a small color palette.
Halftoning uses patterns of dots of varying sizes or densities to create the illusion of continuous shades of gray or color.
Dithering is a digital method of halftoning that uses a dither matrix to determine which pixels should be black or white, simulating a wider range of tones.

Halftoning is a printing technique that simulates continuous tones by using dots of varying size and spacing.

Dithering is a digital method of halftoning that uses a dither matrix to determine which pixels should be turned on or off.

Half-tonning Technique

The process of generating a binary pattern of black and white dots from an image is termed **halftoning**. In traditional newspaper and magazine production, this process is carried out photographically by projection of a transparency through a 'halftone screen' onto film. The pictures produced by halftoning process are called **halftones**. The screen is a glass plate with a grid etched into it. Different screens can be used to control the size and shape of the dots in the halftoned image.

In computer graphics, halftone reproductions are approximated using rectangular pixel regions, say 2x 2 pixels or 3x 3 pixels. These regions arc called halftone patterns or pixel patterns.

The following figure shown the halftone patterns to create number of intensity levels.

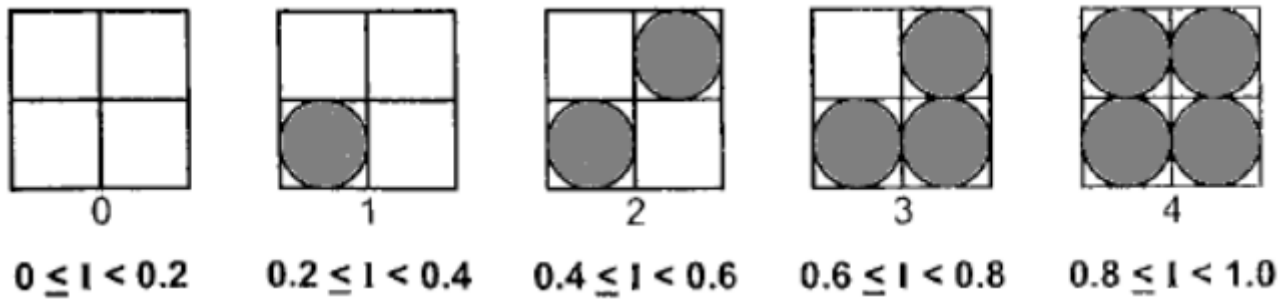


Fig. **2*2 Pixel patterns for creating five intensity levels**

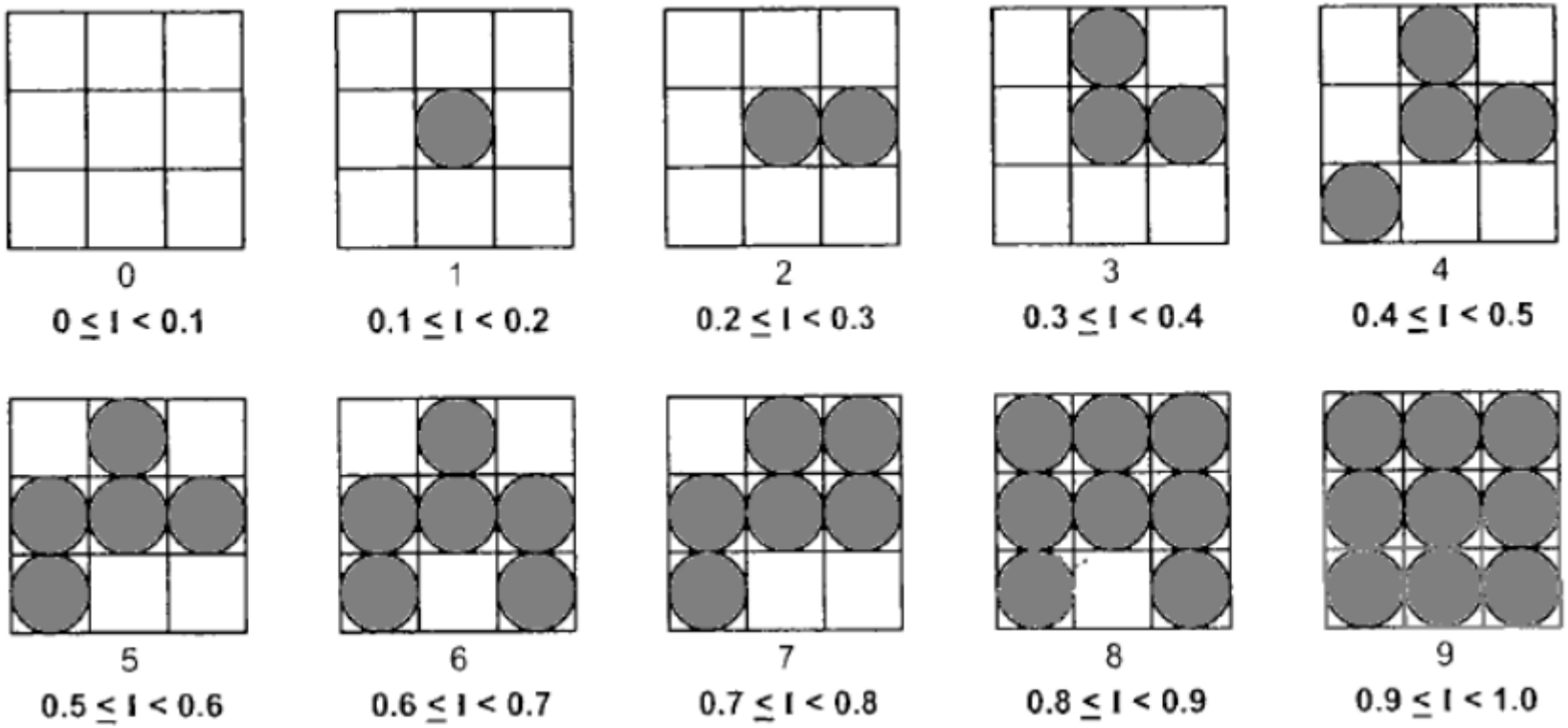


Fig **3*3 Pixel patterns for creating ten intensity levels**

Dithering Techniques

Dithering refers to techniques for **approximating halftones without reducing resolution**, as pixel grid patterns do. The term dithering is also applied to halftone approximation methods using pixel grids, and sometimes it is used to refer to color halftone approximations only.

Dithering is the attempt by a computer program to approximate a color from a mixture of other colors when the required color is not available.

For example, dithering occurs when a color is specified for a Web page that a browser on a particular operating system can't support. The browser will then attempt to replace the requested color with an approximation composed of two or more other colors it can produce. The result may or may not be acceptable to the graphic designer. It may also appear somewhat grainy since it's composed of different pixel intensities rather than a single intensity over the colored space.

Random values added to pixel intensities to break up contours are often referred as **dither noise**. Numbers of methods are used to generate intensity variations.

Ordered dither methods generate intensity variations with a one-to-one mapping of points in a scene to the display pixels.

To obtain n2 intensity levels, it is necessary to set up an n x n dither matrix whose elements are discrete positive integers in the range of 0 to n-1.

For e.g. it is possible to generate four intensity levels with $D_2 = \begin{bmatrix} 3 & 1 \\ 0 & 2 \end{bmatrix}$

And it is possible to generate nine intensity levels with $D_3 = \begin{bmatrix} 7 & 2 & 6 \\ 4 & 0 & 1 \\ 3 & 8 & 5 \end{bmatrix}$

The matrix elements for D2 and D3 are in the same order as the pixel mask for setting up 2 x 2 and 3 x 3-pixel grids respectively. For bi-level system we have to determine display intensity values by comparing input intensities to the matrix elements.

Each input intensity is first scaled to the range **0 ≤ I ≤ n2**. If the intensity I is to be applied to screen position (x, y), we have to calculate row and column numbers for the either matrix as

$$i = (x \bmod n) + 1, \qquad j = (y \bmod n) + 1$$

If $I > D1(i, j)$ the pixel at position (x, y) is turned on; otherwise, the pixel is not turned on.

Typically, the number of intensity levels is taken to be a multiple of 2.

High order dither matrices can be obtained from lower order matrices with the recurrence relation.

$$D_n = \begin{bmatrix} 4\,D_{n/2} + D_2(1,1)\,u_{n/2} & 4\,D_{n/2} + D_2(1,2)\,u_{n/2} \\ 4\,D_{n/2} + D_2(2,1)\,u_{n/2} & 4\,D_{n/2} + D_2(2,2)\,u_{n/2} \end{bmatrix}$$

assuming $n \geq 4$. Parameter $u_{n/2}$ is the unity matrix.