Date

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Assignment : Computer Graphics

Department : Software Engineering

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Date

Computer Graphics Hardware:

(i) Diff b/w Raster Scan System & Random Scan System.

Random Scan	Raster Scan
• It has high resolution.	It has low resolution
• It is less expensive	It is more expensive.
• Modification is easy.	Modification is tough.
• Use Beam penetrate technology	Use Shadow Mask technology.
• Suitable to display line drawing.	Suitable to display realistic images.

(ii) Consider three diff raster systems with resolutions of 800 by 600, 1280 by 960 and 1680 by 1050. What size frame buffer (in bytes) is needed for each of these systems to store 16 bits per pixel? How much storage is required for each system if 32 bits per pixel are to be stored?

Date

(a) Frame Buffer size with 12 bits per pixel.

For 800 by 600:

Size = (800 × 600 × 16)/8 = 960000 bytes

For 1280 by 960:

Size = (1280 × 960 × 16)/8 = 2457600 bytes

For 1680 by 1050:

Size = (1680 × 1050 × 16)/8 = 3528000 bytes

(b) Storage required for each system

For 800 by 600:

Size = (800 × 600 × 32)/8 = 1920000 bytes

For 1280 by 960:

Size = (1280 × 960 × 32)/8 = 4915200 bytes

For 1680 by 1050:

Size = (1680 × 1050 × 32)/8 = 7056000 bytes

Date

Q. How load would it take to load an 800 by 600 frame buffer with 16 bits per pixel, if 105 bits can be transferred per second? How long would it take to load a 32-bit-per-pixel frame buffer with a resolution of 1680 by 1050 using this same transfer rate?

Time to load 800 by 600 frame buffer

Time = (800 x 600 x 16) bits / 105 bits/second = 73142.85 seconds

Time to load 1680 by 1050 frame buffer

Time = (1680 x 1050 x 32) bits / 105 bits/second = 537600 seconds.

(iv) Consider two raster systems with resolutions of 800 by 600 and 1680 by 1050. How many pixels could be accessed per second in each of these systems by a display controller that refreshes the screen at a rate of 60 frames per second? What is the access time per pixel in each system?

Pixels access through 800 by 600 resolution

Date

Pixel/second = (800 x 600 pixels) * 60 frame/second = 480000 pixels/second
Time to access each pixel is 1/480000
= 0.000002 sec

Pixels access through 1680 by 1050 resolution.

Pixels/second = (1680 x 1050 pixels) * 60 frame/second = 1764000 pixels/second
Time to access each pixel is 1/1764000
= 0.0000005 sec

(v) Suppose we have a video monitor with a display area that measures 12 inches across and 9.6 inches high. If the resolution is 1280 by 1024. Find its aspect ratio, pixels per inch (PPI) and the Dot Pitch.

Data:

length of monitor = l = 12 inches
Width of monitor = W = 9.6 inches
Resolution of monitor = 1280 x 1024
pixels along length = 1280
pixels along width = 1024

Required:

Aspect ratio = AR = ?
Pixels per inch = PPI = ?
Dot Pitch = DP = ?

Date

Solution

For AR:

AR = Pixels along length : pixels along width
= 1280 : 1024

AR = 1.25

For PPI:

$dp^2 = (\text{pixels along width})^2 + (\text{pixels along length})^2$

$= (1024)^2 + (1280)^2$

$= 1048576 + 1638400$

$= 2686976$

$\sqrt{dp^2} = \sqrt{2686976}$

$dp = 1639.199805$ pixels

di = length of monitor × width of monitor

$= 12 \times 9.6$

di = 115.2 inches

ppi = dp/di = 1639.199805/115.2

ppi = 14.229 pixels

For Dot Pitch:

Dot Pitch = diagonal in inches / diagonal in pixels × 25.4 mm/inch

$= (1639.199805/115.2) \times 25.4$

Dot Pitch = 1.78506 mm

Date

2 Implementation Algorithms for Graphics Primitives & Attributes.

(i) Describe key features like Drawing Algorithm used in computer graphics.

A line consists of two points. It is a basic element in graphics. A line drawing algorithm which is used to represent the line segment on discrete graphical media, i.e.; printer and pixel-based media. There are following algorithms used for drawing a line:

- DDA (Digital Differential Analyser).
- Bresenham's Line Drawing Algorithm
- Mid point Line Drawing Algorithm.

(ii) How is circle drawing different then line drawing. Use the mid point method to derive decision parameters that can be used to gurantee a circle?

In line we need two end points between which we can draw a line. But, drawing a circle is a little complex because it is an eight-way symmetric figure which can be divided into four quadrants and each quadrant has two octants. This symmetry helps in drawing a circle on computer

Date

by knowing only one point of any octant.

Derivation of decision parameter using mid point method (MP):

$MP = (x_k + 1, y_k - \frac{1}{2})$

Now, put MP is the equation of circle $x^2 + y^2 - r^2 = 0$:

$(x_k + 1)^2 + (y - 1/2)^2 - y^2$

Let us define this equation as the decision parameter using midpoint:

$P_k = (x_k + 1)^2 + (y_k - 1/2)^2 - r^2$.

(iii) We wish to draw a line from (0,0) to (5,3) in device space. Show relation computation using.

(a) DDA Line Algorithm

Starting Coordinates = $(x_1, y_1) = (0,0)$

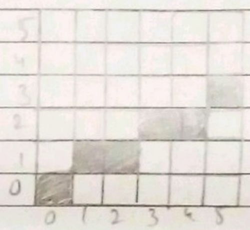
Ending Coordinates = $(x_2, y_2) = (5,3)$

Slope (M) $= \frac{\Delta Y}{\Delta X} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{3-0}{5-0} = \frac{3}{5} = 0.6$

$m < 1$ therefore $x_1 = x_1 + 1$ and $y_1 = y_1 + M$

Date

Slope	$x_1 = x_1 + 1$	$y_1 = y_1 + M$	Pixel Plotted
1	1	0.6 ~ 1	(1,1)
2	2	1.2 ~ 1	(2,1)
3	3	1.8 ~ 2	(3,2)
4	4	2.4 ~ 2	(4,2)
5	5	3	(5,3)



(ii) Bresenham's line Drawing Alg.

Starting Point = $(x_1, y_1) = (0,0)$

Ending Point = $(x_2, y_2) = (5,3)$

$\Delta x = x_2 - x_1 = 5 - 0 = 5$

$\Delta y = y_2 - y_1 = 3 - 0 = 3$

$P_k = 2\Delta y - \Delta x$

$= 0 \times 3 2 - 5$

$= 6 - 5$

$P_k = 1$

Case 1: If $P_k < 0$

$P_{k+1} = P_k + 2\Delta y$

$x_{k+1} = x_k + 1$

Case 2: If $P_k \geq 0$

$P_{k+1} = P_k + 2\Delta y - 2\Delta x$

$x_{k+1} = x_k + 1$

Date

$y_{k+1} = y_k$ $\qquad$ $y_{k+1} = y_k - 1$

P_k	P_{k+1}	x_{k+1}	y_{k+1}
1	-3	1	1
-3	3	2	1
3	-1	3	2
-1	5	4	2
5	1	5	3

(iv) (a) Use the midpoint circle algorithm to draw the circle centered at (0,0) with radius 12.

Center Coordinates = (0,0)
radius = 12
Initial Point $(x_0, y_0) = (0, 12)$
$p_0 = 1 - r = 1 - 12 = -11$

$p_0 < 0 \rightarrow p_1 = p_0 + 2x_0 + 3 = -11 + 2(0) + 3$
$= -8 \quad (1, 12)$
$p_1 < 0 \rightarrow p_2 = -8 + 2(1) + 3 = -3 \; (2, 12)$
$p_2 < 0 \rightarrow p_3 = -3 + 2(2) + 3 = 4 \; (3, 11)$
$p_3 > 0 \rightarrow p_4 = p_i + 2(x_i - y_i) + 5$
$= 4 + 2(3 - 11) + 5 = -7 \; (4, 11)$
$p_4 < 0 \rightarrow p_5 = -7 + 2(4) + 3$
$p_5 > 0 \rightarrow p_6 = 4 + 2(5 - 10) + 5 = -1 \; (6, 10)$
$p_6 < 0 \rightarrow p_7 = -1 + 2(6) + 5 = 14 \; (7, 9)$
$p_7 > 0 \rightarrow p_8 = 14 + 2(7 - 9) + 5 = 15 \; (8, 8)$

1

Date

(iv) (b) Calculate the required points to plot the following circle using the midpoint circle algorithm
radius = 10, center (3,4) $P_0 = 1 - r = -9$,
Initial Point $(x_0, y_0) = (0, 10)$

$r = 10$
center = (3, 4)
$P_0 = 1 - r = -9$
Initial Point $(x_0, y_0) = (0, 10)$
$p_0 < 0 \rightarrow p_1 = -9 + 2(0) + 3 = -6 \; (1, 10)$
$p_1 < 0 \rightarrow p_2 = -6 + 2(1) + 3 = -1 \; (2, 10)$
$p_2 < 0 \rightarrow p_3 = -1 + 2(2) + 3 = 6 \; (3, 9)$
$p_3 > 0 \rightarrow p_4 = 6 + 2(3 - 9) + 5 = -1 \; (4, 9)$
$p_4 < 0 \rightarrow p_5 = -1 + 2(4) + 3 = 10 \; (5, 8)$
$p_5 > 0 \rightarrow p_6 = 10 + 2(5 - 8) + 5 = 9 \; (6, 7)$
$p_6 > 0 \rightarrow p_7 = 9 + 2(6 - 7) + 5 = 12 \; (7, 6)$

(0,10) = (3,14)
(1,10) = (4,14)
(2,10) = (5,14)
(3,9) = (6,13)
(4,9) = (7,13)
(5,8) = (8,12)
(6,7) = (9,11)
(7,6) = (10,10)

Date

(v) a Given input ellipse parameter $r_x = 8$ and $r_y = 6$, determine pixel positions along the ellipse path in the first quadrant using the mid point ellipse algorithm.

(x_k, y_k)	Decision Parameter	x_{k+1}, y_{k+1}	$dx\ 2x_{k+1}r_y^2$	$dy\ 2y_{k+1}r_x^2$
(0,6)	-332	(1,6)	72	768
(1, 6)	-224	(2,6)	144	768
(2, 6)	-44	(3,6)	216	768
(3, 6)	208	(4,5)	288	640
(4, 5)	-108	(5, 5)	360	640
(5, 5)	288	(6,4)	432	512
(6, 4)	244	(7,3)	504	384
(7, 3)	-23	(8,2)	576	256
(8, 2)	361	(8, 1)	576	128
(8, 1)	297	(8,0)		
(8, 0)				

Date

Now draw a same ellipse with $r_x = 6$ and $r_y = 8$.

x_k, y_k	Decision Parameter	x_{k+1}, y_{k+1}	$dx\ 2x_{k+1}r_y^2$	$dy\ 2y_{k+1}r_x^2$
(0,6)	-332	(1,6)	72	768
(1,6)	-224	(2,6)	144	768
(2,6)	-44	(3,6)	216	768
(3,6)	208	(4,5)	288	640
(4,6)	-108	(5,5)	360	640
(5,5)	288	(6,4)	432	512
(6,4)	244	(7,3)	504	384
(7,3)	-23	(8,2)	576	256
(8,2)	361	(8,1)	576	128
(8,1)	297	(8,0)	-	-
(8,0)				

Date ____________

(3) Transformations & View Clipping

(i) Discuss Different types of Transformation and Write down 4 * 4 matrices for each of the following:

(a) To translate by the vector (1,2,3)

(b) To scale with respect to the origin by the amount (2,4,6)

(c) To rotate around the z-axis by 45 degrees (note sin 45 = cos 45 = 1/sqrt(2))

(d) To rotate around the x-axis by 45 degrees

Transformation: Transformation means changing some graphics into something else by applying rules.

Types Of Transformation:

Various types of transformation such as:

1. Translation: Change in position.
2. Scaling: Change in size shape.
3. Rotation: Movement along circular path.
4. Reflection: To produce a mirror image of an object.
5. Shearing: It distorts the shape of the object.

(a)
$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 1 & 2 & 3 & 0 \end{bmatrix}$$

Date

(2) $\begin{bmatrix} 2 & 0 & 0 & 0 \\ 0 & 4 & 0 & 0 \\ 0 & 0 & 6 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

(3) $\begin{bmatrix} S & S & 0 & 0 \\ -S & S & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

(4) $\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & S & S & 0 \\ 0 & -S & S & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

(ii) Sequence of transformations can often be simplified. Suppose we have the following sequence of 2D transformations:
R(90) T(0,1) R(90) T(2,0)

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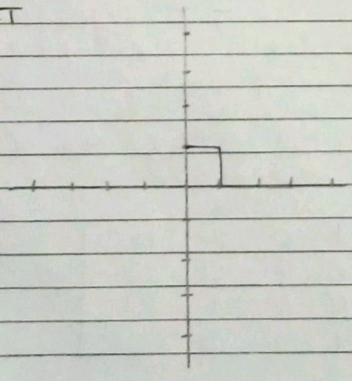
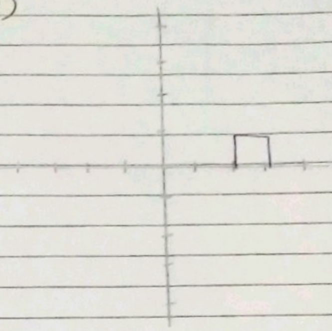
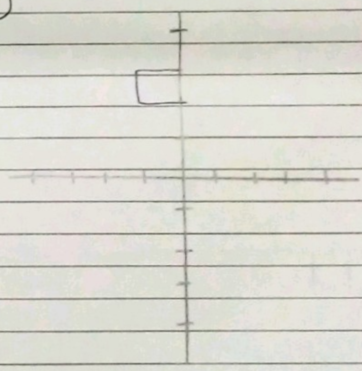


Date

T(2,0)

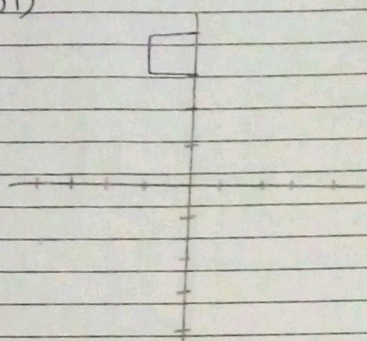


R(90)

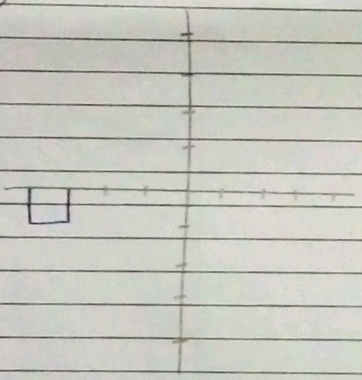


Date ________

T(0,1)



R(90)



This transformation in the reverse order

Date ________

iii Describe in detail the Cohen-Sutherland clipping algorithm for clipping a line segment.

Line Clipping: It is the process of removing lines or portions of lines that lie outside the clipping window.

A line segment can be,

Visible : if both endpoints of the line lie inside the clip window.

Not Visible : if the line lies completely outside the window.

Partially Visible: line intersects the clip window at one or more points

Cohen-Sutherland Algorithm

1001	1000	1010
0001	0000	0010
0101	0100	0110

$x < x_{min}$ -> left of Window

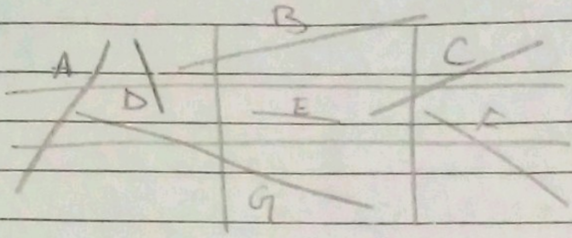
$x > x_{max}$ -> Right of Window

$y < y_{min}$ -> bottom of Window

$y > y_{max}$ -> at top of window

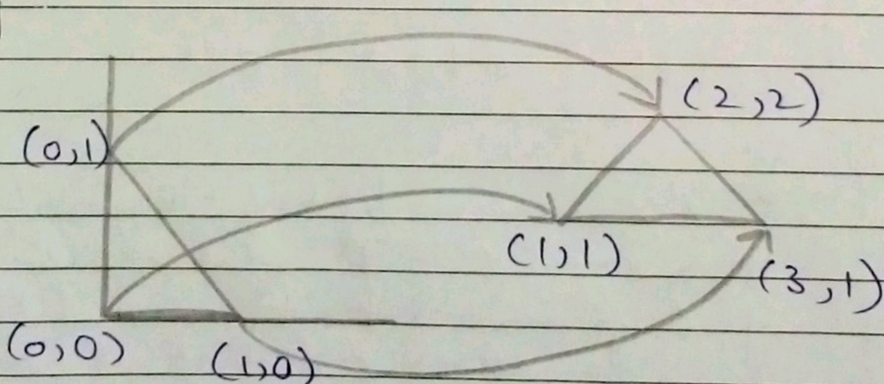
Date ____

(iv) For the fig below list all the line segments that can be trivially culled away in the first step based on their "outcodes" in a Cohen Sutherland line clipping algorithm



A, B, C, F and G. These line segments are trivially rejected in the first in a Cohen-Sutherland line clipping Algorithm.

(ii) Suppose we have a unit triangle (shown on the left) and we want to transform it into the triangle on the right. Write a matrix that transforms that triangle in the desired way.

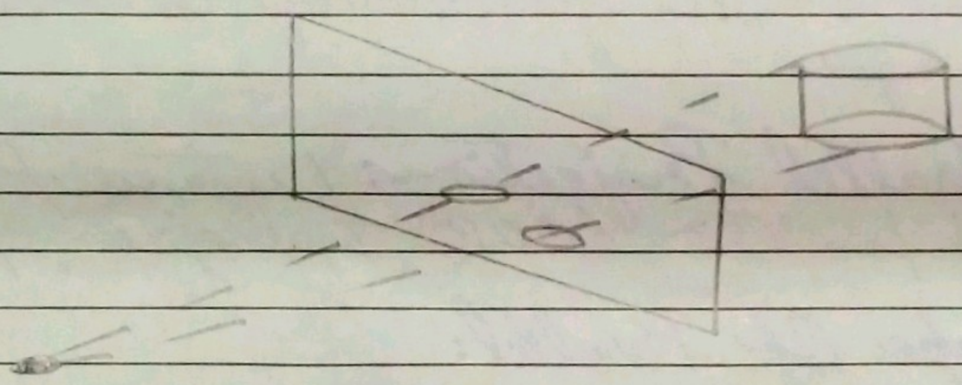


Date ____

4 Miscellaneous:

(i) Describe different type of projections?

Projections: Projection transform points in n-space to m-space, where m<n. In 3D, we map points from 3-space to the projection plane (PP) along projectors emanating from the center of projection (COP).



There are two basic types of projections

① **Perspective:** Distance from center of projection to projection plane finite.

Types Of Perspective: Perspective drawings are often classified by the number of principal vanishing point.

- One-point perspective: simplest to draw.
- Two-point perspective: gives better impression of depth.
- Three-point perspective: most difficult

to draw.

Advantages:

- Better look.
- Clear Representation

Disadvantages:

- Difficult to Draw.
- Not suitable for many dimensional images.

② **Parallel Projection:** Distance from center of projection (COP) to projection plane (PP).

Types Of Parallel:

There are two types of parallel projection:

- Orthographic Projection: Direction of projection perpendicular to projection plane.
- Oblique Projection: Direction of projection not perpendicular to projection plane.

There are two especially useful kinds of oblique projections:

(i) Cavalier projection:

- Direction of projection makes 45° angle with projection plane.
- Does not foreshorten lines perpendicular to projection plane.

(ii) Cabinet projection:

- Direction of projection makes 63.4° angle with projection plane.
- Foreshorten lines perpendicular to projection plane by one half.

Advantages

- Good for exact measurement.
- Parallel lines remain parallel.

Disadvantages

- Less Realistic looking.
- Angles are not preserved.

(ii) Describe methods for visible surface detection, especially back face detection using Z-buffer (Depth Buffer Method)

Visible Surface Detection:

When a picture that contains the non-transparent objects and surfaces are viewed, the objects that are behind the objects that are closer cannot be viewed. To obtain a realistic screen image, these hidden surfaces need to be removed. This process of identification and removal of these surfaces is known as

Date

Hidden-surface problem. The hidden surface problems can be solved by two methods - Object-Space method and Image space method. In physical coordinate system, object-space method is implemented and in case of screen coordinate system, image-space method is implemented.
When a 3D object need to be displayed on the 2D screen the parts of the screen that are visible from the chosen viewing position is identified.

Back-Face Detection: The back faces of the polyhedron are identified on the basis of "inside-outside" tests. A point (X,Y,Z) is "inside" a polygon surface with plane parameters A,B,C and D if when an inside point is along the line of sight to the surface, the polygon must be a backface. This test is simplified by the normal vector N to the polygon surface having Cartesian components (A,B,C). The polygon is backface if,

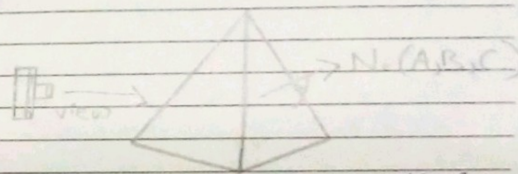
$$V \cdot N > 0$$

If object descriptions are converted to projection coordinates and your viewing direction is parallel to the viewing Z-axis, then $V = (0, 0, V_Z)$ and $V \cdot N = V_Z C$. Hence only C of the component of the normal vector N is

Date

considered. The polygon is backface if $C < 0$, for a right-handed viewing system with viewing direction along the negative Z_V axis. Hence, in general any polygon is named as ~~backbone~~ face if the normal vector has the Z component value.

$$C <= 0$$



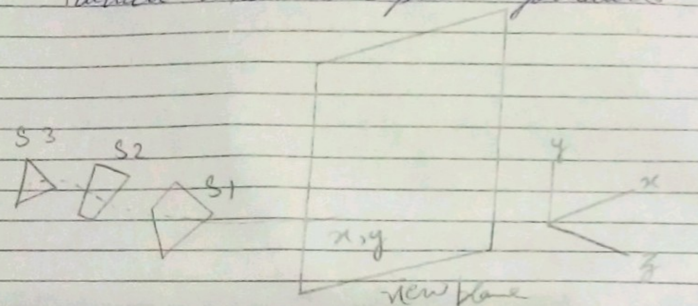
The packages can use similar methods for employing a left-handed viewing system. The polygon vertex coordinates are used for calculating A,B,C and D. Normal vectors are available for back-faces that are used for pointing away from the viewing position and identified by $C >= 0$, along the Z_V axis. All the back faces are easily identified.

Depth Buffer (Z-Buffer Method)

- It is the most commonly used image-space approach to find visible surface.
- It is a depth buffer method, which compares surface depth at each pixel position on the projection plane.
- Z-buffer can be considered as an

Date

extension of Frame buffer.
- A frame buffer is used to store the visible pixel in the image space.
- In this algorithms, a buffer of same size as that of frame buffer is used which holds the depth information.



Algorithm:

(1) Initialize
(a) For each buffer position (x, y)
depth (x, y) = 0
refresh (x, y) = background color
(2) For each polygon
(a) Compute depth z for each (x, y) position on the polygon
If z > depth (x, y) then
depth (x, y) ← z
refresh (x, y) ← color of the polygon at (x, y)

Date

Depth Calculation

Equation of plane = $ax+by+cz+d=0$

$$\therefore \quad z = -\frac{(ax+by+d)}{c}$$

Advantages:

(1) Easy to implement.
(2) No sorting of surface is required.
(3) Polygons may be processed in any order.

Disadvantages:

(1) Requires 2 buffer → depth + refresh
(2) It can only find one visible surface at each pixel position.
(3) It deals with only opaque surface.
(4) It is a time consuming process.

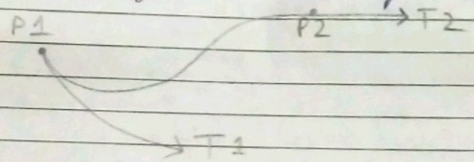
(iii) Discuss the following curves:
(a) Hermite Curves (b) Bezier Curves (c) B-spline

Hermite Curves:

Hermite curves are the curves defined by four control points and a cubic polynomial.
Hermite curve is a spline curve, it is mathematical representation as a

Date

link between algebric and geometric form.
Defined by specifying the end points and tangent vectors at the end points.
Use of control points.
Geometric points that control the shape.
Algebraically used for linear combination of basis functions.
The following vector need to complete Hermite curves.
P1 : The start point of the Hermite curve.
T1 : The tangent to start point.
P2 : The endpoint of the Hermite curve.
T2 : The tangent to the endpoint.



Important Characteristics:
Universality: Hold for all cubic Hermite curves.
Dimensional independence: extend to higher dimensional.
It can be extended to higher degree curves.
Main Drawback:
Requires the specification of the tangents. This information is not always available.

Date

② **Bezier Curve:** A Bezier curve is a line or "path" used to create vector graphics. It consists of two or more control points. Approximate tangents by using control points are used to generate curve. The Bezier curve can be represented mathematically as:-

$$\sum_{k=0}^{n} P_i B_i^n(t)$$

Where p_i is the set of points and $B_i^n(t)$ represents the Bernstein polynomials which are given by:-

$$B_i^n(t) = \binom{n}{i}(1-t)^{n-i} t^i$$

Where n is the polynomials degree, i is the index, and t is the variable.

③ **B-spline Curve:-** The Bezier-curve produced by the Bernstein basis function has limited flexibility.
First, the number of specified polygon vertices fixes the order of the resulting polynomials which defines the curves.
The second limiting characteristic is that the value of the blending function is non zero for all parameter values over the entire curve.
The B-spline basis contains the Bernstein basis as the special ~~as~~ case. The B-spline basis is non-globa

Date

A B-spline curve is defined as a linear combination of control points P_i and B-spline basis function $N_{i,k}$ t given by:-

$$C(t) = \sum_{i=0}^{n} P_i N_{i,k}(t), \quad n \geq k-1,$$
$$t \in [t_{k-1}, t_{n+1}]$$

(4) In Illumination Models, Shading, and Ray Tracing; Define the following
(a) Specular Diffusion Model
(b) Gouraud Shading
(c) Visible Surface Ray Tracing.

Specular Diffusion Model:

In this model the degree of realism in 3-D object in combination of 3 elements
(a) Diffuse
(b) Specular
(c) ambient light

It has several assumptions
(a) All lights are points.
(b) Only surface geometry is considered.
(c) Only local modelling of diffuse and specular exists.
(d) Specular color is same as light color
(e) Ambient is a global constant.

So intensity of Specular Diffusion Model are it is the combination of ambient light, diffuse light and specular light.

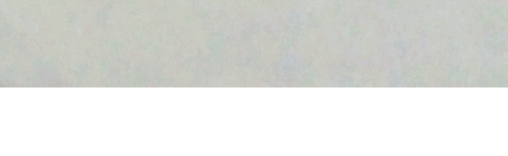
Date

Gouraud Shading:

Gouraud Shading is a method used in computer graphics to simulate the differing effects of light and color across the surface of an object. In practice, Gouraud shading is used to achieve smooth lighting on low-polygon surfaces without the heavy computational requirements of calculating lighting for each pixel.

Visible Surface Ray Tracing.

Visible surface ray tracing in short VSRT, is a method to determine visibility of a surface by tracing rays of light from the viewers eye to the objects in the scene. It is an image precision algorithm. VSRT is sometimes called "Ray Casting".



Date

(4) Discuss the following Animation Techniques:

Inbetweening: Inbetweening, also commonly known as tweening, is a process in animation that involves generating intermediate frames, called inbetweens, between two keyframes.

Double Buffering: It is a common solution used for the problems faced during low or variation in refresh-rate while displaying complex or animated images.
There will be a two frame buffers.
1. Front Buffer: is the one that is used for displaying.
2. Back Buffer: is the one used for constructing.

Kinematics: The term "kinematics" refers to the study of the translational and rotational motion of objects without reference to mass, force or torque.