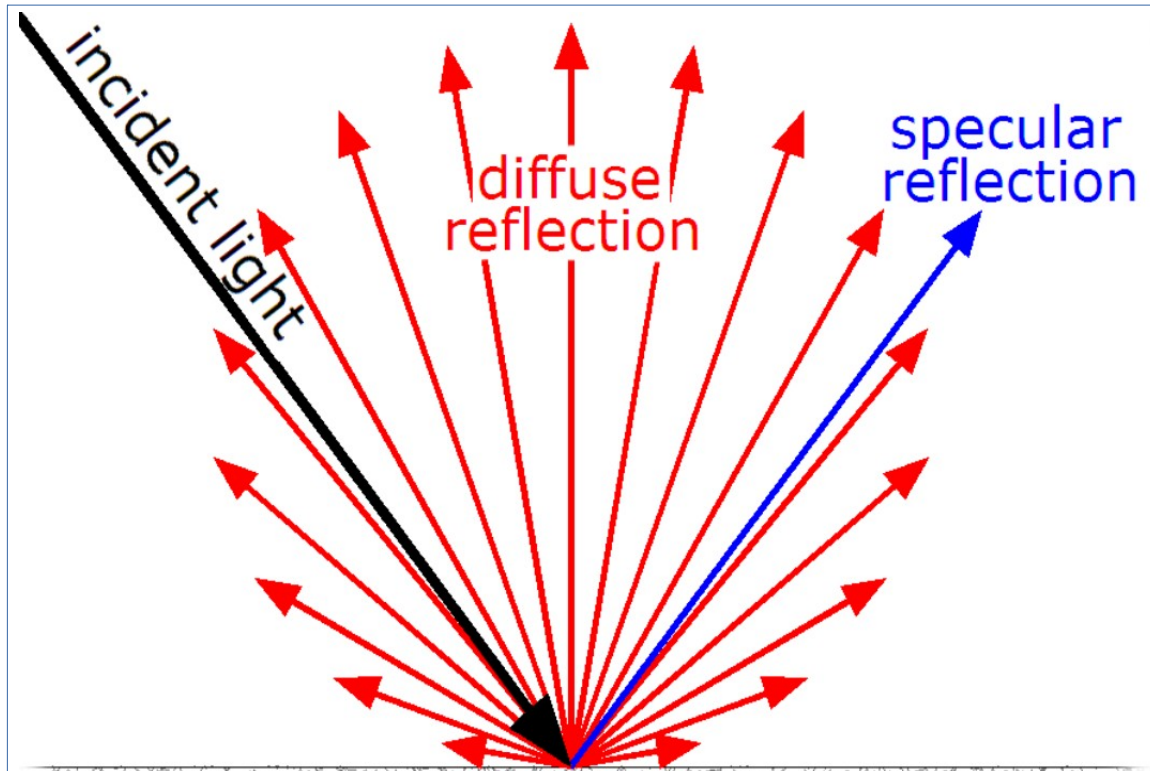


Diffuse Reflection



Two Key Characteristics:

1. The surface with reflectivity as $K_d = (k_r, k_g, k_b)$, e.g., diffuse coefficients;

2. The decay of incident light is inverse proportional to its distance from the source to the surface point. e.g., $1/(r^2)$, where r is being the distance from the light source to the surface.

Specular vs. diffuse reflection

https://en.wikipedia.org/wiki/Diffuse_reflection

Diffuse Reflection: the reflection of light uniformly in all different directions, the surface of this reflection exhibits Lambert reflection, e.g., equal luminance when viewed from all directions.

Diffuse Reflection Formulation

Light source $I_s(x,y)$ consists of r, g, b 3 primitive colors as follows, but let's simplify it as white color, so r, g, b all equal and have the highest value (if in graphics, they are 255)

$$\vec{I}_s(x,y,z) = (I_r(x,y,z), I_g(x,y,z), I_b(x,y,z)) \quad \dots (1)$$

Object surface consists of reflectivity, e.g., coefficient of reflection

$$\vec{K}_d = (K_r, K_g, K_b) \quad \dots (2)$$

\vec{r}_d vector in Equation (1) is a ray equation, just like $I_s(x,y,z)$ but has no r, g, b primitive color defined in it for the matter of simplicity.

Diffuse Reflection Equation

Let's consider white color of the point light source, then each primitive color r , g , b of the object surface $I(x,y,z)$ can be computed as follows:

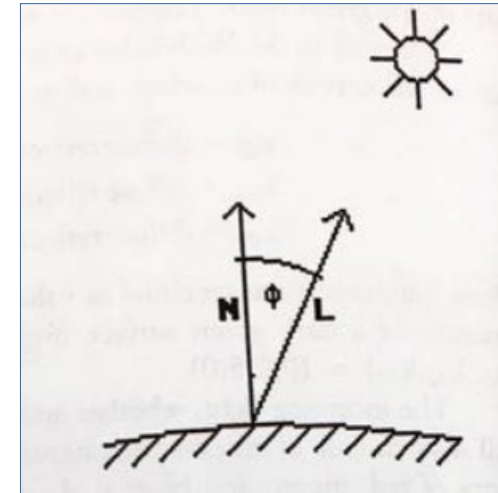
$$I_r = K_{dr} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} \frac{1}{\|\vec{r}\|_2} \quad \dots (1.1)$$

where

$$\|\vec{r}\|_2^2 = x_r^2 + y_r^2 + z_r^2$$

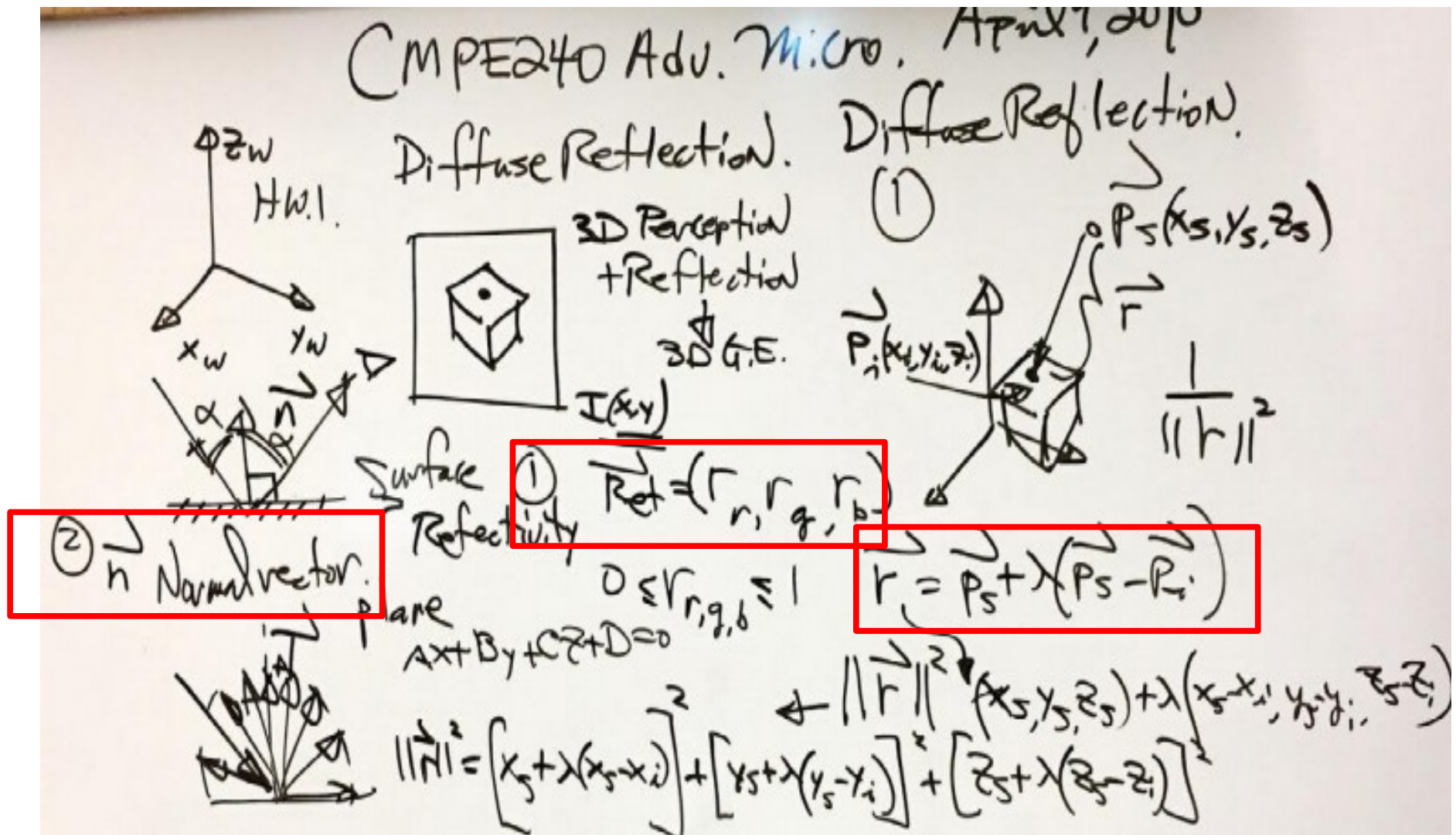
$$I_g = K_{dg} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} \cdot \frac{1}{\|\vec{r}\|_2} \quad \dots (1.2)$$

$$I_b = K_{db} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} \cdot \frac{1}{\|\vec{r}\|_2} \quad \dots (1.3)$$



Reference: Computer Graphics, C. K. Pokorny, C. F. Gerald, pp. 514

Formulation Of Diffuse Reflection Equation



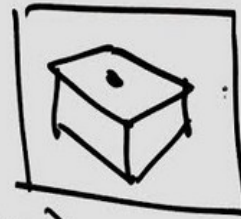
Point Light Source And Incident Angle

Point light source

CMPE240 Adv. Micro, April 9, 2018

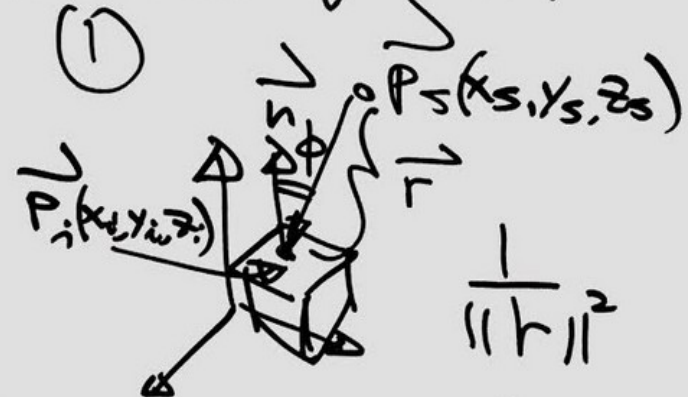
② $\vec{P}_s(x_s, y_s, z_s) = (r_{ps}, g_{ps}, b_{ps})$

$0 \leq r, g, b \leq 1$
16 bits / 24 bits.
"The Sun"



Diffuse Reflection.

①



③

$$\vec{n} \cdot \vec{r} = |\vec{n}| |\vec{r}| \cos \phi$$

$$\cos \phi = \frac{\vec{n} \cdot \vec{r}}{|\vec{r}| |\vec{n}|}$$

$$I_{diff}(x, y, z) = k \frac{1}{||r||^2} \frac{\vec{n} \cdot \vec{r}}{||\vec{n}|| ||\vec{r}||} (r, g, b)$$

$$\vec{r} = \vec{P}_s + \lambda (\vec{P}_s - \vec{P}_i)$$

$$||\vec{r}||^2 = [x_s + \lambda(x_s - x_i)]^2 + [y_s + \lambda(y_s - y_i)]^2 + [z_s + \lambda(z_s - z_i)]^2$$

Angle of incident light

Step 1-5 For Diffuse Reflection Computation

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Consider "Paint" Diff. Reflection Diffuse Reflection.

ONLY

Step 1. $\{ \vec{P}_i(x_i, y_i, z_i) | i \in I \}$

Step 2. \vec{P}_S white, Step 3.

$\vec{R} = (r, g, b) = (1.0, 0.0, 0.0)$ "Red"

Step 4. Eq(1)

$$I_{diff}(x, y, z) = k \frac{1}{\|r\|^2} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} (r, g, b)$$

Compute Diff. Reflection ON Each Face (1) (2) ... (1)

"Visible" $\vec{P}_i(x_i, y_i, z_i)$ (x_w, y_w, z_w) world

Step 5. Transformation Pipeline (World-2-Viewer + Perspective projection)

$P_1 \rightarrow P_2 \rightarrow P_3 \rightarrow P_4$
Counter Clockwise

Arrange vertex in contour clock wise direction when viewing from outside

Step 6 For Diffuse Reflection Computation

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Consider "Paint" Diff. Reflection Diffuse Reflection.

ON LCD

Step 6. Compute Colour On Each Line (Linked by $\vec{P}_i \neq \vec{P}_j$)

Interpolation (B_i for $x \neq y$)

$I_{diff}(x,y,z) = k \frac{1}{\|\vec{r}\|^2} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} (r, g, b)$

Given \vec{P}_i, \vec{P}_j , Draw a line Linking $\vec{P}_i \neq \vec{P}_j$ "GAPS"

D.D.A. $y = ax + b$

Step 5. Transformation Pipeline

Example On Diffuse Reflection Computation (1)

April 16, 2018 CMPE240 Adv. Micro HL 1/

- 1) Homework Submission via E-mail (Project w/ Source Code). the 2nd ONE ON SPI-Slave Due ^{Exported.} this Week;
- 2) Roadmap: Objective - 3D G.E. < 3D Diffuse Reflection
- 2D G.E. S.P.I. (master/slave) I/P
- 3) INTER for Summer (2 pos). (Hardware I/P)
ARM/CPU (Linux Device Driver.) LCD Driver*
Vision/Machine Learning

Example: Ray Equation. Continued from the Last Lecture.

$I_{diff, P_2}(x_2, y_2, z_2)$ in $x_w - y_w - z_w$ World

$E(200, 200, 200)$, Perspective Projection

Input (2D LCD)

Viewer Coordinate System

focal Distance $D = 100$

Input (x_i, y_i, z_i)

Viewer Coordinate System

... (1)

Diagram 1: A 3D coordinate system with axes x, y, z . A point P_2 is shown in the 3D space. A ray is drawn from the origin through P_2 .

Diagram 2: A 2D coordinate system with axes x', y' . A point $(0,0)$ is shown. A ray is drawn from the origin through a point (x', y') .

Diagram 3: A 2D coordinate system with axes x, y . A point $(0,0)$ is shown. A ray is drawn from the origin through a point (x, y) .

Example On Diffuse Reflection Computation (2)

$\{\vec{P}_i(x_i, y_i, z_i) | i=0, 1, \dots, 6\}$
 Hence, from P.P. (Eqn-1), we have
 Suppose $D=10$, find
 $\{\vec{P}_i(x_i, y_i) | i=0, 1, \dots, 6\}$

Example: Given $(x_0, y_0) = (1, 1), (x_1, y_1) = (3, 5)$
D.D.A. to Draw a Line
 $Slope = a = \frac{y_1 - y_0}{x_1 - x_0} = \frac{5-1}{3-1} = 2$
 (Note: if $|a| < 1$, then No GAP,
 $y_{k+1} = a x_{k+1} + b, x_{k+1} = x_k$)
 Switch x and y.
 $\frac{x - x_1}{x_2 - x_1} = \frac{y - y_1}{y_2 - y_1}$
 $y = y_1 + \frac{y_2 - y_1}{x_2 - x_1}(x - x_1)$
 $= \frac{y_2 - y_1}{x_2 - x_1}x + y_1 - \frac{y_2 - y_1}{x_2 - x_1}x_1$
 $y = ax + b, \frac{1}{a}y = x + \frac{b}{a} (1,1)$
 $\therefore x = \frac{1}{a}y - \frac{b}{a} \dots (2)$
 $x = \frac{1}{2}y + \frac{1}{2} \begin{cases} x_{k+1} = x+1 \\ x_{k+1} = \frac{1}{2}y_{k+1} + \frac{1}{2} \end{cases}$

(Location + Color)
Interpolation to find Color
Find Boundaries?
 Find Boundary: $y = ax + b$
 $y_{k+1} = ax_{k+1} + b, x_{k+1} = x_{k+1}$
D.D.A. (Digital Differential Algorithm)

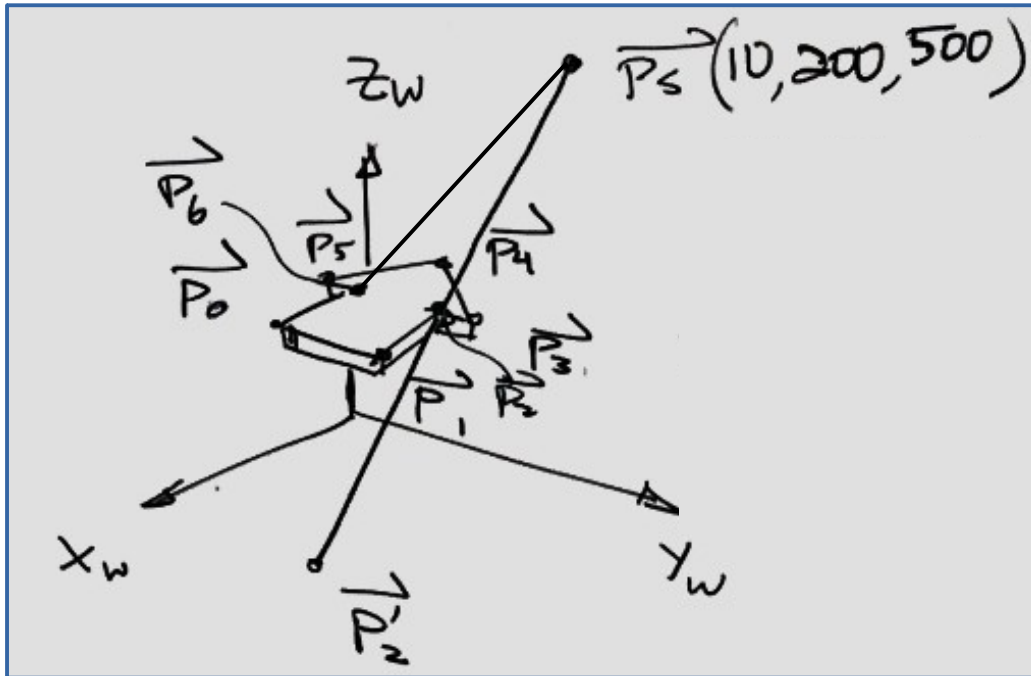
Diagrams showing a square grid with points and a line segment drawn through it, illustrating the DDA algorithm.

0 1 2 3 4 5 6

Example On Diffuse Reflection Computation (3)

Algorithm: 1° Given (x_0, y_0) Starting pt, (x_{N-1}, y_{N-1}) Ending pt.
Find Slope a ;
2° if $|a| < 1$, then $\begin{cases} x_{k+1} = x_k + 1 \\ y_{k+1} = ay_k + b \end{cases}$
3° Finish all pts till Reaching (x_{N-1}, y_{N-1}) or $x = \frac{1}{a}y - \frac{b}{a}$, then $\begin{cases} y_{k+1} = y_k + 1 \\ x_{k+1} = \frac{1}{a}y_{k+1} - \frac{b}{a} \end{cases}$
DDA Algorithm

Diffuse Reflection Example



Example: Suppose we have a single light source $P_s(10, 200, 500)$, now define its (r, g, b) color, so we have single color light source as $I_s(r_s, g_s, b_s) = (1.0, 0.0, 0.0)$, Find the diffuse reflection on the 3D floating arrow by first find color intensity on each of the marked vertex, and then find the color of each pixel of the cursor.

Assume reflection coefficient $K_d = (1.0, 0.0, 0.0)$

Harry Li, Ph.D

From equation (1.1),

$$I_r = K_{dr} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} \frac{1}{\|\vec{r}\|_2^2}$$

... (1.1)

First, find ray equation to, say, one of the vertex, $P_2(25, 70, 50)$.

Then find the distance from light source to P_2 .

Then use the given condition, find the color intensity at P_2 location.

Repeat this process to find color intensity for all the vertex from P_0 to P_6 .

Calculation After Perspective Projection

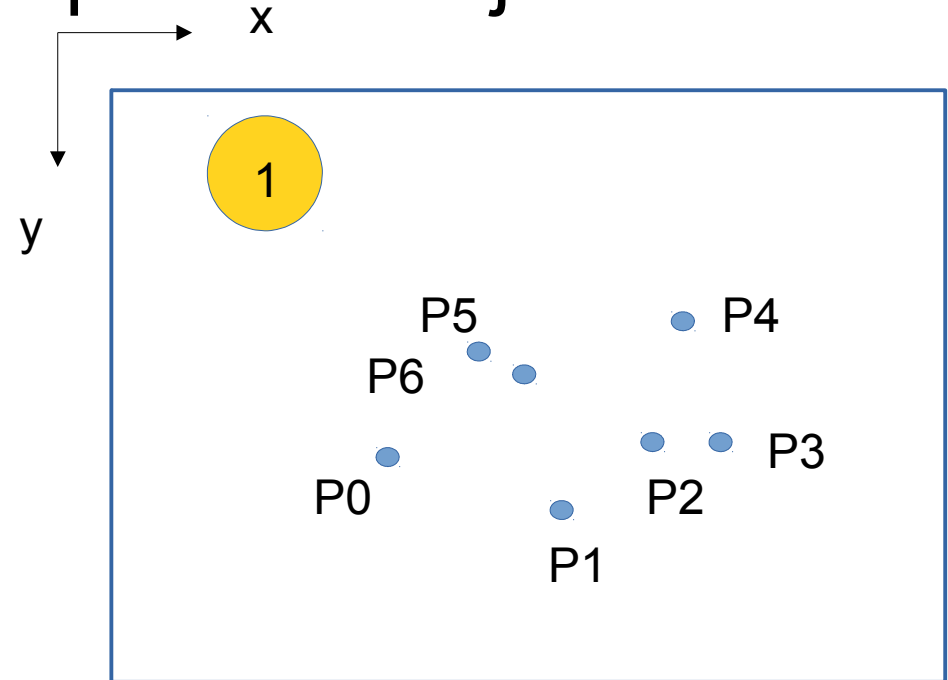
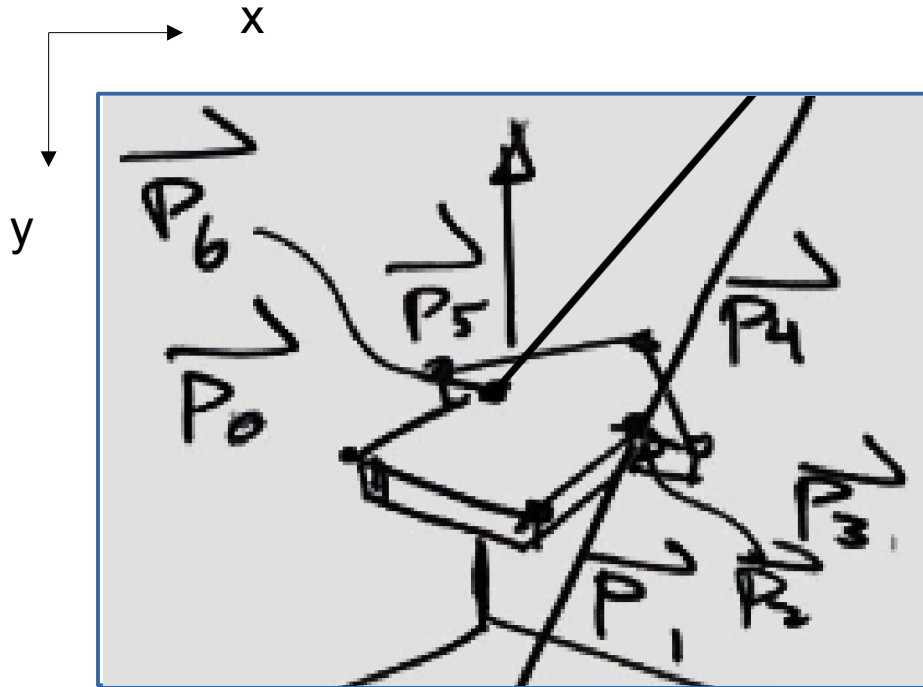
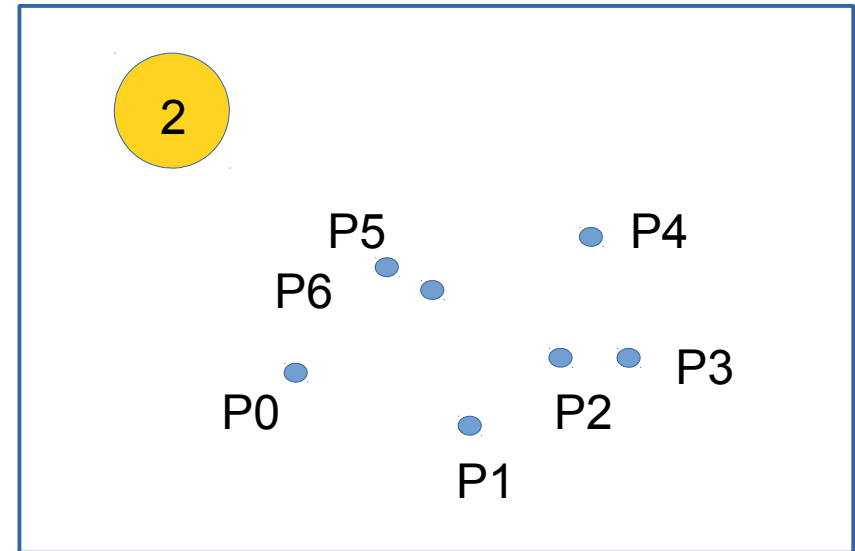
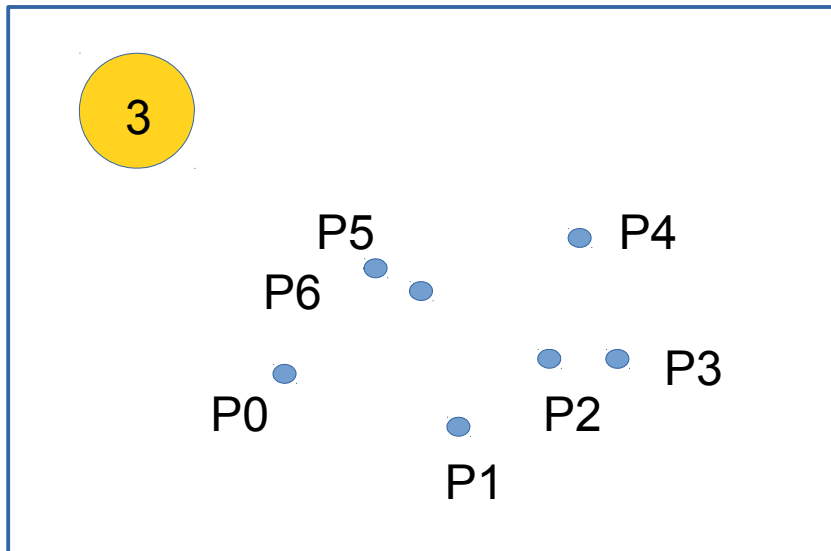
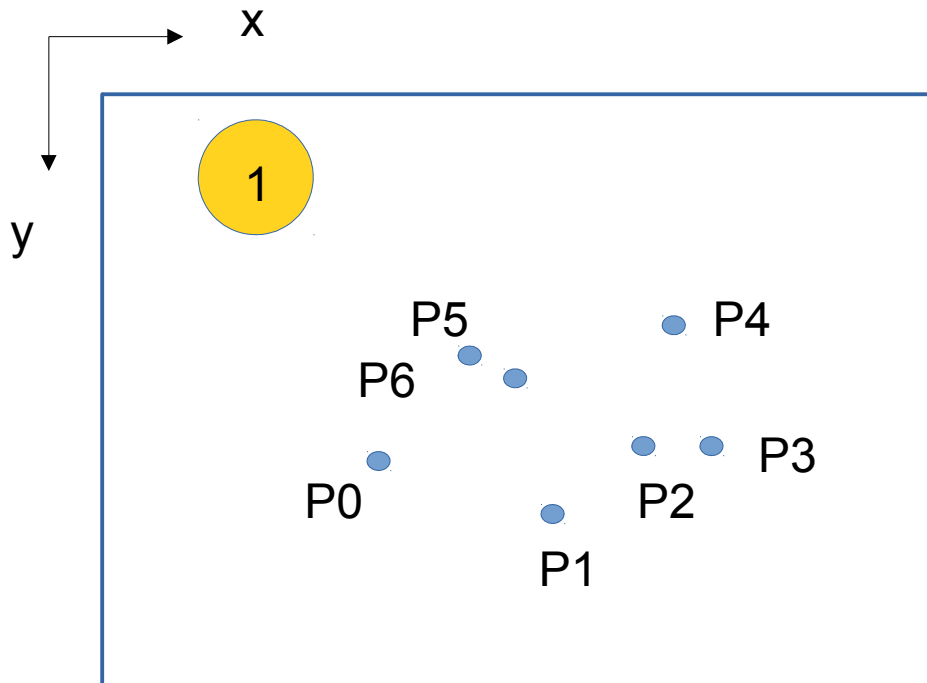


Image (graphics) plane after perspective projection.



Color On The Line Segments (DDA)



Given P_i and $P_{(i+1)}$, find line equation first;

Then, rasterization of the line by using DDA (Digital Differential Algorithm);

Then use bilinear interpolation to find the color on each point on the line. As a result you will have figure labeled as figure 2.

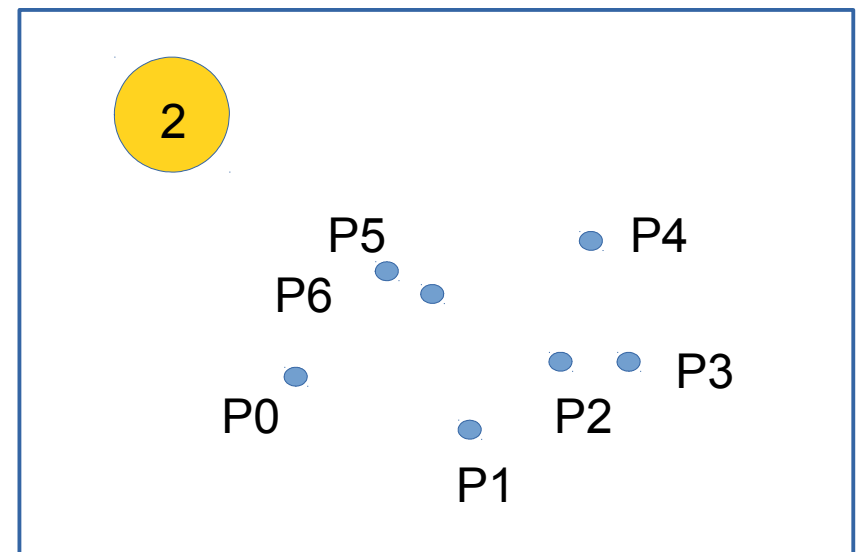
DDA Algorithm Example

The key :

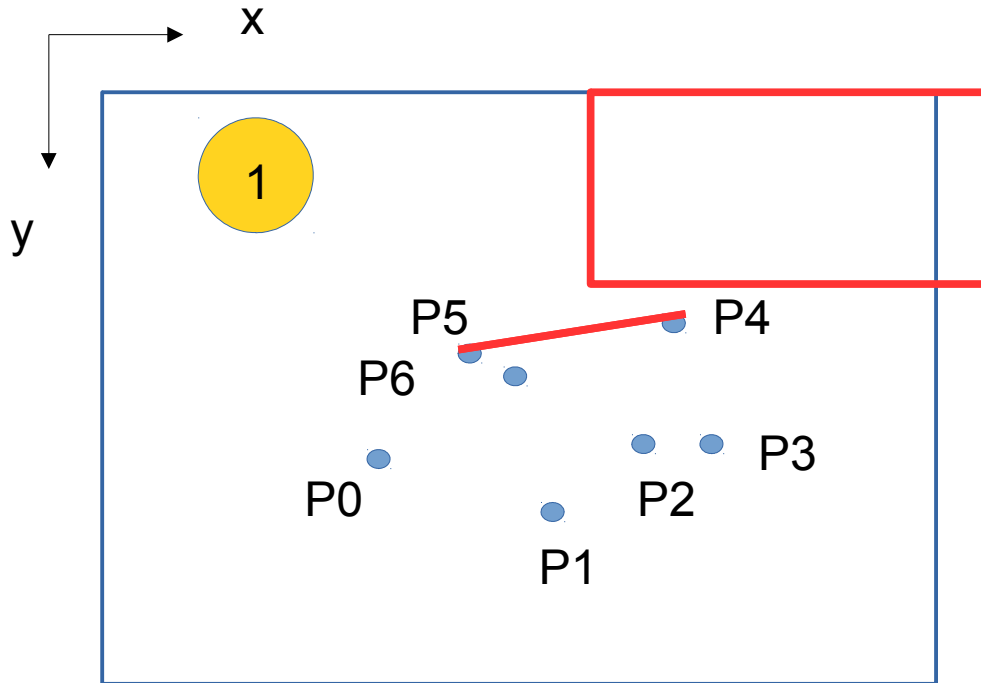
Slop $|a|$ should be less than or equal to 1,
Otherwise will have to swap x and y;

$$y_{(k+1)} = a * x_{(k+1)} + b \quad \dots (1)$$

$$x_{(k+1)} = x_k; \quad \dots (2)$$



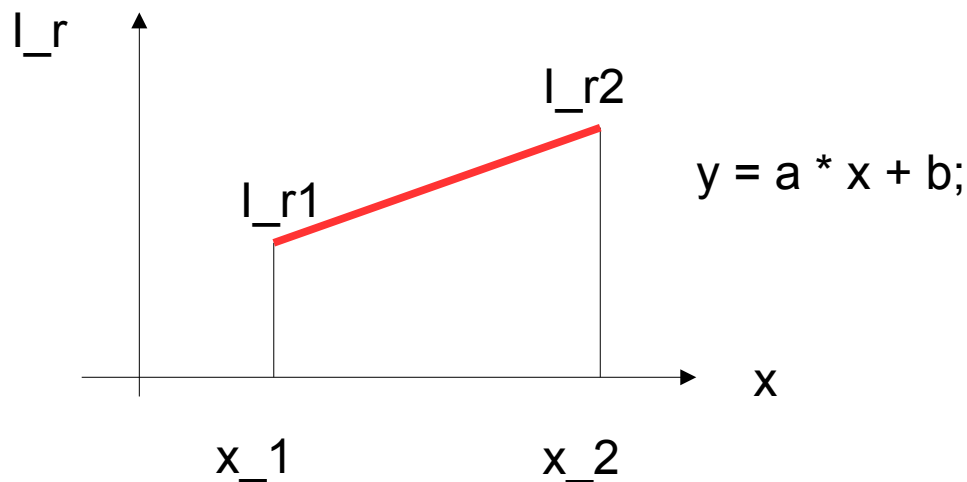
Color On The Line Segments (Interpolation)



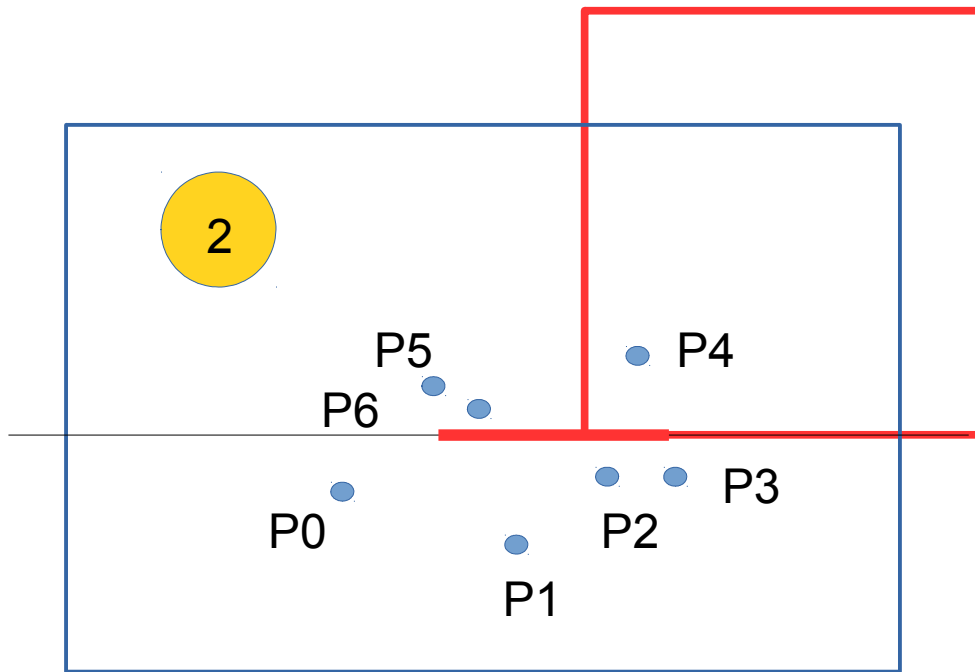
Example: when rasterization is done, then find color for each point on the line by interpolation.

Example (Interpolation)

Step 1. Interpolation along x-direction;
Step 2. Interpolation along y-direction;
Where at each direction, we just use one dimensional interpolation.



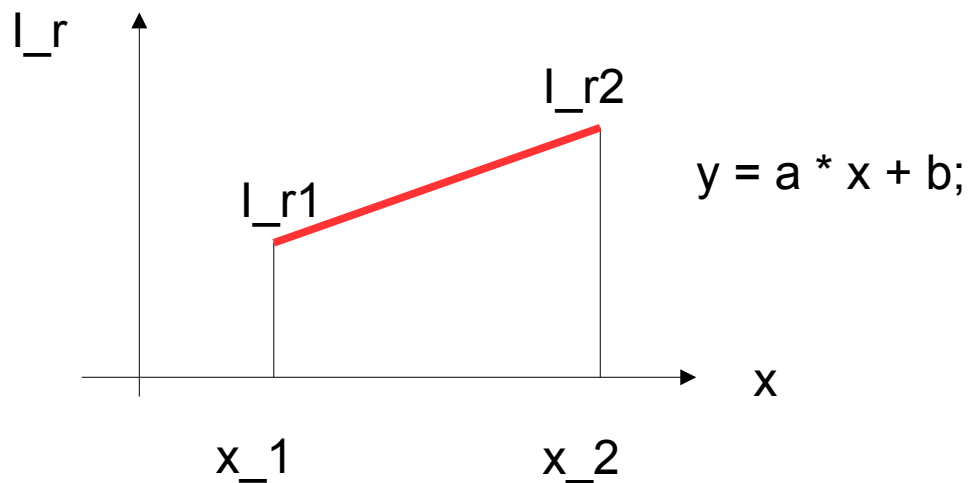
Color Inside the Line Boundary (Interpolation)



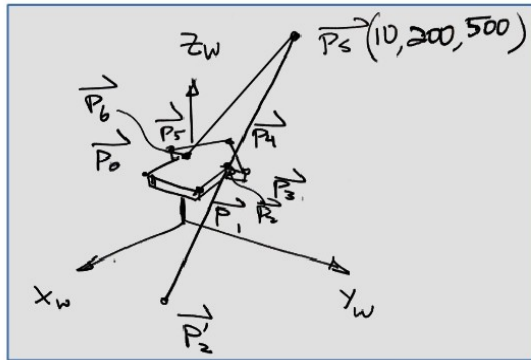
Example: when rasterization is done, then find color for each point on the line inside the boundary lines by interpolation.

Example (Interpolation)

Raster scan the image, use linear interpolation find the color between boundaries.



Diffuse Reflection Example



From equation (1.1),

$$I_r = K_{dr} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} I_s$$

... (1.1)

First, find ray equation to, say, one of the vertex, P₂(25, 70, 50).

Then find the distance from light source to P₂.

Then use the given condition, find the color intensity at P₂ location.

Repeat this process to find color intensity for all the vertex from P₀ to P₆.

Example: Suppose we have a single light source P_s(10,200, 500), now define its (r, g, b) color, so we have single color light source as I_s(r_s, g_s, b_s) = (1.0, 0.0, 0.0), Find the diffuse reflection on the 3D floating arrow by first find color intensity on each of the marked vertex, and then find the color of each pixel of the cursor.

Assume reflection coefficient K_d=(1.0, 0.0, 0.0)
Harry Li, Ph.D

Calculation After Perspective Projection

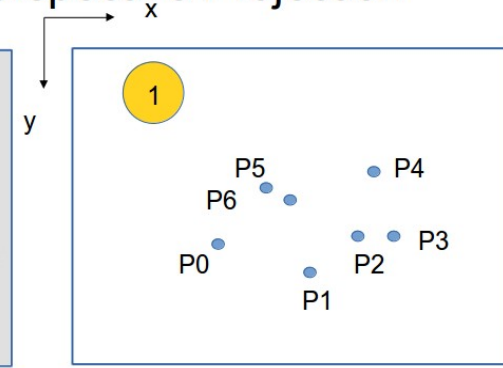
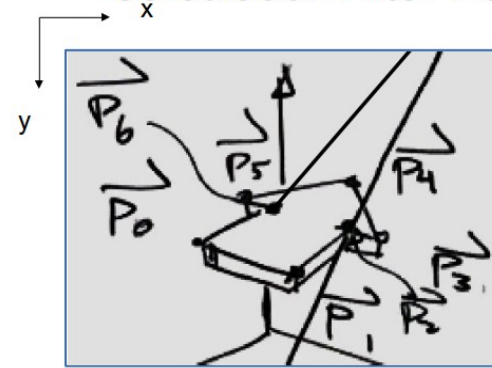


Image (graphics) plane after perspective projection.

