

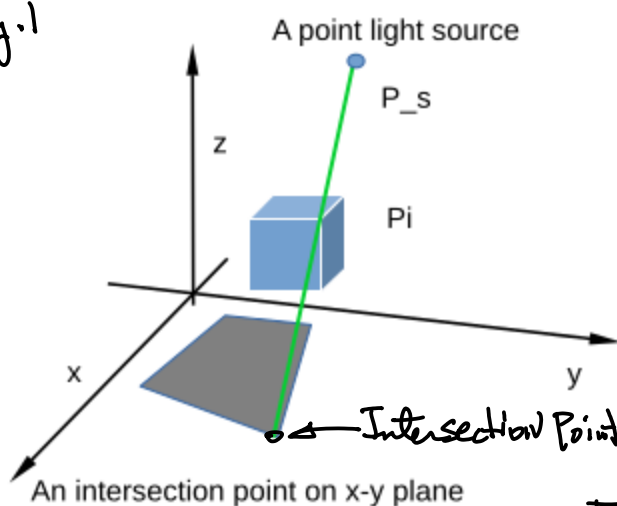
Nov. 15 (Monday)

Example: 3D Shadow Computation.

From Eqn (2) pp. 50.

$$\vec{n} \cdot (\vec{r} - \vec{a}) = 0 \quad \dots (2)$$

Fig. 1



Ray Equation: pp. 46.

$$\vec{r} = \vec{p}_i + \lambda (\vec{p}_s - \vec{p}_i) \quad \dots (3)$$

The Intersection Point on x-y plane, \vec{p}_i'

is a common pt shared by Ray Eqn (3) and plane eqn (2).

$$\vec{r} = \vec{p}_i + \lambda (\vec{p}_s - \vec{p}_i) \quad \dots (4-1)$$

$$\vec{n} \cdot (\vec{r} - \vec{a}) = 0 \quad \dots (4-2)$$

From Eqn (4-2),

$$\vec{n} \cdot (\vec{r} - \vec{a}) = 0$$

$$\vec{r} = \vec{r}$$

$$= \frac{(n_x, n_y, n_z)(a_x, a_y, a_z) - (n_x, n_y, n_z) \cdot (x_i, y_i, z_i)}{(n_x, n_y, n_z) \cdot (x_s - x_i, y_s - y_i, z_s - z_i)}$$

$$\vec{n} \cdot (\vec{r} - \vec{a}) = 0$$

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

$$\vec{n} \cdot (\vec{p}_i + \lambda (\vec{p}_s - \vec{p}_i) - \vec{a}) = 0$$

$$\vec{n} \cdot \vec{p}_i + \lambda \vec{n} \cdot (\vec{p}_s - \vec{p}_i) - \vec{n} \cdot \vec{a} = 0$$

$$\lambda \vec{n} \cdot (\vec{p}_s - \vec{p}_i) = \vec{n} \cdot \vec{a} - \vec{n} \cdot \vec{p}_i$$

$$\lambda = \frac{\vec{n} \cdot \vec{a} - \vec{n} \cdot \vec{p}_i}{\vec{n} \cdot (\vec{p}_s - \vec{p}_i)} \quad \dots (5)$$

Note: λ together with the Ray Equation (3), will give the intersection point.

Example: Given a Single point light

Source $\vec{p}_s(-20, 110, 200)$, $\vec{p}_i(100, 100, 110)$

Find intersection Point to plot Shadow.

sol

From Eqn (5), find λ .

Since

$$\vec{n} = (0, 0, 1), \vec{a} = (0, 0, 0)$$

$$\vec{p}_i = (100, 100, 110)$$

Hence,

$$\lambda = \frac{\vec{n} \cdot \vec{a} - \vec{n} \cdot \vec{p}_i}{\vec{n} \cdot (\vec{p}_s - \vec{p}_i)}$$

$$= \frac{n_x a_x + n_y a_y + n_z a_z - (n_x x_i + n_y y_i + n_z z_i)}{n_x (x_s - x_i) + n_y (y_s - y_i) + n_z (z_s - z_i)}$$

Note: Define Letter(s) for my initial for Linear Decoration.
Letter with Fourth Discussion.

$$n_x = 0, n_y = 0, n_z = 1.$$

Therefore, the above equation becomes

$$= \frac{0 + 0 + 0 - (0 + 0 + 1 \cdot z_i)}{0 + 0 + 1 \cdot (z_s - z_i)}$$

$$= - \frac{z_i}{z_s - z_i} \text{ from the given condition}$$

$$z_i = 110, z_s = 200,$$

$$\therefore \lambda = - \frac{110}{200 - 110} = - \frac{110}{90} = - \frac{11}{9}$$

Substitute λ into the Ray Equation (3)

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

$$= (100, 100, 110) + \lambda ((-20, 110, 200) - (100, 100, 110))$$

$$= (100, 100, 110) - \frac{11}{9} (-130, 10, 90)$$

$$= (100 + \frac{11}{9} \times 130, 100 - \frac{11}{9} \times 10, 110 - \frac{11}{9} \times 90)$$

$$= (100 + \frac{11 \times 130}{9}, 100 - \frac{11 \times 10}{9}, 110 - 11)$$

$$= (100 + \frac{11 \times 130}{9}, 100 - \frac{11 \times 10}{9}, 0)$$

On $x_w - y_w$ plane! so z must be 0!

```
51 typedef struct{
52     float X[30], Y[30];
53 } letter;
```

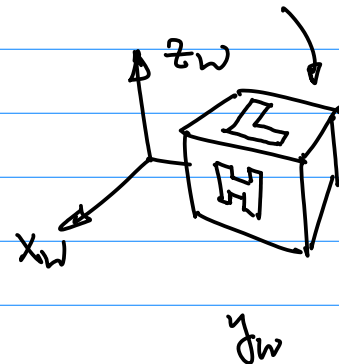
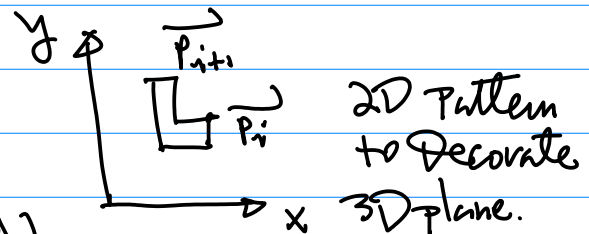


Fig. 2.

Define 2D Patterns



C/C++ Implementation.

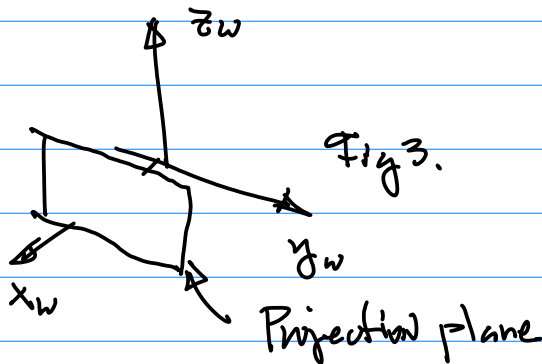
2018F-116-11diffuse20181114.cpp

2018F-117-12dda.cpp

```

84 //define projection plane
85 world.X[4] = 60.0;    world.Y[4] = -50.0;    world.Z[4] = 0.0; //p4 of box
86 world.X[5] = 60.0;    world.Y[5] = 50.0;    world.Z[5] = 0.0; //p5 of box
87
88 world.X[6] = 60.0;    world.Y[6] = 50.0;    world.Z[6] = 100.0; //p6 of box
89 world.X[7] = 60.0;    world.Y[7] = -50.0;    world.Z[7] = 100.0; //p7 of box. Pi

```



(2) Point Light Source $\vec{P}_s(x_s, y_s, z_s)$

```

166 // 47 = normal vector, 46 = A, 45 = Ps, 7 = top left box vertex
167 world.X[45] = -200.0; world.Y[45] = 50.0; world.Z[45] = 200.0; // Ps (point source)
168 world.X[46] = 0; world.Y[46] = 0; world.Z[46] = 0; // arbitrary vector A on x-y plane
169 world.X[47] = 0; world.Y[47] = 0; world.Z[47] = 1; // normal vector for x-y plane

```

① normal vector $\vec{n}(0,0,1)$;

x Computation is implemented Below,

```

171 //-----lambda for Intersection pt on xw-yw plane-----*
172 float temp = (world.X[47]*(world.X[46]-world.X[45]))
173             +(world.Y[47]*(world.Y[46]-world.Y[45]))
174             +(world.Z[47]*(world.Z[46]-world.Z[45]));
175 float lambda = temp / ((world.X[47]*(world.X[45]-world.X[7]))
176                       +(world.Y[47]*(world.Y[45]-world.Y[7]))
177                       +(world.Z[47]*(world.Z[45]-world.Z[7])));
178 float lambda_2 = temp / ((world.X[47]*(world.X[45]-world.X[6]))
179                          +(world.Y[47]*(world.Y[45]-world.Y[6]))
180                          +(world.Z[47]*(world.Z[45]-world.Z[6])));

```

$$\begin{aligned}
 \lambda &= \frac{n_x a_x + n_y a_y + n_z a_z - (n_x x_i + n_y y_i + n_z z_i)}{n_x (x_s - x_i) + n_y (y_s - y_i) + n_z (z_s - z_i)} \quad \text{OR} \\
 &= \frac{n_x (a_x - x_i) + n_y (a_y - y_i) + n_z (a_z - z_i)}{n_x (x_s - x_i) + n_y (y_s - y_i) + n_z (z_s - z_i)}
 \end{aligned}$$

CMPE240 (II)

Nov. 17 (Wed)

3D G.E. Design on Diffuse Reflection

Ref: from class github.

2018F-115-lab-DiffuseReflection-Rubrics.txt

2018F-116-11diffuse20181114.cpp

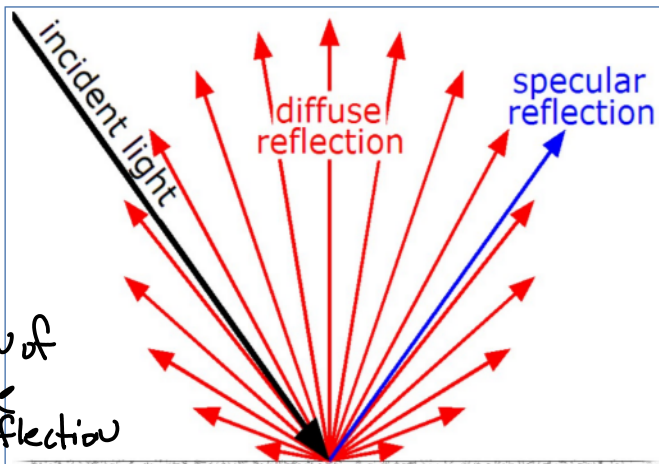
2018F-117-12dda.cpp

2018F-118-13diffuseInterpolation20181127....

2018S-17-Lab-report-rubrics.txt

2018S-22-lec7-Diffuse...

2018S-23-lec7-Diffuse...



① https://en.wikipedia.org/wiki/Diffuse_reflection

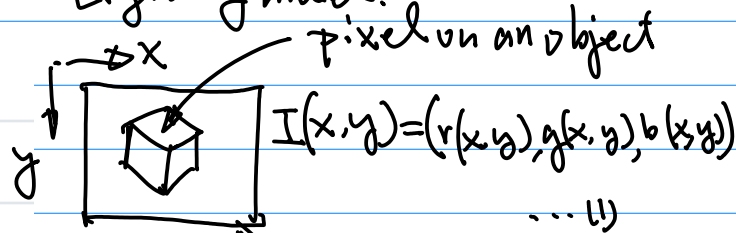
Chapter 12 (2) My Book in progress

Lighting Models with Emphasis on Diffuse Reflection

In the lighting model formulation, very often you will see 3 different type of lighting models as shown in the following Figure:

54

Example: Generate Realistic Looking Graphics, Simulate/Formulate Lighting model.



Color image defined by 3 Primitive colors, r —red, g —green, b —blue

Each primitive color is represented as 8 bit value.

$r(x,y) \in [0,255]$, $g(x,y) \in [0,255]$, and $b(x,y) \in [0,255]$

3 Type of Light Contributors to generate the color

$$I(x,y) = I_1(x,y) + I_2(x,y) + I_3(x,y)$$

Diffuse Reflection Specular Reflection Ambient Light

Note: Specular Reflection is the reflection which generates high light, it is a function of "Eye" e.g. Virtual Camera location.

Ambient Light (Reflection), are those coming from indirect light sources.

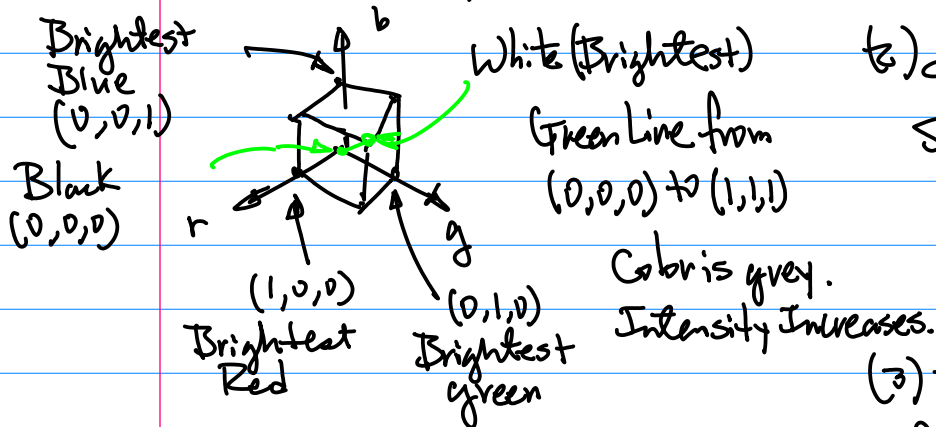
Example: Color Intensity generated by indirect light when viewing the objects, for example, underneath a table.

Math Description: A constant.

Diffuse Reflection

A Reflection reflects in-coming light uniformly in all different directions

3D Vector Color Space



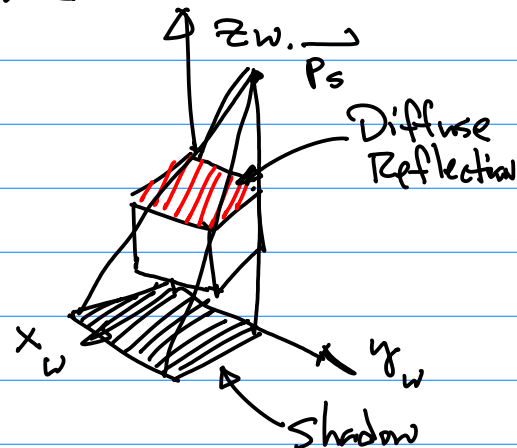
About color of An Object: Characteristic of the Object. It depends on reflectivity of the object itself.

Nov. 2nd (Monday)

Note: Last Project Diffuse Reflection + Decoration Algorithm → 3D Graphics Processing Engine

2021F-109b-project-DiffuseReflection-Rubrics...

1. Can't 20 pts. Due Dec 8th (Wed) 11:59 pm. (No Late Submission) Submission on CANVAS.
2. (1) Solid Cube



- (2) Diffuse Reflection on the top Surface, with 1 primitive color, Red

- (3) Tree on One surface



3. Please follow the requirements posted on Line

- (1) IEEE Style Report 5 pages.
- (2) Exported Project; (3) photo of the Implementation; (4) 5 Second Video Clips

Diffuse Reflection Formulation.

2018S-23-lec7-DiffuseRefl...

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

k coefficient of Reflectivity.

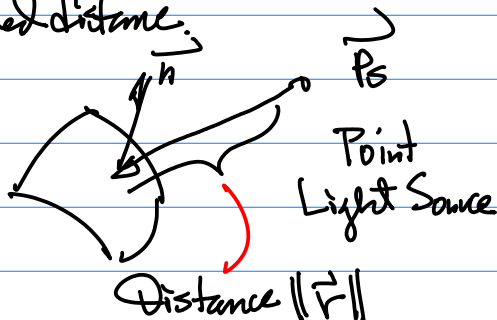
K_d : "d" for diffuse Reflection.

$\vec{K}_d(k_r, k_g, k_b)$
 Reflectivity for Red ~ for green ~ for Blue

$$0 \leq k_r \leq 1, 0 \leq k_g \leq 1, 0 \leq k_b \leq 1 \quad \dots (1)$$

If $k_r = k_g = 0, k_b = 1$. then we have "blue" color (Highest Full Reflection of Blue).

2. Light (color) Intensity from P_s to a surface is formulated as a decay function to the squared distance.

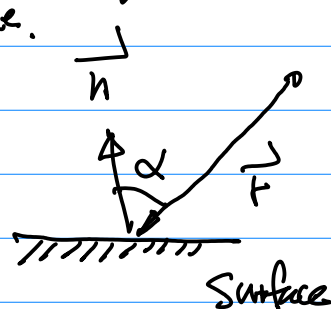


\vec{r} Ray Equation from P_s to P_i on the surface.

Intensity (color)

$$\frac{1}{(\sqrt{x_r^2 + y_r^2 + z_r^2})^2} = \frac{1}{\|\vec{r}\|^2}$$

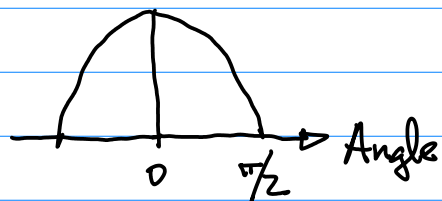
3. Intensity (color) is a function of the angle of the incoming point light Source.



$$\vec{I}_{diff} = (\text{Reflectivity}) \left(\frac{1}{\|\vec{r}\|^2} \right) (\text{Angle of the incoming light}) \quad \dots (2)$$

at a particular point on a surface

$\cos(\text{Angle of the incoming light})$:



Mathematically :

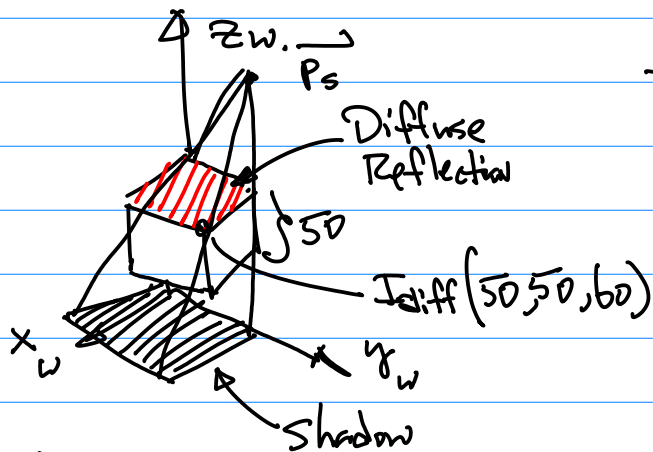
$$\vec{r} \cdot \vec{n} = \|\vec{r}\| \|\vec{n}\| \cos \alpha \quad \dots (3)$$

$$\cos \alpha = \frac{\vec{r} \cdot \vec{n}}{\|\vec{r}\| \|\vec{n}\|} \quad \dots (3-b)$$

Hence:

$$\begin{aligned} I_{\text{diff}} &= k_d \cdot \frac{1}{\|\vec{r}\|^2} \cdot \cos \alpha \\ &= k_d \cdot \frac{1}{\|\vec{r}\|^2} \cdot \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} \end{aligned} \quad \dots (4)$$

Example: Given Conditions



$\vec{P}_s(40, 60, 120)$. Cube is floating by $z=10$.

Find $I_{\text{diff}}(50, 50, 60) = ?$

Sol: First, $k_d = (k_r, k_g, k_b) = (0.8, 0, 0)$

Then, the distance from \vec{P}_s to $\vec{P}_i(50, 50, 60)$

$$\begin{aligned} \|\vec{r}\|^2 &= (x_s - x_i)^2 + (y_s - y_i)^2 + (z_s - z_i)^2 \\ &= (40 - 50)^2 + (60 - 50)^2 + (120 - 60)^2 \\ &= 10^2 + 10^2 + 60^2 \end{aligned}$$

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

Where $\vec{n} = (0, 0, 1)$,

Compt 240(I) $(50, 50, 60) - (40, 60, 120) = (10, -10, -60)$ 50

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

! for this calculation
 $= (50, 50, 60) + \lambda((40, 60, 120) - (50, 50, 60))$
 $= (50, 50, 60) + \lambda(-10, 10, 60)$

Let $\lambda = 1$. $\vec{r}|_{\lambda=1} = (50, 50, 60) + (-10, 10, 60)$
 $= (40, 60, 120)$

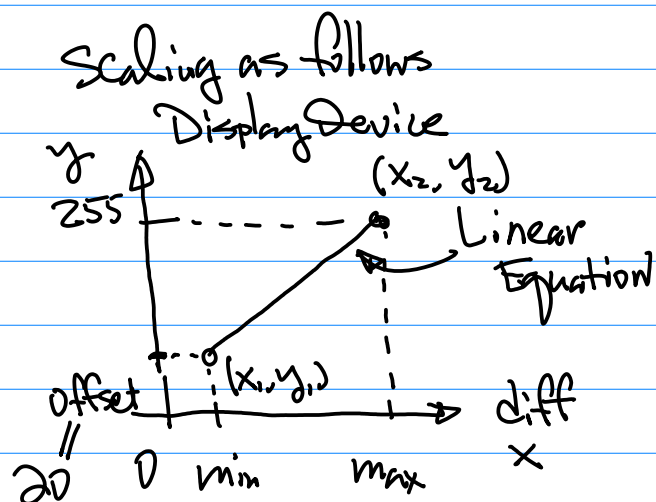
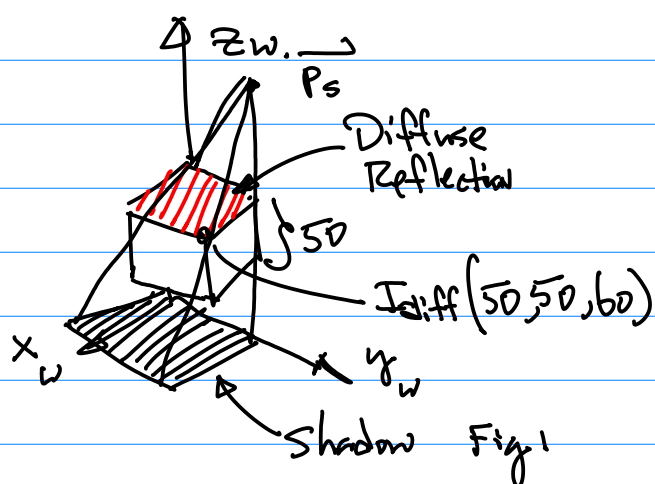
$$\vec{n} \cdot \vec{r} = (0, 0, 1) \cdot (40, 60, 120) = 0 \times 40 + 0 \times 60 + 1 \times 120 = 120$$

$$\frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} = \frac{120}{1 \cdot \sqrt{40^2 + 60^2 + 120^2}} = \frac{120}{\sqrt{40^2 + 60^2 + 120^2}}$$

Therefore

$$I_{\text{diff}}(50, 50, 60) = (0.8, 0, 0) \cdot \frac{1}{10^2 + 10^2 + 60^2} \cdot \frac{120}{\sqrt{40^2 + 60^2 + 120^2}}$$

Red: $I_{\text{diff}, r} = \frac{0.8 \times 120}{(10^2 + 10^2 + 60^2) \times (\sqrt{40^2 + 60^2 + 120^2})}$



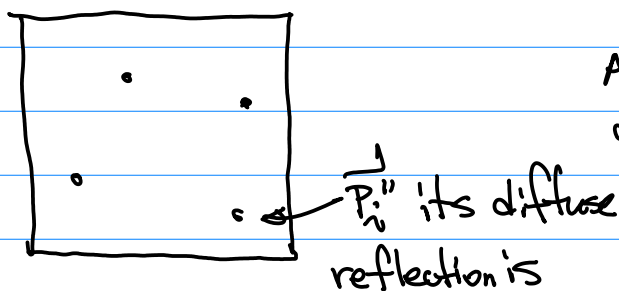
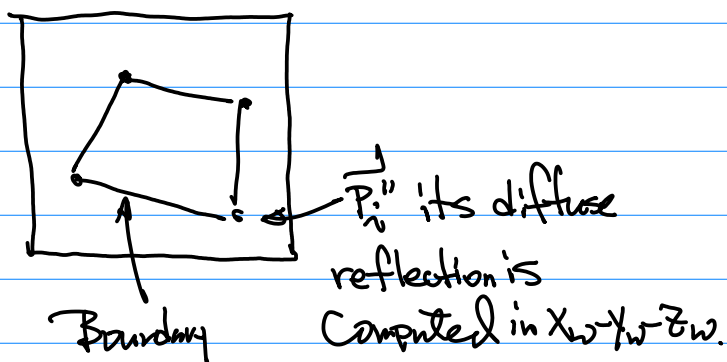
Note: The Computation is carried out in x_w, y_w, z_w .

You can compute diffuse reflection for the rest 3 vertices

$$\vec{P}(50, 0, 60), \vec{P}(0, 50, 60), \vec{P}(0, 0, 60)$$

Note: To plot these 4 point with the color, use Transformation Pipeline,

Example: Compute Boundary Color



Two Steps Process.

After Perspective Projection, we have to deal with finite Resolution of the display device.

D.D.A

Fig. 2

Their locations are Computed by Transformation Pipeline !!!

Important! To make the Diff.

Reflection Result Visible, use

2. Final Exam

Nov. 29 (Mon.)

Group I Classes

Group I classes are those classes which meet M, W, F, MTW, MWR, MTWF, MWRF, MTWRF, MW, WF, MWF, MF, TW, WR, MT.

Regular Class Start Times	Final Examination Days	Final Examination Times
7:00 through 8:25 AM	Tuesday, December 14	7:15-9:30 AM
8:30 through 9:25 AM	Thursday, December 9	7:15-9:30 AM
9:30 through 10:25 AM	Monday, December 13	7:15-9:30 AM
10:30 through 11:25 AM	Wednesday, December 8	9:45 AM-12:00 PM
11:30 AM through 12:25 PM	Friday, December 10	9:45 AM-12:00 PM
12:30 through 1:25 PM	Tuesday, December 14	12:15-2:30 PM
1:30 through 2:25 PM	Thursday, December 9	12:15-2:30 PM
2:30 through 3:25 PM	Monday, December 13	12:15-2:30 PM
3:30 through 4:25 PM*	Wednesday, December 8	2:45-5:00 PM
4:30* through 5:25 PM*	Friday, December 10	2:45-5:00 PM

Need to use Prototype Board to Answer Questions.

$$\frac{x - x_2}{x_1 - x_2} = \frac{y - y_2}{y_1 - y_2} \dots (1)$$

$$\frac{y_1 - y_2}{x_1 - x_2} (x - x_2) = y - y_2$$

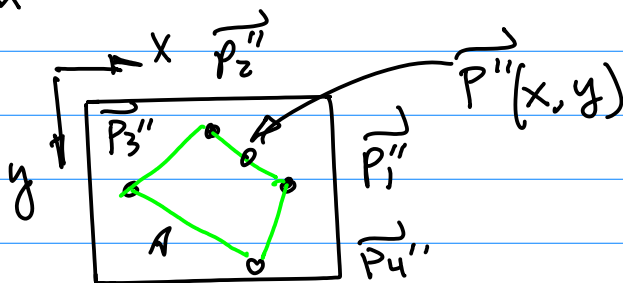
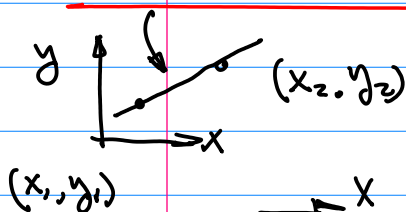


Fig. 1.

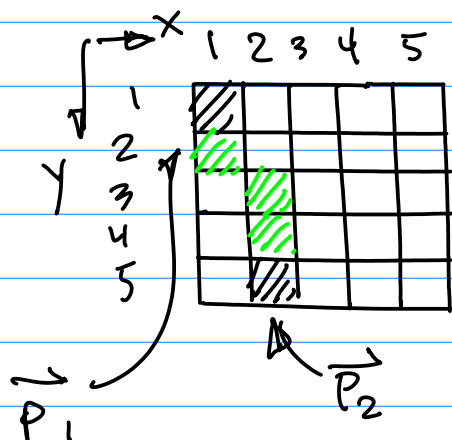


Fig. 2

CMPE240

Due Dec 6 (1:30pm)

59

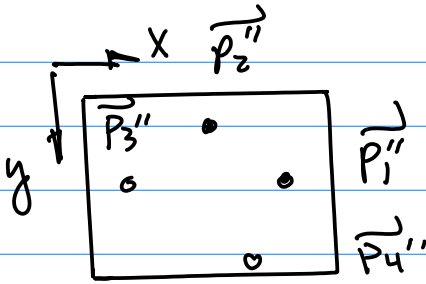
- Last Homework, take photos and submit them as one pdf document.
 - Entire System (Host Laptop LTC1769);
 - LTC1769 w/ Display (one photo) of Shadow Graphics. (Trees). One photo.
 - Screen Capture of NXP XPRESSO. with Console Display of Name, ID, 3D Graphics. Submit to CANVAS

$$y = \frac{y_1 - y_2}{x_1 - x_2} (x - x_2) + y_2$$

$$y = \frac{y_1 - y_2}{x_1 - x_2} x - \frac{y_1 - y_2}{x_1 - x_2} x_2 + y_2 \dots (1b)$$

Note: 1° 4 vertices pts $\vec{P}_1'', \vec{P}_2'', \dots, \vec{P}_4''$ have diffuse Reflection; 2° Extend the diffuse Reflection to Each Boundary Line (Green);

"Plot" Diffuse Reflection in 3D Space



$\vec{P}_1'', \vec{P}_2'', \dots, \vec{P}_4''$ Fig.3.

Note: Example for Interpolation.
is to use Sin/Cos Table

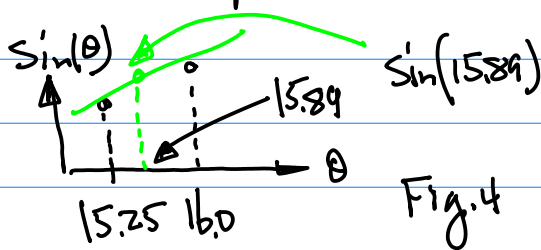
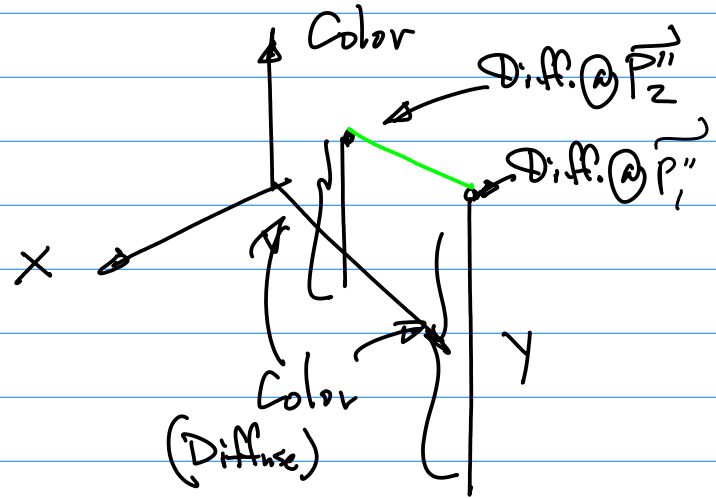


Fig.4

Note: Diffuse reflection on the green line in Fig.3 is a function of Both x, y . therefore we will treat interpolation separately, one interpolation for x , one interpolation for y .

To visualize these 2 interpolations, we have the following illustration, 20215-1056 ~ Ref from github.



Project Fig.3 As function of one variable x , so, we have Fig.5

x — Independent variable
Diffuse Reflection — Function.

$$I_{diff} = ax + b \quad \dots (2)$$

where a, b are determined by Eqn. (1b).

Similarly, in Fig.6. Diff. Reflection is a function of y .

$$I_{diff} = a'y + b' \quad \dots (3)$$

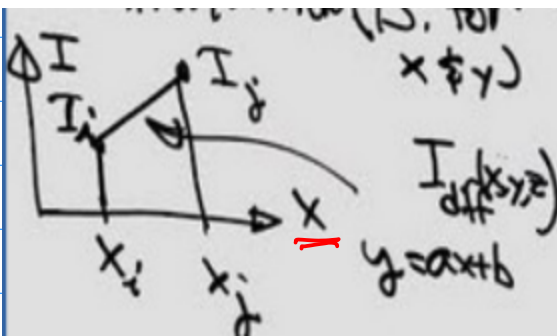


Fig.5

use eqn(1b) to find a', b' .

Then, Take Average.

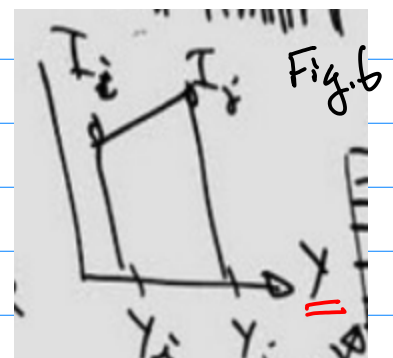


Fig.6

Example: Suppose $I_{diff} = 0.78$ for red @ $\vec{P}_1(x_1, y_1) = \vec{P}_1(20, 30)$

$I_{diff} = 0.5$ for red @ $\vec{P}_2(x_2, y_2) = \vec{P}_2(10, 40)$ (Note: Arbitrary pt., Real value location, see Actual Calculation)

for y , we have

$I_{diff, y}$

$y_1 = 30, y_2 = 40$ (Indep)

Hence,

$$I_{diff}(20, 30) = 0.78$$

$$I_{diff}(10, 40) = 0.5$$

Therefore

To find $I_{diff}(15, 35) = ?$

Step 1. Derive Interpolation formula for x Based Equation (1b)

$$y = \frac{y_1 - y_2}{x_1 - x_2} x - \frac{y_1 - y_2}{x_1 - x_2} x_2 + y_2 \quad \dots (1b)$$

Treat x as independent variable

y is diffuse Reflection Value

from the given condition

$$x_1 = 20, y_1 = I_{diff} = 0.78$$

$$x_2 = 10, y_2 = I_{diff} = 0.5$$

Substitute x_1, y_1, x_2, y_2 into eqn(1b),

$$I_{diff} = \frac{0.78 - 0.5}{20 - 10} x - \frac{0.78 - 0.5}{20 - 10} \cdot 10 + 0.5$$

Let $x = 15$, find I_{diff} .

$$I_{diff, x} = \frac{0.28}{10} x \Big|_{x=15} - \frac{0.25}{10} \times 10 + 0.5$$

$$= 0.28 \times \frac{3}{2} - 0.25 + 0.5 = 0.42 + 0.25 = 0.67$$

$$I_{diff, y} = \frac{0.78 - 0.5}{30 - 40} y - \frac{0.78 - 0.5}{30 - 40} \cdot 40 + 0.5$$

$$= \frac{0.28}{10} y - \frac{0.28}{10} \cdot 40 + 0.5 \quad y=35$$

$$= \frac{0.28}{10} \times 35 - 0.28 \times 4 + 0.5$$

$$= 0.14 \times 7 - 1.04 + 0.5$$

$$= 0.91 + 0.5 - 1.04 = 1.41 - 1.04$$

$$= 0.37$$

Finally, Average them.

$$I_{diff}(15, 35) = \frac{1}{2} (I_{diff, x} + I_{diff, y})$$

$$= \frac{1}{2} (0.67 + 0.37)$$