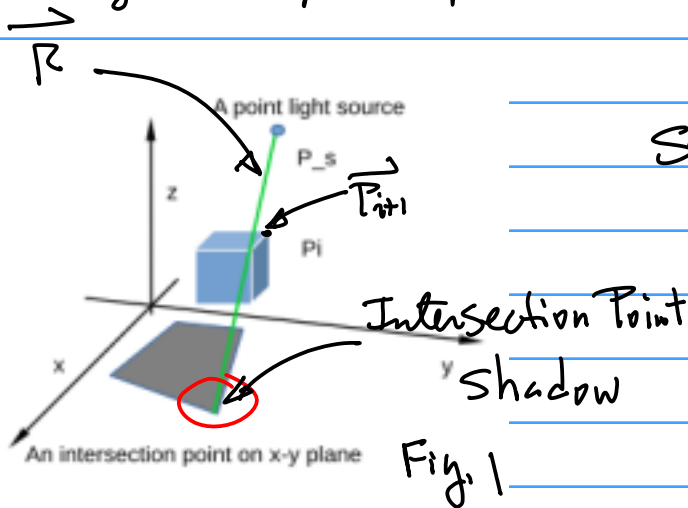


April 4 (Monday).

Topics: 1. 3D GE focused on Shadow Computation.

Example: Given

1. $x_w-y_w-z_w$ World coordinateRight Hand System. $\vec{P}_i + \lambda(\vec{P}_s - \vec{P}_i)$ Between Ray $\vec{r}(x,y)$, and x_w-y_w plane.

$$\vec{R} = \vec{P}_i + \lambda(\vec{P}_s - \vec{P}_i) \quad \dots (1)$$

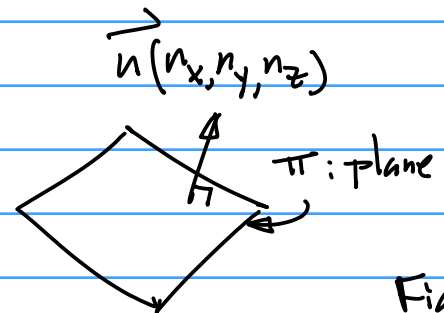
Starting from \vec{P}_s , Passing through \vec{P}_i

$$\vec{r}(x,y) = \vec{P}_s - \vec{P}_i \quad \dots (1b)$$

Intersection Point: \vec{P}_i Between Ray $\vec{r}(x,y)$, and x_w-y_w plane.Step 2. To find the intersection Point on x_w-y_w plane

Define a plane equation.

a. Define A Normal Vector

2. A Given Cube $\{\vec{P}_i(x_i, y_i, z_i) | i=1, 2, \dots, N\}$

Counter Clockwise

3. A given point light Source

$$\vec{P}_s(x_s, y_s, z_s)$$

4. Generate Ray Equation / Ray Cast
 x_w-y_w plane, Produces
Shadow if Blocked by the
Cube.use the normal vector to define the plane π .b. Form a vector (on a plane) from \vec{P}_i and \vec{P}_{i+1} , $(\vec{P}_{i+1} - \vec{P}_i)$ a line

$$\vec{n} \cdot (\vec{P}_{i+1} - \vec{P}_i) = 0 \quad \dots (2)$$

Take

 $\vec{v}(v_x, v_y, v_z)$, $\vec{a}(a_x, a_y, a_z)$
to Replace \vec{P}_i, \vec{P}_{i+1}

References:

2021F-101b-notes-cmpe240-2021-12-1.pdf

Step 1. Generate A Ray Cast / Equation

Assume $\vec{a}(a_x, a_y, a_z)$ is a known vector; And

$\vec{v}(v_x, v_y, v_z)$ is unknown, But an arbitrary Point on the plane π .

Hence, Eqn(2) becomes

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

Now, find the intersection point defined By the Ray Eqn(1). In order to that, we will need to find λ .

Since the intersection point \vec{P}_i is the common Point By the Ray and the plane π . we have

$$\begin{cases} \vec{R} = \vec{P}_i + \lambda(\vec{P}_s - \vec{P}_i) & \dots (3a) \\ \vec{n} \cdot (\vec{v} - \vec{a}) = 0 & \dots (3b) \end{cases}$$

$\vec{n}(n_x, n_y, n_z)$, Normal Vector

has to be known,

$\vec{a}(a_x, a_y, a_z)$ is known on π .

Starting from the plane Eqn(3b).

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

where $\vec{v} = \vec{R}$, e.g.

$$\vec{n} \cdot (\vec{v} - \vec{a}) \Big|_{\vec{v} = \vec{R}} = 0 \quad \dots (4)$$

$$\vec{n} \cdot (\vec{R} - \vec{a}) \Big|_{\vec{R} = \vec{P}_i + \lambda(\vec{P}_s - \vec{P}_i)} = 0$$

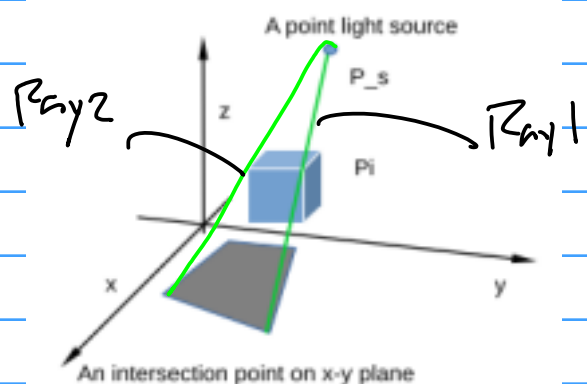
$$\vec{n} \cdot (\vec{P}_i + \lambda(\vec{P}_s - \vec{P}_i) - \vec{a}) = 0$$

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

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

$$\begin{aligned} \lambda &= \frac{\vec{n} \cdot \vec{a} - \vec{n} \cdot \vec{P}_i}{\vec{n} \cdot (\vec{P}_s - \vec{P}_i)} \\ &= \frac{\vec{n} \cdot (\vec{a} - \vec{P}_i)}{\vec{n} \cdot (\vec{P}_s - \vec{P}_i)} \quad \dots (5) \end{aligned}$$

Note λ is NOT the intersection Pt. it allows us to use Ray Eqn(1) to find the intersection.



use Eqn(5) to find more than one intersection

April 7th (Wed) CmpE240 April 4, 22

3/.

Example: Ref (see PP.1. github
Lecture Notes, 2021F-101b-v)

Given $\vec{P}_s(-20, 110, 200)$, A

vertex of a given cube

$\vec{P}_i(100, 100, 110)$. Find the intersection

pt to draw shadow.

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

Where $\vec{a} = (0, 0, 0)$, Hence,

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

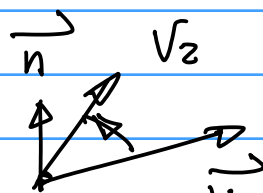
Sol First, Ray Equation, Eqn(1): Now, hand Calculation, also

$$\vec{R} = \vec{P}_i + \lambda(\vec{P}_s - \vec{P}_i) \dots (1)$$

then, plane Eqn for Xw-Yw
plane

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

Find \vec{n} ,



$$\vec{v}_1 \times \vec{v}_2 = \vec{n} \dots (2)$$

$$\text{Let } \vec{v}_1 = x_w \vec{i}, \vec{v}_2 = y_w \vec{j}$$

$$\vec{n} = x_w \vec{i} \times y_w \vec{j}$$

$$= (0, 0, 1)$$

Then, 2nd find λ for the
Ray Equation, from
Eqn.

for coding

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

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

From the given condition

$\vec{n}(0, 0, 1)$, Therefore

$$\lambda = \frac{-n_z z_i}{n_z \cdot (z_s - z_i)} = - \frac{z_i}{z_s - z_i}$$

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

Now, back to the Ray Equation

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

$$\begin{aligned}
 \vec{r} &= (100, 100, 110) - \frac{11}{9}(-20, 10, 90) \\
 &= (100, 100, 110) - \frac{11}{9}(-120, 10, 90) \\
 &= \left(\frac{1100 \times 120}{9}, -\left(100 - \frac{110}{9}\right), 110 - 110 \right) \\
 &= \left(\frac{1100 \times 120}{9}, \frac{110}{9} - 100, 0 \right) = (246.7, 87.8, 0)
 \end{aligned}$$

please finish this calculation.

Now, Coding part. Same Code on github.

Note:

2018F-116-11diffuse20181114.cpp

169 world.X[47] = 0; world.Y[47] = 0; world.Z[47] = 1; // normal vector for x-y plane

39 typedef struct {
40 float x[UpperBD], y[UpperBD], z[UpperBD];
41 } pworld;
42

72 pworld world;
73 pviewer viewer;

a. Define Normal vector \vec{n} for $x_w y_w$ plane

b. Note the "typedef struct" for Defining 3D points.

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

Now, λ Calculation. Egn(5)

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

$$n_x(x_s - x_i) + n_y(y_s - y_i) + n_z(z_s - z_i)$$

```

171 //-----lambda for Intersection pt on xw-vw 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])));

```

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Note, Substitute λ to Ray Equation to find the intersection point

```

182 //-----ray equation to find intersection pts-----*
183 world.X[48] = world.X[45] + lambda*(world.X[45] - world.X[7]); // Intersection pt p7
184 world.Y[48] = world.Y[45] + lambda*(world.Y[45] - world.Y[7]); // Intersection pt p7
185 world.Z[48] = 0.0;
186
187 world.X[49] = world.X[45] + lambda_2*(world.X[45] - world.X[6]); //intersection pt p6
188 world.Y[49] = world.Y[45] + lambda_2*(world.Y[45] - world.Y[6]); //intersection pt p6
189 world.Z[49] = 0.0;

```

$$\vec{R} = \vec{P}_i + \lambda(\vec{P}_s - \vec{P}_i) \rightarrow \begin{aligned} x &= x_i + \lambda(x_s - x_i) \\ y &= y_i + \lambda(y_s - y_i) \\ z &= z_i + \lambda(z_s - z_i) \end{aligned}$$

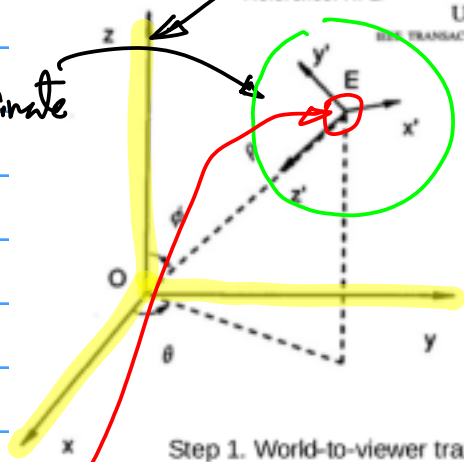
Assignment in-Class Show & Tell. Implement Intersection Computation on L&C 17ba, "Show & Tell" Demo in Class. On April 11 (Monday),

To Be Able to Display 3D Graphics on 2D Display Devices. Let's Define

Transformation Pipeline. 1. Define World Coordinate System; Right Hand System $x_w - y_w - z_w$

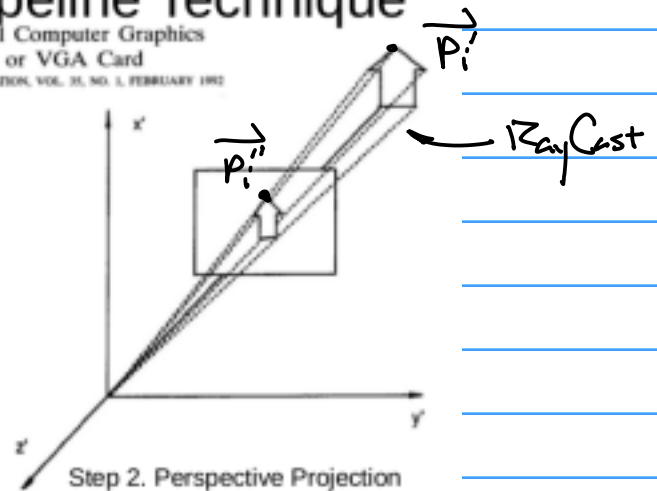
3D Transformation Pipeline Technique

Reference: H. Li Three-Dimensional Computer Graphics Using EGA or VGA Card
IBM TRANSACTIONS ON EDUCATION, VOL. 35, NO. 1, FEBRUARY 1992



Step 1. World-to-viewer transform

$$T = \begin{bmatrix} -\sin \theta & \cos \theta & 0 & 0 \\ -\cos \phi \cos \theta & -\cos \phi \sin \theta & \sin \phi & 0 \\ -\sin \phi \cos \theta & -\sin \phi \sin \theta & -\cos \phi & \rho \\ 0 & 0 & 0 & 1 \end{bmatrix}$$



Step 2. Perspective Projection

$$\begin{aligned} x_p &= x_e \left(\frac{D}{z_e} \right) \\ y_p &= y_e \left(\frac{D}{z_e} \right) \end{aligned}$$

Hany Li, Ph.D.

2. Viewer Coordinate System $x_v - y_v - z_v$

Left-Hand System

3. Virtual Camera is located \vec{E} (e_x, e_y, e_z)

Example: Display Shadows on 2D Display Device.

Step 1. World To Viewer Transform.

$$T = \begin{bmatrix} -\sin \theta & \cos \theta & 0 & 0 \\ -\cos \phi \cos \theta & -\cos \phi \sin \theta & \sin \phi & 0 \\ -\sin \phi \cos \theta & -\sin \phi \sin \theta & -\cos \phi & \rho \\ 0 & 0 & 0 & 1 \end{bmatrix} \dots (1)$$

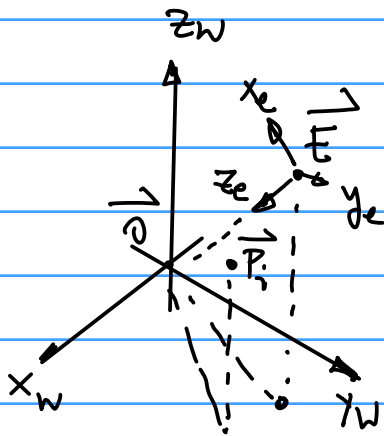


Fig. 1.

Everything is defined in the World Coordinate System $X_w-Y_w-Z_w$ including a Virtual Camera. $\vec{E}(x_e, y_e, z_e)$, $x_e-y_e-z_e$ "Viewer" Coordinate System.

Given $\vec{P}_i(x_i, y_i, z_i)$ in $X_w-Y_w-Z_w$ World Coordinate, Represent this point in $x_e-y_e-z_e$ Coordinate System.

\vec{P}_i

$$\begin{bmatrix} x_i \\ y_i \\ z_i \\ 1 \end{bmatrix} = \begin{bmatrix} -\sin \theta & \cos \theta & 0 & 0 \\ -\cos \phi \cos \theta & -\cos \phi \sin \theta & \sin \phi & 0 \\ -\sin \phi \cos \theta & -\sin \phi \sin \theta & -\cos \phi & \rho \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_i \\ y_i \\ z_i \\ 1 \end{bmatrix} \dots (1-b)$$

Assume $\vec{E}(x_e, y_e, z_e) = (200, 200, 200)$
Physical meaning of Transformation Matrix T.

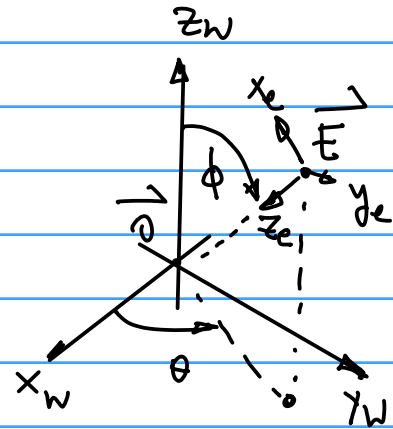


Fig. 2

θ : Angle from the dash line on X_w-Y_w plane w.r.t positive X_w -axis
 ϕ : Angle Between Z_w & Z_e .

ρ (rho): $\rho = \sqrt{x_e^2 + y_e^2 + z_e^2} \dots (2)$
distance from \vec{E} to the origin \vec{O} of $X_w-Y_w-Z_w$.

Suppose $\vec{E}(200, 200, 200)$ is given, Find $\cos \theta, \sin \theta, \cos \phi, \sin \phi$ for T-matrix.

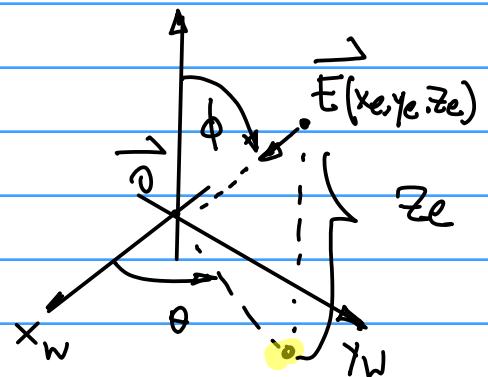


Fig. 3

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Draw A Line Passing through \vec{E}
Perpendicular to $x_w-y_w \rightarrow$ Form
an intersection point.

Draw A Line Passing through the
intersection point on x_w-y_w plane
on the plane and Perpendicular to
 x_w -axis.

Find $\cos \phi$. z_w

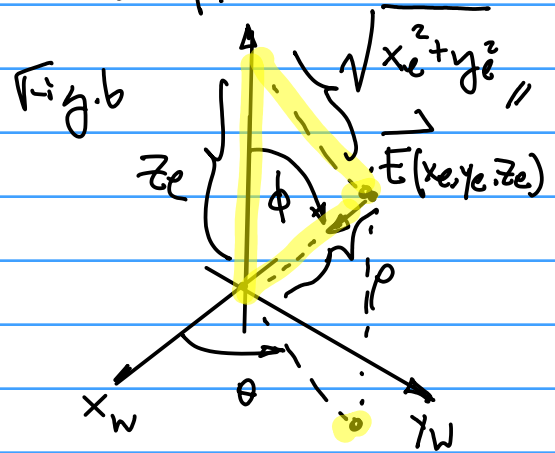
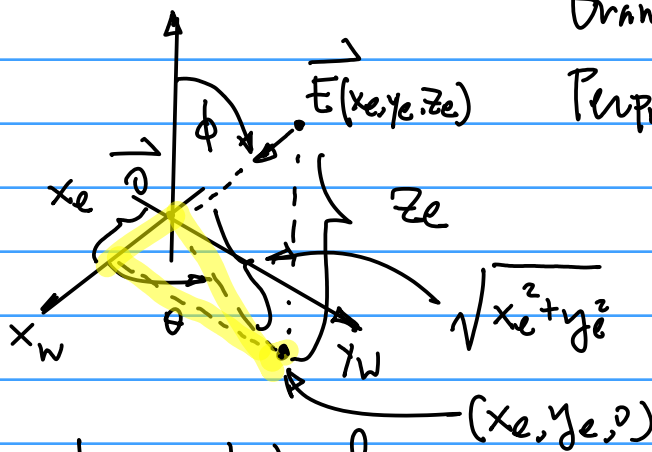


Fig. 4



Draw A Line Passing $\vec{E}(x_e, y_e, z_e)$
Perpendicular to z_w -axis

$$\cos \phi = \frac{z_e}{p} = \frac{z_e}{\sqrt{x_e^2 + y_e^2 + z_e^2}}$$

$$= \frac{200}{200\sqrt{3}} = \frac{1}{\sqrt{3}}$$

We can form a triangle on
 x_w-y_w plane, as in Fig. 4, hence

$$\cos \theta = \frac{x_e}{\sqrt{x_e^2 + y_e^2}} = \frac{200}{200\sqrt{2}} = \frac{1}{\sqrt{2}}$$

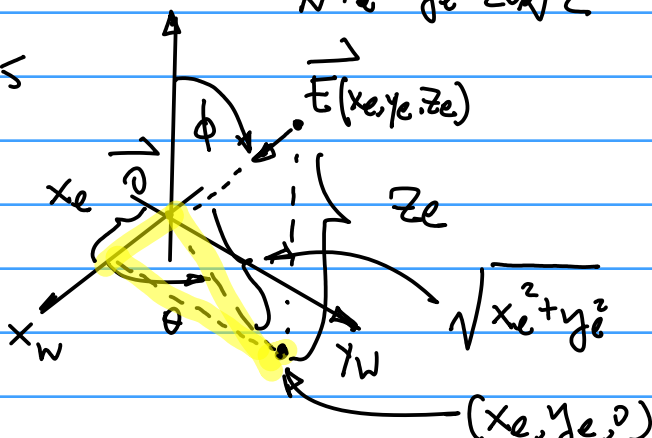
Similarly, $\sin \theta = \frac{y_e}{\sqrt{x_e^2 + y_e^2}} = \frac{200}{200\sqrt{2}} = \frac{1}{\sqrt{2}}$

$$\sin \phi = \frac{\sqrt{x_e^2 + y_e^2}}{\sqrt{x_e^2 + y_e^2 + z_e^2}} = \frac{200\sqrt{2}}{200\sqrt{3}}$$

$$= \frac{\sqrt{2} \cdot \sqrt{3}}{3} = \frac{\sqrt{6}}{3}$$

Homework: Due April 18th
(Monday)

Fig. 5



1. Draw A world Coordinate System $x_w-y_w-z_w$ axis, with x_w Red, y_w Green, z_w Blue

2. Draw A cube, size Length = 100,
floats 10 unit Above x_w-y_w plane.
in other word $\vec{P}_i(100,100,110)$;

On to ^a 2D Display Device, like
LCD.

ATul 13 (Wed)

Topics: 1° Perspective Projection
2° Diffuse Reflection

3. Draw a point light Source
 $\vec{P}_s(-20,110,200)$, And RayCast
to connect \vec{P}_s to \vec{P}_i ; use green
color.

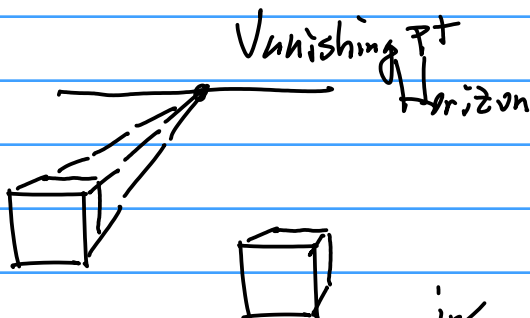
4. Compute the Shadow point \vec{P}_i' ,
Draw the intersection Point to link
 $\vec{P}_s - \vec{P}_i - \vec{P}_i'$

Note: You may want to Adjust the
 \vec{P}_s position, So this \vec{P}_i' (Intersection
Point) can be visible on your Display.

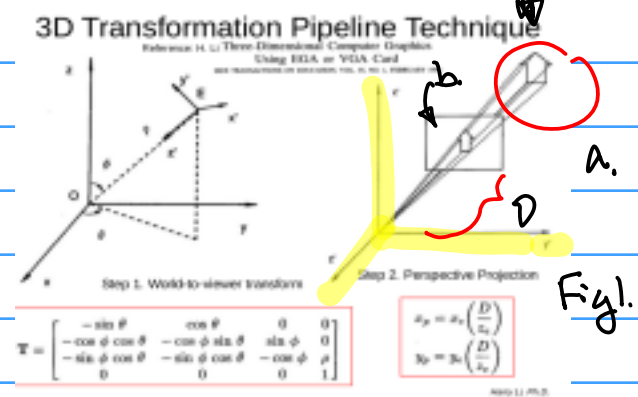
Step 2. Perspective Projection

$$\begin{aligned} x_p &= x_c \left(\frac{D}{z_c} \right) \\ y_p &= y_c \left(\frac{D}{z_c} \right) \end{aligned}$$

... (3)



Eqn (3) project a point $\vec{P}_i(x_i, y_i, z_i)$ in $x_c-y_c-z_c$

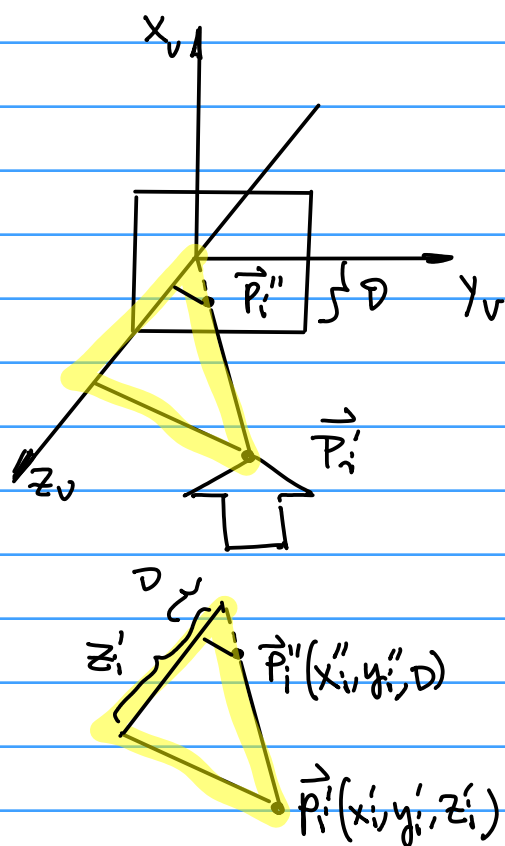


Note: $x_v-y_v-z_v$ is Left Hand
System.

a. It is a 3D object
b. projection Plane, distance
to the viewer coordinate
System $(0,0,0) \rightarrow (x_c, y_c, z_c)$
D is the distance in $x_w-y_w-z_w$

c. Origin of $x_v-y_v-z_v \rightarrow$
Camera Location, Camera
is modeled as "pin-Hole"
model.

Projection is formulated By
using Similar Triangles in Fig. 1



2. Design By Defining Dimension of a Cube.

(Example: length = 100)

$$\vec{P}_i(x_i, y_i, z_i) = (100, 100, 110)$$

Elevate the cube By 10 units.

3. Draw the Cube on the LCD

4. Submission:

a. Screen Capture of your 0.5 pt XPRESSO Screen, which Shows your Name (Folder Name) And your Program (Partial)

b. Take a photo of your display. 0.5 pt. With Entire Prototype System of your own

5. Submission to CANVAS.

Note: You will need transform from a virtual coordinate system to physical coordinate

$$x_p = \frac{D}{z_e} x_e \text{ from Eqn (5)}$$

Or,

$$x_i'' = \frac{D}{z_i'} x_i'$$

Similarly,

$$y_p = \frac{D}{z_e} y_e \text{ or}$$

$$y_i'' = \frac{D}{z_i'} y_i'$$

Homework, Due A week from Today
April 20th

1. Draw a World Coordinate System, x_w : Red, y_w : Green, z_w : Blue, Design the size ($x_w, y_w, z_w, 50$ units)

Consider Diffuse Reflection.

2. Color Space. R, G, B

2018S-23-lec7-DiffuseReflection-v6-2018-4-25.pdf

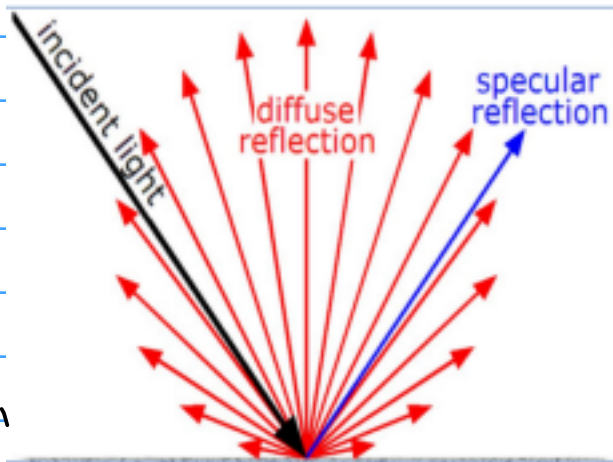


Fig. 1

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

Definition: A Reflection from an object
Surface uniformly in all directions.

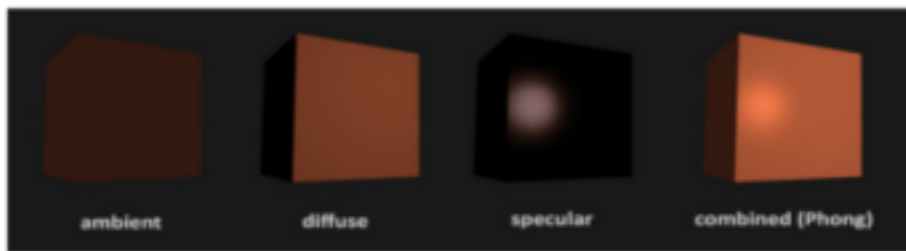


Fig 2.

1. Define Reflectivity, A property of An object surface.

$$\vec{K}_r = (K_r, K_g, K_b) = (r, g, b) \dots (1)$$

$$0 \leq r, g, b \leq 1$$

Note: for a Black object,

$$r=0, g=0, b=0$$

for a green leaf.

$$r \approx 0; g \neq 0, 0 < g; b \approx 0$$

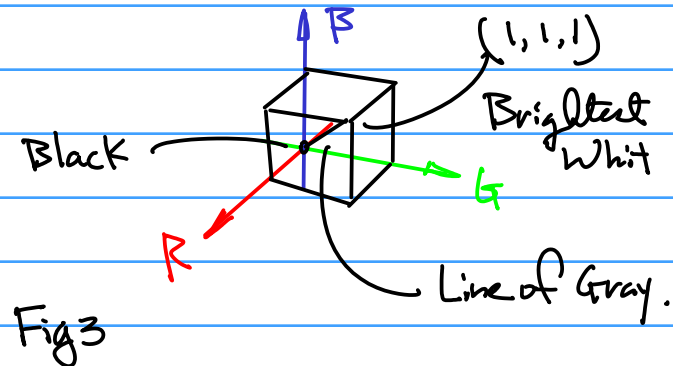
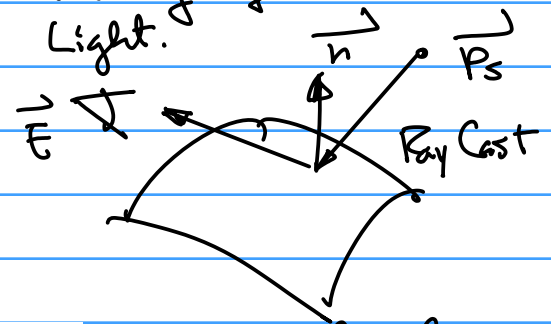


Fig 3

3. Viewing Angle v.s. Incident Light.



a. Perceived color is independent of viewing Angle.

b. Normal vector \vec{n} and incident Light \vec{L} (\vec{L} Ray Cast) form an Angle ϕ , the color Intensity follows

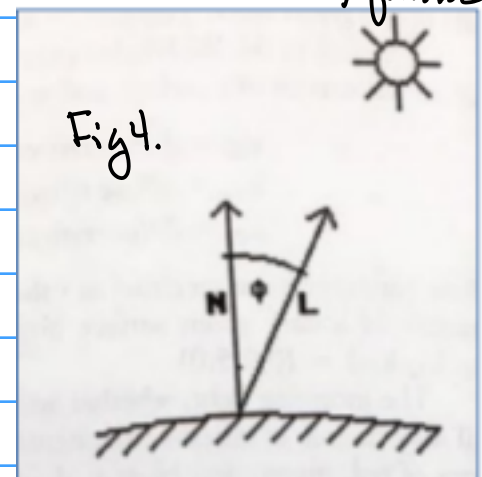


Fig 4.

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$\cos \phi$ function.

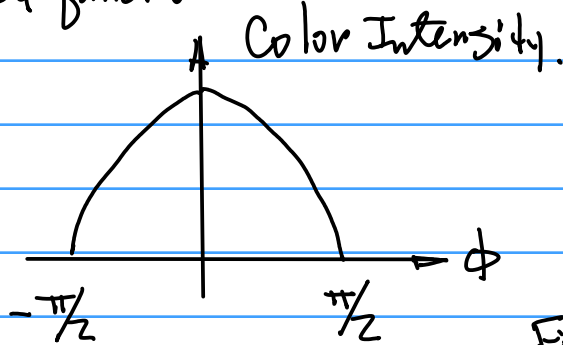


Fig. 5.

$\phi = 0$, $\cos \phi = 1$, Strongest Reflection.
Highest Intensity.

$\phi = \pi/2$, $\cos \phi = 0$, No Reflection,
None, no color.

4. Distance.

April 18 (Monday)

Topics: Continuous Diffuse Reflection.

Light Intensity. Satisfies the
relationship Below.

$$\text{Intensity} \sim \frac{1}{\|r\|^2} \dots (1)$$

\vec{r} Ray Equation.

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

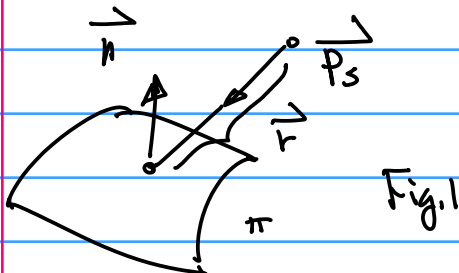


Fig. 1

Example: Given $\vec{P}_s(x_s, y_s, z_s)$ And A
Cube.

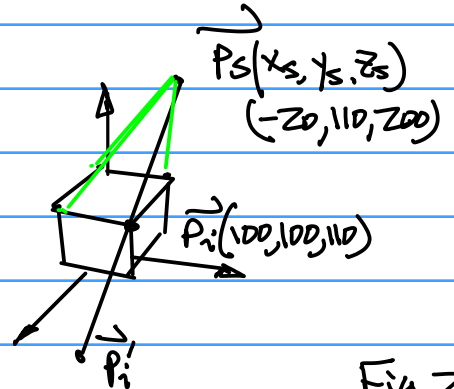


Fig. 2

\vec{P}_i shadow point.

Find Diffuse Reflection at $\vec{P}_i(x_i, y_i, z_i)$

Sol: Formulation.

$$\vec{I}_{\text{diff}}(x, y, z) = (I_{\text{diff}, r}(x, y, z), I_{\text{diff}, g}(x, y, z), I_{\text{diff}, b}(x, y, z))$$

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

$$0 \leq K_r, K_g, K_b \leq 1$$

Note: For Simplicity, we will focus on
one type of Reflectivity for Now, "r" red

$$I_r = K_{dr} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} \frac{1}{\|\vec{r}\|^2} \dots (3)$$

Reflectivity
for "r"

$\cos \phi$

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

$$\|\vec{r}\|_2 = \sqrt{(x_s - x_i)^2 + (y_s - y_i)^2 + (z_s - z_i)^2} \quad \dots (4)$$

$$\|\vec{r}\|_2^2 = (x_s - x_i)^2 + (y_s - y_i)^2 + (z_s - z_i)^2$$

Suppos $\vec{P}_s(-20, 10, 200)$, $\vec{P}_i(100, 100, 110)$

Assum: $K_{dr} = 0.8$

Find Norm Vector for the Cube Surface.

\vec{n} Defined By Vector Cross Product
 $\vec{n} = \vec{A} \times \vec{B}$

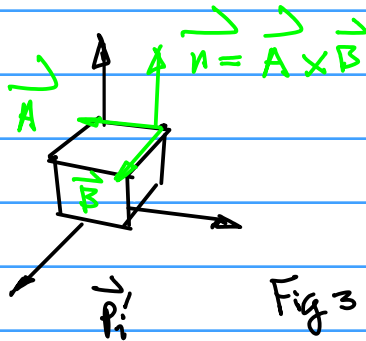


Fig 3

But the Surface of the Cube is in Parallel with $x-y-z$ plane.

$$\therefore \vec{n}(0, 0, 1)$$

Now, find

$$\begin{aligned} \cos \phi &= \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} \quad \text{Directional vector of } \vec{r} \\ &= \frac{(n_x, n_y, n_z) \cdot (x_i - x_s, y_i - y_s, z_i - z_s)}{\sqrt{n_x^2 + n_y^2 + n_z^2} \sqrt{(x_i - x_s)^2 + (y_i - y_s)^2 + (z_i - z_s)^2}} \end{aligned}$$

Substitute the given Condition, So

$$\cos \phi = \frac{z_i - z_s}{\sqrt{(100 + 20)^2 + 10^2 + 90^2}} = \frac{110 - 200}{\sqrt{\Delta}}$$

$$\begin{aligned} \text{Therefore } \cos \phi &= \left| \frac{110 - 200}{\sqrt{\Delta}} \right| \\ &= \left| \frac{-90}{\sqrt{\Delta}} \right| = \frac{90}{\sqrt{\Delta}} \quad \frac{1}{\sqrt{\Delta}} \ll 1. \end{aligned}$$

And the distance from \vec{P}_s to \vec{P}_i

$$\begin{aligned} \|\vec{r}\|_2^2 &= (x_s - x_i)^2 + (y_s - y_i)^2 + (z_s - z_i)^2 \\ &= 120^2 + 10^2 + 90^2 \end{aligned}$$

Therefore, we have

$$I_{diff} = 0.8 \times \frac{90}{\sqrt{\Delta}} \times \frac{1}{120^2 + 10^2 + 90^2}$$

Note: Very Small! Need Post Processing for Better Visualization.

$$= 0.8 \times \frac{90}{\sqrt{120^2 + 10^2 + 90^2}} \times \frac{1}{120^2 + 10^2 + 90^2} =$$

Since the result is 2.12×10^{-5} Very Small, we need to Perform Post Processing.

Note: Directional vector $\vec{P}_i - \vec{P}_s$ gives Negative Value, $\vec{P}_s - \vec{P}_i$ Positive

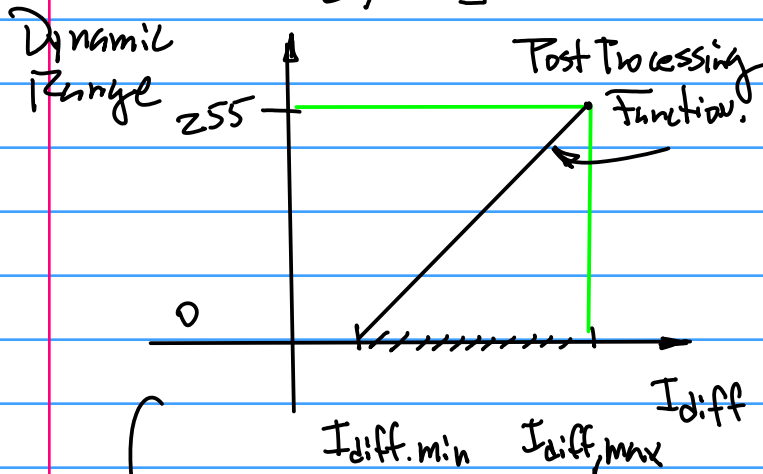
\Rightarrow take Absolute Value.

Objective: To Scale up the result in Eqn (3), to match the entire dynamic range of the display device.

1. Dynamic Range of the Display Device \rightarrow 8 bits for Each Primitive color.

$2^8 = 256$. Dynamic Range

$[0, 255]$



By Eqn (3)

Add An offset to this function

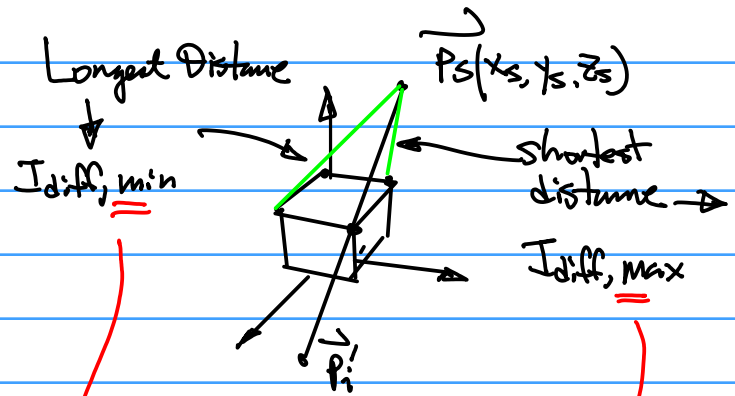
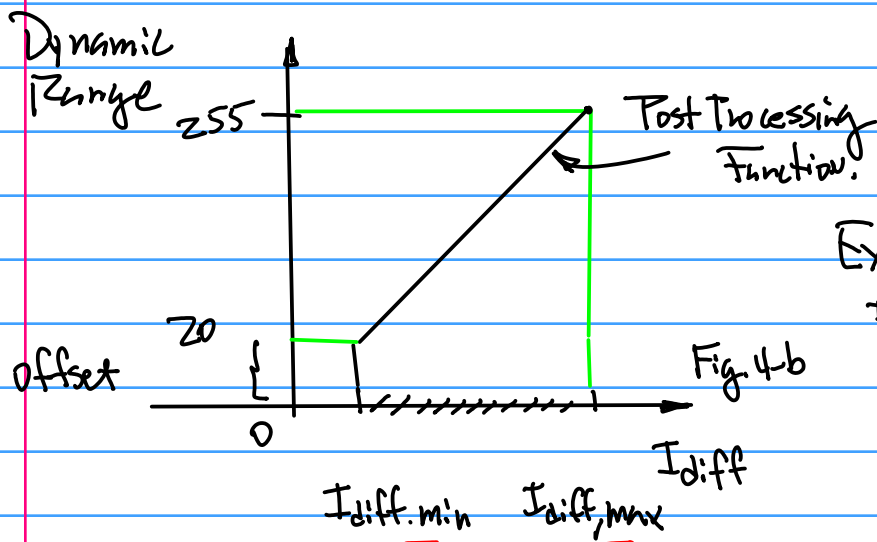


Fig. 5

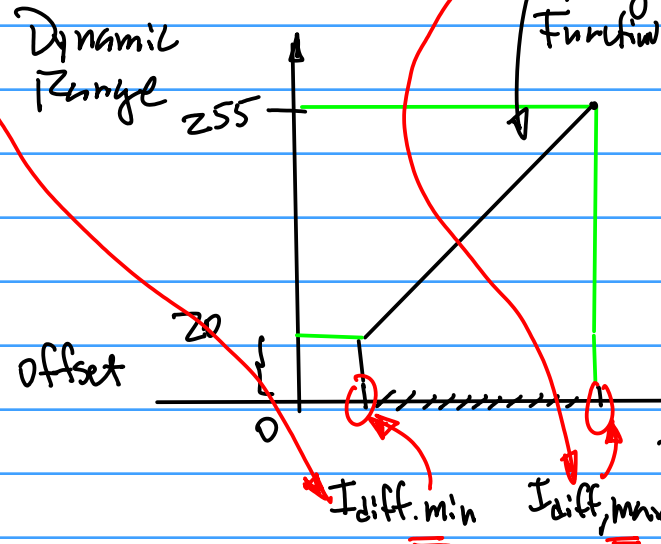
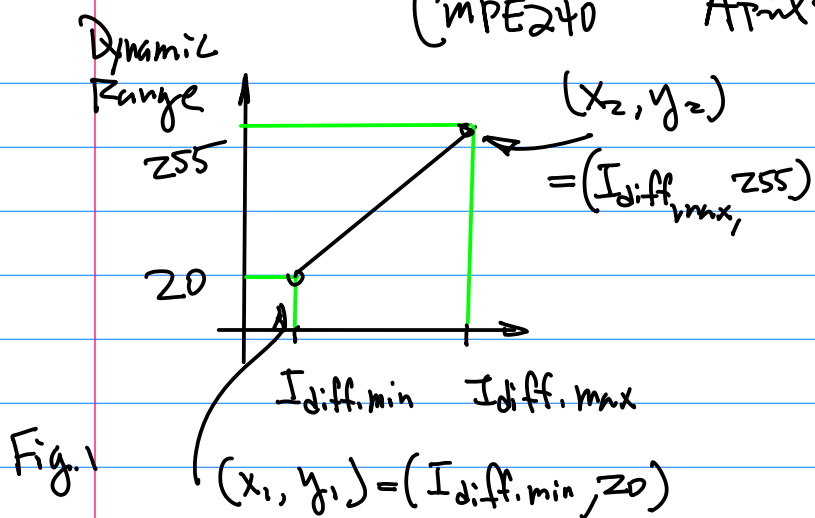


Fig (4-a) Post processing function

$$\frac{x - x_2}{y - y_2} = \frac{x_1 - x_2}{y_1 - y_2} \quad \dots (5)$$

April 20 (Wed)

Example: Post Processing Technique From Fig 5, And Eqn (5).



From Eqn (5),

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

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

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

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

... (1)

a $y = bx + c$, $y = \frac{b}{a} x + \frac{c}{a}$

$$\frac{b}{a} = \frac{y_2 - y_1}{x_2 - x_1} \quad \dots (2)$$

$$\frac{c}{a} = -\frac{y_2 - y_1}{x_2 - x_1} x_2 + y_2 \quad \dots (2-c)$$

Substitute $(I_{diff, min}, 20)$, $(I_{diff, max}, 255)$

$$I_{dyn} = \frac{255 - 20}{I_{diff, max} - I_{diff, min}} x - \frac{255 - 20}{I_{diff, max} - I_{diff, min}} I_{diff, max} + 255$$

Project on Diffuse Reflection
Due May 8th (Sunday)

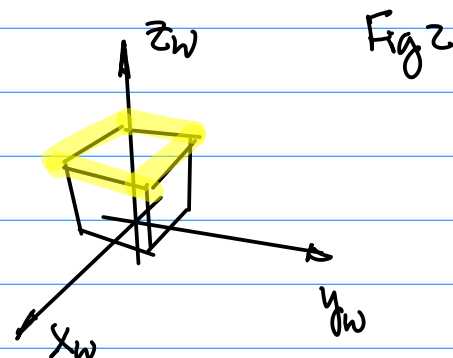
Compute Diffuse Reflection.

You can work the Diffuse Reflection on 4 corners of the Cube.

Make sure post processing is Implemented good.

General Guide for Diffuse Reflection

Point(s) \rightarrow Line(s) \rightarrow Surface/plane
Vertex \rightarrow Boundaries \rightarrow planes



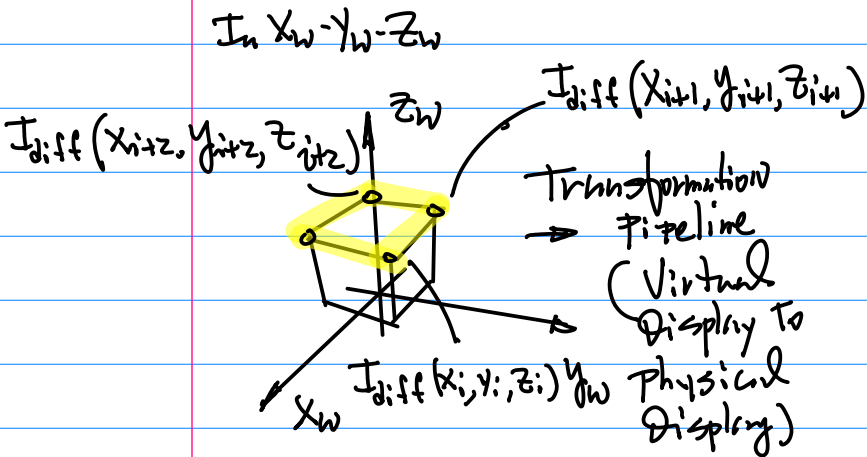
Two Phased Approach

Phase I: Compute Diffuse Reflection
After Transformation Pipeline
Phase II: Map the Diffuse Reflection
Result in Phase I to Actual
Hardware Display Device

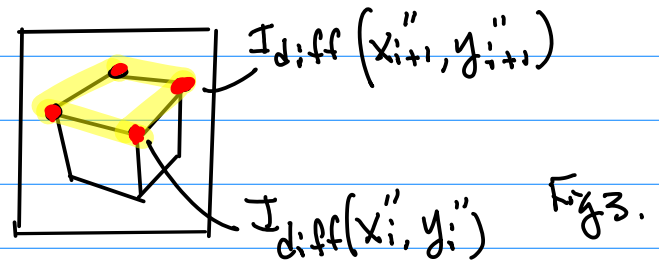
CME 240 April 20, Wed, 22

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Example: Thuse I Computation



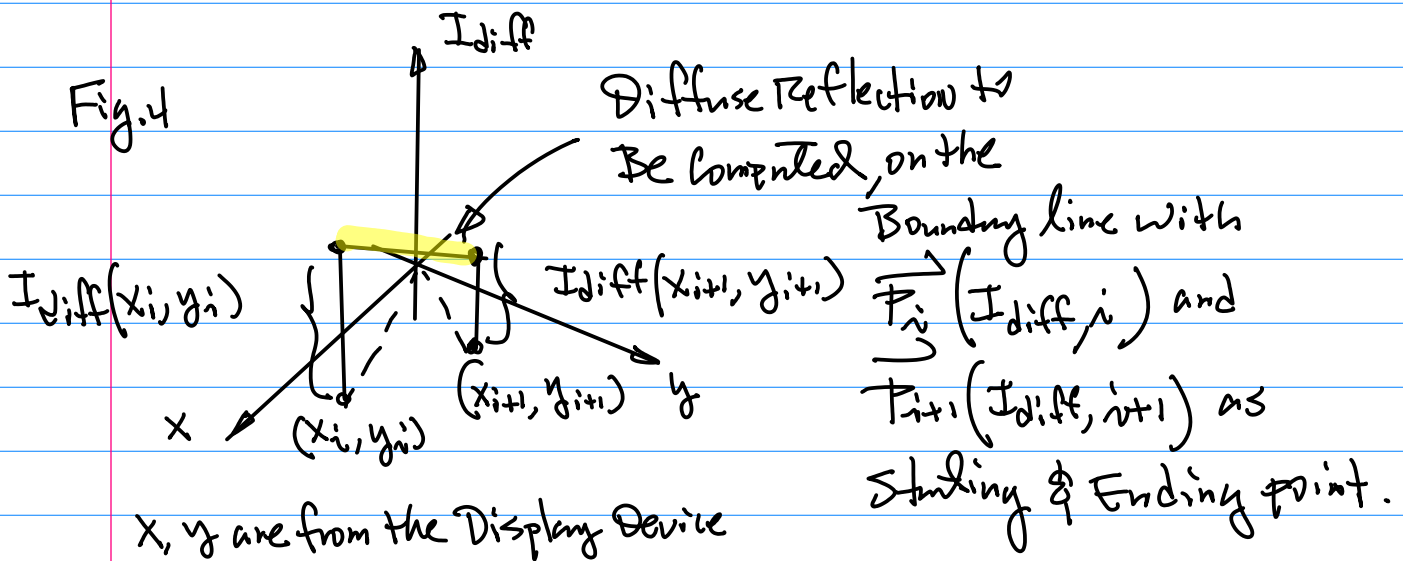
Display Device



Diffuse Reflections
on 4 Corners Are Computed
Already.

For Simplicity Purpose, with the
Understanding of working on the
Physical display, we use (x_i, y_i)
not (x''_i, y''_i) .

/ 2018F / 2020S-APL29-BilinearDiff1.jpg



/ 2018F / 2020S-APL27-Bilinear1.jpg

Project the 'yellow line' to $x-z$ plane in Fig 4. → Similarly, project the 'yellow line'
So it is just a function of x ,
then Compute Diffuse Reflection.
to $y-z$ plane, a function of y .
then Compute Diffuse Reflection
↓
Combine both By Average operation.