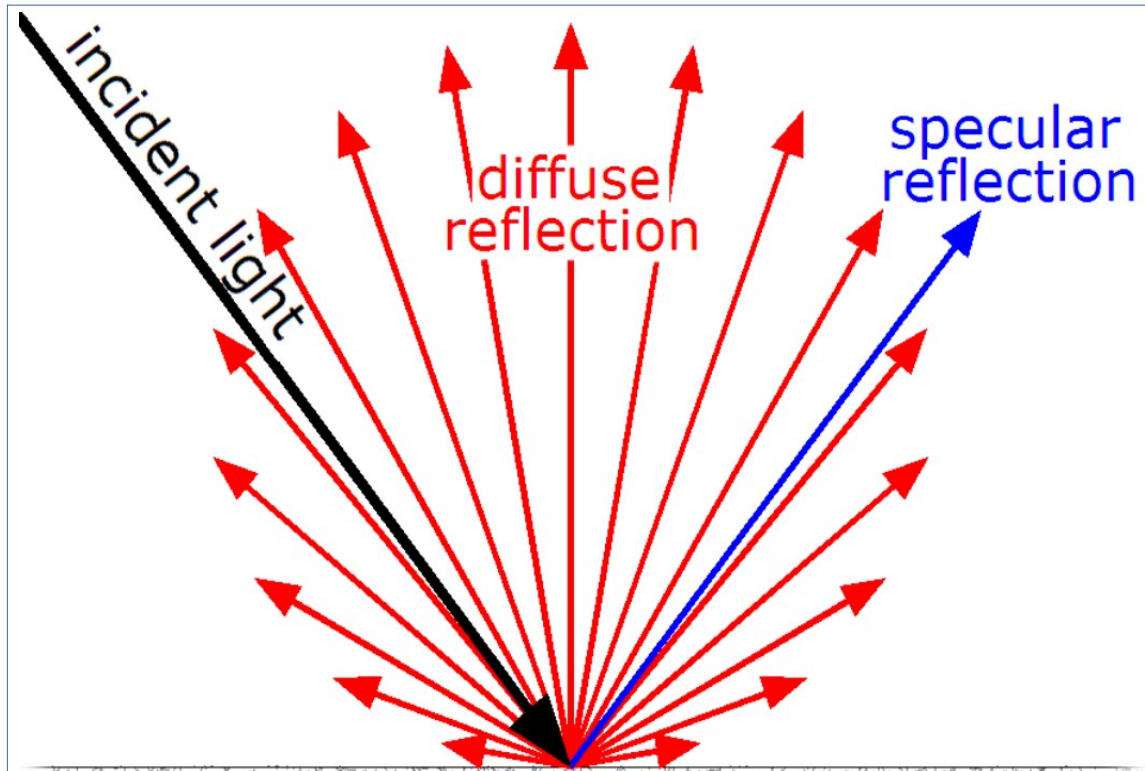


Diffuse Reflection



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 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:

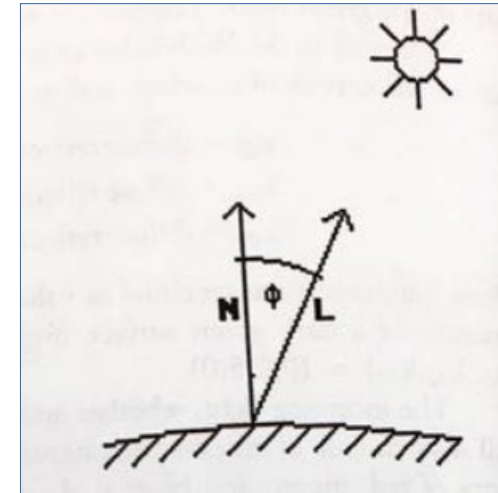
$$I_r = K_{dr} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} \frac{1}{\|\vec{r}\|_2} \quad \dots (1.1)$$

where

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

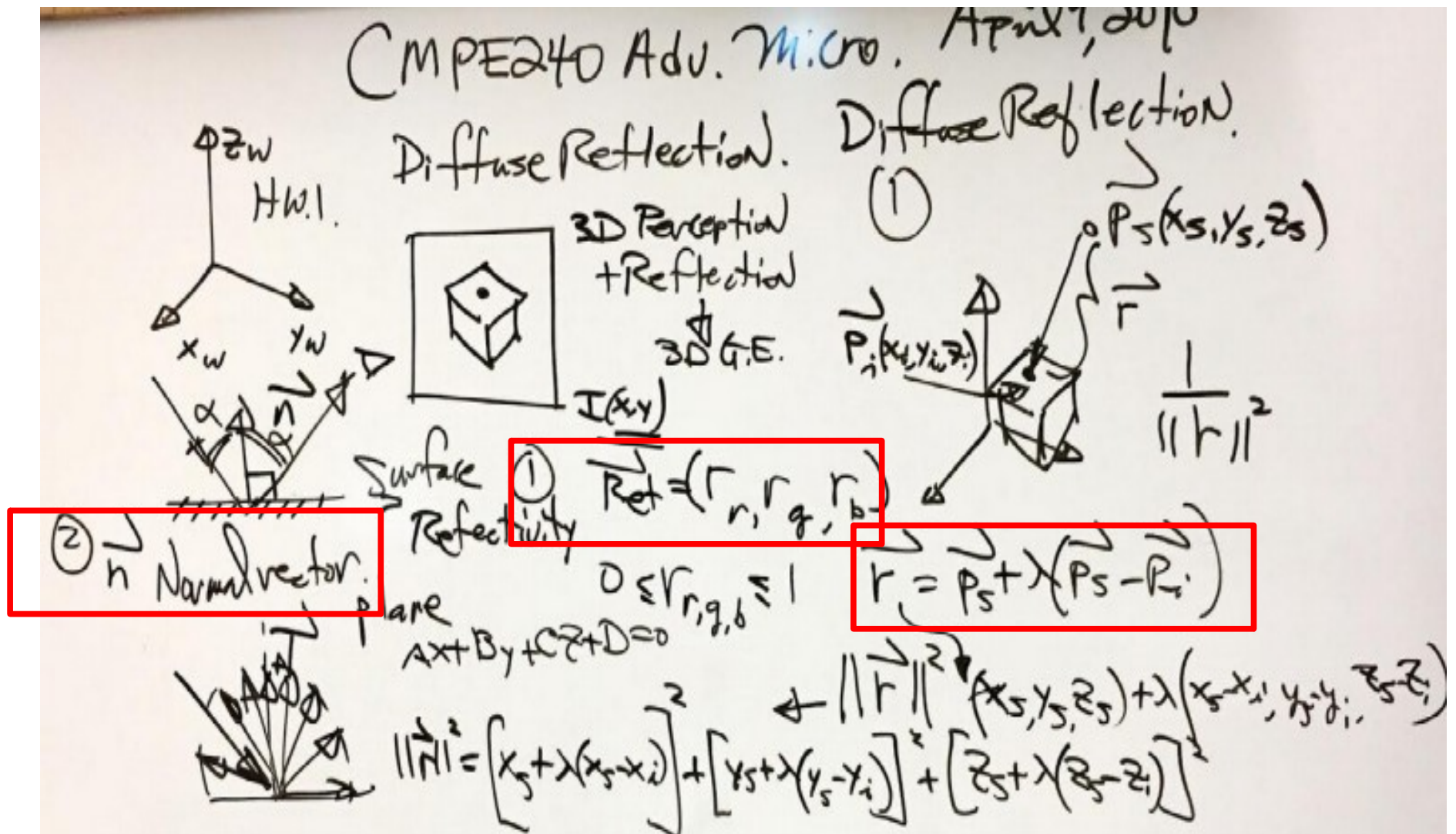
$$I_g = K_{dg} \frac{\vec{n} \cdot \vec{r}}{\|\vec{n}\| \|\vec{r}\|} \cdot \frac{1}{\|\vec{r}\|_2} \quad \dots (1.2)$$

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



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

Formulation Of Diffuse Reflection Equation



Point Light Source And Incident Angle

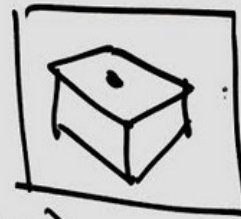
Point light source

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

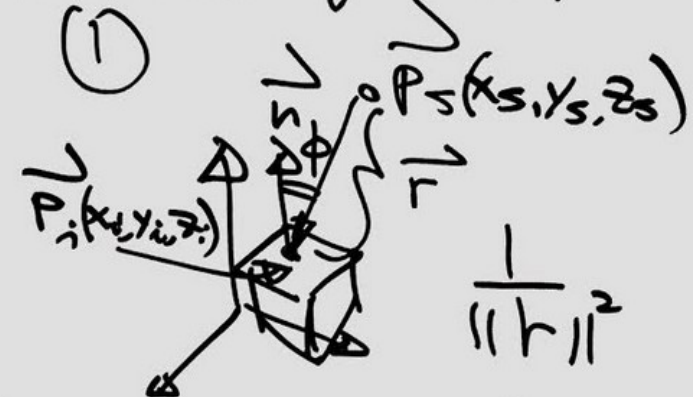


$0 \leq r, g, b \leq 1$
16 bits / 24 bits.
"The Sun"



Diffuse Reflection.

①



③

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

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

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

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

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

Angle of incident light

Step 1-5 For Diffuse Reflection Computation

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Consider "Paint" Diff. Reflection

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)

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

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

"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 $x \neq y$)

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

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

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

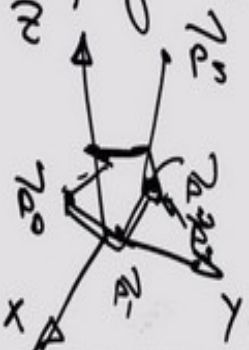
Step 5. Transformation Pipeline

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 this Week; ^{Exported.}
- 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/Coll 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 (x_i, y_i, z_i)

Viewer Coordinate System

Output (2D LCD)

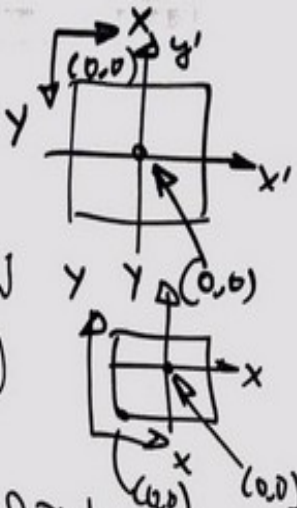
Focal Distance $D = 100$

Equations:

$$x''_i = \frac{D}{z_i} \cdot x_i$$

$$y''_i = \frac{D}{z_i} \cdot y_i$$

... (1)



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
 $\{\vec{P}_i(x_i, y_i) | i=0, 1, \dots, 6\}$

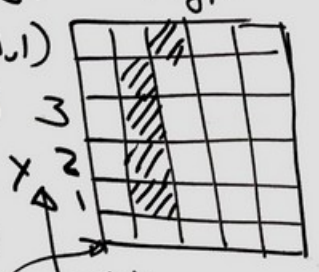
Example: Given $(x_0, y_0) = (1, 1), (x_1, y_1) = (3, 5)$
D.D.A. to Draw a Line
 $Slope = a = \frac{y_1 - y_0}{x_1 - x_0} = \frac{5-1}{3-1} = 2$
 (Note: if $|a| < 1$, then No GAP,
 $y_{k+1} = a x_{k+1} + b, x_{k+1} = x_k$)
 Switch x and y.
 $\frac{x - x_1}{x_2 - x_1} = \frac{y - y_1}{y_2 - y_1}$
 $y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

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

0 1 2 3 4 5 6

Use DDA Algorithm To Find Boundary Points

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 $\begin{cases} x_{k+1} = x_k + 1 \\ y_{k+1} = ax_{k+1} + b \end{cases}$
 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

Harry LI CMPE240 Adv. Micro April 18, 2018. y.
 Diffuse Reflection Computation.
 D.D.A (github/rualili)
 Example: Fig. 1
 Starting pt. (1,1)
 Ending (2,5)
 Slope: $\frac{y_2 - y_1}{x_2 - x_1} = \frac{5-1}{2-1} = 4$ (0,0)

 $y = ax + b \rightarrow x = \frac{1}{a}y + \left(-\frac{b}{a}\right)$
 For $y_3 = y_2 + 1 = 2 + 1 = 3$
 $x_3 = \frac{1}{a}y_3 + \left(-\frac{b}{a}\right) = \frac{1}{4} \cdot 3 + \frac{1}{4} = \frac{4}{4} = 1$ $a=4, b=-1$
 For $y_4 = y_3 + 1 = 3 + 1 = 4$
 $x_4 = \frac{1}{a}y_4 + \left(-\frac{b}{a}\right) = \frac{1}{4} \cdot 4 + \frac{1}{4} = \frac{5}{4}$ $a=4, b=-1$
 Next. Diffuse Reflection ON Boundaries.
 Index: $y_{k+1} = y_k + 1$
 $= \frac{1}{4} \cdot 2 + \left(-\frac{1}{4}\right) = \frac{3}{4}$ $y_k = 1$
 $x_{k+1} = \frac{1}{a}y_{k+1} + \left(-\frac{b}{a}\right)$

[illegible]

1. Derive linear interpolation technique, equation (1) and (2), to find the boundary color along x-dimension and y-dimension respectively;
2. Then calculate average of the color from x-dimension and y-dimension as in Equation (3).

$$I_{diff}(y) = \frac{I_{diff}(y_i) - I_{diff}(y_j)}{y_i - y_j} y - \frac{y_j (I_{diff}(y_i) - I_{diff}(y_j))}{y_i - y_j} + I_{diff}(y_j) \quad (2)$$

$$I_{\text{diff}}(x, y) = \frac{1}{2} (I_{\text{diff}}(x) + I_{\text{diff}}(y)) \quad \dots (3)$$

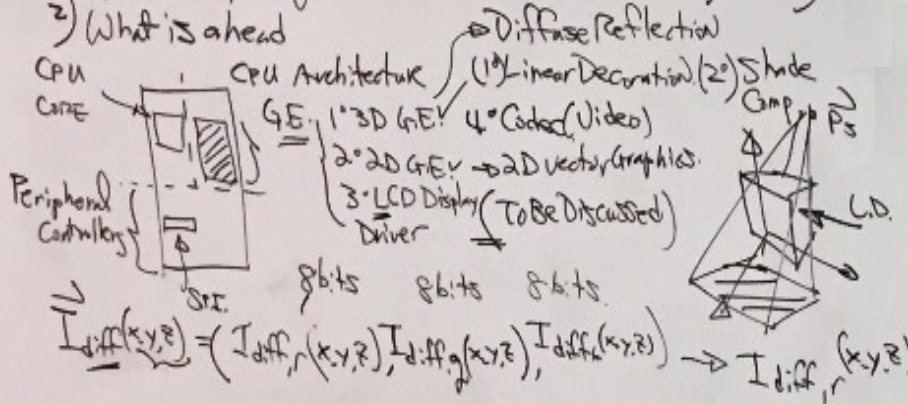
where $(x, y) \in \Omega_{\text{DDA}}(\text{DDA} + \delta)$

GE (Graphics Engine) Aspects

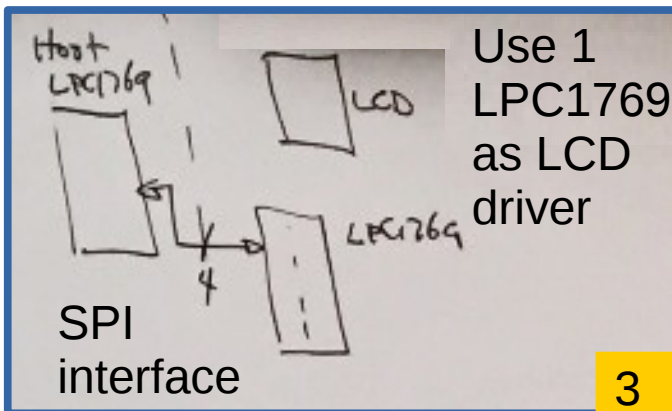
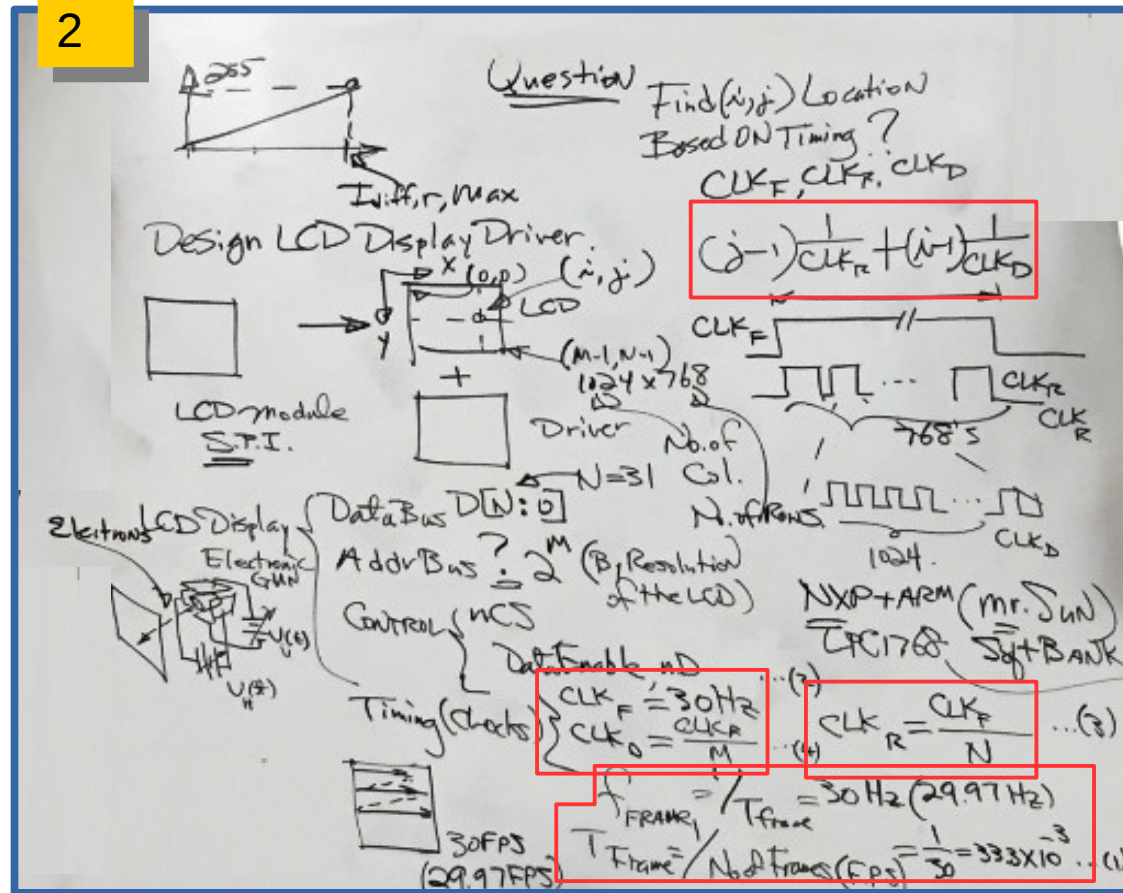
1

CMPE240 Adv. Micro, April 23rd, 18 14L

- 1) Lab ON 3D G.E. w/ Dual LPC1769 Due May 7th.
(Rubrics & Requirements to Be Posted ON Line, github)
- 2) What is ahead



2



3