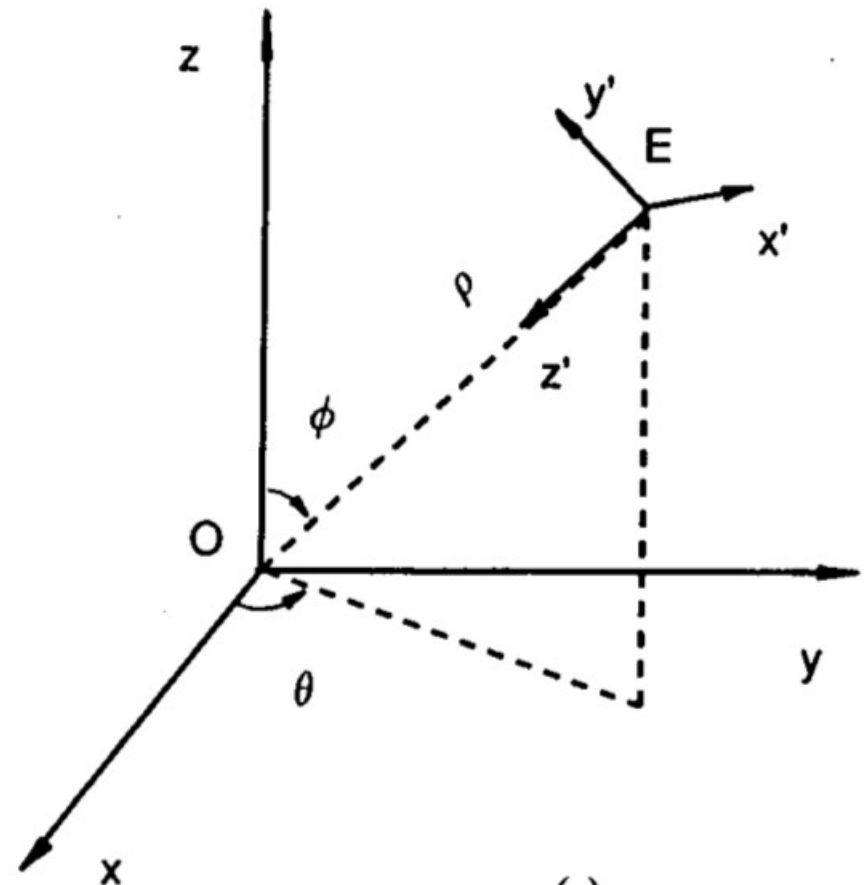
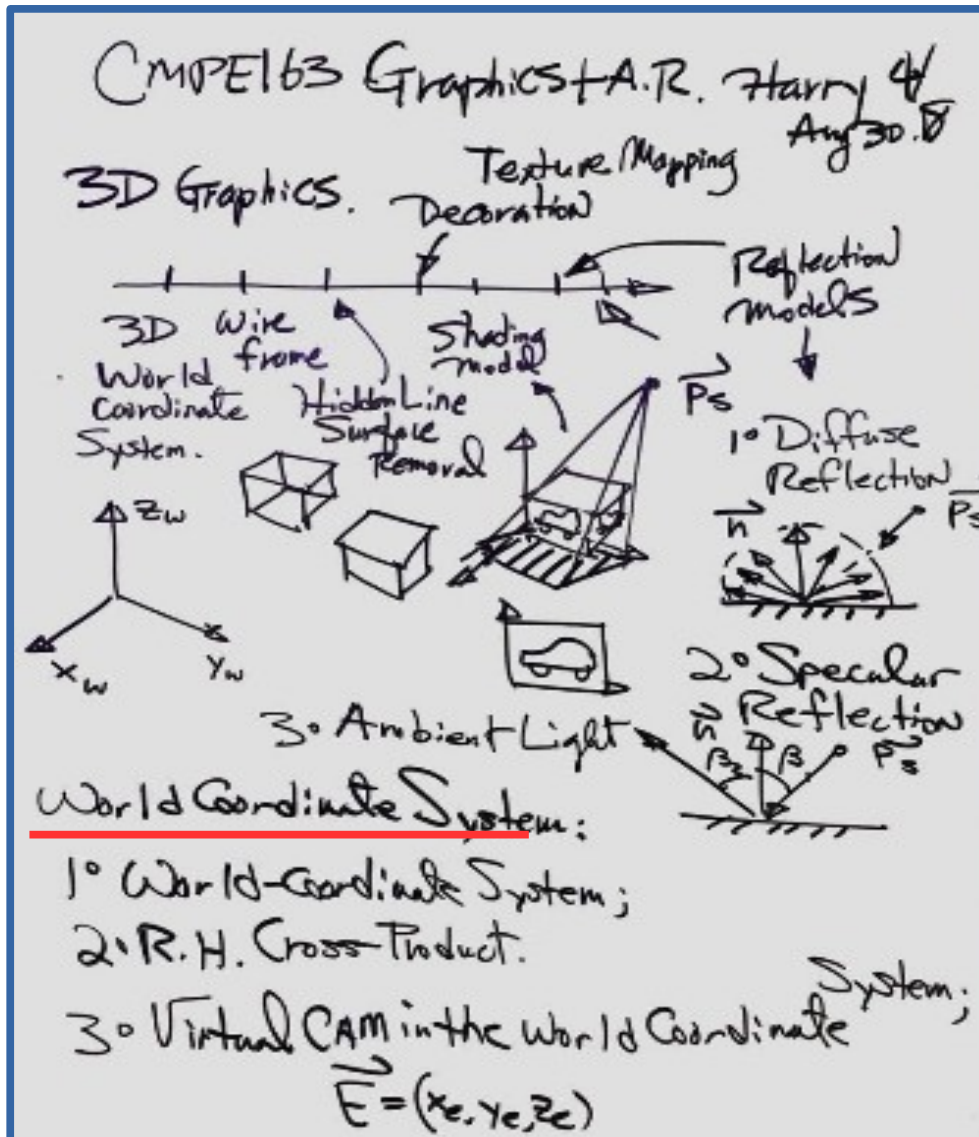


3D World Coordinate System

Reference: H. Li Three-Dimensional Computer Graphics
Using EGA or VGA Card

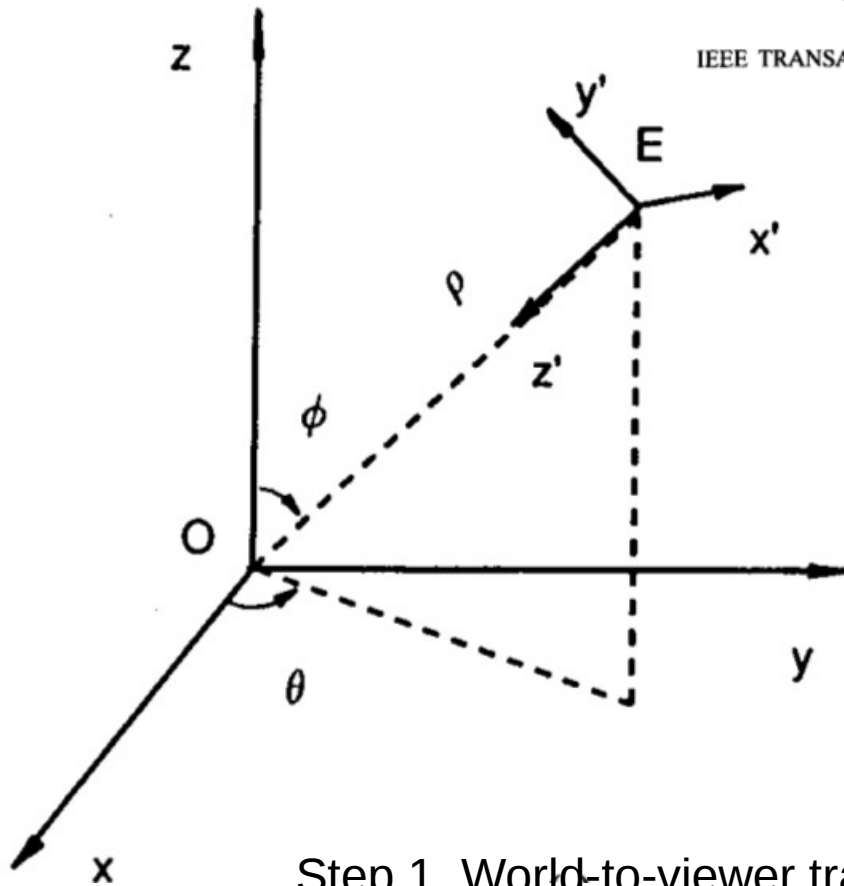
IEEE TRANSACTIONS ON EDUCATION, VOL. 35, NO. 1, FEBRUARY 1992



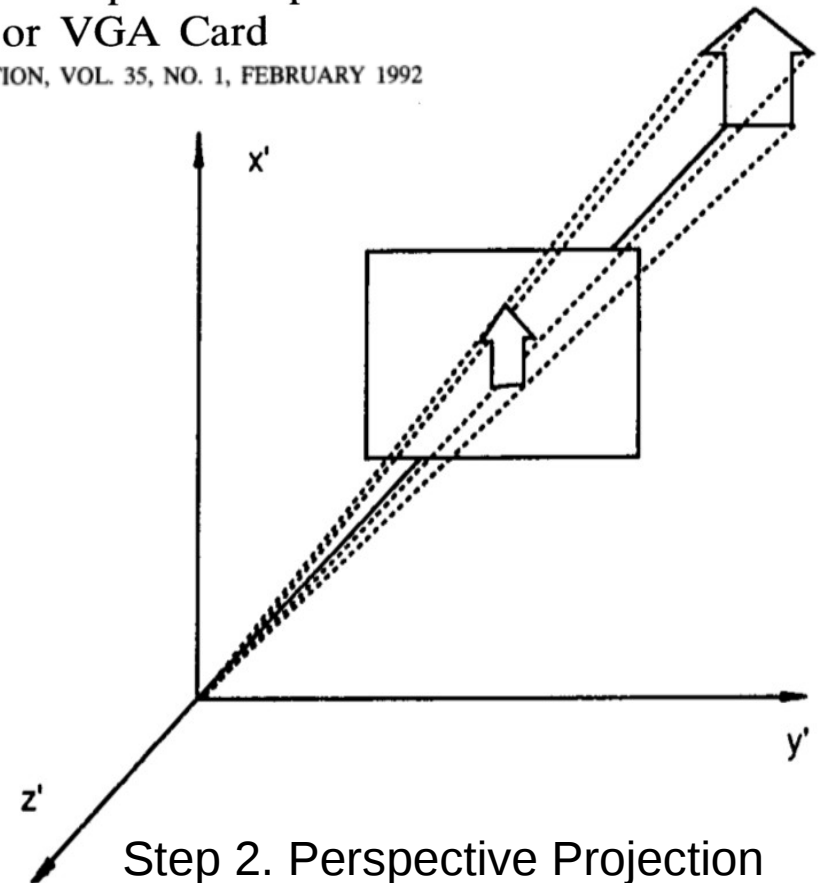
3D Transformation Pipeline Technique

Reference: H. Li Three-Dimensional Computer Graphics
Using EGA or VGA Card

IEEE TRANSACTIONS ON EDUCATION, VOL. 35, NO. 1, FEBRUARY 1992



Step 1. World-to-viewer transform



Step 2. Perspective Projection

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

$$x_p = x_e \left(\frac{D}{z_e} \right)$$

$$y_p = y_e \left(\frac{D}{z_e} \right)$$

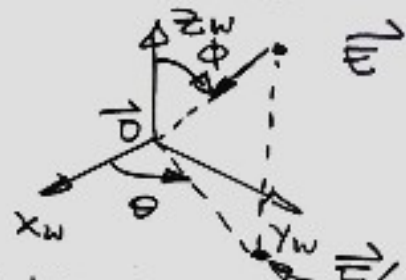
9-6-2018: Viewer Coordinate System And Virtual Camera

Reference: H. Li Three-Dimensional Computer Graphics
Using EGA or VGA Card

IEEE TRANSACTIONS ON EDUCATION, VOL. 35, NO. 1, FEBRUARY 1992

CMPE163. Sept. 6, 2018. 1/
Harry Li.

TOPICS: 1' World-Coordinate System.
Transformation pipeline
= T.P.



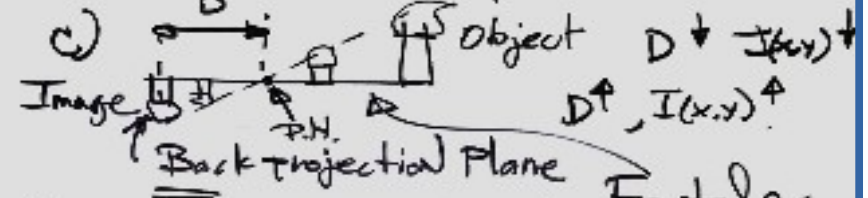
Note: 1' R.H. System. $X_w(\vec{i}) \rightarrow Y_w(\vec{j})$

2' Virtual CAM $Z_w(\vec{k}) \leftarrow$ Cross product
 $Z_w \vec{k} = X_w \vec{i} \times Y_w \vec{j}$
 $E = E(x_e, y_e, z_e) = (x_e, y_e, z_e)$, projected ON to
 X_w-Y_w plane, form a vector OE' , then Angle θ
then EO vector v.s. $Z_w \vec{k}$ (Clockwise) CounterClockwise

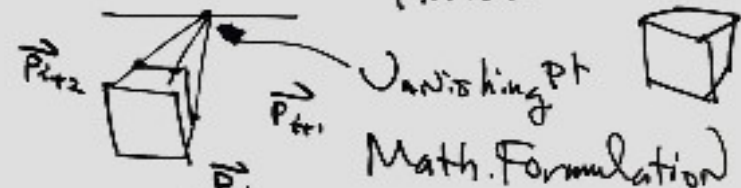
Example: Find Distance p from O to E
(rho) $p = \sqrt{x_e^2 + y_e^2 + z_e^2} \dots (1)$ 3' Virtual CAM.
"pin-hole"

CMPE163. Sept 6, 2018 HL 2/.

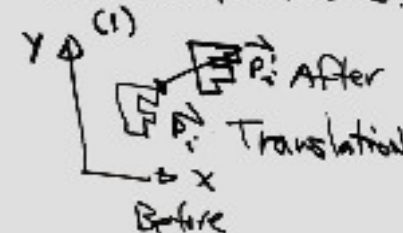
c) Only "Ray" Reaches the Back projection
plan \Rightarrow is the Ray Through the
pin-hole; b) $d_{T.H.} \Rightarrow 0, \lim d_{T.H.} = 0$



4' Perspective Projection No "Sign
Needed.
Horizon



1. 2D Transformations. (2) ϕ



9-6-2018 World-to-Viewer Transforms

Reference: H. Li Three-Dimensional Computer Graphics
Using EGA or VGA Card


IEEE TRANSACTIONS ON EDUCATION, VOL. 35, NO. 1, FEBRUARY 1992

Example: CMPE163. Sept. 6, 2018 HL !.

From World to Viewer Transform Equation

Suppose $E(200, 200, 200)$, find T.P. Equation

After "Viewer" $\begin{pmatrix} x'_i \\ y'_i \\ z'_i \\ 1 \end{pmatrix} = [T.P.]_{4 \times 4} \begin{pmatrix} x_i \\ y_i \\ z_i \\ 1 \end{pmatrix}$ Before "World"



$$\sin \theta = \frac{b}{c} \quad \left| \begin{array}{l} b = 200(y) \\ c = \sqrt{200^2 + 200^2} = 200\sqrt{2} \end{array} \right. = \frac{200}{200\sqrt{2}} = \frac{1}{\sqrt{2}} = \frac{\sqrt{2}}{2}$$

$$\cos \theta = \frac{a}{c} \quad \left| \begin{array}{l} a = 200 \\ c = 200\sqrt{2} \end{array} \right. = \frac{200}{200\sqrt{2}} = \frac{1}{\sqrt{2}} = \frac{\sqrt{2}}{2}$$

$$\cos \phi = \frac{p}{q} \quad \left| \begin{array}{l} p = 200 \\ q = \sqrt{200^2 + 200^2 + 200^2} = 200\sqrt{3} \end{array} \right. = \frac{200}{200\sqrt{3}} = \frac{1}{\sqrt{3}} = \frac{\sqrt{3}}{3}$$


$$\sin \phi = \frac{m}{q}$$

Example: $= \frac{200\sqrt{2}}{200\sqrt{3}} = \frac{\sqrt{2}\sqrt{3}}{3} = \frac{1.414 \times 1.732}{3}$

Perspective Projection

$\vec{P}_i \rightarrow \vec{P}'_i \rightarrow \vec{P}''_i$

$(x_i, y_i, z_i) \rightarrow (x'_i, y'_i, z'_i) \rightarrow (x''_i, y''_i, z''_i)$



$\begin{pmatrix} x'_i \\ y'_i \\ z'_i \\ 1 \end{pmatrix}$

9-6-2018 World-to-Viewer Transforms

Reference: H. Li Three-Dimensional Computer Graphics
Using EGA or VGA Card


IEEE TRANSACTIONS ON EDUCATION, VOL. 35, NO. 1, FEBRUARY 1992

Example: CMPE163. Sept. 6, 2018 HL !.

From World to Viewer Transform Equation

Suppose $E(200, 200, 200)$, find T.P. Equation

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$$\sin \theta = \frac{b}{c} \quad \left| \begin{array}{l} b = 200(y) \\ c = \sqrt{200^2 + 200^2} = 200\sqrt{2} \end{array} \right. = \frac{200}{200\sqrt{2}} = \frac{1}{\sqrt{2}} = \frac{\sqrt{2}}{2}$$

$$\cos \theta = \frac{a}{c} \quad \left| \begin{array}{l} a = 200 \\ c = 200\sqrt{2} \end{array} \right. = \frac{200}{200\sqrt{2}} = \frac{1}{\sqrt{2}} = \frac{\sqrt{2}}{2}$$

$$\cos \phi = \frac{p}{q} \quad \left| \begin{array}{l} p = 200 \\ q = \sqrt{200^2 + 200^2 + 200^2} = 200\sqrt{3} \end{array} \right. = \frac{200}{200\sqrt{3}} = \frac{1}{\sqrt{3}} = \frac{\sqrt{3}}{3}$$


$$\sin \phi = \frac{m}{q}$$

Example: $= \frac{200\sqrt{2}}{200\sqrt{3}} = \frac{\sqrt{2}\sqrt{3}}{3} = \frac{1.414 \times 1.732}{3}$

Perspective Projection

$\vec{P}_i \rightarrow \vec{P}'_i \rightarrow \vec{P}''_i$

$(x_i, y_i, z_i) \rightarrow (x'_i, y'_i, z'_i) \rightarrow (x''_i, y''_i, z''_i)$



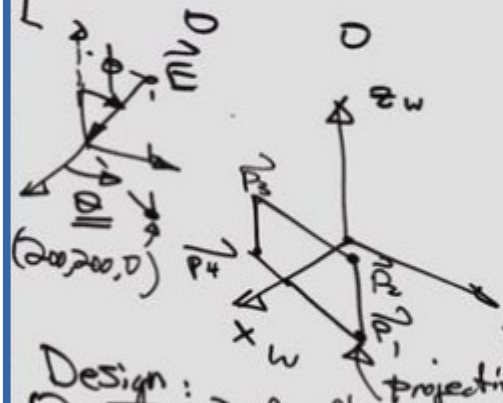
$\begin{pmatrix} x'_i \\ y'_i \\ z'_i \\ 1 \end{pmatrix}$

9-13-2018 Design 3D Projection In Virtual Space

CME163 Sept. 13, 2018. HL

Homework: Design 3D Projection system.

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



and Compute Transformation Pipeline. Plot the result

Design:

- ① Dataset: $\{P_i(x_i, y_i, z_i) | i=1, 2, \dots, N\}$
 $P_1(x_1, y_1, z_1) = (50, 50, \rho)$, $P_2(x_2, y_2, z_2) = (50, 50, 100)$
 $P_3(x_3, y_3, z_3) = (50, -50, 100)$, $P_4(x_4, y_4, z_4) = (50, -50, 0)$

- ② Define $E(200, 200, 200)$, $\rho = 200\sqrt{3}$ (Hint)

$$\sin\theta = \frac{200}{\sqrt{200^2 + 200^2}} = \frac{\sqrt{2}}{2}, \cos\theta = \frac{\sqrt{2}}{2}, \sin\phi = \frac{200\sqrt{2}}{200\sqrt{3}} = \frac{\sqrt{6}}{3}$$

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

Substitute the Calculation Result into Eqn(1). Hence, we have,

$$\begin{bmatrix} x'_i \\ y'_i \\ z'_i \\ 1 \end{bmatrix} = \begin{bmatrix} -\frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} & 0 & 0 \\ -\frac{\sqrt{2}}{2}\frac{\sqrt{3}}{3} & -\frac{\sqrt{2}}{2}\frac{\sqrt{3}}{3} & \frac{\sqrt{6}}{3} & 0 \\ -\frac{\sqrt{2}}{2}\frac{\sqrt{6}}{3} & -\frac{\sqrt{2}}{2}\frac{\sqrt{6}}{3} & -\frac{\sqrt{3}}{3} & 200\sqrt{3} \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_i \\ y_i \\ z_i \\ 1 \end{bmatrix} \dots (2)$$

After (Viewer)

Therefore, Each P_i in the World Coordinate System Can be Mapped to Viewer Coordinate System.

$P'_i(x'_i, y'_i, z'_i)$: From Eqn(2) for $i=1$.

$$x'_1 = -\frac{\sqrt{2}}{2}x_1 + \frac{\sqrt{2}}{2}y_1 + 0 \cdot z_1 + 0 \cdot 1 = -\frac{\sqrt{2}}{2} \cdot 50 + \frac{\sqrt{2}}{2} \cdot 50 = 0$$

$$y'_1 = -\frac{\sqrt{2}}{2}\frac{\sqrt{3}}{3}x_1 - \frac{\sqrt{2}}{2}\frac{\sqrt{3}}{3}y_1 + \frac{\sqrt{6}}{3}z_1 + 0 \cdot 1 = -50\sqrt{2}\frac{\sqrt{3}}{3}$$

$$z'_1 = -\frac{\sqrt{2}}{2}\frac{\sqrt{6}}{3}x_1 - \frac{\sqrt{2}}{2}\frac{\sqrt{6}}{3}y_1 - \frac{\sqrt{3}}{3}z_1 + 200\sqrt{3} = -50\sqrt{2}\frac{\sqrt{6}}{3} + 200\sqrt{3}$$

$$x'_2 = -\frac{\sqrt{2}}{2}x_2 + \frac{\sqrt{2}}{2}y_2 = 0, y'_2 = -\frac{\sqrt{2}}{2}\frac{\sqrt{3}}{3}x_1 - \frac{\sqrt{2}}{2}\frac{\sqrt{3}}{3}y_1 + \frac{\sqrt{6}}{3}z_1 + 0 \cdot 1 = -50\sqrt{2}\frac{\sqrt{3}}{3} + 100\sqrt{6}$$

$$z'_2 = -\frac{\sqrt{2}}{2}\frac{\sqrt{6}}{3}x_2 - \frac{\sqrt{2}}{2}\frac{\sqrt{6}}{3}y_2 - \frac{\sqrt{3}}{3}z_2 + 200\sqrt{3} = -50\sqrt{2}\frac{\sqrt{6}}{3} + 100\frac{\sqrt{6}}{3} + 200\sqrt{3}$$

9-13-2018 Design 3D Projection In Virtual Space

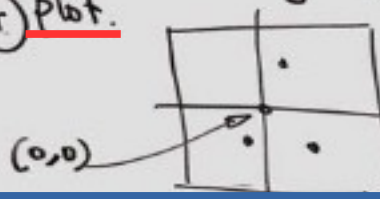
Next, Perspective Projection (3) "Pin Hole" model,
 Before $\vec{P}_i(x_i, y_i, z_i)$ "Viewer"
 After $\vec{P}_i''(x'', y'')$ After Perspective Projection

$$\begin{cases} x'' = \frac{D}{z_i} x_i \\ y'' = \frac{D}{z_i} y_i \end{cases}$$

Suppose $D=20$
 for $i=1$. $x''_1 = \frac{D}{z_1} x'_1 = \frac{20}{(-50\sqrt{16}/3 + 200\sqrt{3})} \times 0$
 $x''_1 = 0, y''_1 = \frac{D}{z_1} y'_1 = \frac{20}{(-50\sqrt{16}/3 + 200\sqrt{3})} (-50\sqrt{16}/3)$

for $i=2$.
 $x''_2 = \frac{D}{z_2} x'_2 = \frac{20}{(-50\sqrt{16}/3 - 100\sqrt{3} + 200\sqrt{3})} \cdot 0 = 0$
 $y''_2 = \frac{D}{z_2} y'_2 = \frac{20}{(-50\sqrt{16}/3 - 100\sqrt{3} + 200\sqrt{3})} \cdot 50\sqrt{3}/3$

(4) plot.

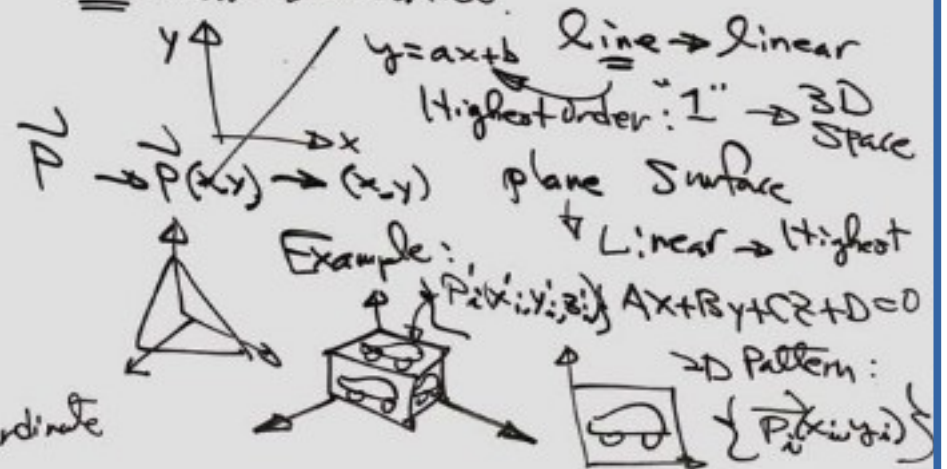


"Link" information for Each P_i
 Note: Draw World Coordinate First.

$$\begin{aligned} X_w: & \vec{P}_{XS}(0,0,0), \vec{P}_{XE}(100,0,0), \text{"red"} \\ & \text{Width } 255 \\ Y_w: & \vec{P}_{YS}(0,0,0), \vec{P}_{YE}(0,100,0), \text{"green"} \\ & 255 \\ Z_w: & \vec{P}_{ZS}(0,0,0), \vec{P}_{ZE}(0,0,100), \text{"Blue"} 255 \end{aligned}$$

Requirements: Design Projection Plane
 Per the Discussion, C/C++ Implementation.
 Submit to SJSU CANVAS on-Line

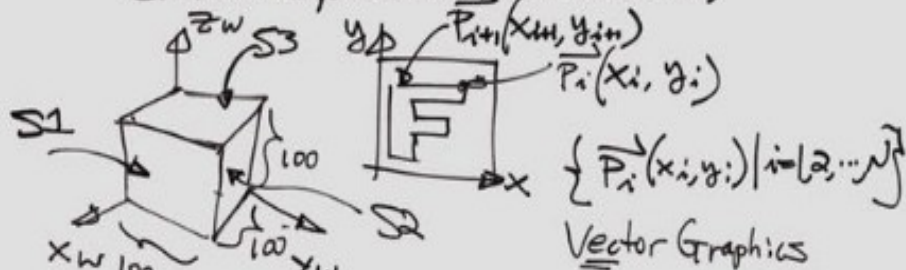
Decoration Technique. Texture Mapping
"Linear" Decoration.



9-13-2018 Linear Decoration in "World"

CMP/E163 Sept. 13, 2018. HL 2/

Example: Suppose a given Cube in the "World" Coordinate System is to be decorated,



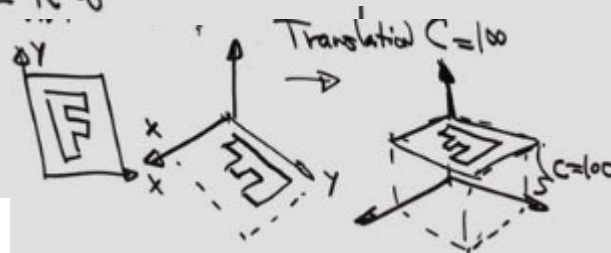
Approach: (1) Redefine 2D Pattern(s) into 3D "World" Coordinate System. (2) Perform 3D Transformations (e.g. Translation, Rotation, Scaling etc) to attach to the Surface to be decorated.

From Given 2D Pattern $\{P_i(x_i, y_i) | i=1, 2, \dots, N\}$, Redefine it in 3D.

$(x_i, y_i) \rightarrow (x_i, y_i, c) | c=0$

Before $P_i(x_i, y_i)$

After $P'_i(x'_i, y'_i, z'_i)$



$$\begin{cases} x'_i = x_i \\ y'_i = y_i \\ z'_i = c \end{cases} \dots (1)$$

S1: ON y_w-z_w plane
Ind. (x_i) $F_n(y_i)$

$$\begin{cases} x'_i = c \\ y'_i = x_i \\ z'_i = y_i \end{cases}$$

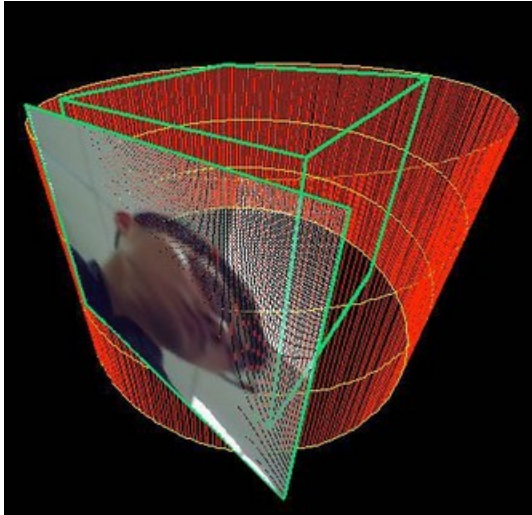
After. Before.

S2: ON z_w-x_w plane
Ind. F_n

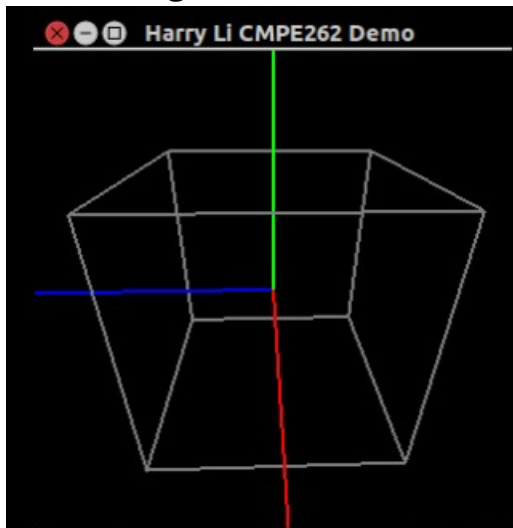
$$\begin{cases} x'_i = y_i \\ y'_i = c \\ z'_i = x_i \end{cases} \dots (2)$$

3D Transformation Pipeline Program (1)

OpenGL/lecWireframe



Create green frame above



```
/*
 * Program: wireframe.c  for CMPE262
 * Date: Sept 12, 2013
 * gcc main.cpp -o main.o -lGL -lGLU -lglut -lm
 * Note: linking be sure to have included math lib
 * e.g., -lm
 */
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <math.h>
#include <GL/glut.h>

void Display(void);
void CreateEnvironment(void);
void MakeGeometry(void);
void MakeLighting(void);
void MakeCamera(int,int,int);
void HandleKeyboard(unsigned char key,int x, int y);
void HandleSpecialKeyboard(int key,int x, int y);
void HandleMouse(int,int,int,int);
void HandleMainMenu(int);
void HandleSpeedMenu(int);
void HandleVisibility(int vis);
void HandleIdle(void);
void DrawTextXY(double,double,double,double,char *);
void GiveUsage(char *);
```

3D Transformation Pipeline Program (2)

```
#define TRUE 1
#define FALSE 0
#define PI 3.141592653589793238462643
#define DRAFT 0
#define MEDIUM 1
#define BEST 2
```

```
int drawquality = DRAFT;
int spincamera = TRUE;
int cameradirection = 1;
double updownrotate = 60;
int ballbounce = TRUE;
double ballspeed = 2;
```

```
#define OVALID 1
#define SPHEREID 2
#define BOXID 3
#define PLANEID 4
#define TEXTID 5
```

```
int main(int argc, char **argv)
{
    int i, j, depth;
    int mainmenu, speedmenu;

    for (i=1; i<argc; i++) {
        if (strstr(argv[i], "-h") != NULL)
            GiveUsage(argv[0]);
        if (strstr(argv[i], "-q") != NULL)
        {
            if (i+1 >= argc)
                GiveUsage(argv[0]);
            drawquality = atoi(argv[i+1]);
            if (drawquality < DRAFT)
                drawquality = DRAFT;
            if (drawquality > BEST)
                drawquality = BEST;
            i++;
        }
    }
}
```

3D Transformation Pipeline Program (3)

```
/* Set things up and go */
glutInit(&argc,argv);
glutInitDisplayMode(GLUT_DOUBLE |
                    GLUT_RGB | GLUT_DEPTH);
glutCreateWindow("Harry Li CMPE262 Demo");
glutDisplayFunc(Display);
glutVisibilityFunc(HandleVisibility);
glutKeyboardFunc(HandleKeyboard);
glutSpecialFunc(HandleSpecialKeyboard);
glutMouseFunc(HandleMouse);

CreateEnvironment();

/* Set up some menus */
speedmenu = glutCreateMenu(HandleSpeedMenu);
glutAddMenuEntry("Slow",1);
glutAddMenuEntry("Medium",2);
glutAddMenuEntry("fast",3);
mainmenu = glutCreateMenu(HandleMainMenu);
glutAddMenuEntry("Toggle camera spin",1);
glutAddMenuEntry("Toggle ball bounce",2);
glutAddSubMenu("Ball speed",speedmenu);
glutAddMenuEntry("Quit",100);
glutAttachMenu(GLUT_RIGHT_BUTTON);

glutMainLoop();
return(0);
}
```

```
/******
This is where global settings are made, that is,
things that will not change in time
******/
void CreateEnvironment(void)
{
    glEnable(GL_DEPTH_TEST);
    if (drawquality == DRAFT) {
        glShadeModel(GL_FLAT);
    }
    if (drawquality == MEDIUM) {
        glShadeModel(GL_SMOOTH);
    }

    if (drawquality == BEST) {
        glEnable(GL_LINE_SMOOTH);
        glEnable(GL_POINT_SMOOTH);
        glEnable(GL_POLYGON_SMOOTH);
        glShadeModel(GL_SMOOTH);
        glDisable(GL_DITHER); /* Assume RGBA */
    }
    glLineWidth(1.0);
    glPointSize(1.0);
    glPolygonMode(GL_FRONT_AND_BACK, GL_FILL);
    glFrontFace(GL_CW);
    glDisable(GL_CULL_FACE);
    glClearColor(0.0,0.0,0.0,0.0); /* Background colour */
    glEnable(GL_COLOR_MATERIAL);
}
}
```


3D Transformation Pipeline Program (4)

```
/* Place a few grey boxes around the place */
glLoadName(BOXID);
glColor3f(0.5,0.5,0.5);
if (drawquality > DRAFT) {
    glMaterialfv(GL_FRONT_AND_BACK,
                 GL_DIFFUSE,mdiff3);
    glMaterialfv(GL_FRONT_AND_BACK,
                 GL_AMBIENT,mamb3);
}
glPushMatrix();
// glTranslatef(1.8,0.2,1.8);
glTranslatef(0,0,0);
if (drawquality > DRAFT)
    glutSolidCube(200);
else
    glutWireCube(200);
/* glTranslatef(-3.6,0.0,0.0);
if (drawquality > DRAFT)
    glutSolidCube(0.4);
else
    glutWireCube(0.4);*/
glPopMatrix();
// Harry Li, 2013-9-12
}
/*****
Set up the lighting environment
*****/
```

```
void MakeLighting(void)
{
    GLfloat globalambient[] = {0.3,0.3,0.3,1.0};

    /* The specifications for 3 light sources */
    GLfloat pos0[] = {1.0,1.0,0.0,0.0}; /* w = 0 == infinite distance */
    GLfloat dif0[] = {0.8,0.8,0.8,1.0};

    GLfloat pos1[] = {5.0,-5.0,0.0,0.0}; /* Light from below */
    GLfloat dif1[] = {0.4,0.4,0.4,1.0}; /* Fainter */

    if (drawquality > DRAFT) {

        /* Set ambient globally, default ambient for light sources is 0 */
        glLightModelfv(GL_LIGHT_MODEL_AMBIENT,globalambient);

        glLightfv(GL_LIGHT0,GL_POSITION,pos0);
        glLightfv(GL_LIGHT0,GL_DIFFUSE,dif0);

        glLightfv(GL_LIGHT1,GL_POSITION,pos1);
        glLightfv(GL_LIGHT1,GL_DIFFUSE,dif1);

        glEnable(GL_LIGHT0);
        glEnable(GL_LIGHT1);
        glEnable(GL_LIGHTING);
    }
}
```

3D Transformation Pipeline Program (5)

```
/******
```

This is the basic display callback routine
It creates the geometry, lighting, and viewing position
In this case it rotates the camera around the scene

```
*****/
```

```
void Display(void)  
{  
    glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);  
    glPushMatrix();  
    MakeCamera(FALSE,0,0);  
    MakeLighting();  
    MakeGeometry();  
    glPopMatrix();  
    /* glFlush(); This isn't necessary for double buffers */  
    glutSwapBuffers();  
}
```

```
/******
```

Create the geometry

```
*****/
```

```
void MakeGeometry(void)  
{  
    int i;  
    double radius = 0.5;  
    static double theta = 0;  
    GLfloat mshin1[] = {5.0};          /* For the sphere */  
    GLfloat mspec1[] = {0.5,0.5,0.5,1.0};  
    GLfloat mdiff1[] = {0.6,0.0,0.6,1.0};
```

```
GLfloat mamb1[] = {0.1,0.0,0.1,1.0};
```

```
GLfloat mdiff2[] = {0.0,1.0,0.0,1.0};  
/* Green plane */
```

```
GLfloat mamb2[] = {0.0,0.2,0.0,1.0};
```

```
GLfloat mdiff3[] = {0.5,0.5,0.5,1.0};  
/* Grey boxes */
```

```
GLfloat mamb3[] = {0.2,0.2,0.2,1.0};
```

```
float ORG[3] = {0,0,0};
```

```
float XP[3] = {500,0,0}, XN[3] = {-1,0,0};
```

```
float YP[3] = {0,500,0}, YN[3] = {0,-1,0};
```

```
float ZP[3] = {0,0,500}, ZN[3] = {0,0,-1};
```

```
/* Create a RGB xyz axis */
```

```
// glClear(GL_CLEAR_COLOR_BUFFER_BIT  
          | GL_DEPTH_BUFFER_BIT);  
glLineWidth (2.0);
```

```
glBegin (GL_LINES);
```

```
glColor3f (1,0,0); // X axis is red.
```

```
glVertex3fv (ORG);
```

```
glVertex3fv (XP );
```

```
glColor3f (0,1,0); // Y axis is green.
```

```
glVertex3fv (ORG);
```

```
glVertex3fv (YP );
```

```
glColor3f (0,0,1); // z axis is blue.
```

```
glVertex3fv (ORG);
```

```
glVertex3fv (ZP );
```

```
glEnd();
```

3D Transformation Pipeline Program (6)

```
/******  
Set up the camera  
Optionally creating a small viewport about  
the mouse click point for object selection  
*****/  
void MakeCamera(int pickmode,int x,int y)  
{  
    static double theta = 0;  
    GLint viewport[4];  
  
    /* Camera setup */  
    glMatrixMode(GL_PROJECTION);  
    glLoadIdentity();  
    if (pickmode == TRUE) {  
        glGetIntegerv(GL_VIEWPORT,viewport);  
        /* Get the viewport bounds */  
        gluPickMatrix(x,viewport[3]-y,3.0,3.0,viewport);  
    }  
    gluPerspective(70.0, /* Field of view */  
        1.0, /* aspect ratio */  
        0.1,1000.0); /* near and far */  
  
    glMatrixMode(GL_MODELVIEW);  
    glLoadIdentity();
```

```
gluLookAt(300*cos(theta*PI/180)*  
    sin(updownrotate*PI/180),  
    300*cos(updownrotate*PI/180),  
    300*sin(theta*PI/180)*  
    sin(updownrotate*PI/180),  
    0.0,0.0,0.0, /* Focus */  
    0.0,1.0,0.0); /* Up */  
    if (spincamera)  
        theta += (cameradirection * 0.2);  
}  
/******  
Deal with plain key strokes  
*****/  
void HandleKeyboard(unsigned char key,int x, int y)  
{  
    switch (key) {  
        case 27: /* ESC */  
        case 'Q':  
        case 'q': exit(0); break;  
        case 's':  
        case 'S': spincamera = !spincamera; break;  
        case 'b':  
        case 'B': ballbounce = !ballbounce; break;  
    }  
}
```


3D Transformation Pipeline Program (7)

```
/*  
*****  
Deal with special key strokes  
*****  
*/  
void HandleSpecialKeyboard(int key,int x, int y)  
{  
    switch (key) {  
        case GLUT_KEY_LEFT:  
            cameradirection = -1; break;  
        case GLUT_KEY_RIGHT:  
            cameradirection = 1; break;  
        case GLUT_KEY_UP:  
            updownrotate -= 2; break;  
        case GLUT_KEY_DOWN:  
            updownrotate += 2; break;  
    }  
}  
/*  
*****  
Handle mouse events  
*****  
*/  
void HandleMouse(int button,int state,int x,int y)  
{  
    int i,maxselect = 100,nhits = 0;  
    GLuint selectlist[100];  
    if (state == GLUT_DOWN) {  
        glSelectBuffer(maxselect,selectlist);  
        glRenderMode(GL_SELECT);  
        glInitNames();  
        glPushName(-1);
```

```
glPushMatrix();  
    MakeCamera(TRUE,x,y);  
    MakeGeometry();  
    glPopMatrix();  
    nhits = glRenderMode(GL_RENDER);  
  
    if (button == GLUT_LEFT_BUTTON) {  
  
    } else if (button == GLUT_MIDDLE_BUTTON) {  
  
    } /* Right button events are passed to menu handlers */  
  
    if (nhits == -1)  
        fprintf(stderr,"Select buffer overflow\n");  
  
    if (nhits > 0) {  
        fprintf(stderr,"\nPicked %d objects: ",nhits);  
        for (i=0;i<nhits;i++)  
            fprintf(stderr,"%d ",selectlist[4*i+3]);  
        fprintf(stderr,"\n"); }  
  
    }  
}
```

3D Transformation Pipeline Program (8)

```
/*  
*****  
    Handle the main menu  
*****  
*/  
void HandleMainMenu(int whichone)  
{  
    switch (whichone) {  
        case 1: spincamera = !spincamera; break;  
        //case 2: ballbounce = !ballbounce; break;  
        case 100: exit(0); break;  
    }  
}  
/*  
*****  
    Handle the ball speed sub menu  
*****  
*/  
void HandleSpeedMenu(int whichone)  
{  
    switch (whichone) {  
        case 1: ballspeed = 0.5; break;  
        case 2: ballspeed = 2; break;  
        case 3: ballspeed = 10; break;  
    }  
}  
*/
```

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```
/*  
*****  
    Handle visibility  
*****  
*/  
void HandleVisibility(int visible)  
{  
    if (visible == GLUT_VISIBLE)  
        glutIdleFunc(HandleIdle);  
    else  
        glutIdleFunc(NULL);  
}  
/*  
*****  
    On an idle event  
*****  
*/  
void HandleIdle(void)  
{ glutPostRedisplay(); }  
/*  
*****  
    Draw text in the x-y plane  
    The x,y,z coordinate is the bottom left corner  
    (looking down -ve z axis)  
*****  
*/  
void DrawTextXY(double x,double y,double z,double scale,char *s)  
{  
    int i;  
    glPushMatrix();  
    glTranslatef(x,y,z);  
    glScalef(scale,scale,scale);  
    for (i=0;i<strlen(s);i++)  
        glutStrokeCharacter(GLUT_STROKE_ROMAN,s[i]);  
    glPopMatrix();  
}
```

3D Transformation Pipeline Program (9)

```
/******  
Display the program usage information  
*****/  
void GiveUsage(char *cmd)  
{  
    fprintf(stderr,"Usage:  %s [-h] [-q n]\n",cmd);  
    fprintf(stderr,"      -h  this text\n");  
    fprintf(stderr,"      -q n quality, 0,1,2\n");  
    fprintf(stderr,"Key Strokes and Menus:\n");  
    fprintf(stderr,"      q - quit\n");  
    fprintf(stderr,"      s - toggle camera spin\n");  
    fprintf(stderr,"      b - toggle ball bounce\n");  
    fprintf(stderr," left arrow - change  
              rotation direction\n");  
    fprintf(stderr," right arrow - change  
              rotation direction\n");  
    fprintf(stderr," down arrow - rotate  
              camera down\n");  
    fprintf(stderr," up arrow - rotate  
              camera up\n");  
    exit(-1);  
}
```