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CSE 420-01

Homework 3

Homework 3 Report

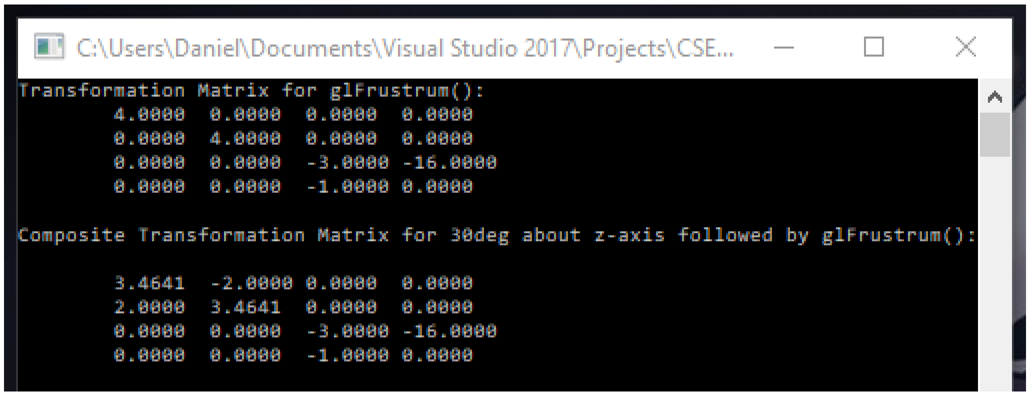
Part 1: (success)

A = (2,2,1) B = (1,-2,0)

Proj$_B$ **A** = (**A**·**B** / |**B**|^2) **B =** [-2 / sqrt(5)] * (1,-2,0) = <u>(-0.894, 1.789, 0)</u>

Perp$_B$ **A** = **A** - Proj$_B$ **A =** (2,2,1) – (-0.894, 1.789, 0) = <u>(1.106, 0.211, 1)</u>

Part 2: (success)

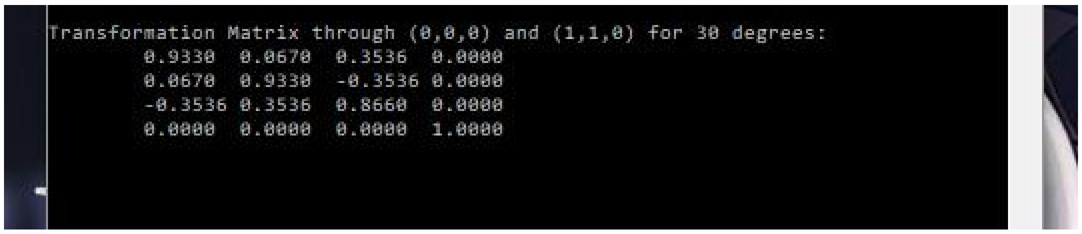


C:\Users\Daniel\Documents\Visual Studio 2017\Projects\CSE...

```
Transformation Matrix for glFrustrum():
        4.0000  0.0000  0.0000  0.0000
        0.0000  4.0000  0.0000  0.0000
        0.0000  0.0000  -3.0000 -16.0000
        0.0000  0.0000  -1.0000 0.0000

Composite Transformation Matrix for 30deg about z-axis followed by glFrustrum():

        3.4641  -2.0000 0.0000  0.0000
        2.0000  3.4641  0.0000  0.0000
        0.0000  0.0000  -3.0000 -16.0000
        0.0000  0.0000  -1.0000 0.0000
```

```
glLoadIdentity();
	glFrustum(-1.0, 1.0, -1.0, 1.0, 4.0, 8.0);
	glGetFloatv(GL_MODELVIEW_MATRIX, &p[0][0]);
	cout << "Transformation Matrix for glFrustrum():" << endl;
	print_mat(p);

	glPushMatrix();
	glLoadIdentity();
	glRotatef(30, 0, 0, 1);
	glFrustum(-1.0, 1.0, -1.0, 1.0, 4.0, 8.0);
	glGetFloatv(GL_MODELVIEW_MATRIX, &p[0][0]);
	cout << "Composite Transformation Matrix for 30deg about z-axis 
followed by glFrustrum():" << endl;
	print_mat(p);
```

Part 3: (success)



```
Transformation Matrix through (0,0,0) and (1,1,0) for 30 degrees:
        0.9330  0.0670  0.3536  0.0000
        0.0670  0.9330  -0.3536 0.0000
        -0.3536 0.3536  0.8660  0.0000
        0.0000  0.0000  0.0000  1.0000
```

```
glLoadIdentity();
	glTranslatef(1, 1, 0);
	glRotatef(30, 1, 1, 0);
	glTranslatef(-1, -1, 0);
	glGetFloatv(GL_MODELVIEW_MATRIX, &p[0][0]);
	cout << "Transformation Matrix through (0,0,0) and (1,1,0) for 30 
degrees:" << endl;
	print_mat(p);
```

Part 4: (success)

$-1 \le x \le 2$, $6 \le y \le 8$, and $0 \le z \le 6$

Viewpoint @ (8, 6, 9)

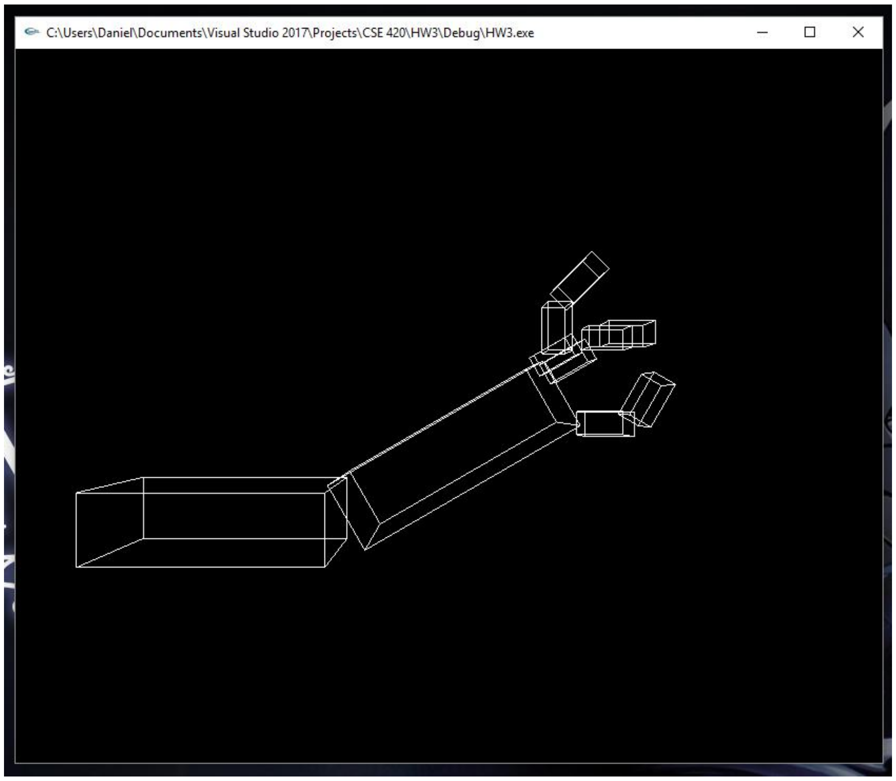
Center @ (0.5, 7, 3)

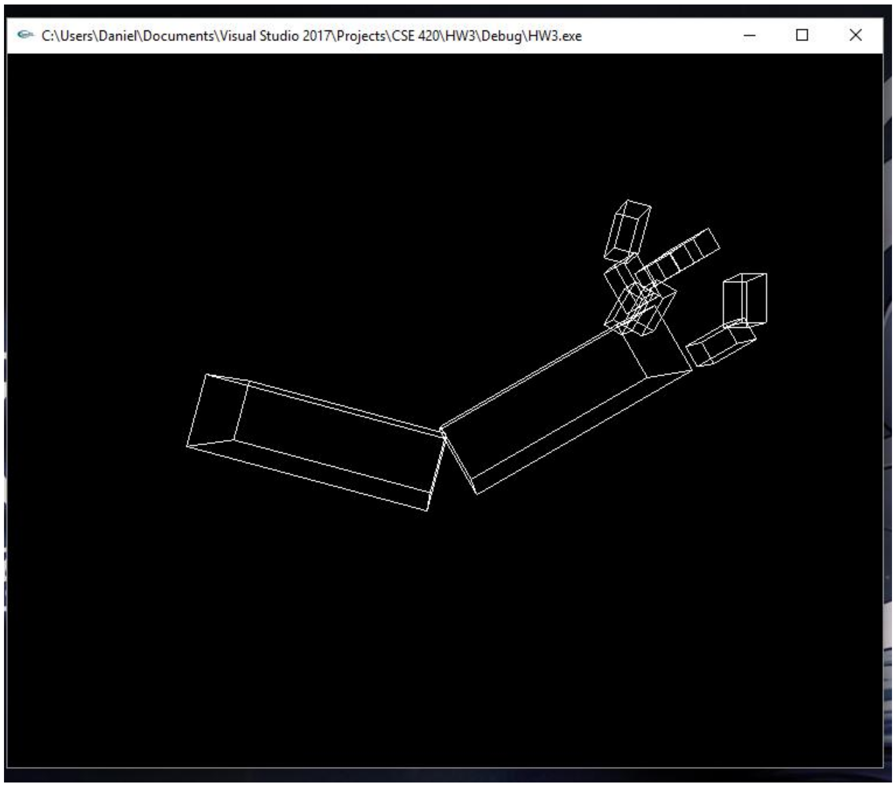
r = ½ * size = sqrt[$(2 – 0.5)^2 + (8 - 7)^2 + (6 - 3)^2$] = sqrt(12.25) = 3.5

d = sqrt[$(8 - 0.5)^2 + (6 - 7)^2 + (9 - 3)^2$] = sqrt(93.25) = 9.656

theta = 2arcTan(r / d) = 2arcTan(3.5 / 9.656) = 2 * 19.924 = <u>39.848 degrees</u>

Part 5: (success)


C:\Users\Daniel\Documents\Visual Studio 2017\Projects\CSE 420\HW3\Debug\HW3.exe


C:\Users\Daniel\Documents\Visual Studio 2017\Projects\CSE 420\HW3\Debug\HW3.exe

```
static int shoulder = 0, elbow = 0, hand = 0;
```

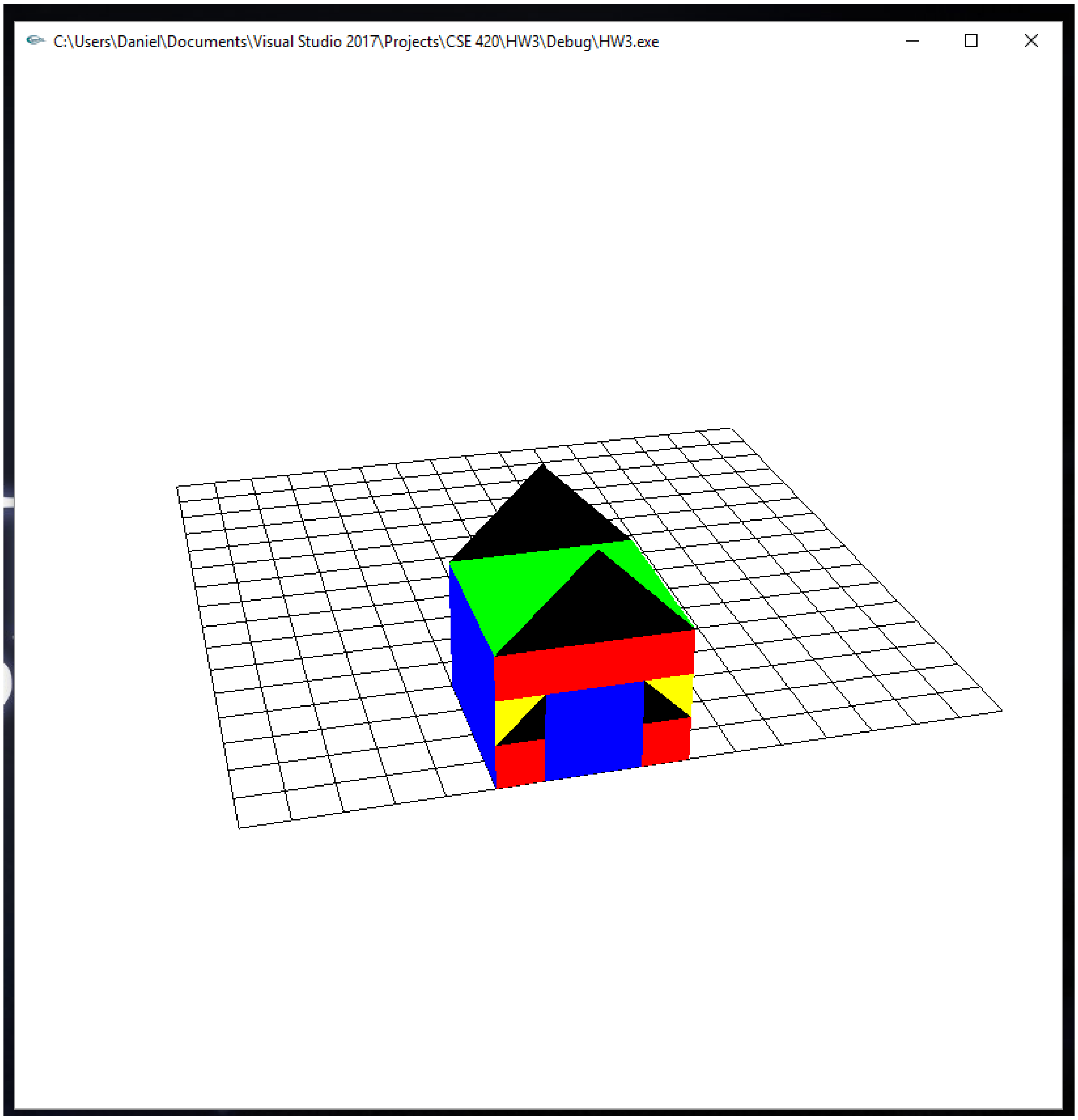
```c
static int fingers = 0, thumb = 0;
static int armX = 0, armY = 0;

void init(void)
{
	glClearColor(0.0, 0.0, 0.0, 0.0);
	glShadeModel(GL_FLAT);
}

void display(void)
{
	glClear(GL_COLOR_BUFFER_BIT);
	glPushMatrix();
	glTranslatef((GLfloat)armX, armY, 0);
	glTranslatef(-1.0, 0.0, 0.0);
	glRotatef((GLfloat)shoulder, 0.0, 0.0, 1.0);
	glTranslatef(1.0, 0.0, 0.0);
	glPushMatrix();
	glScalef(2.0, 0.6, 1.0);
	//	glScalef( 2.0, 0.1, 1.0 );
	glutWireCube(1.0);

	glPopMatrix();

	glTranslatef(1.0, 0.0, 0.0);
	glRotatef((GLfloat)elbow, 0.0, 0.0, 1.0);
	glRotatef(30, 0.0, 0.0, 1.0);
	glTranslatef(1.2, 0.0, 0.0);
	glPushMatrix();
	glScalef(2.0, 0.6, 1.0);
	glutWireCube(1.0);

	glPopMatrix();

	//thumb
	glTranslatef(1.0, 0.0, 0.0);
	glRotatef((GLfloat)thumb, 0.0, 0.0, 1.0);
	glRotatef(-30, 0.0, 0.0, 1.0);
	glTranslatef(0.4, -0.25, 0.3);
	glPushMatrix();
	glScalef(0.4, 0.2, 0.3);
	glutWireCube(1.0);

	glPopMatrix();

	//FINGER 1
```

```
glTranslatef(-0.4, 0.8, 0.0);
glRotatef(90, 0.0, 0.0, 1.0);
glPushMatrix();
glScalef(0.4, 0.2, 0.3);
glutWireCube(1.0);

glPopMatrix();

//FINGER 2
glTranslatef(0.0, 0.0, -0.3);
glRotatef(-60, 0.0, 0.0, 1.0);
glTranslatef(0.0, -0.3, 0.0);
glPushMatrix();
glScalef(0.4, 0.2, 0.3);
glutWireCube(1.0);

glPopMatrix();

//Finger 3
glTranslatef(0.0, 0.0, -0.3);
glTranslatef(0.0, 0.1, 0.0);
glPushMatrix();
glScalef(0.4, 0.2, 0.3);
glutWireCube(1.0);

glPopMatrix();

//Finger tip 3
glTranslatef(0.5, -0.1, 0.0);
glRotatef(-30, 0.0, 0.0, 1.0);
glPushMatrix();
glScalef(0.4, 0.2, 0.3);
glutWireCube(1.0);

glPopMatrix();

//Finger tip 2
glTranslatef(0.1, 0.0, 0.3);
glPushMatrix();
glScalef(0.4, 0.2, 0.3);
glutWireCube(1.0);

glPopMatrix();

//Finger tip 1
glTranslatef(-0.5, 0.4, 0.3);
```

```
	glRotatef(45, 0.0, 0.0, 1.0);
	glPushMatrix();
	glScalef(0.4, 0.2, 0.3);
	glutWireCube(1.0);

	glPopMatrix();

	//Thumb tip
	glTranslatef(-0.3, -1.1, 0.0);
	glRotatef(15, 0.0, 0.0, 1.0);
	glPushMatrix();
	glScalef(0.4, 0.2, 0.3);
	glutWireCube(1.0);

	glPopMatrix();

	glPopMatrix();
	glutSwapBuffers();
}

void reshape(int w, int h)
{
	glViewport(0, 0, (GLsizei)w, (GLsizei)h);
	glMatrixMode(GL_PROJECTION);
	glLoadIdentity();
	gluPerspective(65.0, (GLfloat)w / (GLfloat)h, 1.0, 20.0);
	glMatrixMode(GL_MODELVIEW);
	glLoadIdentity();
	glTranslatef(0.0, 0.0, -5.0);
}
void keyboard(unsigned char key, int x, int y)
{
	switch (key) {
	case 's':
		shoulder = (shoulder + 5) % 360;
		glutPostRedisplay();
		break;
	case 'S':
		shoulder = (shoulder - 5) % 360;
		glutPostRedisplay();
		break;
	case 'e':
		elbow = (elbow + 5) % 360;
		glutPostRedisplay();
		break;
	case 'E':
			elbow = (elbow - 5) % 360;
			glutPostRedisplay();
			break;
		case 'h':
			hand = (hand + 5) % 360;
			glutPostRedisplay();
			break;
		case 'H':
			hand = (hand - 5) % 360;
			glutPostRedisplay();
			break;
		case 'f':
			fingers = (fingers + 5) % 360;
			thumb = (thumb - 5) % 360;
			glutPostRedisplay();
			break;
		case 'F':
			fingers = (fingers - 5) % 360;
			thumb = (thumb + 5) % 360;
			glutPostRedisplay();
			break;
		case 'a':
			armX = (armX + 1) % 360;
			glutPostRedisplay();
			break;
		case 'A':
			armX = (armX - 1) % 360;
			glutPostRedisplay();
			break;
		case 'z':
			armY = (armY + 1) % 360;
			glutPostRedisplay();
			break;
		case 'Z':
			armY = (armY - 1) % 360;
			glutPostRedisplay();
			break;
		case 27:
			exit(0);
			break;
		default:
			break;
		}
}

int main(int argc, char** argv)
```

```
{
	glutInit(&argc, argv);
	glutInitDisplayMode(GLUT_DOUBLE | GLUT_RGB);
	glutInitWindowSize(500, 500);
	glutInitWindowPosition(100, 100);
	glutCreateWindow(argv[0]);
	init();
	glutDisplayFunc(display);
	glutReshapeFunc(reshape);
	glutKeyboardFunc(keyboard);
	glutMainLoop();
	return 0;
}
```

Extra Credit: (success)


C:\Users\Daniel\Documents\Visual Studio 2017\Projects\CSE 420\HW3\Debug\HW3.exe

```
#include <stdio.h>
#include <GL/glut.h>

float tx = 0, ty = 0, tz = 0;       // translations
float ax = -45, ay = 0, az = 0;     // rotations

bool triangles = false;
```

```
class Quads
{
public:
	float x[4], y[4], z[4];
	float r, g, b;
};

Quads Q[100];
int nQuads = 0;
int sideQ = 0;

class Triangles
{
public:
	float x[3], y[3], z[3];
	float r, g, b;
};

Triangles T[100];
int nTriangles = 0;
int sideT = 0;

void addQuad()
{
	Q[nQuads].x[sideQ] = tx;
	Q[nQuads].y[sideQ] = ty;
	Q[nQuads].z[sideQ] = tz;
	sideQ++;
	if (sideQ > 3) {
		nQuads++;
		sideQ = 0;
	}
}

void drawQuads()
{
	for (int i = 0; i < nQuads; i++) {
		glColor3f(Q[i].r, Q[i].g, Q[i].b);
		glBegin(GL_QUADS);
		for (int j = 0; j < 4; j++)
			glVertex3f(Q[i].x[j], Q[i].y[j], Q[i].z[j]);
		glEnd();
	}

}
```

```
void addTriangle()
{
	T[nTriangles].x[sideT] = tx;
	T[nTriangles].y[sideT] = ty;
	T[nTriangles].z[sideT] = tz;
	sideT++;
	if (sideT > 2)
	{
		nTriangles++;
		sideT = 0;
	}
}

void drawTriangle()
{
	for (int i = 0; i < nTriangles; i++) {
		glColor3f(T[i].r, T[i].g, T[i].b);
		glBegin(GL_TRIANGLES);
		for (int j = 0; j < 3; j++)
			glVertex3f(T[i].x[j], T[i].y[j], T[i].z[j]);
		glEnd();
	}
}

//initialization
void init(void)
{
	glClearColor(1.0, 1.0, 1.0, 0.0);	//get white background
color
	glColor3f(0.0f, 0.0f, 0.0f);	//set drawing color
	glMatrixMode(GL_PROJECTION);
	glLoadIdentity();
	gluPerspective(35, 1.0f, 4.0f, 1000);
	glMatrixMode(GL_MODELVIEW);
	glLoadIdentity();
}

void drawGrid()
{
	glColor3f(0, 0, 0);
	for (int i = 0; i < 34; i++) {
		glPushMatrix();
		if (i < 17)
			glTranslatef(0, i, 0);
		else {
```

```
                glTranslatef(i - 17, 0, 0);
                glRotatef(90, 0, 0, 1);  //rotate about z-axis by 90
CCW
            }
            glBegin(GL_LINES);
            glVertex3f(0, 0, 0);
            glVertex3f(16, 0, 0);
            glEnd();
            glPopMatrix();
        }

}

void drawCube()
{
        glColor3f(1, 0, 0);
        glPushMatrix();
        glTranslatef(tx, ty, tz);
        glutSolidCube(0.5);
        glPopMatrix();
}

void display(void)
{
        glClear(GL_COLOR_BUFFER_BIT);    //clear screen
        glLoadIdentity();
        gluLookAt(0.0, 0.0, 40.0, 0.0, 0.0, 0.0, 0.0, 1.0, 0.0);
        glRotatef(ax, 1, 0, 0);
        glRotatef(ay, 0, 1, 0);
        glRotatef(az, 0, 0, 1);
        glTranslatef(-8, -8, 0);
        drawGrid();
        drawCube();
        drawQuads();
        drawTriangle();
        glFlush();                  //send all output to screen
}

void setColor(float r, float g, float b)
{
        Q[nQuads].r = r;
        Q[nQuads].g = g;
        Q[nQuads].b = b;
}
void keyboard(unsigned char key, int mousex, int mousey)
{
```

```
switch (key) {
case 'u':       // up
      tz += 1;
      break;
case 'd':       // down
      tz -= 1;
      break;
case 'a':   //rotation angle
      ax -= 1;
      break;
case 'A':   //rotation angle
      ax += 1;
      break;
case 'z':   //rotation angle
      az -= 1;
      break;
case 'Z':   //rotation angle
      az += 1;
      break;

case 32:        //space
      if (triangles == false)
            addQuad();
      else if(triangles == true)
            addTriangle();
      break;
case 'R':
      setColor(1, 0, 0);
      break;
case 'G':
      setColor(0, 1, 0);
      break;
case 'B':
      setColor(0, 0, 1);
      break;
case 'Y':
      setColor(1, 1, 0);
      break;

case 't':
      if (triangles == false)
            triangles = true;
      else  if(triangles == true)
            triangles = false;
      break;
case 27:        // escape
```

```
            exit(-1);
      }
      glutPostRedisplay();
}

void specialKey(int key, int mousex, int mousey)
{
      switch (key) {
      case GLUT_KEY_UP:
            ty += 1;
            break;
      case GLUT_KEY_DOWN:
            ty -= 1;
            break;
      case GLUT_KEY_LEFT:
            tx -= 1;
            break;
      case GLUT_KEY_RIGHT:
            tx += 1;
            break;
      }
      glutPostRedisplay();
}

void myMouse(int button, int state, int x, int y)
{
      if (button == GLUT_LEFT_BUTTON && state == GLUT_DOWN);
      glFlush();                                  //send all output to screen
}

void reshape(int w, int h)
{
      glViewport(0, 0, (GLsizei)w, (GLsizei)h);
      glMatrixMode(GL_PROJECTION);
      glLoadIdentity();
      gluPerspective(35, (GLfloat)w / (GLfloat)h, 4.0f, 1000);
      //  gluPerspective(65.0, (GLfloat) w/(GLfloat) h, 1.0, 20.0);
      glMatrixMode(GL_MODELVIEW);
      glLoadIdentity();
      glTranslatef(0.0, 0.0, -5.0);
}


/*  Main Loop
 *  Open window with initial window size, title bar,
 *  RGBA display mode, depth buffer.
 */
int main(int argc, char** argv)
{
	glutInit(&argc, argv);	//initialize toolkit
	glutInitDisplayMode(GLUT_SINGLE | GLUT_RGB);	//set display 
mode
	glutInitWindowSize(800, 800);		//set window size on screen
	glutInitWindowPosition(100, 150);	//set window position on 
screen
	glutCreateWindow(argv[0]);	//open screen widow
	init();
	glutDisplayFunc(display);	//points to display function
	glutKeyboardFunc(keyboard);
	glutSpecialFunc(specialKey);
	glutMouseFunc(myMouse);
	glutReshapeFunc(reshape);


	glutMainLoop();		//go into perpetual loop
	return 0;
}
```

Summary:

This homework assignment focused on matrix multiplication and order of affine transformations. The first part of the assignment asked that we calculate Proj$_B$ **A** and Perp$_B$ **A** for the following points: A = (2,2,1) and B = (1,-2, 0) which yielded Proj$_B$ **A** = (-0.894, 1.789, 0) and Perp$_B$ **A =** (1.106, 0.211, 1). For the next part of the assignment I had to perform the given glFrustrum command print the corresponding transformation matrix which was then followed by performing a rotation on the matrix about the z-axis and printing the corresponding composite matrix of which both can be seen above. For the third part of the assignment I found the transformation matrix rotating about the axis through two given points and printed the answer found in my OpenGL program I used to verify my answer. For the next part of the assignment I had to find the angle of the FOV for the given viewpoint and x,y,z bounding coordinates. TO find the angle I first had to find the center and calculate the radius and distance. Using the radius and distance I calculated the angle by multiplying the arc tangent of the radius, divided by the distance, by 2. This produced an angle of 39.848 degrees. For the last part of the assignment I had to produce the robot arm introduced in the lecture notes and apply functionality for rotating, swinging, and translating the arm along with finger gripping motions. I also added appropriate keyboard commands to perform each of these actions. Finally, for the extra credit portion, I modified the drawGrid program we had worked on in class to also draw triangles, which can be toggled using ‘t’ and then to showcase this, created a simple house with a roof, windows, and door. Each portion of the assignment compiled and executed correctly and as such feel I earned 80 points (60 for base assignment, 20 for Extra Credit).