Homework 3 Report

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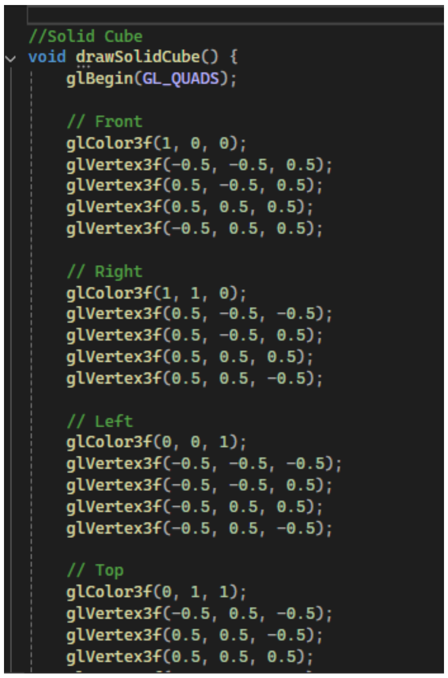
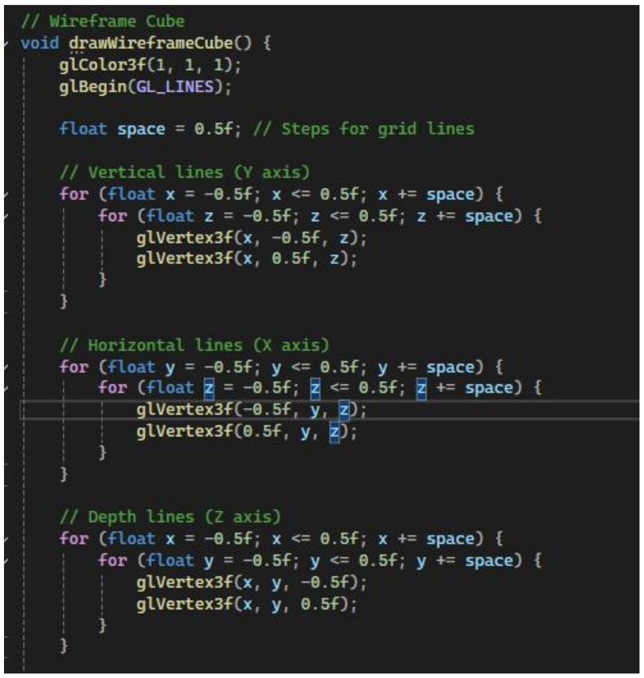
In this homework, we are asked to do the basic projection in a 3D scene.

What I do first is creating a cube using GL_QUADS. Basically, I just draw six rectangles. I want the user to be able to switch between the solid mode or wireframe mode. So, instead of GL_QUADS, I use GL_LINES to draw the line in wireframe mode. Specifically, in drawWireframeCube(), first I determine the space or the steps to draw the line. Then, for each destined steps on Y axis (from bottom to top), I draw a vertical line. Then, I also draw the horizontal line (x axis). Finally, I draw the z axis line as well. These two drawing functions will be called on display().



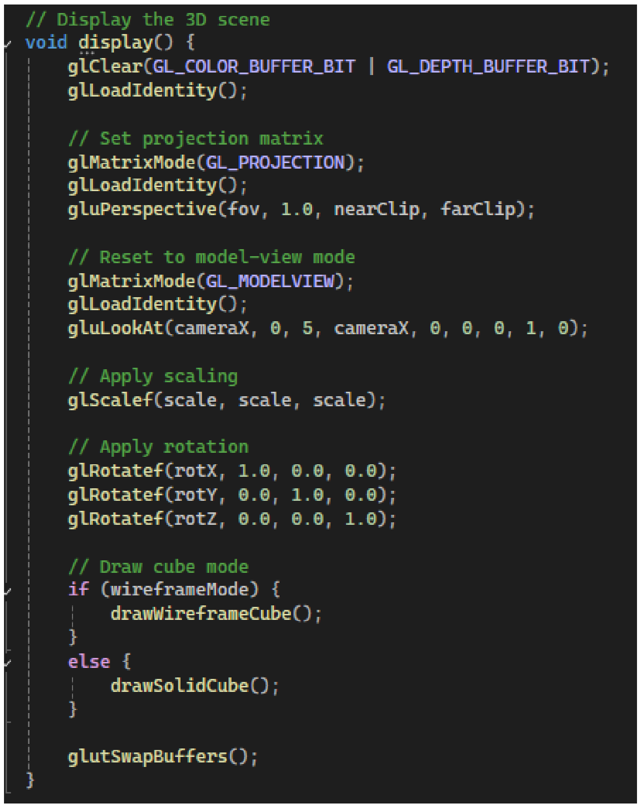
```
//Solid Cube
void drawSolidCube() {
    glBegin(GL_QUADS);

    // Front
    glColor3f(1, 0, 0);
    glVertex3f(-0.5, -0.5, 0.5);
    glVertex3f(0.5, -0.5, 0.5);
    glVertex3f(0.5, 0.5, 0.5);
    glVertex3f(-0.5, 0.5, 0.5);

    // Right
    glColor3f(1, 1, 0);
    glVertex3f(0.5, -0.5, -0.5);
    glVertex3f(0.5, -0.5, 0.5);
    glVertex3f(0.5, 0.5, 0.5);
    glVertex3f(0.5, 0.5, -0.5);

    // Left
    glColor3f(0, 0, 1);
    glVertex3f(-0.5, -0.5, -0.5);
    glVertex3f(-0.5, -0.5, 0.5);
    glVertex3f(-0.5, 0.5, 0.5);
    glVertex3f(-0.5, 0.5, -0.5);

    // Top
    glColor3f(0, 1, 1);
    glVertex3f(-0.5, 0.5, -0.5);
    glVertex3f(0.5, 0.5, -0.5);
    glVertex3f(0.5, 0.5, 0.5);
```



```
// Wireframe Cube
void drawWireframeCube() {
    glColor3f(1, 1, 1);
    glBegin(GL_LINES);

    float space = 0.5f; // Steps for grid lines

    // Vertical lines (Y axis)
    for (float x = -0.5f; x <= 0.5f; x += space) {
        for (float z = -0.5f; z <= 0.5f; z += space) {
            glVertex3f(x, -0.5f, z);
            glVertex3f(x, 0.5f, z);
        }
    }

    // Horizontal lines (X axis)
    for (float y = -0.5f; y <= 0.5f; y += space) {
        for (float z = -0.5f; z <= 0.5f; z += space) {
            glVertex3f(-0.5f, y, z);
            glVertex3f(0.5f, y, z);
        }
    }

    // Depth lines (Z axis)
    for (float x = -0.5f; x <= 0.5f; x += space) {
        for (float y = -0.5f; y <= 0.5f; y += space) {
            glVertex3f(x, y, -0.5f);
            glVertex3f(x, y, 0.5f);
        }
    }
```

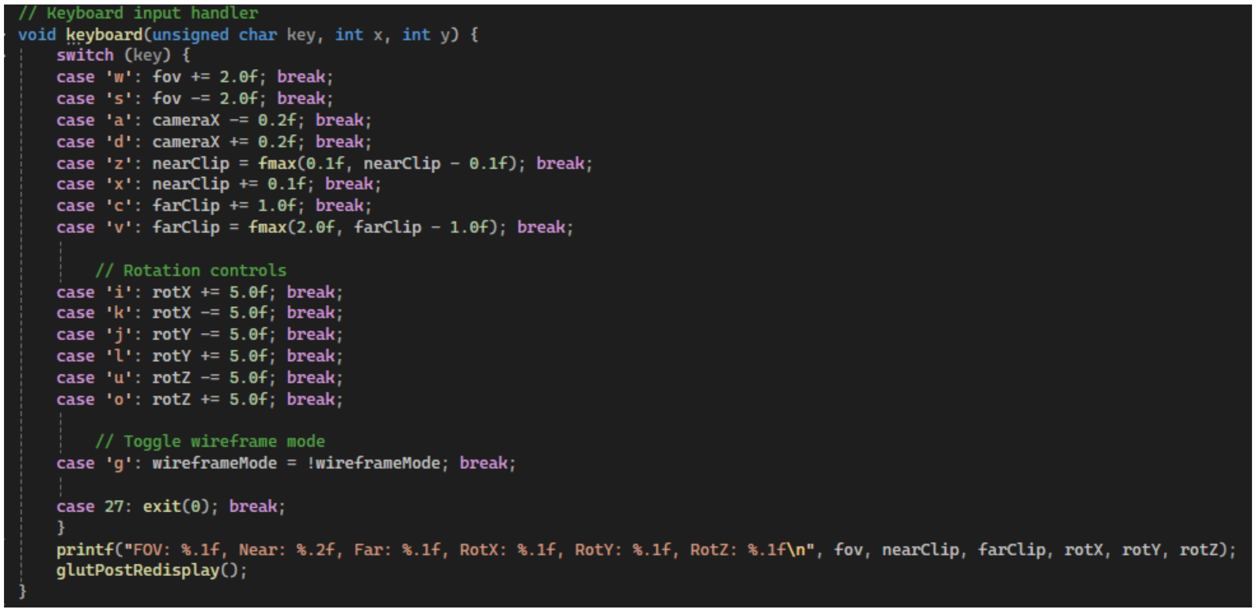
On the display(), we will display the previously drawing functions and also apply some transformation. The first thing I do is configure the projection matrix, including the perspective projection, aspect ratio, near and far clipping plane. gluLookA() set the camera view positioned at (cameraX, 0, 5) and looks at (cameraX, 0, 0), with the up vector pointing along the positive Y-axis (0, 1, 0). Right after, I apply the transformation of scale and rotation.

Finally, according whether the user press the “g” button, the drawing cube mode is changed accordingly.

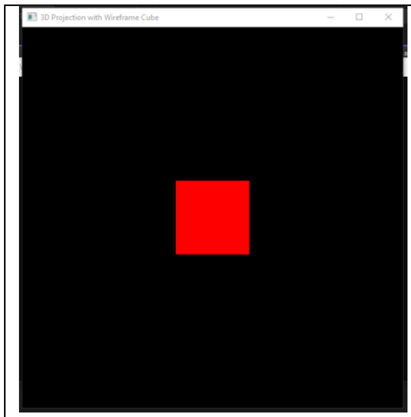


```
// Display the 3D scene
void display() {
    glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
    glLoadIdentity();

    // Set projection matrix
    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    gluPerspective(fov, 1.0, nearClip, farClip);

    // Reset to model-view mode
    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity();
    gluLookAt(cameraX, 0, 5, cameraX, 0, 0, 0, 1, 0);

    // Apply scaling
    glScalef(scale, scale, scale);

    // Apply rotation
    glRotatef(rotX, 1.0, 0.0, 0.0);
    glRotatef(rotY, 0.0, 1.0, 0.0);
    glRotatef(rotZ, 0.0, 0.0, 1.0);

    // Draw cube mode
    if (wireframeMode) {
        drawWireframeCube();
    }
    else {
        drawSolidCube();
    }

    glutSwapBuffers();
}
```

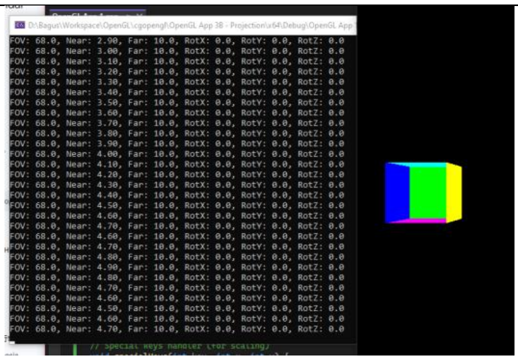
To do the projection operations, I implement some keyboard keys as the control. Finally, just call the display(), keyboard() functions.



```
// Keyboard input handler
void keyboard(unsigned char key, int x, int y) {
    switch (key) {
    case 'w': fov += 2.0f; break;
    case 's': fov -= 2.0f; break;
    case 'a': cameraX -= 0.2f; break;
    case 'd': cameraX += 0.2f; break;
    case 'z': nearClip = fmax(0.1f, nearClip - 0.1f); break;
    case 'x': nearClip += 0.1f; break;
    case 'c': farClip += 1.0f; break;
    case 'v': farClip = fmax(2.0f, farClip - 1.0f); break;

        // Rotation controls
    case 'i': rotX += 5.0f; break;
    case 'k': rotX -= 5.0f; break;
    case 'j': rotY -= 5.0f; break;
    case 'l': rotY += 5.0f; break;
    case 'u': rotZ -= 5.0f; break;
    case 'o': rotZ += 5.0f; break;

        // Toggle wireframe mode
    case 'g': wireframeMode = !wireframeMode; break;

    case 27: exit(0); break;
    }
    printf("FOV: %.1f, Near: %.2f, Far: %.1f, RotX: %.1f, RotY: %.1f, RotZ: %.1f\n", fov, nearClip, farClip, rotX, rotY, rotZ);
    glutPostRedisplay();
}
```

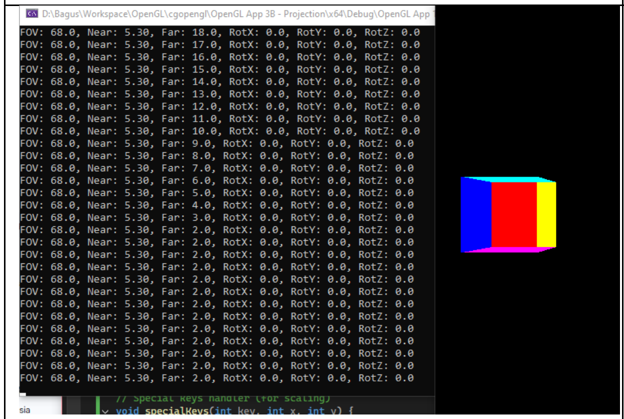


Initial display (front view)



```
D:\Bagus\Workspace\OpenGL\cgopengl\OpenGL App 3B - Projection\x64\Debug\OpenGL App
FOV: 68.0, Near: 2.90, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 3.00, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 3.10, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 3.20, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 3.30, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 3.40, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 3.50, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 3.60, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 3.70, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 3.80, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 3.90, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 4.00, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 4.10, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 4.20, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 4.30, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 4.40, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 4.50, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 4.60, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 4.70, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 4.60, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 4.70, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 4.80, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 4.90, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 4.80, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 4.70, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 4.60, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 4.50, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 4.60, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 4.70, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
```

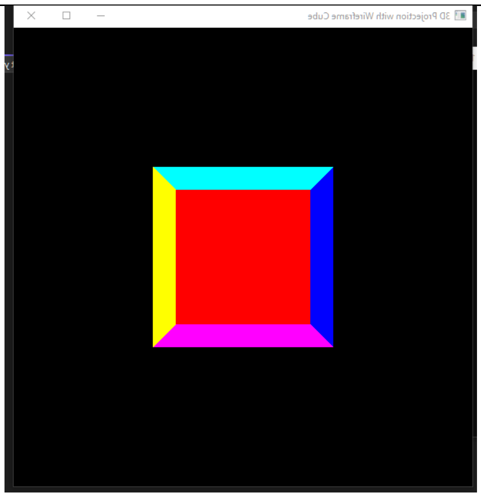
Near clipping



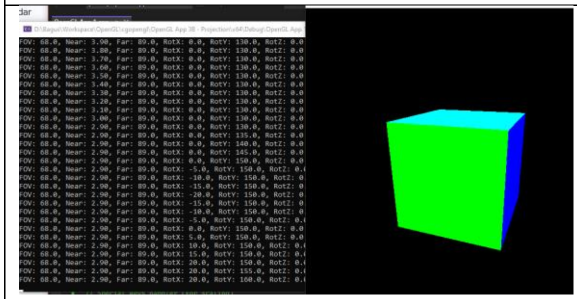
```
D:\Bagus\Workspace\OpenGL\cgopengl\OpenGL App 3B - Projection\x64\Debug\OpenGL App
FOV: 68.0, Near: 5.30, Far: 18.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 17.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 16.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 15.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 14.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 13.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 12.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 11.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 10.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 9.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 8.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 7.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 6.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 5.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 4.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 3.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 2.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 2.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 2.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 2.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 2.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 2.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 2.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 2.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 2.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 2.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 2.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
FOV: 68.0, Near: 5.30, Far: 2.0, RotX: 0.0, RotY: 0.0, RotZ: 0.0
```

```
// Special keys handler (for scaling)
void specialKeys(int key, int x, int y) {
```

Far clipping

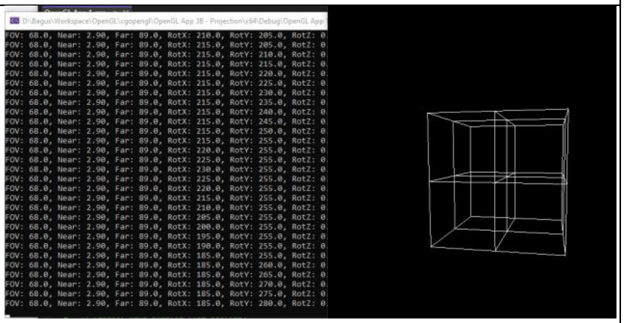


Zoom



```
D:\Bagus\Workspace\OpenGL\cgopengl\OpenGL App 3B - Projection\x64\Debug\OpenGL App
FOV: 68.0, Near: 3.90, Far: 89.0, RotX: 0.0, RotY: 130.0, RotZ: 0.0
FOV: 68.0, Near: 3.80, Far: 89.0, RotX: 0.0, RotY: 130.0, RotZ: 0.0
FOV: 68.0, Near: 3.70, Far: 89.0, RotX: 0.0, RotY: 130.0, RotZ: 0.0
FOV: 68.0, Near: 3.60, Far: 89.0, RotX: 0.0, RotY: 130.0, RotZ: 0.0
FOV: 68.0, Near: 3.50, Far: 89.0, RotX: 0.0, RotY: 130.0, RotZ: 0.0
FOV: 68.0, Near: 3.40, Far: 89.0, RotX: 0.0, RotY: 130.0, RotZ: 0.0
FOV: 68.0, Near: 3.30, Far: 89.0, RotX: 0.0, RotY: 130.0, RotZ: 0.0
FOV: 68.0, Near: 3.20, Far: 89.0, RotX: 0.0, RotY: 130.0, RotZ: 0.0
FOV: 68.0, Near: 3.10, Far: 89.0, RotX: 0.0, RotY: 130.0, RotZ: 0.0
FOV: 68.0, Near: 3.00, Far: 89.0, RotX: 0.0, RotY: 130.0, RotZ: 0.0
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 0.0, RotY: 130.0, RotZ: 0.0
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 0.0, RotY: 135.0, RotZ: 0.0
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 0.0, RotY: 140.0, RotZ: 0.0
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 0.0, RotY: 145.0, RotZ: 0.0
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 0.0, RotY: 150.0, RotZ: 0.0
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: -5.0, RotY: 150.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: -10.0, RotY: 150.0, RotZ: 0
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: -15.0, RotY: 150.0, RotZ: 0
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: -20.0, RotY: 150.0, RotZ: 0
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: -15.0, RotY: 150.0, RotZ: 0
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: -10.0, RotY: 150.0, RotZ: 0
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: -5.0, RotY: 150.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 0.0, RotY: 150.0, RotZ: 0.0
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 5.0, RotY: 150.0, RotZ: 0.0
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 10.0, RotY: 150.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 15.0, RotY: 150.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 20.0, RotY: 150.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 20.0, RotY: 155.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 20.0, RotY: 160.0, RotZ: 0.
```

Rotation



```
D:\Bagus\Workspace\OpenGL\cgopengl\OpenGL App 3B - Projection\x64\Debug\OpenGL App
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 210.0, RotY: 205.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 215.0, RotY: 205.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 215.0, RotY: 210.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 215.0, RotY: 215.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 215.0, RotY: 220.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 215.0, RotY: 225.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 215.0, RotY: 230.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 215.0, RotY: 235.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 215.0, RotY: 240.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 215.0, RotY: 245.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 215.0, RotY: 250.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 215.0, RotY: 255.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 220.0, RotY: 255.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 225.0, RotY: 255.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 230.0, RotY: 255.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 225.0, RotY: 255.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 220.0, RotY: 255.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 215.0, RotY: 255.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 210.0, RotY: 255.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 205.0, RotY: 255.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 200.0, RotY: 255.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 195.0, RotY: 255.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 190.0, RotY: 255.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 185.0, RotY: 255.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 185.0, RotY: 260.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 185.0, RotY: 265.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 185.0, RotY: 270.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 185.0, RotY: 275.0, RotZ: 0.
FOV: 68.0, Near: 2.90, Far: 89.0, RotX: 185.0, RotY: 280.0, RotZ: 0.
```

Wireframe

Notes:

- I push my code here: https://github.com/ardiawanbagusharisa/cgopengl

The complete code:

```
#
#include <GL/glew.h>
#include <GL/freeglut.h>
#include <cmath>
#include <stdio.h>

// Parameters for perspective projection
float fov = 60.0f;              // Field of view
float nearClip = 0.1f;          // Near clipping plane
float farClip = 10.0f;            // Far clipping plane
float scale = 1.0f;               // Scaling factor
float cameraX = 0.0f;            // Camera's X position
float rotX = 0.0f, rotY = 0.0f, rotZ = 0.0f;

bool wireframeMode = false;

void initGL() {
    glEnable(GL_DEPTH_TEST);
    glClearColor(0.0f, 0.0f, 0.0f, 1.0f);
}

//Solid Cube
void drawSolidCube() {
    glBegin(GL_QUADS);

    // Front
    glColor3f(1, 0, 0);
    glVertex3f(-0.5, -0.5, 0.5);
    glVertex3f(0.5, -0.5, 0.5);
    glVertex3f(0.5, 0.5, 0.5);
    glVertex3f(-0.5, 0.5, 0.5);

    // Right
    glColor3f(1, 1, 0);
    glVertex3f(0.5, -0.5, -0.5);
    glVertex3f(0.5, -0.5, 0.5);
    glVertex3f(0.5, 0.5, 0.5);
    glVertex3f(0.5, 0.5, -0.5);

    // Left
    glColor3f(0, 0, 1);
    glVertex3f(-0.5, -0.5, -0.5);
    glVertex3f(-0.5, -0.5, 0.5);
    glVertex3f(-0.5, 0.5, 0.5);
    glVertex3f(-0.5, 0.5, -0.5);
    // Top
    glColor3f(0, 1, 1);
    glVertex3f(-0.5, 0.5, -0.5);
    glVertex3f(0.5, 0.5, -0.5);
    glVertex3f(0.5, 0.5, 0.5);
    glVertex3f(-0.5, 0.5, 0.5);

    // Bottom
    glColor3f(1, 0, 1);
    glVertex3f(-0.5, -0.5, -0.5);
    glVertex3f(0.5, -0.5, -0.5);
    glVertex3f(0.5, -0.5, 0.5);
    glVertex3f(-0.5, -0.5, 0.5);

    // Back
    glColor3f(0, 1, 0);
    glVertex3f(-0.5, -0.5, -0.5);
    glVertex3f(0.5, -0.5, -0.5);
    glVertex3f(0.5, 0.5, -0.5);
    glVertex3f(-0.5, 0.5, -0.5);

    glEnd();
}

// Wireframe Cube
void drawWireframeCube() {
    glColor3f(1, 1, 1);
    glBegin(GL_LINES);

    float space = 0.5f; // Steps for grid lines

     // Vertical lines (Y axis)
    for (float x = -0.5f; x <= 0.5f; x += space) {
        for (float z = -0.5f; z <= 0.5f; z += space) {
            glVertex3f(x, -0.5f, z);
            glVertex3f(x, 0.5f, z);
        }
    }

    // Horizontal lines (X axis)
    for (float y = -0.5f; y <= 0.5f; y += space) {
        for (float z = -0.5f; z <= 0.5f; z += space) {
            glVertex3f(-0.5f, y, z);
            glVertex3f(0.5f, y, z);
        }
    }
    // Depth lines (Z axis)
    for (float x = -0.5f; x <= 0.5f; x += space) {
        for (float y = -0.5f; y <= 0.5f; y += space) {
            glVertex3f(x, y, -0.5f);
            glVertex3f(x, y, 0.5f);
        }
    }

    glEnd();
}

// Display the 3D scene
void display() {
    glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
    glLoadIdentity();

    // Set projection matrix
    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    gluPerspective(fov, 1.0, nearClip, farClip);

    // Reset to model-view mode
    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity();
    gluLookAt(cameraX, 0, 5, cameraX, 0, 0, 0, 1, 0);

    // Apply scaling
    glScalef(scale, scale, scale);

    // Apply rotation
    glRotatef(rotX, 1.0, 0.0, 0.0);
    glRotatef(rotY, 0.0, 1.0, 0.0);
    glRotatef(rotZ, 0.0, 0.0, 1.0);

    // Draw cube mode
    if (wireframeMode) {
        drawWireframeCube();
    }
    else {
        drawSolidCube();
    }

    glutSwapBuffers();
}

// Keyboard input handler
void keyboard(unsigned char key, int x, int y) {
    switch (key) {
    case 'w': fov += 2.0f; break;
    case 's': fov -= 2.0f; break;
    case 'a': cameraX -= 0.2f; break;
    case 'd': cameraX += 0.2f; break;
    case 'z': nearClip = fmax(0.1f, nearClip - 0.1f); break;
    case 'x': nearClip += 0.1f; break;
    case 'c': farClip += 1.0f; break;
    case 'v': farClip = fmax(2.0f, farClip - 1.0f); break;

        // Rotation controls
    case 'i': rotX += 5.0f; break;
    case 'k': rotX -= 5.0f; break;
    case 'j': rotY -= 5.0f; break;
    case 'l': rotY += 5.0f; break;
    case 'u': rotZ -= 5.0f; break;
    case 'o': rotZ += 5.0f; break;

        // Toggle wireframe mode
    case 'g': wireframeMode = !wireframeMode; break;

    case 27: exit(0); break;
    }
    printf("FOV: %.1f, Near: %.2f, Far: %.1f, RotX: %.1f, RotY:
%.1f, RotZ: %.1f\n", fov, nearClip, farClip, rotX, rotY, rotZ);
    glutPostRedisplay();
}

// Special keys handler (for scaling)
void specialKeys(int key, int x, int y) {
    if (key == GLUT_KEY_UP) scale += 0.1f;
    if (key == GLUT_KEY_DOWN) scale = fmax(0.1f, scale - 0.1f);
    glutPostRedisplay();
}

// Main function
int main(int argc, char** argv) {
    glutInit(&argc, argv);
    glutInitDisplayMode(GLUT_DOUBLE | GLUT_RGB | GLUT_DEPTH);
    glutInitWindowSize(600, 600);
    glutCreateWindow("3D Projection with Wireframe Cube");

    glewInit();
    initGL();

    glutDisplayFunc(display);
    glutKeyboardFunc(keyboard);
    glutSpecialFunc(specialKeys);

    glutMainLoop();
    return 0;
}
```