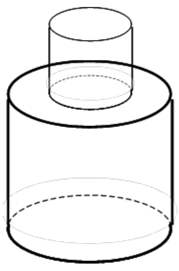
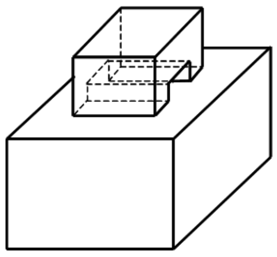
Lab07 for CPT205 Computer Graphics

Part 1. Exercise on Representations of 3 Models

1) Given the following objects below

a) Identify if they are manifold or nonmanifold.
b) Show if they obey the Euler's law.





2) A simple polyhedron is cut by a plane into two. Show that Euler's law holds for the new objects.

3) Investigate the main strengths and drawbacks of B-Rep model in terms of

a) data available and data structure
b) ease of modelling
c) implementation requirements
d) applications

4) Compare and contrast between wireframe, surface, CSG and B-Rep models, and further investigate their applications.

Part 2. Sample code for Boolean operations / geometric modelling

Compile and run the following code and observe how geometric modelling and Boolean operations work. Note that you can right click the mouse to see a simple menu for the operations. There are functions that will be explained and used in later lectures (e.g. hidden surface removal).

```
#define FREEGLUT_STATIC
#define GLUT_DISABLE_ATEXIT_HACK
#include <GL/freeglut.h>
#include <math.h>
#include <STDLIB.H>

//Hide the terminal windows
#pragma comment(linker, "/subsystem:\"windows\" /entry:\"mainCRTStartup\"")

#define SPHERE 1
#define CONE   2
#define CUBE   3

// csgOperation
// types of CSG operations
typedef enum {
        CSG_A,
        CSG_B,
        CSG_A_OR_B,
        CSG_A_AND_B,
        CSG_A_SUB_B,
        CSG_B_SUB_A
} csgOperation;

// globals
GLint Width;
GLint Height;

GLfloat zoom = 0.0;

GLfloat cone_x = 0.0;
GLfloat cone_y = 0.0;
GLfloat cone_z = 0.0;

GLfloat cube_x = 0.0;
GLfloat cube_y = 0.0;
GLfloat cube_z = 0.0;

GLfloat sphere_x = 0.0;
GLfloat sphere_y = 0.0;
GLfloat sphere_z = 0.0;

GLint mouse_state = -1;
GLint mouse_button = -1;

csgOperation Op = CSG_A_OR_B;

/* Both A and B are function pointers.
These function pointers are defined for pointing to the various shape functions, i.e. sphere(), cube()
and cone(). */
void(*A)(void);
void(*B)(void);

// functions

// one()
// draw a single object
void one(void(*a)(void))  // pointer as parameter
{
        glEnable(GL_DEPTH_TEST);
        a();
        glDisable(GL_DEPTH_TEST);
}

// or()
// boolean A or B (draw wherever A or B)
// algorithm: simple, just draw both with depth test enabled
void Or(void(*a)(void), void(*b)())
{
        glEnable(GL_DEPTH_TEST);
        a(); b();
}

// inside()
// sets stencil buffer to show the part of A
// (front or back face according to 'face')
// that is inside of B.
void inside(void(*a)(void), void(*b)(void), GLenum face, GLenum test)
{
        GLint i;
        // draw A into depth buffer, but not into color buffer
        glEnable(GL_DEPTH_TEST);
        glColorMask(GL_FALSE, GL_FALSE, GL_FALSE, GL_FALSE);
        glCullFace(face);  // back face is culled
        a();

        // use stencil buffer to find the parts of A that are inside of B
        // by first incrementing the stencil buffer wherever B's front faces
        // are

        glDepthMask(GL_FALSE);
        glEnable(GL_STENCIL_TEST);
        glStencilFunc(GL_ALWAYS, 0, 0);
        glStencilOp(GL_KEEP, GL_KEEP, GL_INCR);
        glCullFace(GL_BACK);
        b();

        //.then decrement the stencil buffer wherever B's back faces are
        glStencilOp(GL_KEEP, GL_KEEP, GL_DECR);
        glCullFace(GL_FRONT);
        b();

        // now draw the part of A that is inside of B
        glDepthMask(GL_TRUE);
        glColorMask(GL_TRUE, GL_TRUE, GL_TRUE, GL_TRUE);
        glStencilFunc(test, 0, 1);
        glDisable(GL_DEPTH_TEST);
        glCullFace(face);
        a();

        // reset stencil test
        glDisable(GL_STENCIL_TEST);
}

// fixup()
// fixes up the depth buffer with A's depth values
void fixup(void(*a)(void))
{
        // fix up the depth buffer
        glColorMask(GL_FALSE, GL_FALSE, GL_FALSE, GL_FALSE);
        glEnable(GL_DEPTH_TEST);
        glDisable(GL_STENCIL_TEST);
        glDepthFunc(GL_ALWAYS);
        a();

        // reset depth func
        glDepthFunc(GL_LESS);
}

// and()
// Boolean A and B (draw wherever A intersects B)
// algorithm: find where A is inside B, then find where
//            B is inside A
void And(void(*a)(void), void(*b)(void))
{
        inside(a, b, GL_BACK, GL_NOTEQUAL);
#if 1  // set to 0 for faster, but incorrect results
        fixup(b);
#endif
        inside(b, a, GL_BACK, GL_NOTEQUAL);
}

// sub()
// Boolean A subtract B (draw wherever A is and B is NOT)
// algorithm: find where a is inside B, then find where
//            the BACK faces of B are NOT in A
void sub(void(*a)(void), void(*b)(void))
```

```
{
        inside(a, b, GL_FRONT, GL_NOTEQUAL);
#if 1  // set to 0 for faster, but incorrect results
        fixup(b);
#endif
        inside(b, a, GL_BACK, GL_EQUAL);
}

// sphere()
// draw a yellow sphere
void sphere(void)
{
        glPushMatrix();
        glTranslatef(sphere_x, sphere_y, sphere_z);
        glTranslatef(4, 0, 0);
        glColor3f(1.0, 1.0, 1.0);
        glutSolidSphere(5.0, 16, 16);
        glPopMatrix();
}

// cube()
// draw a red cube
void cube(void)
{
        glPushMatrix();
        glTranslatef(cube_x, cube_y, cube_z);
        glColor3f(1.0, 0.0, 0.0);
        glutSolidCube(8.0);
        glPopMatrix();
}

// cone()
// draw a green cone
void cone(void)
{
        glPushMatrix();
        glTranslatef(cone_x, cone_y, cone_z);
        glColor3f(0.0, 1.0, 0.0);
        glTranslatef(0.0, 0.0, -6.5);
        glutSolidCone(4.0, 15.0, 16, 16);
        glRotatef(180.0, 1.0, 0.0, 0.0);
        glutSolidCone(4.0, 0.0, 16, 1);
        glPopMatrix();
}

void init(void)
{
        GLfloat lightposition[] = { -3.0, 3.0, 3.0, 0.0 };

        glDepthFunc(GL_LESS);
        glEnable(GL_DEPTH_TEST);

        glEnable(GL_LIGHT0);
        glEnable(GL_LIGHTING);
        glLightfv(GL_LIGHT0, GL_POSITION, lightposition);
        glLightModeli(GL_LIGHT_MODEL_TWO_SIDE, GL_TRUE);

        glEnable(GL_COLOR_MATERIAL);

        glEnable(GL_CULL_FACE);

        glClearColor(0.0, 0.0, 1.0, 0.0);
}

void reshape(int width, int height)
{
        Width = width;
        Height = height;


        glViewport(0, 0, width, height);

        glMatrixMode(GL_PROJECTION);
        glLoadIdentity();
        glFrustum(-3.0, 3.0, -3.0, 3.0, 64, 256);
        glMatrixMode(GL_MODELVIEW);
        glLoadIdentity();
        glTranslatef(0.0, 0.0, -200.0 + zoom);
}

void display(void)
{
        glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT | GL_STENCIL_BUFFER_BIT);

        glPushMatrix();
        glRotatef(5, 1, 0, 0);
        glRotatef(5, 0, 1, 0);
        switch (Op) {
        case CSG_A:
                one(A);
                break;
        case CSG_B:
                one(B);
                break;
        case CSG_A_OR_B:
                Or(A, B);
                break;
        case CSG_A_AND_B:
                And(A, B);
                break;
        case CSG_A_SUB_B:
                sub(A, B);
                break;
        case CSG_B_SUB_A:
                sub(B, A);
                break;
        }
        glPopMatrix();
        glFlush();
}

void keyboard(unsigned char key, int x, int y)
{
        switch (key) {
        case 'c':
                if (A == cube && B == sphere) {
                        A = sphere;
                        B = cone;
                }
                else if (A == sphere && B == cone) {
                        A = cone;
                        B = cube;
                }
                else { // if(A == cone && B == cube)
                        A = cube;
                        B = sphere;
                }
                break;
        case 'a':
                Op = CSG_A;
                break;
        case 'b':
                Op = CSG_B;
                break;
        case '|':
                Op = CSG_A_OR_B;
                break;
        case '&':
                Op = CSG_A_AND_B;
                break;
        case '-':
                Op = CSG_A_SUB_B;
                break;
        case '_':
                Op = CSG_B_SUB_A;
                break;
        case 'z':
                zoom -= 6.0;
                reshape(Width, Height);
                break;
        case 'Z':
                zoom += 6.0;
                reshape(Width, Height);
                break;
```

```c
        case 27:
                exit(0);
                break;
        case '\r':
                break;
        default:
                return;
        }

        glutPostRedisplay();
}

void menu(int item)  //mouse and keyboard can control the display altogether
{
        keyboard((unsigned char)item, 0, 0);
}

int main(int argc, char** argv)
{
        int ops, zoom;

        glutInit(&argc, argv);
        glutInitDisplayMode(GLUT_RGB | /*GLUT_DOUBLE |*/ GLUT_DEPTH | GLUT_STENCIL);
        glutInitWindowPosition(100, 100);
        glutInitWindowSize(500, 500);
        glutCreateWindow("CSG Operations Demo");

        glutDisplayFunc(display);
        glutReshapeFunc(reshape);
        glutKeyboardFunc(keyboard);

        ops = glutCreateMenu(menu);
        glutAddMenuEntry("A only          (a)", 'a');
        glutAddMenuEntry("B only          (b)", 'b');
        glutAddMenuEntry("A or B          (|)", '|');
        glutAddMenuEntry("A and B         (&)", '&');
        glutAddMenuEntry("A sub B         (-)", '-');
        glutAddMenuEntry("B sub A         (_)", '_');
        zoom = glutCreateMenu(menu);
        glutAddMenuEntry("Zoom decrease   (z)", 'z');
        glutAddMenuEntry("Zoom increase   (Z)", 'Z');
        glutCreateMenu(menu);
        glutAddMenuEntry("CSG Operations Demo", '\0');
        glutAddMenuEntry("                   ", '\0');
        glutAddSubMenu("Operations         ", ops);
        glutAddSubMenu("Zoom               ", zoom);
        glutAddMenuEntry("                   ", '\0');
        glutAddMenuEntry("Change shapes   (c)", 'c');
        glutAddMenuEntry("                   ", '\0');
        glutAddMenuEntry("Quit          (Esc)", '\033');
        glutAttachMenu(GLUT_RIGHT_BUTTON);

        init();

        A = cube;
        B = sphere;

        glutMainLoop();
}
```