Assignment 8: Curves & Surfaces

1 代码实现

1.1 Spline

```
class Spline
{
public:

    Spline()
    {
        B_Bezier = getB_Bezier();
        B_BSpline = getB_BSpline();
        B_BezierToB_BSpline = getB_BesierToB_BSpline();
        B_BSplineToB_Bezier = getB_BSplinerToB_Bezier();
    }


    // FOR VISUALIZATION
    virtual void Paint(ArgParser* args)
    {

    }

    // FOR CONVERTING BETWEEN SPLINE TYPES
    virtual void OutputBezier(FILE* file)
    {

    }
    virtual void OutputBSpline(FILE* file)
    {

    }

    // FOR CONTROL POINT PICKING
    virtual int getNumVertices()
    {
        return controlPoints.size();
    }
    virtual Vec3f getVertex(int i)
    {
        return controlPoints[i];
    }

    // FOR EDITING OPERATIONS
    virtual void moveControlPoint(int selectedPoint, float x, float y)
    {
        controlPoints[selectedPoint].Set(0, x);
        controlPoints[selectedPoint].Set(1, y);
    }


    virtual void set(int index, Vec3f point)
    {
        controlPoints.insert(controlPoints.begin() + index, point);
        updateNumSplines();

    }

    virtual void addControlPoint(int selectedPoint, float x, float y)
    {
        controlPoints.insert(controlPoints.begin() + selectedPoint, Vec3f(x, y,
0));
        updateNumSplines();

    }

    virtual void deleteControlPoint(int selectedPoint)
    {
        controlPoints.erase(controlPoints.begin() + selectedPoint);
        updateNumSplines();
    }

    // FOR GENERATING TRIANGLES
    virtual TriangleMesh* OutputTriangles(ArgParser* args)
    {
        return NULL;
    }


    virtual Vec3f Q(float t)
    {
        return Vec3f(1, 1, 1);
    }


protected:
    Matrix B_Bezier;
    Matrix B_BSpline;
    Matrix B;
    Matrix B_BezierToB_BSpline;
    Matrix B_BSplineToB_Bezier;
    vector<Vec3f> controlPoints;
    int numSplines;

    Vec4f getT(float t)
    {
        //assert(t >= 0 && t <= 1);
        float power = 1;
        Vec4f T;
        for (int i = 0; i < 4; i++)
        {
            T.Set(i, power);
            power *= t;
        }
        return T;
    }


private:
    virtual void updateNumSplines()
    {

    }


};
```

1.2 Q函数的实现

曲线的Q函数为给定参数计算贝塞尔曲线插值点的函数

实现了插值点的复用以支持不为3整数倍和个数小于3的控制点

t的有效范围为 0-numSplines

贝塞尔曲线的Q函数

```
    virtual Vec3f Q(float t)
    {
        assert(numSplines > 0);
        int splineIndex;

        splineIndex = floor(t);

        if (splineIndex >= numSplines)
        {
            splineIndex = numSplines - 1;
        }
        else if (splineIndex < 0)
        {
            splineIndex = 0;
        }

        t = t - splineIndex;
        Vec3f localControlPoints[4];
        assert(controlPoints.size() > 3 * splineIndex);
        for (int i = 0; i < 4; i++)
        {
            if (controlPoints.size() > 3 * splineIndex + i)
            {
                localControlPoints[i] = controlPoints[3 * splineIndex + i];
            }
            else
            {
                localControlPoints[i] = localControlPoints[i-1];
            }
        }

        Vec3f Q;
        Vec4f T = getT(t);
        B.Transform(T);

        Matrix G;
        G.Clear();
        for (int i = 0; i < 3; i++)
        {
            for (int j = 0; j < 4; j++)
            {
                G.Set(j, i, localControlPoints[j][i]);
            }
        }

        G.Transform(T);

        Q.Set(T[0], T[1], T[2]);

        return Q;
    }
```

B样条曲线的Q函数

```
    virtual Vec3f Q(float t)
    {
        assert(numSplines > 0);

        int splineIndex;

        splineIndex = floor(t);
        if (splineIndex >= numSplines)
        {
            splineIndex = numSplines - 1;
        }
        else if (splineIndex < 0)
        {
            splineIndex = 0;
        }

        t = t - splineIndex;

        Vec3f localControlPoints[4];
        assert(controlPoints.size() > 0);
        for (int i = 0; i < 4; i++)
        {

            if(controlPoints.size() > splineIndex + i)
            {
                localControlPoints[i] = controlPoints[splineIndex + i];
            }
            else
            {
                localControlPoints[i] = localControlPoints[i - 1];
            }
        }

        Vec3f Q;
        Vec4f T = getT(t);
        B.Transform(T);


        Matrix G;
        G.Clear();
        for (int i = 0; i < 3; i++)
        {
            for (int j = 0; j < 4; j++)
            {
                G.Set(j, i, localControlPoints[j][i]);
            }
        }

        G.Transform(T);

        Q.Set(T[0], T[1], T[2]);

        return Q;
    }
```

1.3 Curve::Paint

Paint函数通过生成一系列离散的t值调用Q函数获取插值点并在OpenGL中绘制

```
    virtual void Paint(ArgParser* args)
    {

        if (numSplines <= 0)
        {
            return;
        }

        glLineWidth(3);
        glColor3f(0, 0, 1);
        glBegin(GL_LINE_STRIP);
        for (auto i = controlPoints.begin(); i != controlPoints.end(); i++)
        {
            glVertex3f(i->x(), i->y(), i->z());
        }
        glEnd();

        glLineWidth(3);
        glColor3f(0, 1, 0);
        glBegin(GL_LINE_STRIP);
        float step= 1.0 / (float)args->curve_tessellation;
        float t = 0;

        for (int i = 0; i < numSplines; i++)
        {
            t = i;
            for (int j = 0; j <= args->curve_tessellation; j++)
            {
                Vec3f vertex = Q(t);
                glVertex3f(vertex[0], vertex[1], vertex[2]);
                t += step;
            }
        }
        glEnd();

        //control points
        glPointSize(5);
        glColor3f(1, 0, 0);
        glBegin(GL_POINTS);
        for (auto i = controlPoints.begin(); i != controlPoints.end(); i++)
        {
            glVertex3f(i->x(), i->y(), i->z());
        }
        glEnd();
    }
```

1.4 贝塞尔曲线和B样条曲线转换

使用基矩阵的逆实现转换

贝塞尔转B样条

```
    //G_BSpline = G_Bezier * B_BSplineToB_Bezier
    virtual void OutputBSpline(FILE* file)
    {
        Matrix G_Bezier;
        G_Bezier.Clear();
        for (int i = 0; i < 3; i++)
        {
            for (int j = 0; j < 4; j++)
            {
                G_Bezier.Set(j, i, controlPoints[j][i]);
            }
        }

        Matrix G_BSpline = G_Bezier * B_BSplineToB_Bezier;
        fprintf(file, "bspline ");
        fprintf(file, "num_vertices %d", 4);
        for (int i = 0; i < 4; i++)
        {
            fprintf(file, " %f %f %f", G_BSpline.Get(i,0), G_BSpline.Get(i, 1),
G_BSpline.Get(i, 2));
        }
        fprintf(file, "\n");



    }
```

B样条转贝塞尔

```
    //G_Bezier = G_BSpline * B_BezierToB_BSpline
    virtual void OutputBezier(FILE* file)
    {
        Matrix G_BSpline;
        G_BSpline.Clear();
        for (int i = 0; i < 3; i++)
        {
            for (int j = 0; j < 4; j++)
            {
                G_BSpline.Set(j, i, controlPoints[j][i]);
            }
        }
        Matrix G_Bezier = G_BSpline * B_BezierToB_BSpline;

        fprintf(file, "bezier ");
        fprintf(file, "num_vertices %d", 4);
        for (int i = 0; i < 4; i++)
        {
            fprintf(file, " %f %f %f", G_Bezier.Get(i, 0), G_Bezier.Get(i, 1),
G_Bezier.Get(i, 2));
        }
        fprintf(file, "\n");

    }
```

1.5 SurfaceOfRevolution

```
class SurfaceOfRevolution : public Surface
{
public:
    SurfaceOfRevolution(Curve *c):curve(c)
    {
    }

    virtual void Paint(ArgParser* args)
    {
        curve->Paint(args);
    }

    // FOR GENERATING TRIANGLES
    virtual TriangleMesh* OutputTriangles(ArgParser* args)
    {
        return curve->OutputTriangles(args);
    }


    virtual void addControlPoint(int selectedPoint, float x, float y)
    {
        curve->addControlPoint(selectedPoint, x, y);
    }

    virtual void deleteControlPoint(int selectedPoint)
    {
        curve->deleteControlPoint(selectedPoint);
    }


    virtual void moveControlPoint(int selectedPoint, float x, float y)
    {
        curve->moveControlPoint(selectedPoint, x, y);
    }


    // FOR CONVERTING BETWEEN SPLINE TYPES
    virtual void OutputBezier(FILE* file)
    {
        curve->OutputBezier(file);
    }
    virtual void OutputBSpline(FILE* file)
    {
        curve->OutputBSpline(file);
    }

    // FOR CONTROL POINT PICKING
    virtual int getNumVertices()
    {
        return curve->getNumVertices();
    }
    virtual Vec3f getVertex(int i)
    {
        return curve->getVertex(i);
    }

    virtual void set(int index, Vec3f point)
    {
        curve->set(index, point);
    }


private:
    Curve* curve;
};
```

1.6 OutputTriangle

```
    // FOR GENERATING TRIANGLES
    virtual TriangleMesh* OutputTriangles(ArgParser* args)
    {
        TriangleNet* triangleNet=new TriangleNet(args-
>revolution_tessellation,args->curve_tessellation*numSplines);


        float uStep = 2.0f * PI / (float) args->revolution_tessellation;
        float vStep = 1.0f / (float)args->curve_tessellation;
        float phi = 0;

        for (int k = 0; k <= args->revolution_tessellation; k++)
        {
            float cosPhi = cosf(phi);
            float sinPhi = sinf(phi);
            for (int i = 0; i < numSplines; i++)
            {
                float t = i;
                for (int j = 0; j <= args->curve_tessellation; j++)
                {
                    Vec3f vertex = Q(t);
                    float length = sqrtf(powf(vertex.x(), 2) + powf(vertex.z(),
2));
                    triangleNet->SetVertex( k , i * args->curve_tessellation +
j, Vec3f(length*cosPhi,vertex.y(), length *sinPhi));
                    t += vStep;
                }
            }

            phi += uStep;
        }
        return triangleNet;

    }
```

#####

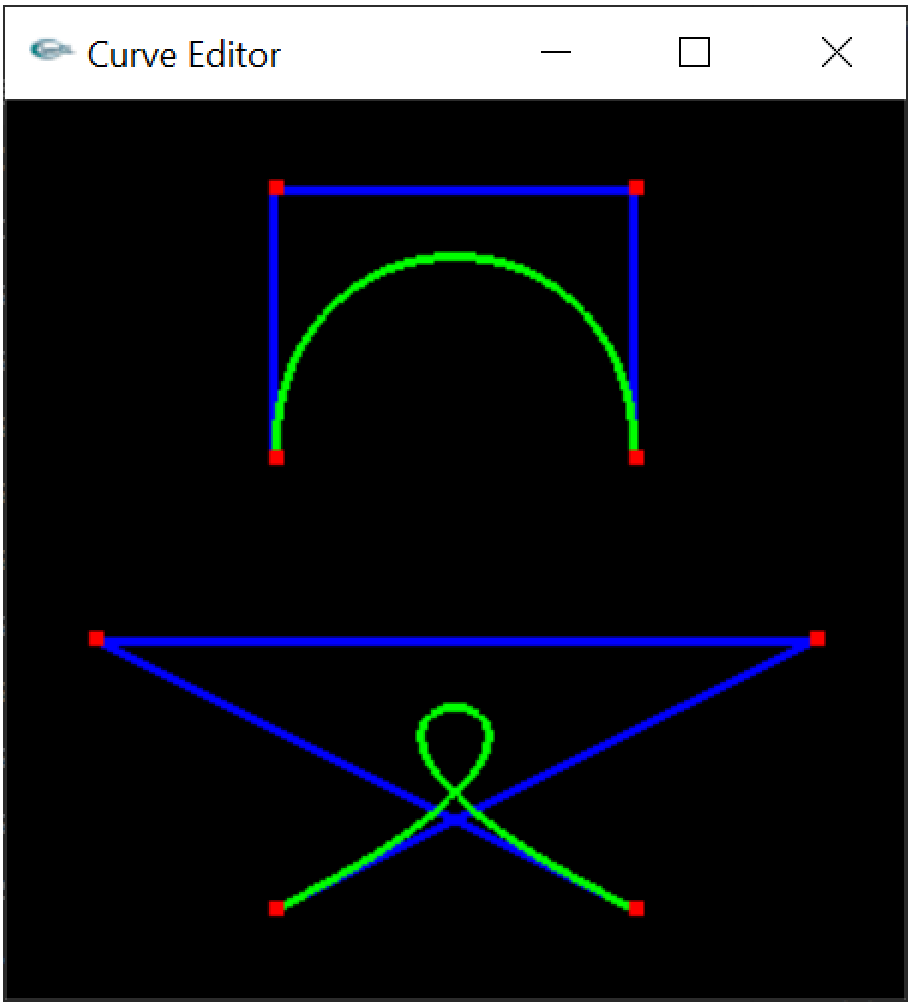
1.7 BezierPatch

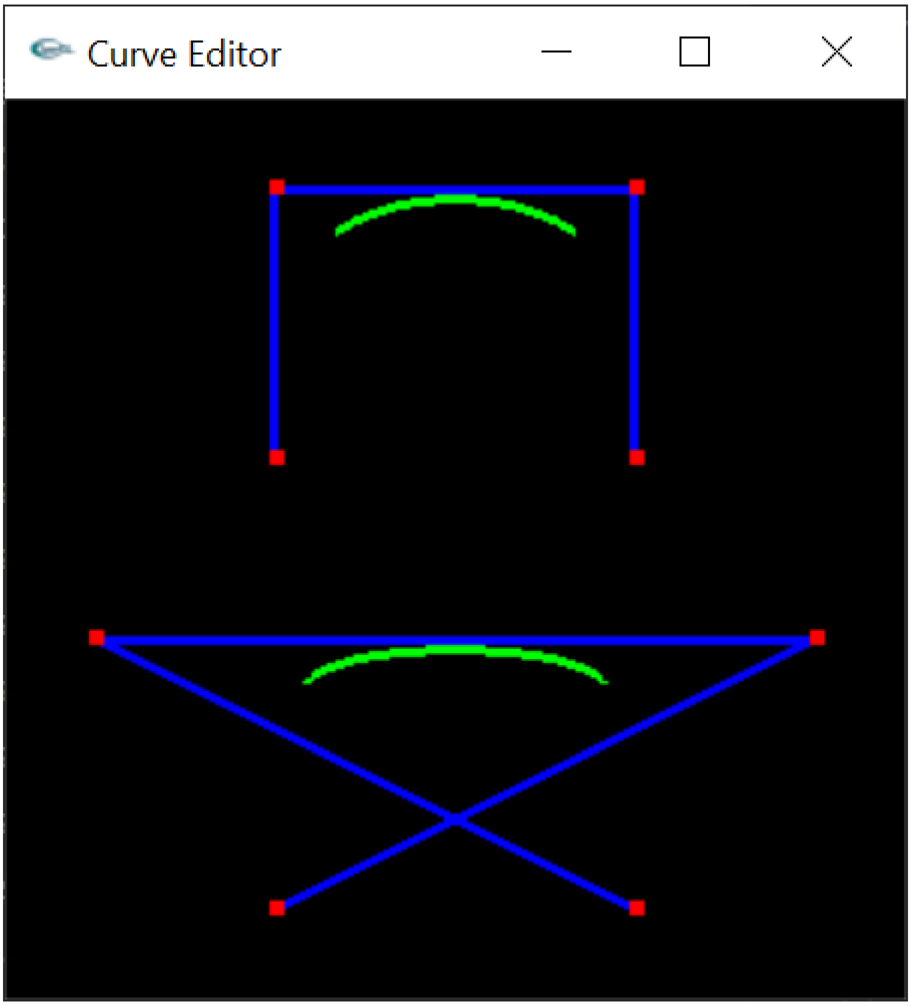
由8个贝塞尔曲线组成

```
class BezierPatch : public Surface
{
public:
    BezierPatch()
    {
        controlPoints.reserve(16);

        for (int i = 0; i < 4; i++)
        {
            uBezierCurves[i] = new BezierCurve(4);
            vBezierCurves[i] = new BezierCurve(4);
        }

    }

    virtual void set(int index, Vec3f point)
    {
        controlPoints.insert(controlPoints.begin() + index, point);
        if (controlPoints.size() == 16)
        {
            for (int i = 0; i < 4; i++)
            {
                for (int j = 0; j < 4; j++)
                {
                    uBezierCurves[i]->set(j, controlPoints[i * 4 + j]);
                    vBezierCurves[i]->set(j, controlPoints[j * 4 + i]);
                }
            }
        }
    }

    virtual void Paint(ArgParser* args)
    {

        for (int i = 0; i < 4; i++)
        {
            uBezierCurves[i]->Paint(args);
            vBezierCurves[i]->Paint(args);
        }
    }

    virtual TriangleMesh* OutputTriangles(ArgParser* args)
    {
        float step = 1.0 / (float)args->patch_tessellation;
        TriangleNet* triangleNet = new TriangleNet(args->patch_tessellation, args->patch_tessellation);

        float u = 0;
        for (int i = 0; i <= args->patch_tessellation; i++)
        {
            BezierCurve newCurve(4);
            for (int k = 0; k < 4; k++)
            {
                newCurve.set(k, uBezierCurves[k]->Q(u));
            }

            float v = 0;
            for (int j = 0; j <= args->patch_tessellation; j++)
            {
                Vec3f vertex=newCurve.Q(v);
                triangleNet->SetVertex(i, j, vertex);
                v += step;
            }
            u += step;
        }

        return triangleNet;
    }



private:
    BezierCurve* uBezierCurves[4];
    BezierCurve* vBezierCurves[4];


};
```

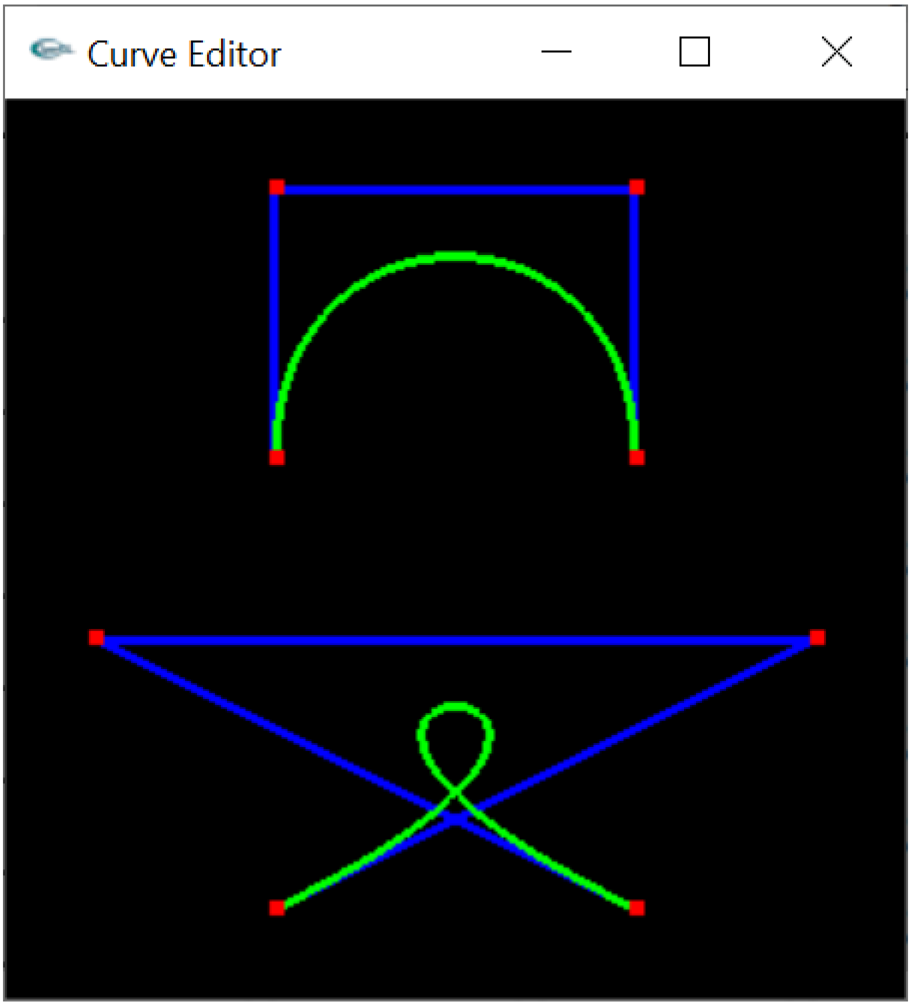
2 实验结果

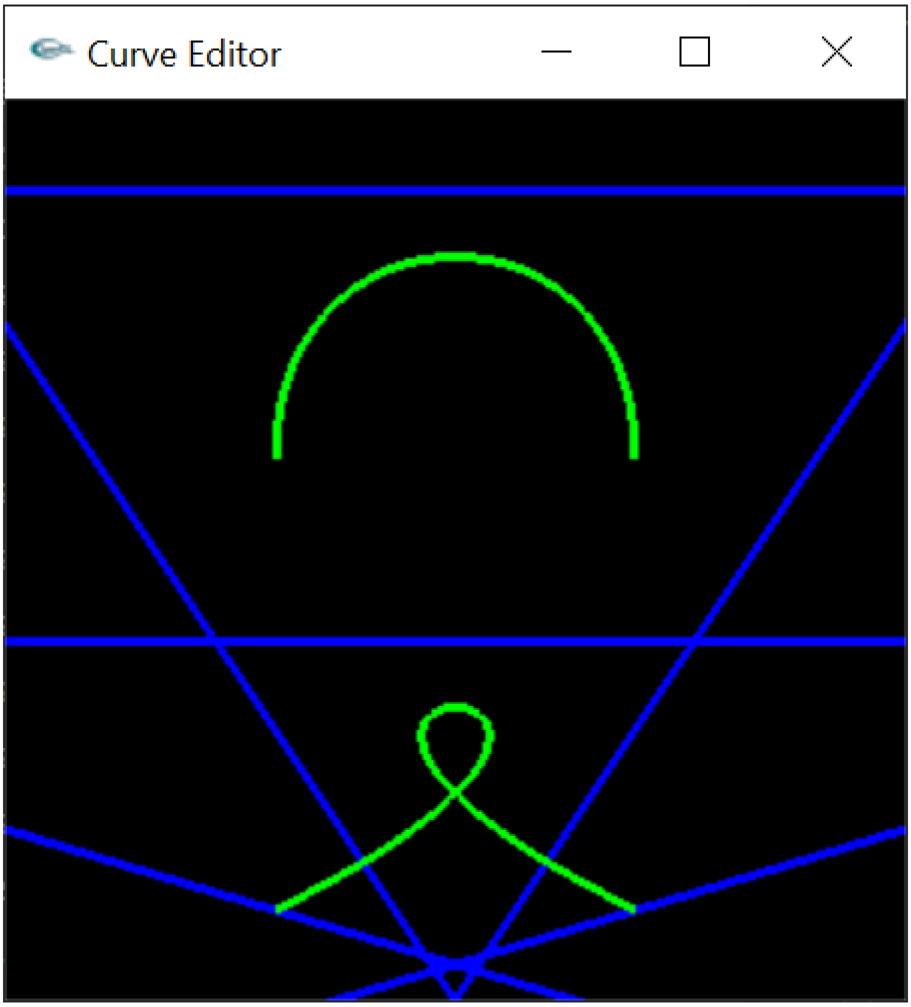
```
curve_editor -input spline8_01_bezier.txt -gui -curve_tessellation 30
curve_editor -input spline8_02_bspline.txt -gui -curve_tessellation 30
```

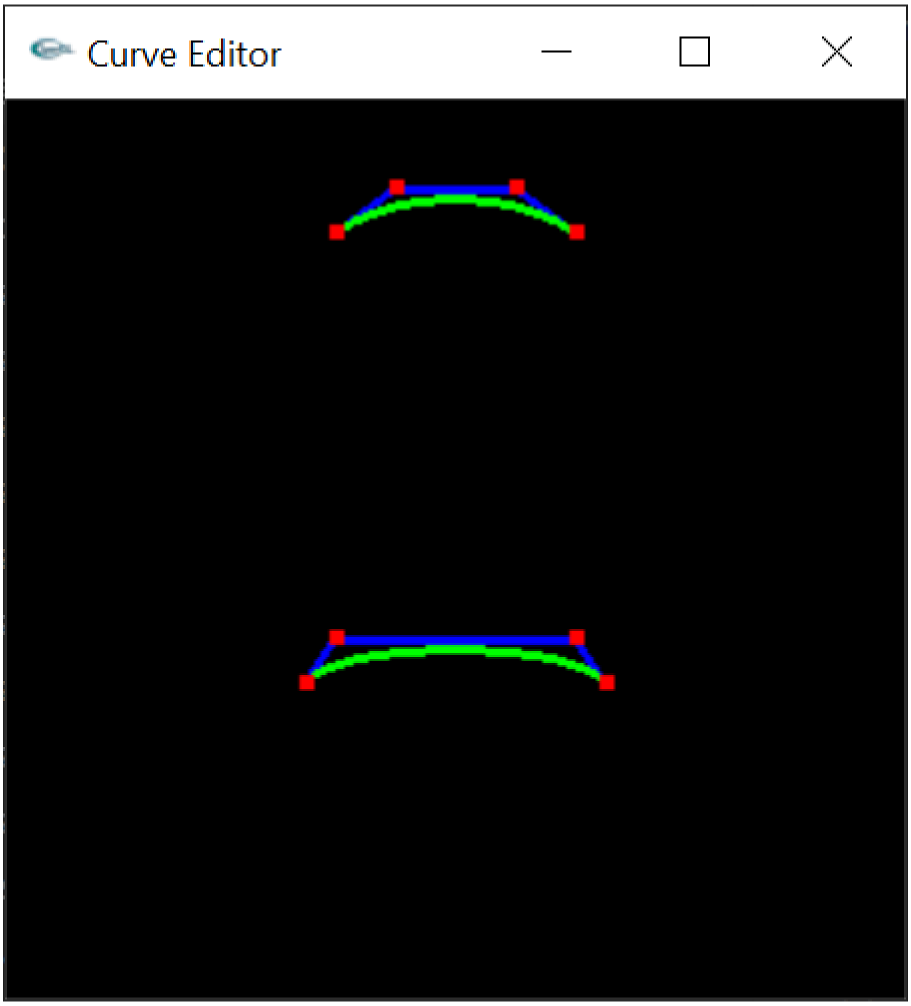




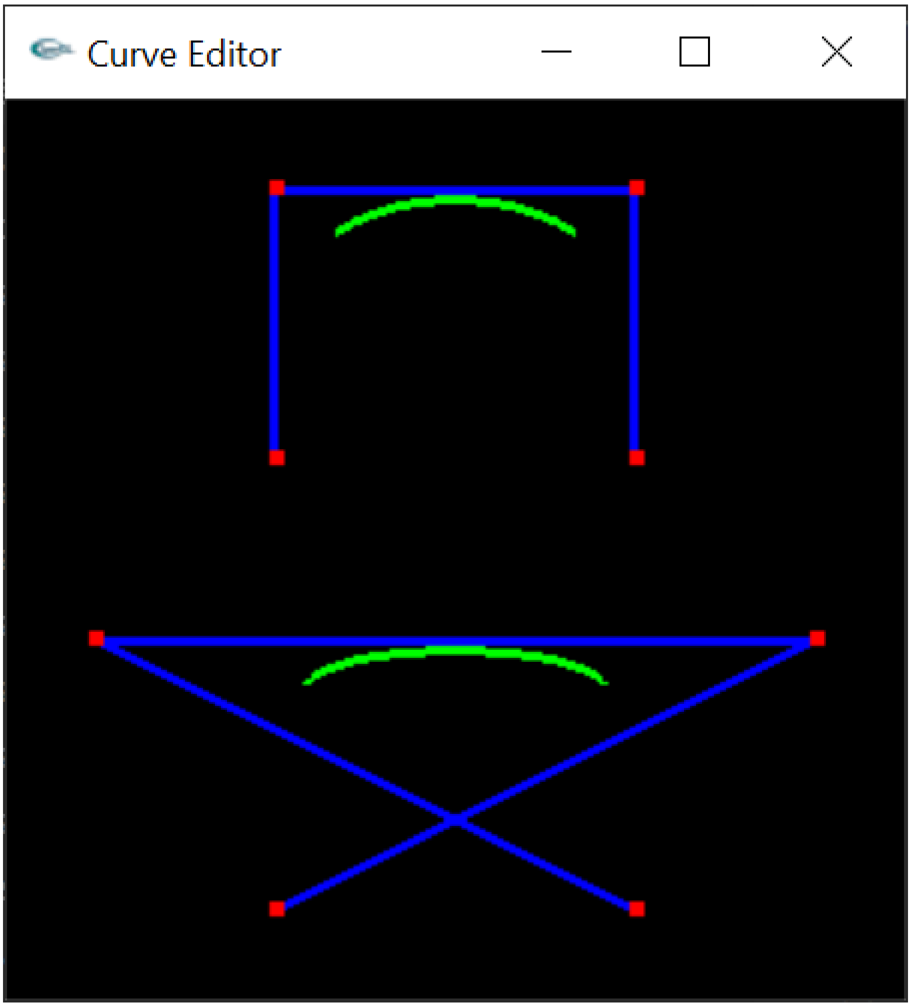
```
curve_editor -input spline8_01_bezier.txt -output_bezier output8_01_bezier.txt
curve_editor -input spline8_01_bezier.txt -output_bspline output8_01_bspline.txt
curve_editor -input spline8_02_bspline.txt -output_bezier output8_02_bezier.txt
curve_editor -input spline8_02_bspline.txt -output_bspline
output8_02_bspline.txt
curve_editor -input output8_01_bezier.txt -gui -curve_tessellation 30
curve_editor -input output8_01_bspline.txt -gui -curve_tessellation 30
curve_editor -input output8_02_bezier.txt -gui -curve_tessellation 30
curve_editor -input output8_02_bspline.txt -gui -curve_tessellation 30
```


Curve Editor


Curve Editor

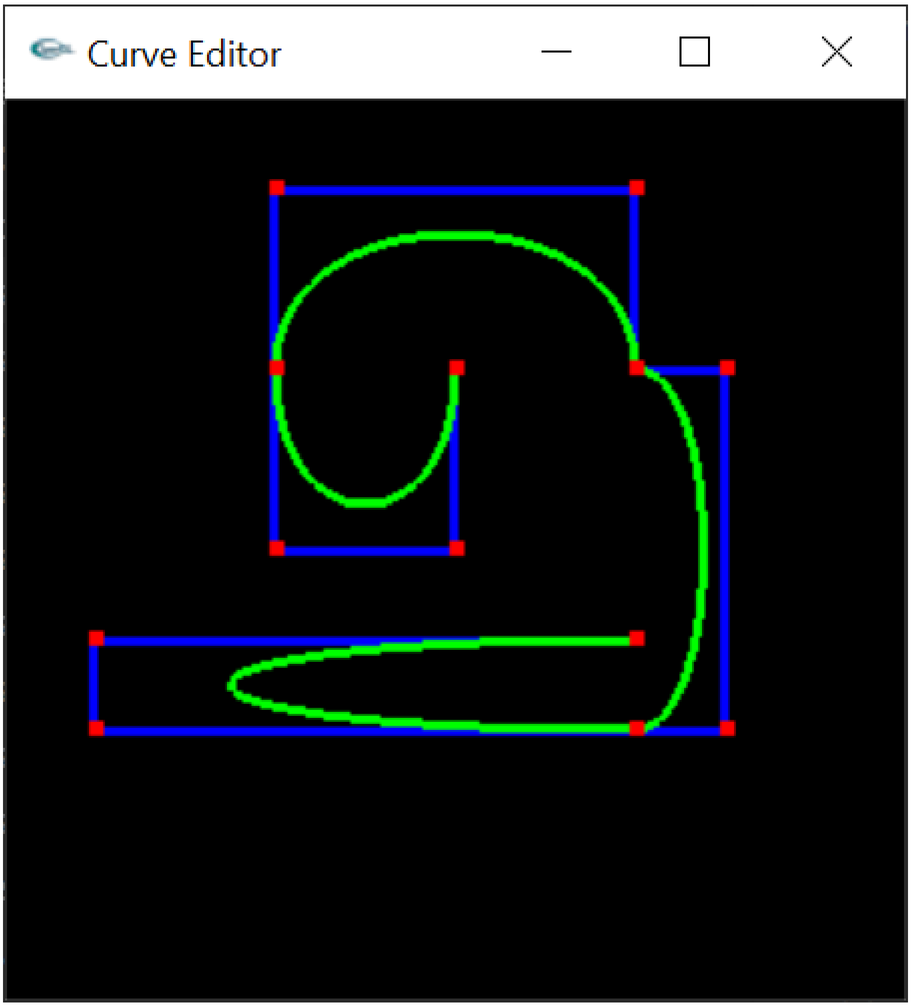


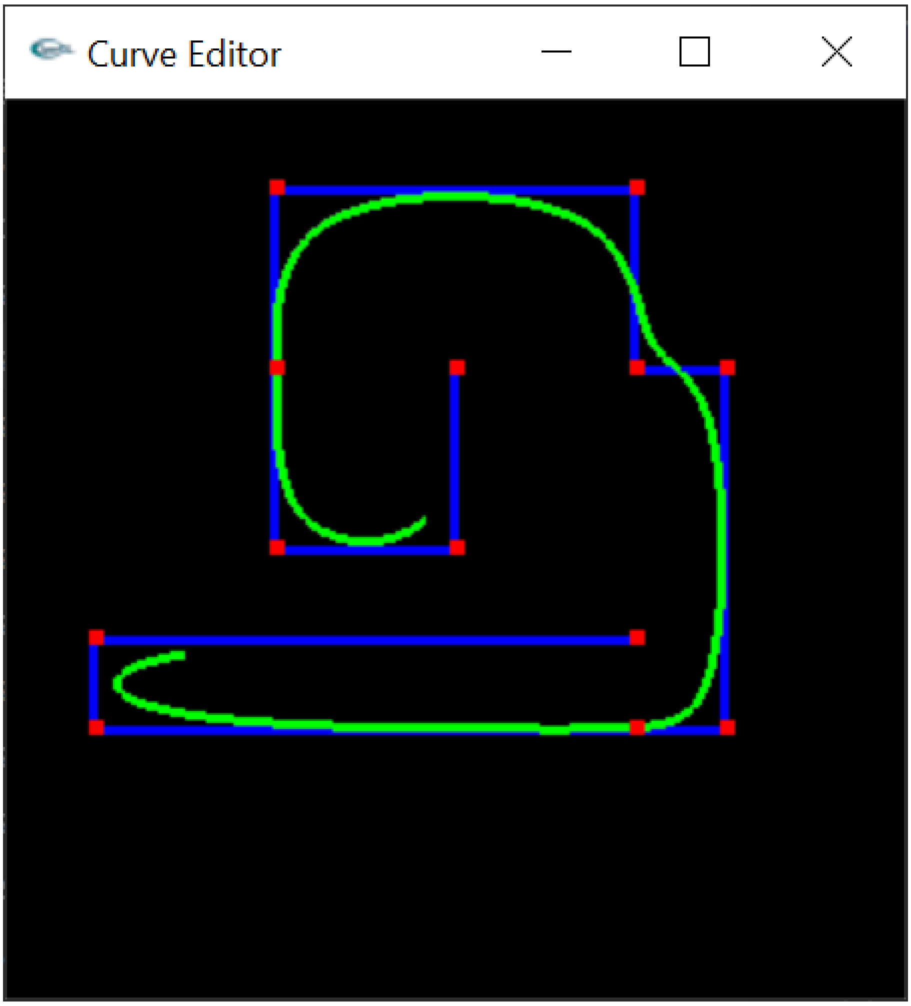
Curve Editor

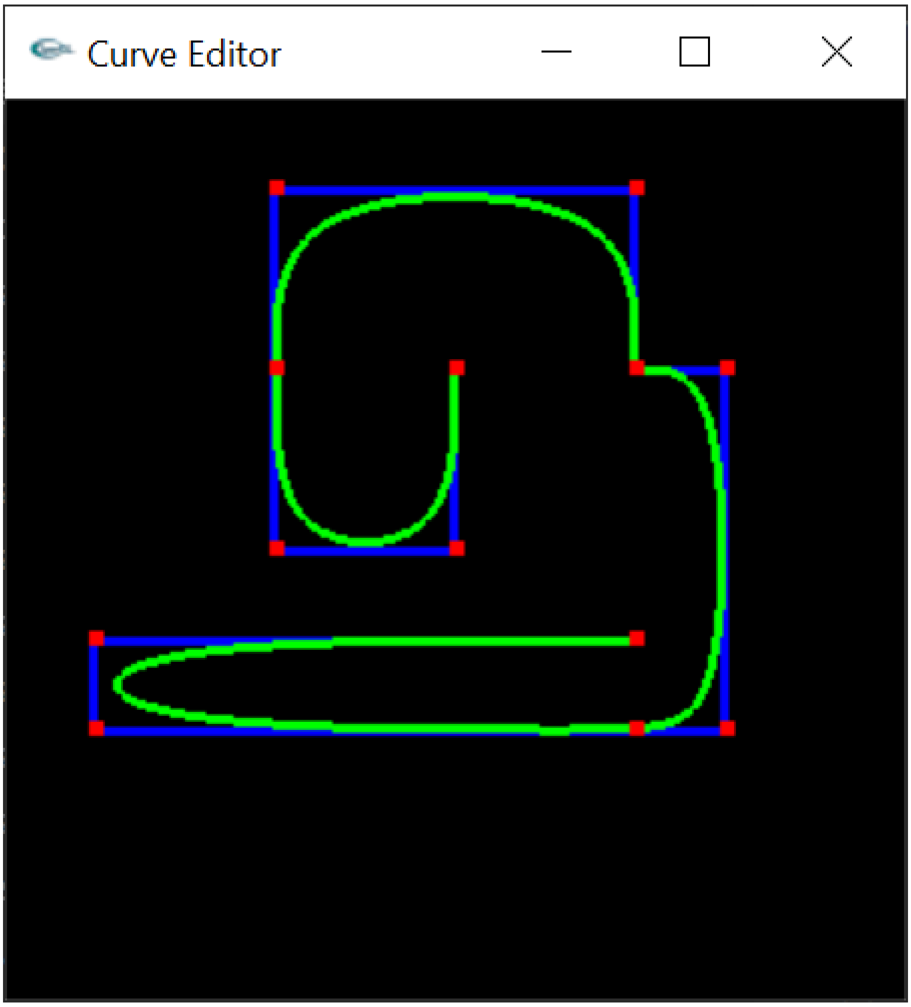


Curve Editor

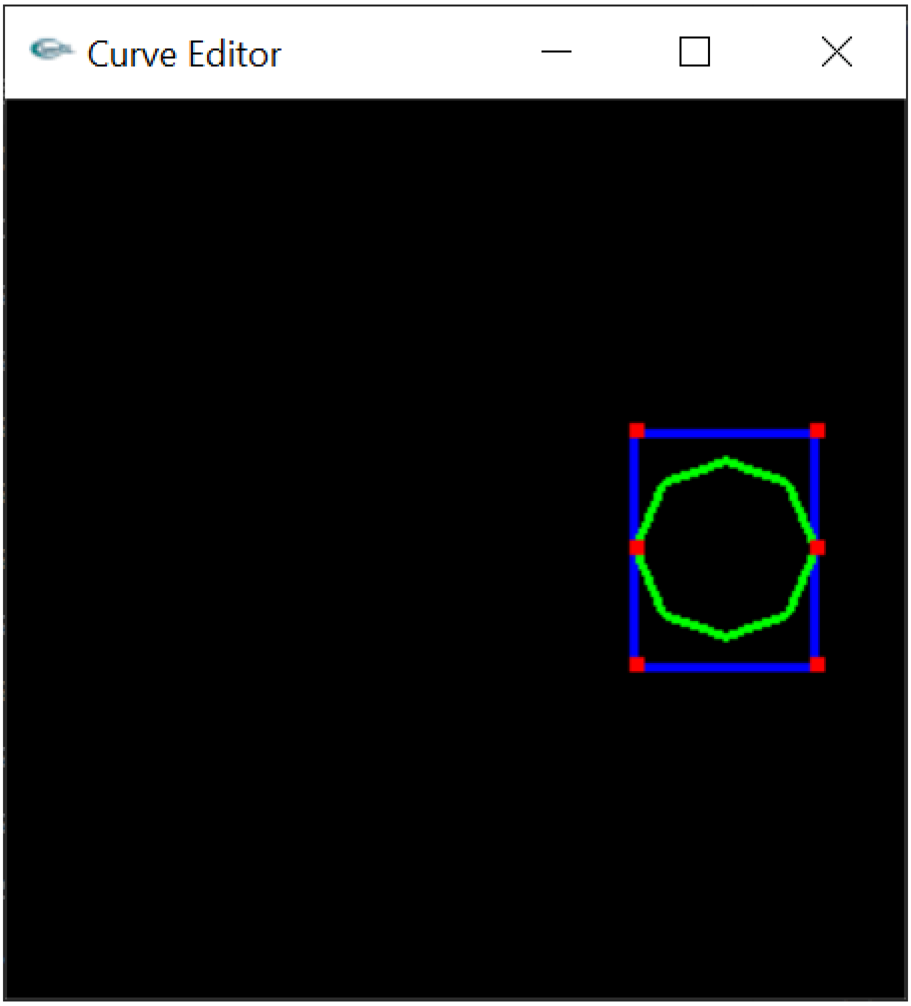
```
curve_editor -input spline8_03_bezier.txt -gui -curve_tessellation 30
curve_editor -input spline8_04_bspline.txt -gui -curve_tessellation 30
curve_editor -input spline8_05_bspline_dups.txt -gui -curve_tessellation 30
```

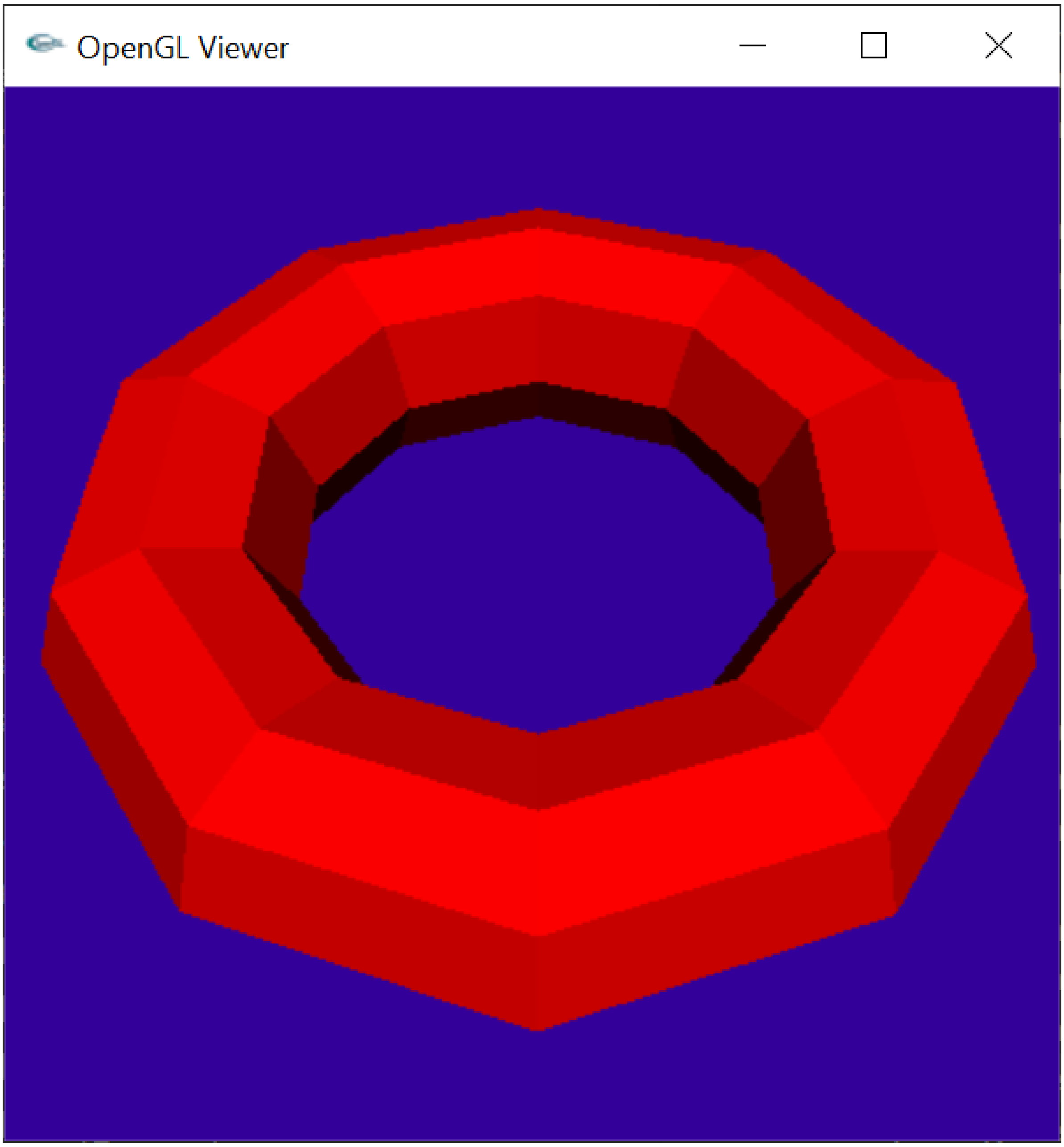



Curve Editor

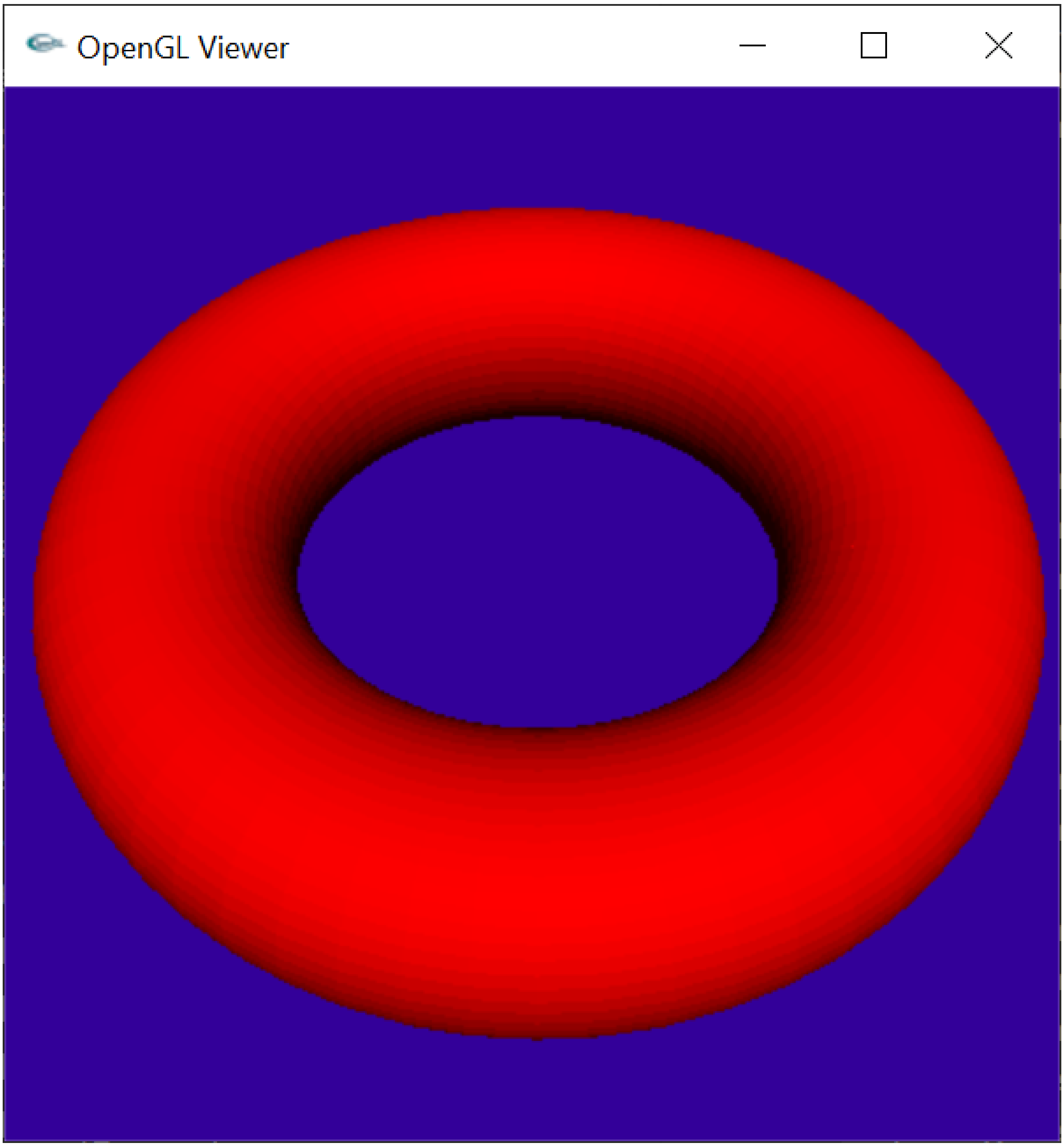

Curve Editor

```
curve_editor -input spline8_06_torus.txt -curve_tessellation 4 -gui
curve_editor -input spline8_06_torus.txt -curve_tessellation 4 -
revolution_tessellation 10 -output torus_low.obj
curve_editor -input spline8_06_torus.txt -curve_tessellation 30 -
revolution_tessellation 60 -output torus_high.obj
raytracer -input scene8_06_torus_low.txt -gui -size 300 300
raytracer -input scene8_06_torus_high.txt -gui -size 300 300
```

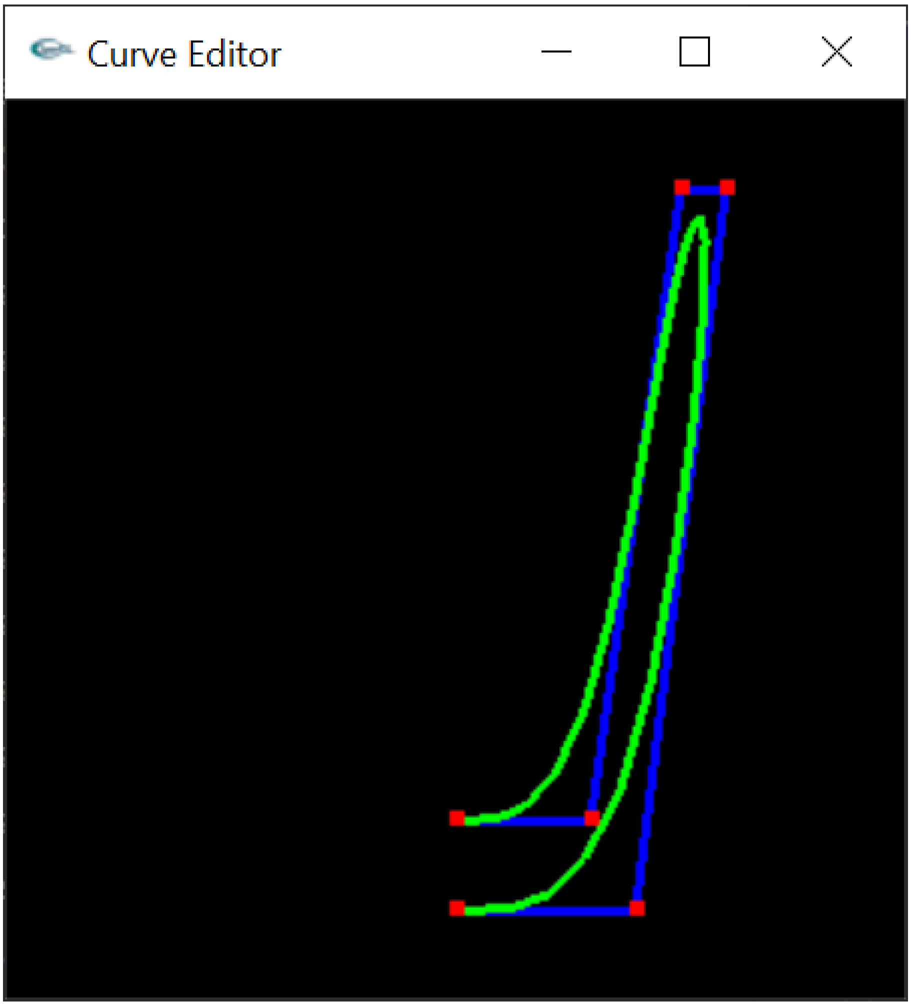




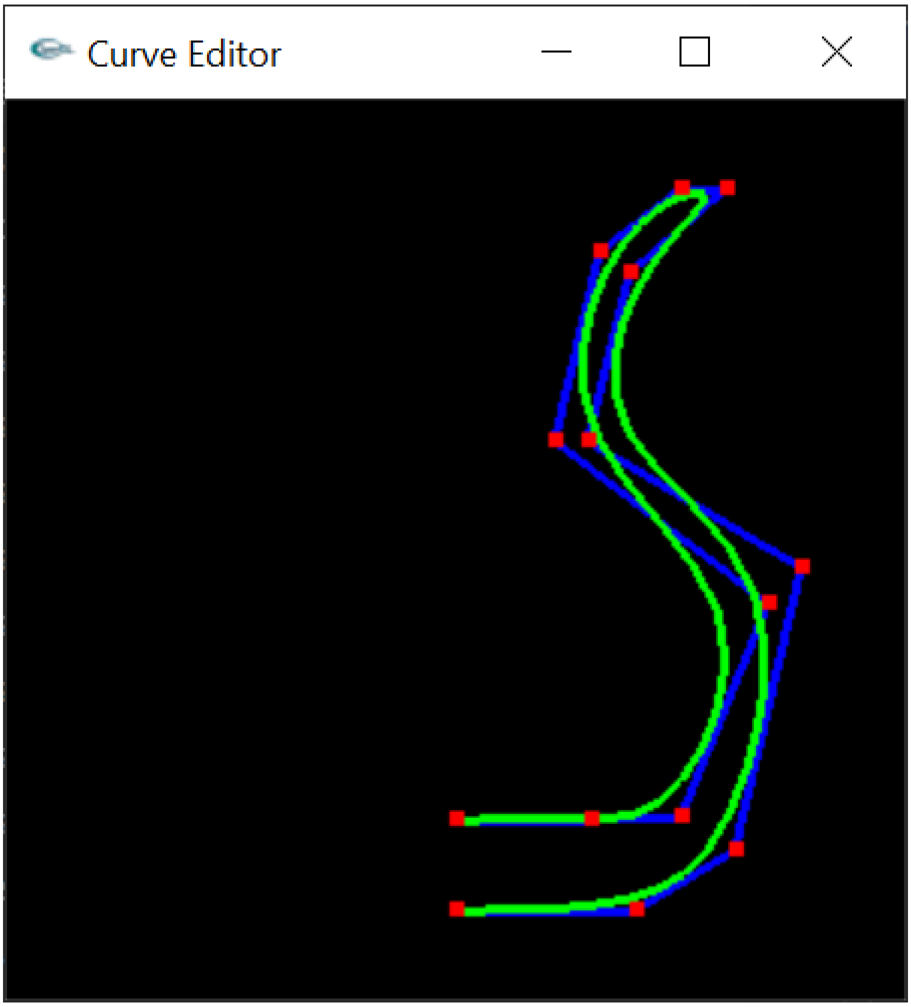
OpenGL Viewer



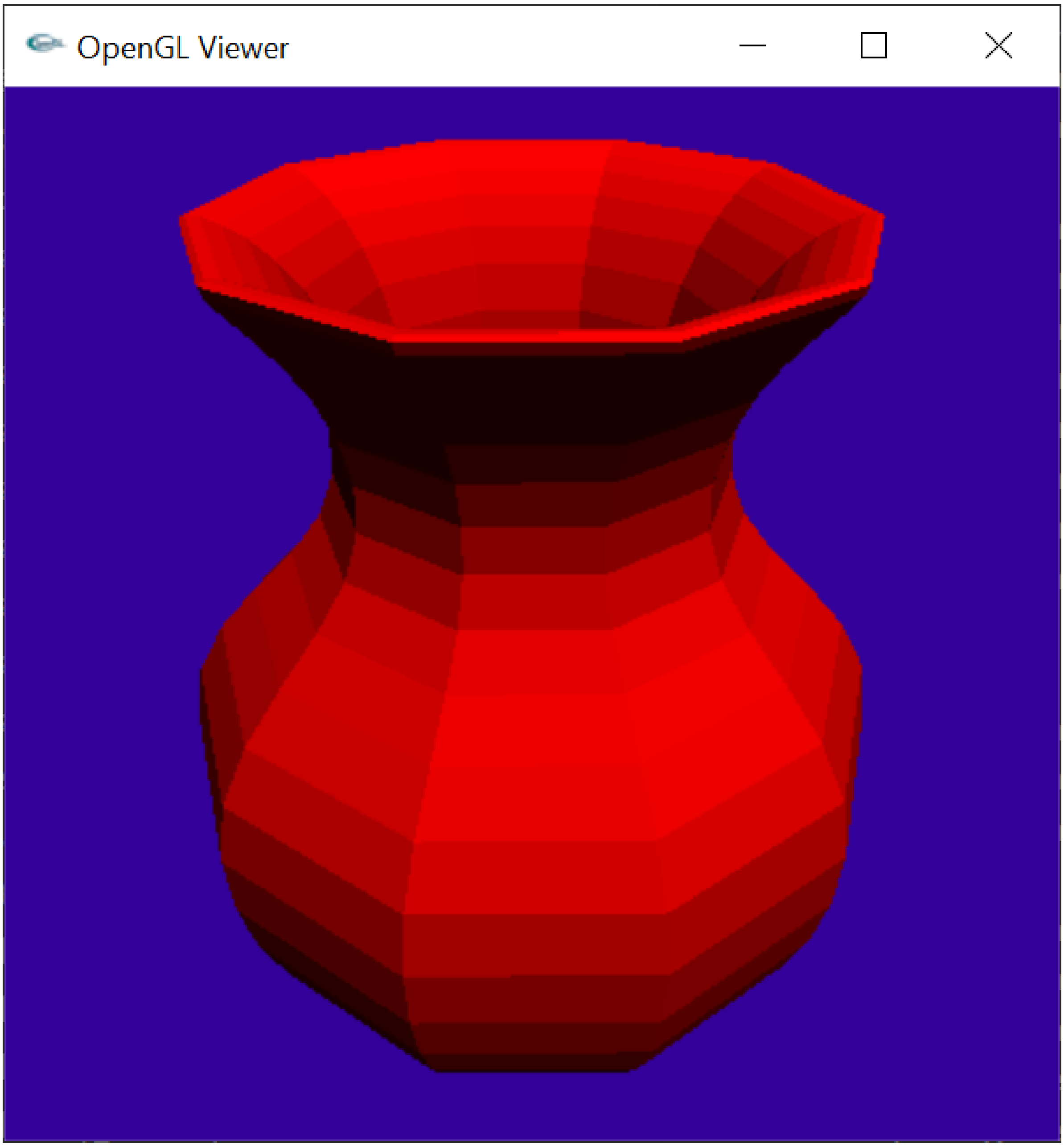
```
curve_editor -input spline8_07_vase.txt -curve_tessellation 4 -output_bspline output8_07_edit.txt -gui
curve_editor -input output8_07_edit.txt -curve_tessellation 4 -revolution_tessellation 10 -output vase_low.obj
curve_editor -input output8_07_edit.txt -curve_tessellation 10 -revolution_tessellation 60 -output vase_high.obj
raytracer -input scene8_07_vase_low.txt -gui -size 300 300
raytracer -input scene8_07_vase_high.txt -gui -size 300 300
```

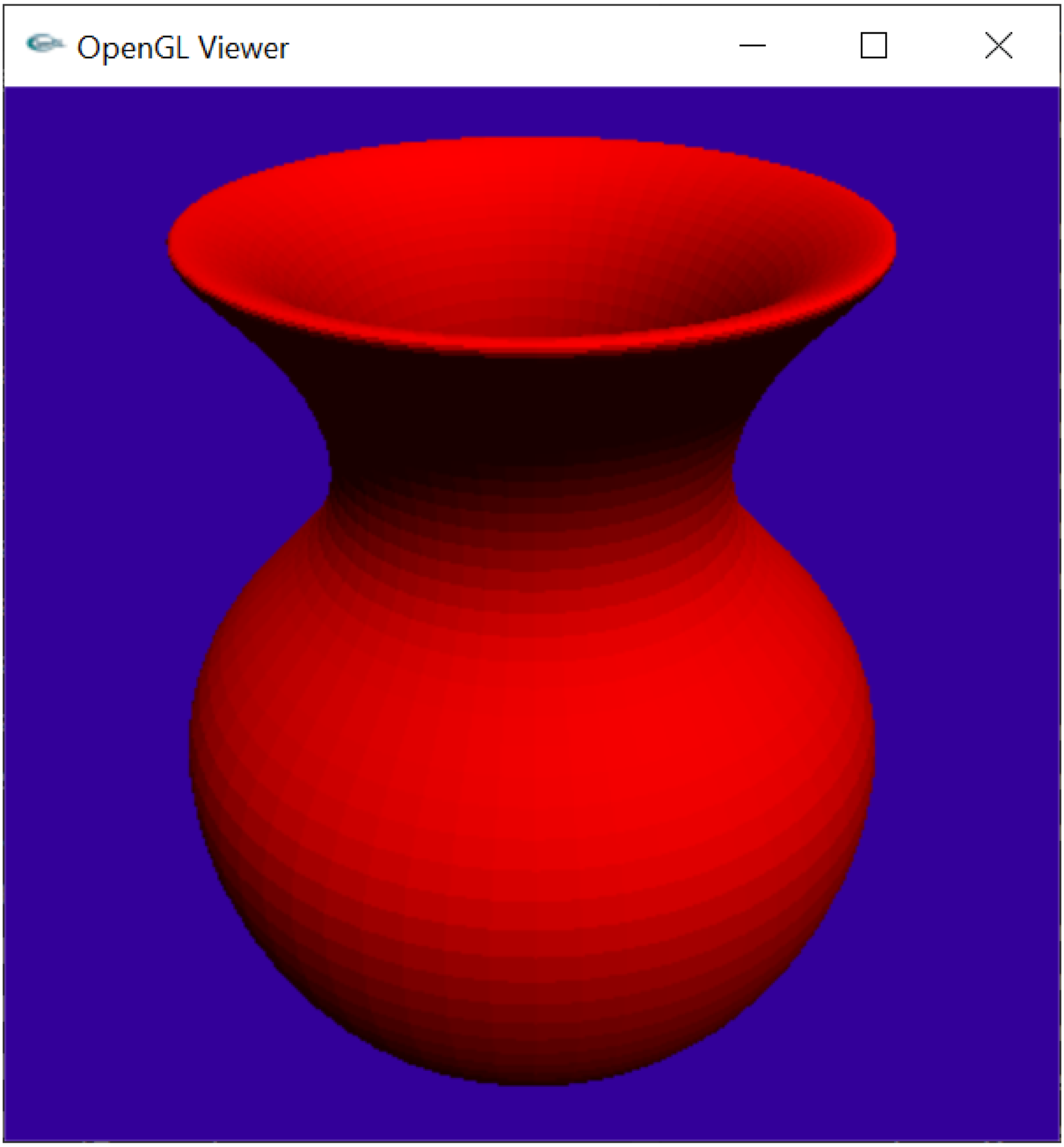


Curve Editor

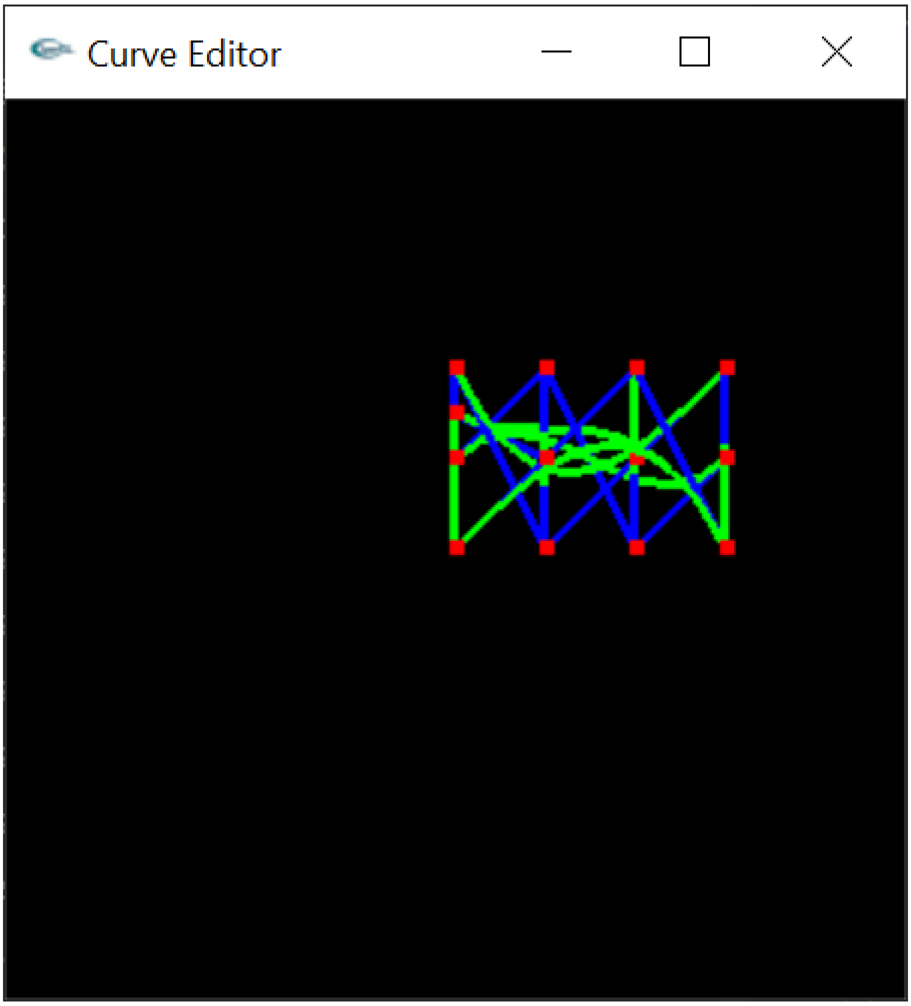


Curve Editor

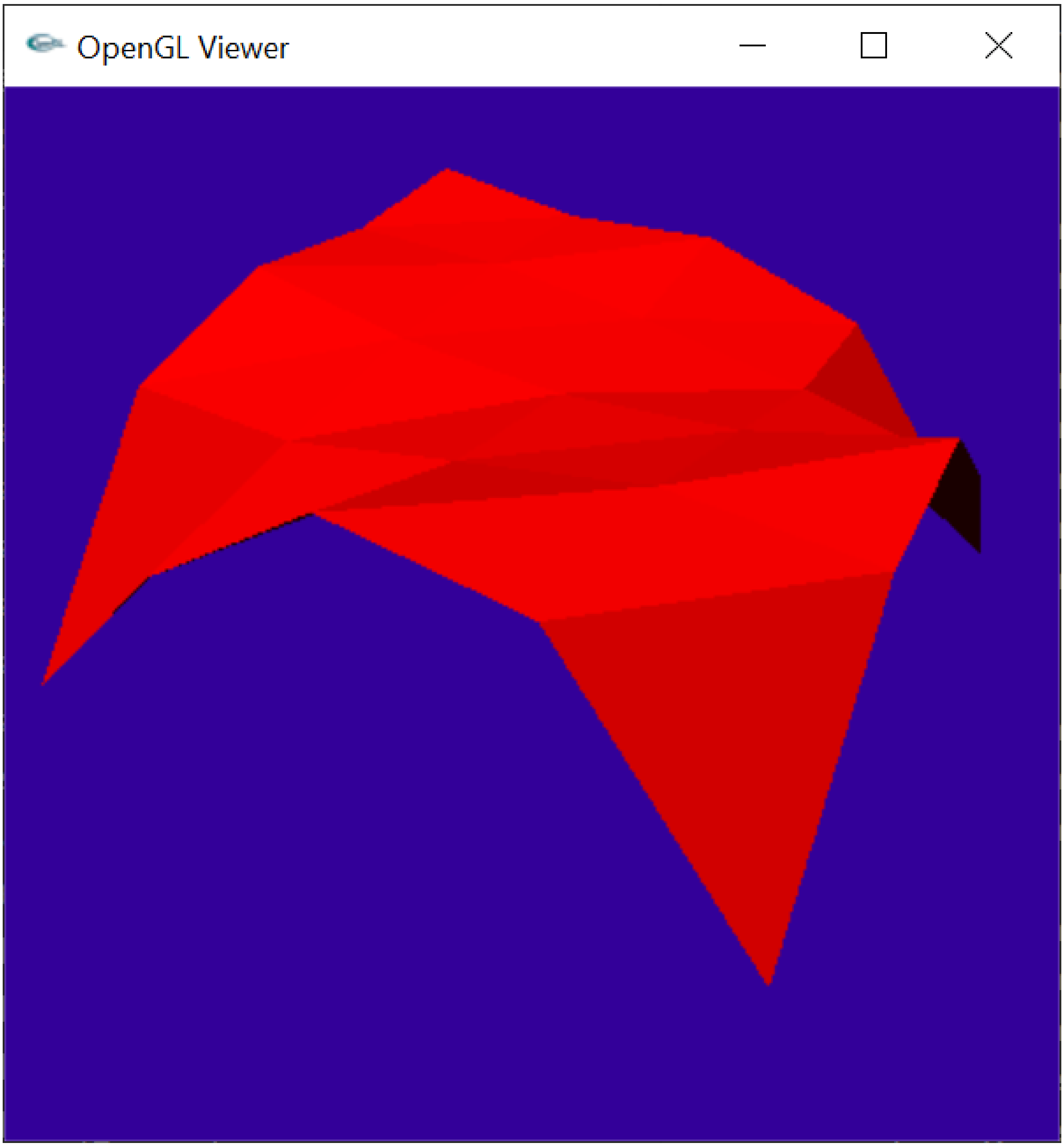

OpenGL Viewer

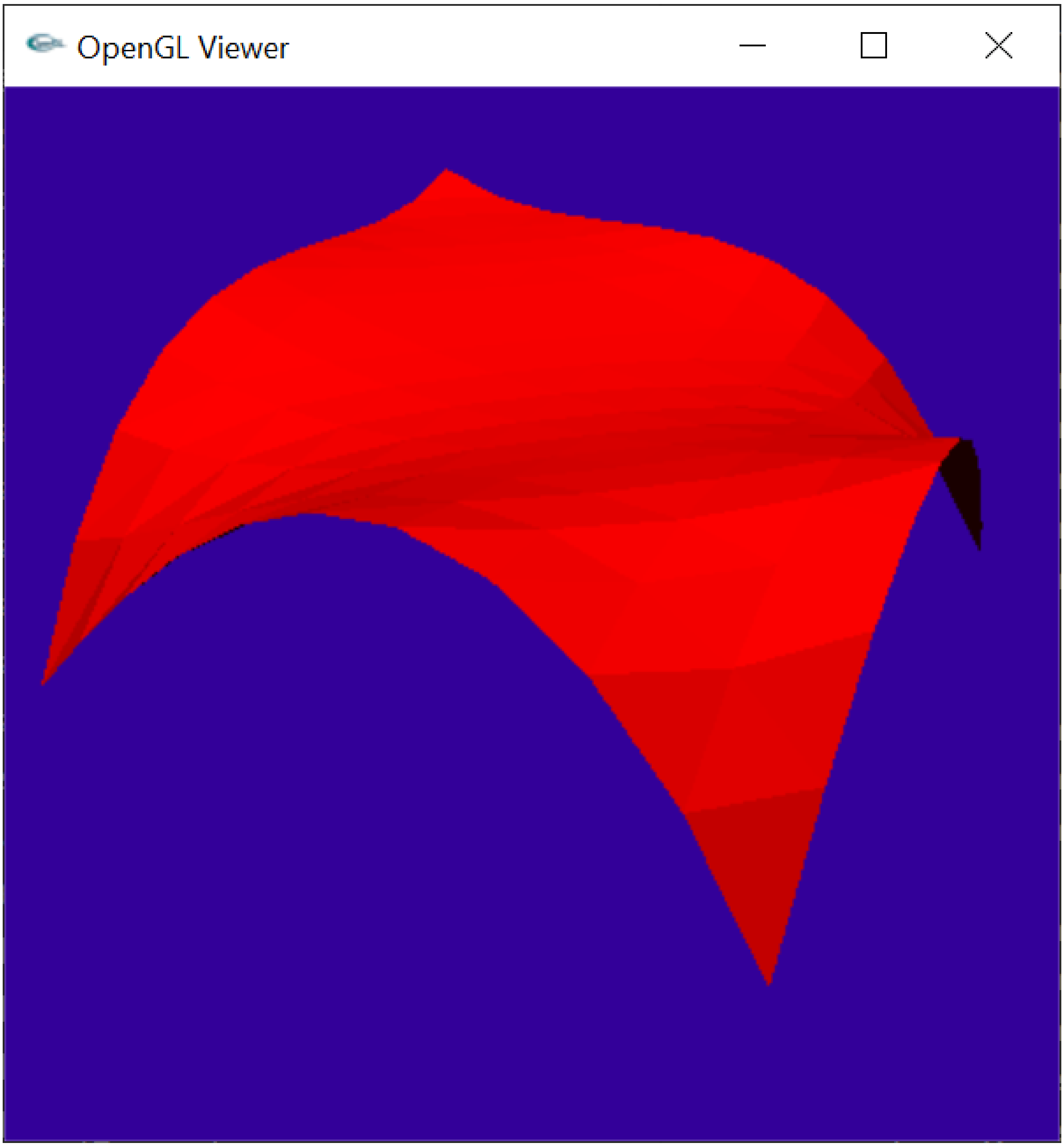


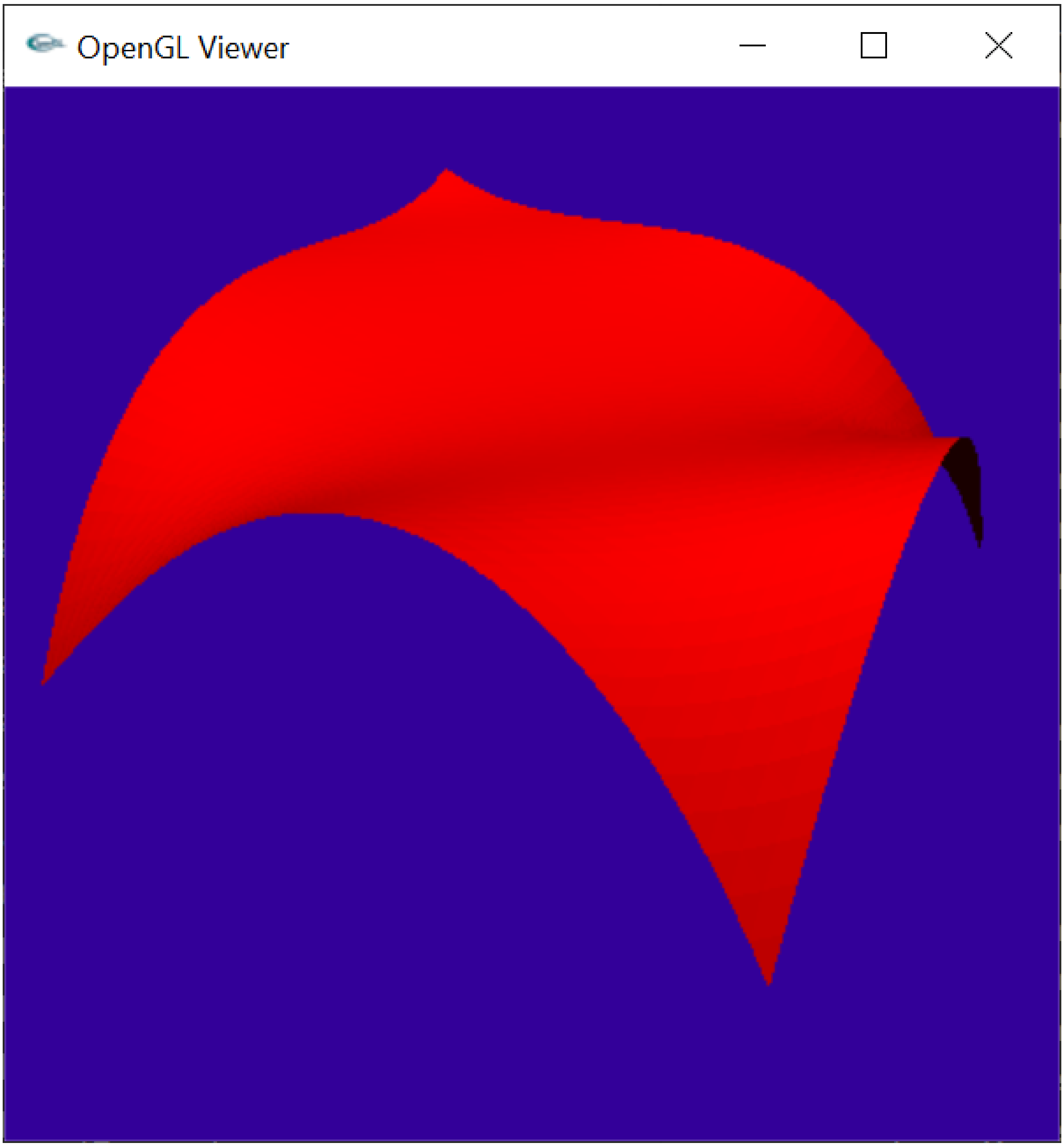
```
curve_editor -input spline8_08_bezier_patch.txt -gui
curve_editor -input spline8_08_bezier_patch.txt -patch_tessellation 4 -output
patch_low.obj
curve_editor -input spline8_08_bezier_patch.txt -patch_tessellation 10 -output
patch_med.obj
curve_editor -input spline8_08_bezier_patch.txt -patch_tessellation 40 -output
patch_high.obj
raytracer -input scene8_08_bezier_patch_low.txt -gui -size 300 300
raytracer -input scene8_08_bezier_patch_med.txt -gui -size 300 300
raytracer -input scene8_08_bezier_patch_high.txt -gui -size 300 300
```



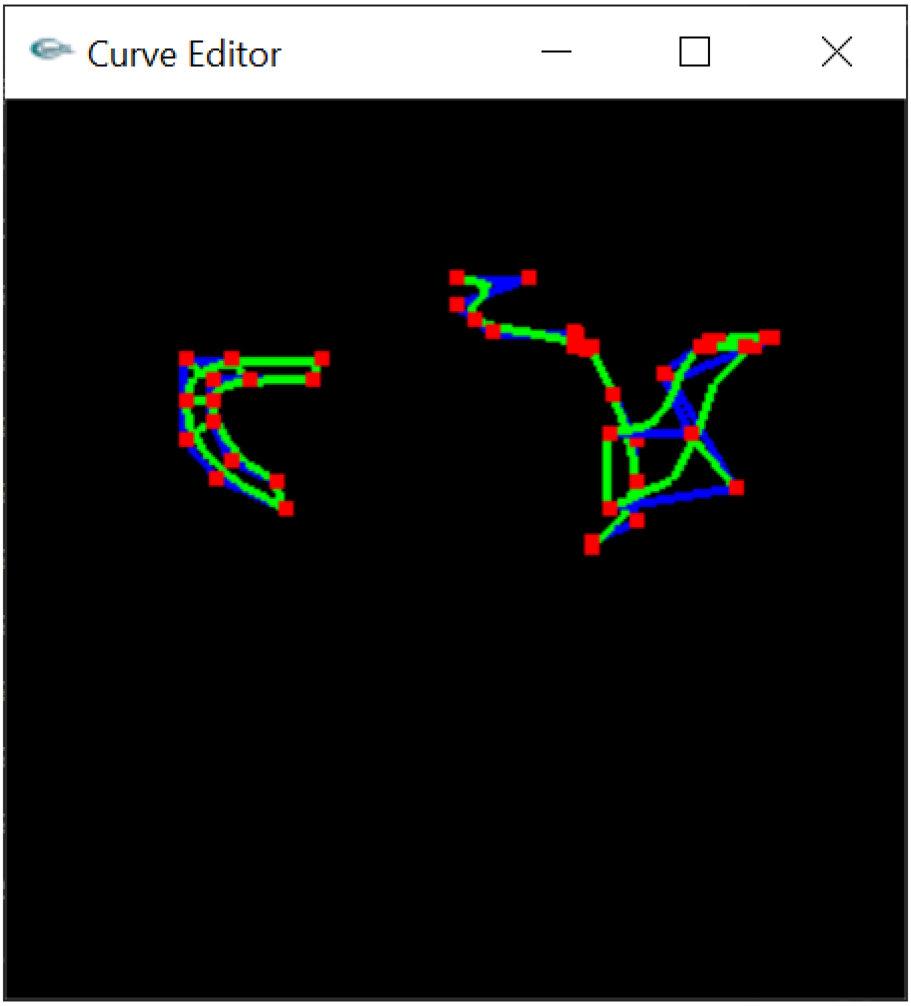
Curve Editor

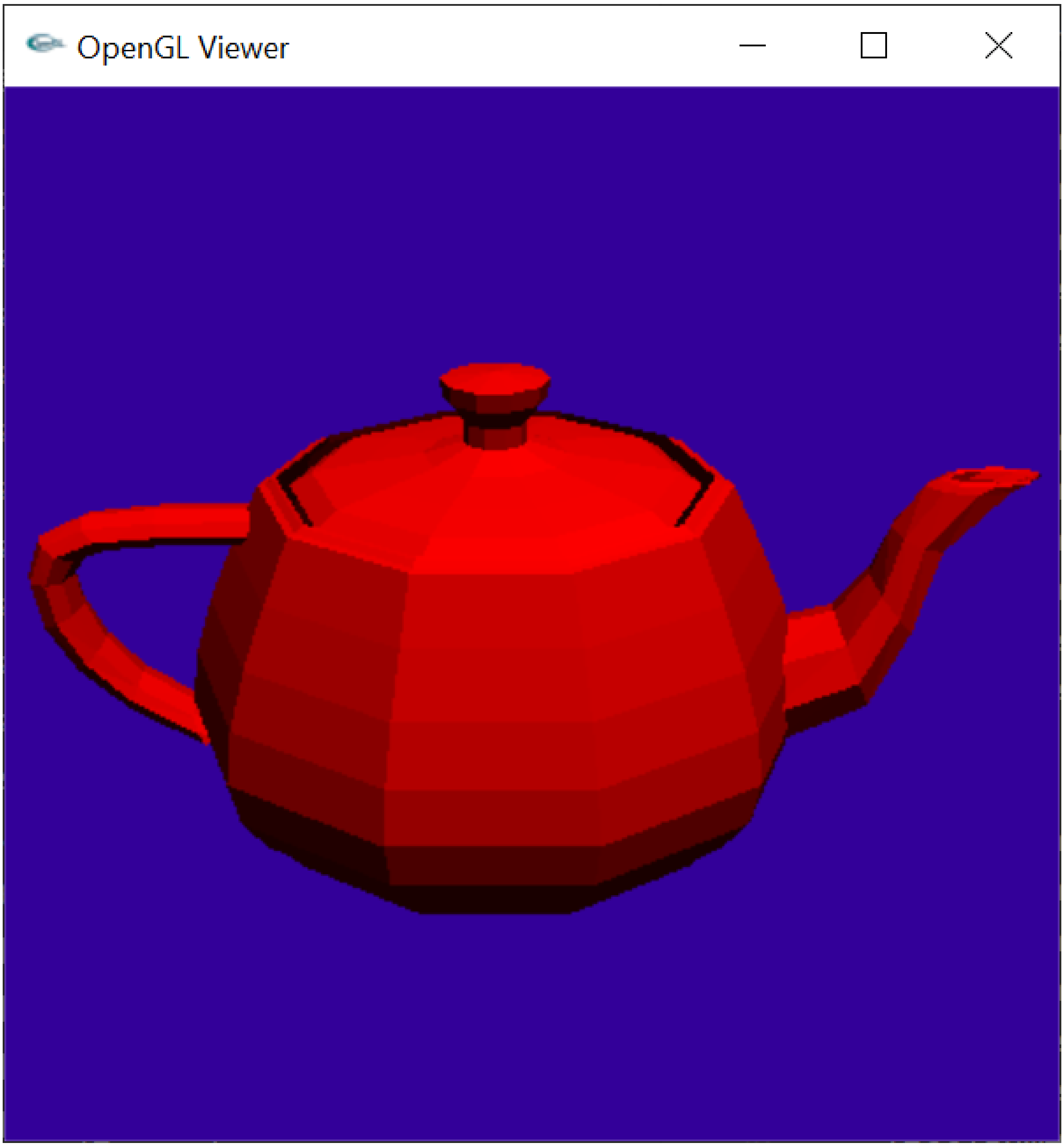

OpenGL Viewer

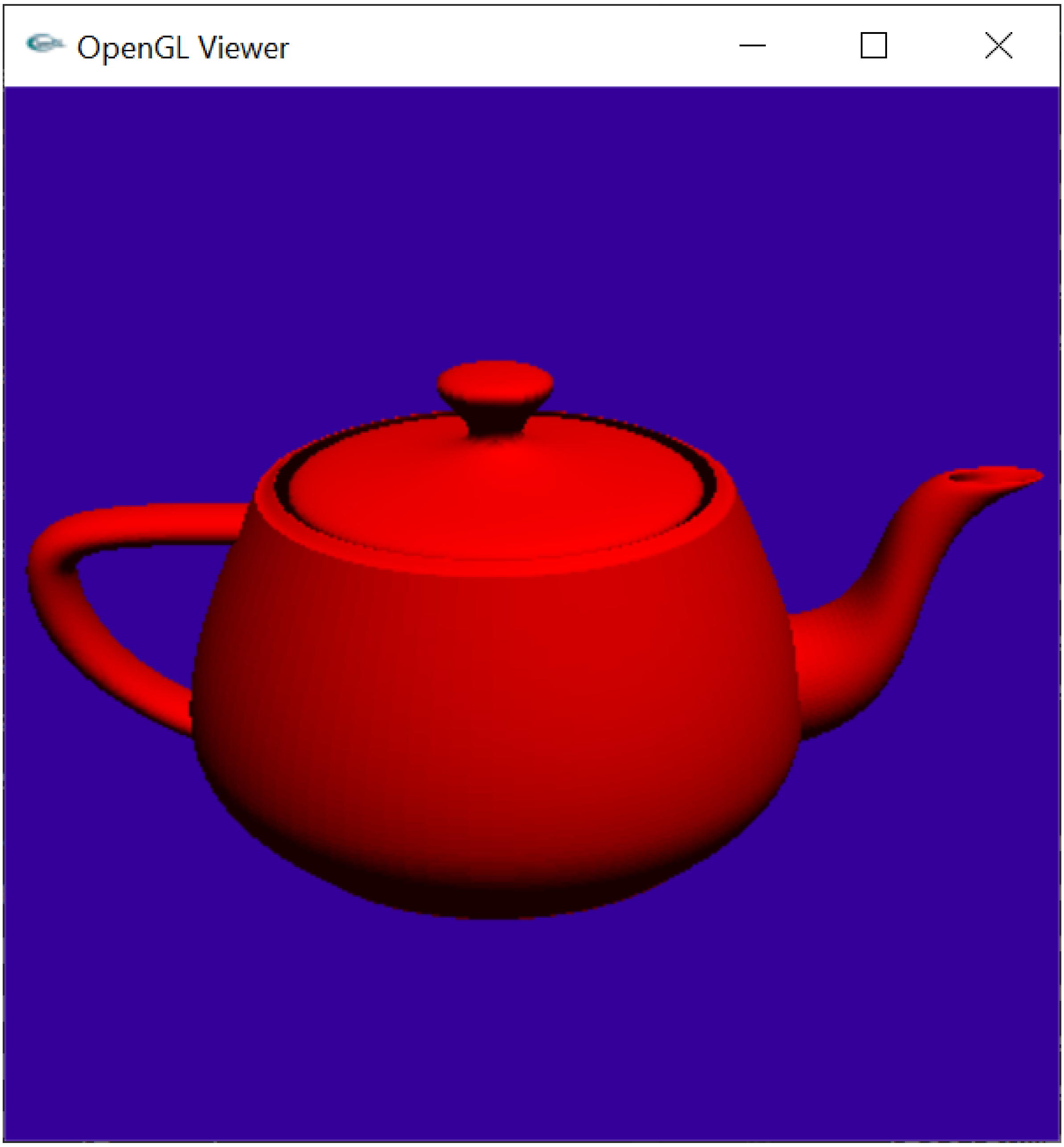

OpenGL Viewer



```
curve_editor -input spline8_09_teapot.txt -curve_tessellation 4 -gui
curve_editor -input spline8_09_teapot.txt -patch_tessellation 4 -curve_tessellation 4 -revolution_tessellation 10 -output teapot_low.obj
curve_editor -input spline8_09_teapot.txt -patch_tessellation 30 -curve_tessellation 30 -revolution_tessellation 100 -output teapot_high.obj
raytracer -input scene8_09_teapot_low.txt -gui -size 300 300
raytracer -input scene8_09_teapot_high.txt -gui -size 300 300
```


Curve Editor


OpenGL Viewer



```
curve_editor -input output8_07_edit.txt -curve_tessellation 20 -
revolution_tessellation 100 -output vase_very_high.obj
raytracer -input scene8_10_transparent_vase.txt -output output8_10.tga -grid 30
30 30 -size 300 300 -bounces 4 -shade_back -jittered_samples 9 -tent_filter 1.0
-shadows
raytracer -input scene8_11_reflective_teapot.txt -output output8_11.tga -grid 50
30 30 -size 300 300 -bounces 4 -shade_back -jittered_samples 9 -tent_filter 1.0
-shadows
```