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CSE 520

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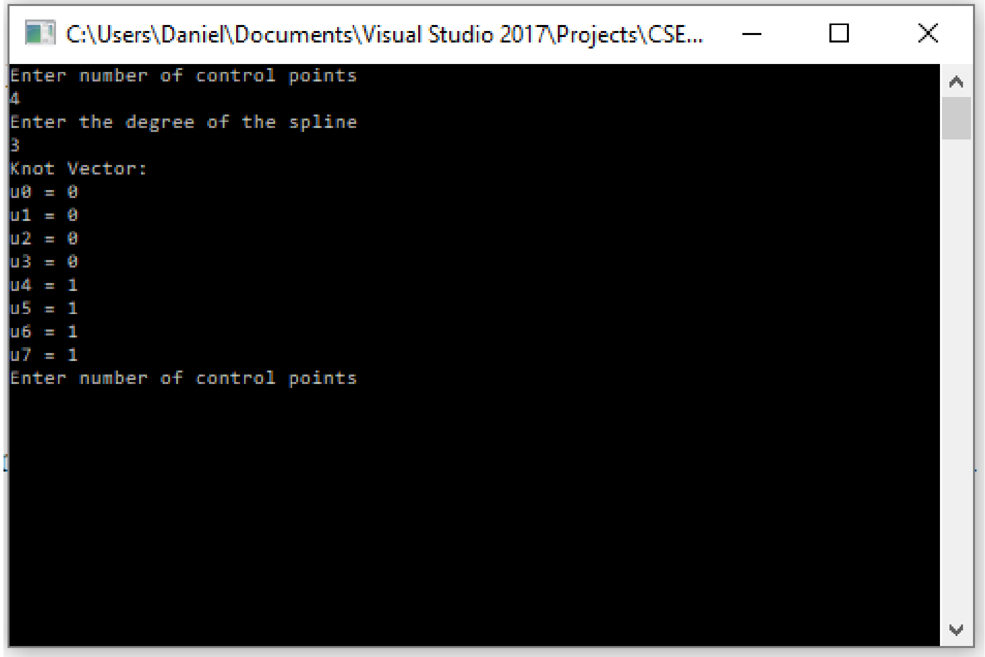
Homework 2 Report

Part 1 (success):



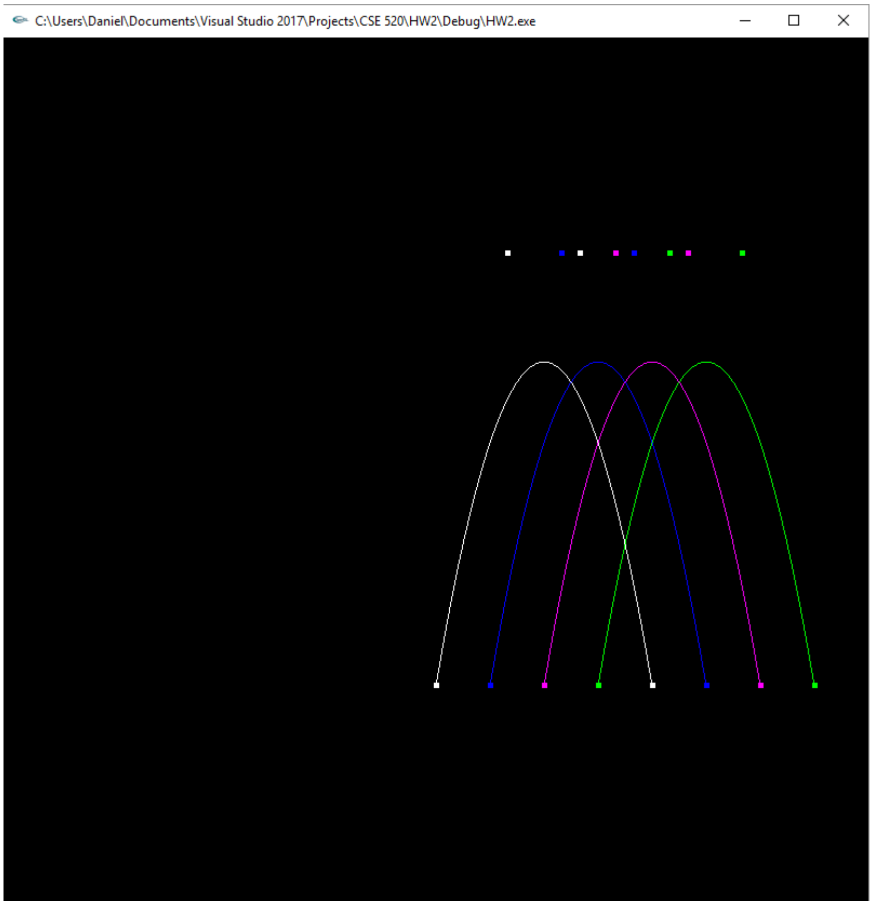
C:\Users\Daniel\Documents\Visual Studio 2017\Projects\CSE...

```
Enter number of control points
4
Enter the degree of the spline
3
Knot Vector:
u0 = 0
u1 = 0
u2 = 0
u3 = 0
u4 = 1
u5 = 1
u6 = 1
u7 = 1
Enter number of control points
```

```
#include <stdlib.h>
#include <iostream>
#include <GL/glut.h>

using namespace std;

const int screenHeight = 800;
const int screenWidth = 800;

/*
 * Build standard knot vector for n control points
 * and B-splines of order m
 */
void buildKnots(int m, int n, float knot[])
{
	if (n < m) return;		//not enough control points
	for (int i = 0; i < n + m; ++i) {
		if (i < m) knot[i] = 0.0;
```

```
        else if (i < n) knot[i] = i - m + 1;        //i is at least
m here
        else knot[i] = n - m + 1;
    }
}


void init(void)
{
    glClearColor(0.0, 0.0, 0.0, 1.0);
    glShadeModel(GL_FLAT);
    glEnable(GL_MAP1_VERTEX_3);
}

void display(void)
{

    glClear(GL_COLOR_BUFFER_BIT);

    int numControlPoints = 0;
    int splineDegree = 0;

    cout << "Enter number of control points" << endl;
    cin >> numControlPoints;

    cout << "Enter the degree of the spline" << endl;
    cin >> splineDegree;

    splineDegree += 1; //degree + 1 = order

    if (splineDegree > numControlPoints)
    {
        cout << "Invalid order" << endl;
    }
    else
    {
        float *knot = new float[numControlPoints + splineDegree];
        buildKnots(splineDegree, numControlPoints, knot);

        cout << "Knot Vector: " << endl;
        for (int i = 0; i < numControlPoints + splineDegree; i++)
        {
            cout << "u" << i << " = " << knot[i] << endl;
        }
    }
    glFlush();
}

void reshape(int w, int h)
{

    glViewport(0, 0, (GLsizei)w, (GLsizei)h);
    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    gluOrtho2D(0, 800, 0, 800);
    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity();


    glViewport(0, 0, (GLsizei)w, (GLsizei)h);
    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    if (w <= h)
        glOrtho(-6.0, 6.0, -6.0*(GLfloat)h / (GLfloat)w,
            6.0*(GLfloat)h / (GLfloat)w, -6.0, 6.0);
    else
        glOrtho(-6.0*(GLfloat)w / (GLfloat)h,
            6.0*(GLfloat)w / (GLfloat)h, -6.0, 6.0, -6.0, 6.0);
    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity();
}

void keyboard(unsigned char key, int x, int y)
{
    switch (key) {
    case 27:
        exit(0);
        break;
    }
}

int main(int argc, char** argv)
{
    glutInit(&argc, argv);
    glutInitDisplayMode(GLUT_SINGLE | GLUT_RGB);
    glutInitWindowSize(screenWidth, screenHeight);
    glutInitWindowPosition(100, 100);
    glutCreateWindow(argv[0]);
    init();
    glutDisplayFunc(display);
    glutReshapeFunc(reshape);
    glutKeyboardFunc(keyboard);

    glutMainLoop();
    return 0;
}
```

Part 2 (success):



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```
#include <stdlib.h>
#include <iostream>
#include <GL/glut.h>

using namespace std;

const int screenHeight = 800;
const int screenWidth = 800;

GLfloat ctrlpoints1[4][3] = {
    {-3, -3, 0.0}, {-2, 3.0, 0.0},
    {-1, 3.0, 0.0}, {0, -3.0, 0.0}
};

GLfloat ctrlpoints0[4][3] = {
    {0, 0, 0.0}, {1, 0.5, 0.0},
    {2.0, 0.5, 0.0}, {3.0, 0.0, 0.0}
};

/*
 * Build standard knot vector for n control points
 * and B-splines of order m
 */
void buildKnots(int m, int n, float knot[])
{
    if (n < m) return;         //not enough control points
    for (int i = 0; i < n + m; ++i) {
        if (i < m) knot[i] = 0.0;
        else if (i < n) knot[i] = i - m + 1;        //i is at least
m here
        else knot[i] = n - m + 1;
    }
}


void init(void)
{
    glClearColor(0.0, 0.0, 0.0, 1.0);
    glShadeModel(GL_FLAT);
    glEnable(GL_MAP1_VERTEX_3);
}

void display(void)
{
    glClear(GL_COLOR_BUFFER_BIT);
    glColor3f(1.0, 1.0, 1.0);
    const int n = 4, m = 4;
    float time[n + m - 1] = { 0, 1, 2, 3, 4, 5, 6 };
    float blendFunc[4];

    float t = time[0];
    t = 0;
    for (int i = 0; i < 4; i++)
    {
        //t = time[i];
        // the t value inverted
        float it = 1.0f - t;

        // calculate blending functions
        float b0 = it * it*it;
        float b1 = 3 * t*it*it;
        float b2 = 3 * t*t*it;
        float b3 = t * t*t;

        blendFunc[i] = b0 * ctrlpoints0[0][0] + b1 *
ctrlpoints0[1][0] + b2 * ctrlpoints0[2][0] + b3 * ctrlpoints0[3][0];
        t += 0.25;
    }

    ctrlpoints1[0][0] = blendFunc[0] + ctrlpoints0[0][0];
    ctrlpoints1[1][0] = blendFunc[0] + ctrlpoints0[1][0];
    ctrlpoints1[2][0] = blendFunc[0] + ctrlpoints0[2][0];
    ctrlpoints1[3][0] = blendFunc[0] + ctrlpoints0[3][0];

    glMap1f(GL_MAP1_VERTEX_3, 0.0, 1.0, 3, 4, &ctrlpoints1[0][0]);
//t0 -> t3
    glColor3f(1.0, 1.0, 1.0);
    glBegin(GL_LINE_STRIP);
    for (int i = 0; i <= 30; i++)
        glEvalCoord1f((GLfloat)i / 30.0);
    glEnd();
    glPointSize(5.0);
    glColor3f(1.0, 1.0, 1.0);
    glBegin(GL_POINTS);
    for (int i = 0; i < n; i++)
        glVertex3fv(&ctrlpoints1[i][0]);
    glEnd();

    ctrlpoints1[0][0] = blendFunc[1] + ctrlpoints0[0][0];
    ctrlpoints1[1][0] = blendFunc[1] + ctrlpoints0[1][0];
    ctrlpoints1[2][0] = blendFunc[1] + ctrlpoints0[2][0];
    ctrlpoints1[3][0] = blendFunc[1] + ctrlpoints0[3][0];

    glMap1f(GL_MAP1_VERTEX_3, 0.0, 1.0, 3, 4, &ctrlpoints1[0][0]);
//t1 -> t4
    glColor3f(0.0, 0.0, 1.0);
    glBegin(GL_LINE_STRIP);
    for (int i = 0; i <= 30; i++)
        glEvalCoord1f((GLfloat)i / 30.0);
    glEnd();
    glPointSize(5.0);
    glColor3f(0.0, 0.0, 1.0);
    glBegin(GL_POINTS);
    for (int i = 0; i < n; i++)
        glVertex3fv(&ctrlpoints1[i][0]);
    glEnd();

    ctrlpoints1[0][0] = blendFunc[2] + ctrlpoints0[0][0];
    ctrlpoints1[1][0] = blendFunc[2] + ctrlpoints0[1][0];
    ctrlpoints1[2][0] = blendFunc[2] + ctrlpoints0[2][0];
    ctrlpoints1[3][0] = blendFunc[2] + ctrlpoints0[3][0];

    glMap1f(GL_MAP1_VERTEX_3, 0.0, 1.0, 3, 4, &ctrlpoints1[0][0]);
//t2 -> t5
    glColor3f(1.0, 0.0, 1.0);
    glBegin(GL_LINE_STRIP);
    for (int i = 0; i <= 30; i++)
        glEvalCoord1f((GLfloat)i / 30.0);
    glEnd();
    glPointSize(5.0);
    glColor3f(1.0, 0.0, 1.0);
    glBegin(GL_POINTS);
    for (int i = 0; i < n; i++)
        glVertex3fv(&ctrlpoints1[i][0]);
    glEnd();

    ctrlpoints1[0][0] = blendFunc[3] + ctrlpoints0[0][0];
    ctrlpoints1[1][0] = blendFunc[3] + ctrlpoints0[1][0];
    ctrlpoints1[2][0] = blendFunc[3] + ctrlpoints0[2][0];
    ctrlpoints1[3][0] = blendFunc[3] + ctrlpoints0[3][0];

    glMap1f(GL_MAP1_VERTEX_3, 0.0, 1.0, 3, 4, &ctrlpoints1[0][0]);
//t3 -> t6
    glColor3f(0.0, 1.0, 0.0);
    glBegin(GL_LINE_STRIP);
    for (int i = 0; i <= 30; i++)
        glEvalCoord1f((GLfloat)i / 30.0);
    glEnd();
    glPointSize(5.0);
    glColor3f(0.0, 1.0, 0.0);
    glBegin(GL_POINTS);
    for (int i = 0; i < n; i++)
        glVertex3fv(&ctrlpoints1[i][0]);
    glEnd();


    glFlush();
}
```

```
void reshape(int w, int h)
{

    glViewport(0, 0, (GLsizei)w, (GLsizei)h);
    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    gluOrtho2D(0, 800, 0, 800);
    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity();


    glViewport(0, 0, (GLsizei)w, (GLsizei)h);
    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    if (w <= h)
        glOrtho(-6.0, 6.0, -6.0*(GLfloat)h / (GLfloat)w,
            6.0*(GLfloat)h / (GLfloat)w, -6.0, 6.0);
    else
        glOrtho(-6.0*(GLfloat)w / (GLfloat)h,
            6.0*(GLfloat)w / (GLfloat)h, -6.0, 6.0, -6.0, 6.0);
    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity();
}

void keyboard(unsigned char key, int x, int y)
{
    switch (key) {
    case 27:
        exit(0);
        break;
    }
}

int main(int argc, char** argv)
{
    glutInit(&argc, argv);
    glutInitDisplayMode(GLUT_SINGLE | GLUT_RGB);
    glutInitWindowSize(screenWidth, screenHeight);
    glutInitWindowPosition(100, 100);
    glutCreateWindow(argv[0]);
    init();
    glutDisplayFunc(display);
    glutReshapeFunc(reshape);
    glutKeyboardFunc(keyboard);
```

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

Part 3 (success):

P(0) = (0,0,0)

P(1/3) = (1,2,2)

P(2/3) = (2,3,4)

P(1) = (4,5,8)

Find P(0.8)

P(u) = B0(u)P0 + B1(u)P1 + B2(u)P2 + B3(u)P3

B0 = 0.008

B1 = 0.096

B2 = 0.384

B3 = 0.512

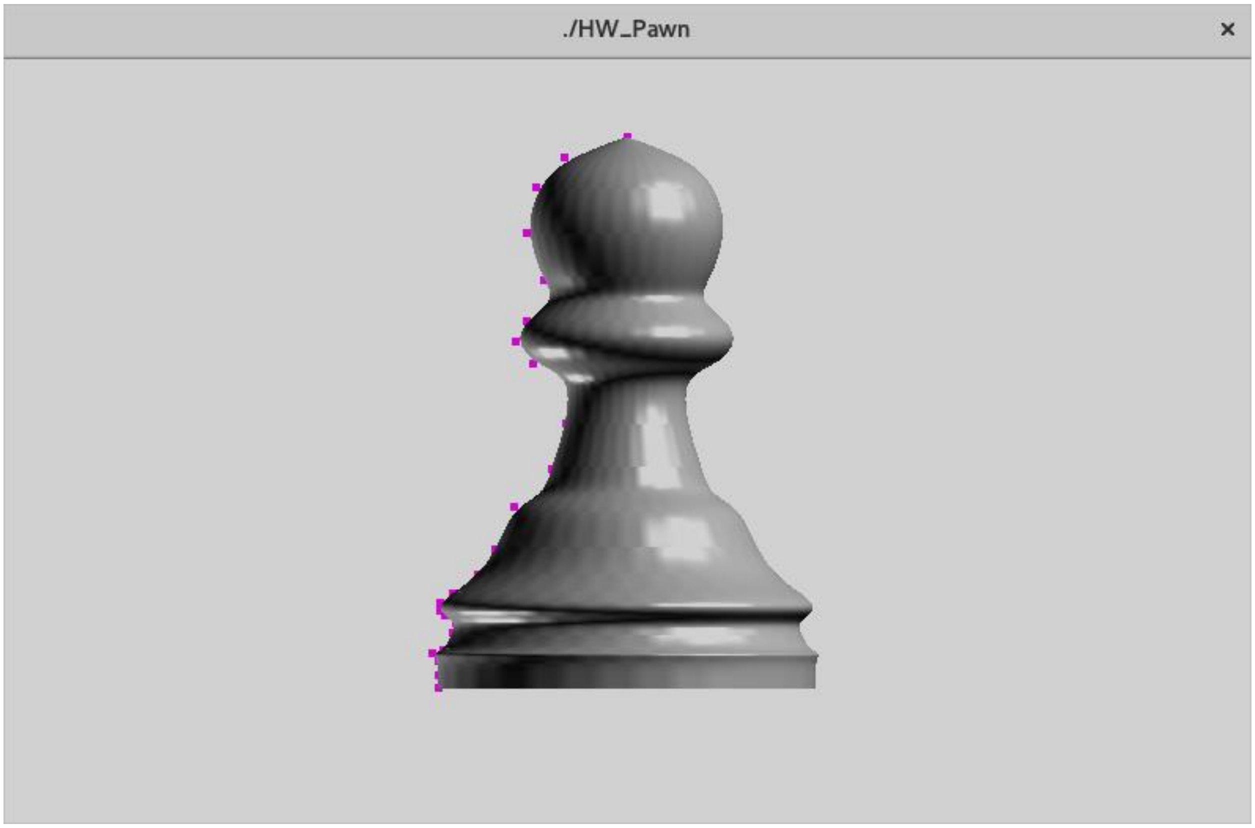
u = 0.8

P(0.8) = (0.008)(0.8)(0,0,0) + (0.096)(0.8)(1,2,2) + (0.384)(0.8)(2,3,4) + (0.512)(0.8)(4,5,8)

= (0,0,0) + (0.0768, 0.1536, 0.1536) + (0.6144, 0.9216, 1.2288) + (1.6384, 2.048, 3.2768)

P(0.8) = (2.3296, 3.1232, 4.6592)

Part 4 (success):



```
#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include <stdlib.h>
#include "lib3ds_vector.h"
#include <GL/glut.h>

using namespace std;

const double PI = 3.14159265389;
const int Npoints = 27;
const int m_order = 4;
int anglex = 0, angley = 0, anglez = 0;          //rotation angles
int window;

GLuint thePawn;
void pawn(int nx, int ntheta, float startx, float endx);

//control points
GLfloat ctrlpoints[Npoints][3] = {
{4.38,0.00, 0},{4.22,0.50, 0},{3.98,0.72, 0},{3.62,0.80,
0},{3.24,0.66, 0},
{3.10,0.56, 0},{2.92,0.80, 0},{2.76,0.88, 0},{2.58,0.74,
0},{2.48,0.44, 0},
{2.10,0.48, 0},{1.74,0.60, 0},{1.54,0.66, 0},{1.44,0.90,
0},{1.10,1.04, 0},
{0.90,1.18, 0},{0.76,1.38, 0},{0.68,1.48, 0},{0.62,1.48,
0},{0.58,1.44, 0},
{0.52,1.36, 0},{0.44,1.38, 0},{0.30,1.46, 0},{0.28,1.54,
0},{0.22,1.50, 0},
{0.10,1.50, 0},{0.00,1.50, 0}
};

void init(void)
{
     glClearColor(1.0, 1.0, 1.0, 1.0);
     glEnable(GL_CULL_FACE);
     glCullFace(GL_BACK);
     glPolygonMode(GL_FRONT, GL_FILL);

     thePawn = glGenLists(1);
     glNewList(thePawn, GL_COMPILE);
     pawn(32, 64, 0, 3.5);
     glEndList();
     glShadeModel(GL_SMOOTH);

     //lighting
     GLfloat mat_specular[] = { 1.0, 1.0, 1.0, 1.0 };
     GLfloat mat_shininess[] = { 50.0 };
     GLfloat light[] = { 1.0, 1.0, 1.0 };
     GLfloat light1[] = { 1.0, 1.0, 1.0 };
     GLfloat light_position[] = { 1.0, 1.0, 1.0, 0.0 };
     GLfloat light_position1[] = { -1.0, -1.0, -1.0, 0.0 };
     GLfloat lmodel_ambient[] = { 0.1, 0.1, 0.1, 1.0 };
     glClearColor(1.0, 1.0, 1.0, 0.0);

     glMaterialfv(GL_FRONT, GL_SPECULAR, mat_specular);
     glMaterialfv(GL_FRONT, GL_SHININESS, mat_shininess);
     glLightfv(GL_LIGHT0, GL_POSITION, light_position);
     glLightfv(GL_LIGHT1, GL_POSITION, light_position1);

     glLightfv(GL_LIGHT0, GL_DIFFUSE, light);
     glLightfv(GL_LIGHT0, GL_SPECULAR, light);
     glLightfv(GL_LIGHT1, GL_DIFFUSE, light1);
     glLightfv(GL_LIGHT1, GL_SPECULAR, light1);
     glLightModelfv(GL_LIGHT_MODEL_AMBIENT, lmodel_ambient);

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

/*
 *   Build standard knot vector for n control points
 *   and B-splines of order m
 */
void buildKnots(int m, int n, float knot[])
{
     if (n < m) return;          //not enough control points
     for (int i = 0; i < n + m; ++i) {
           if (i < m) knot[i] = 0.0;
           else if (i < n) knot[i] = i - m + 1;        //i is at least
m here
           else knot[i] = n - m + 1;
     }
}

//evaluate blending functions recurvsively
float bSpline(int k, int m, float u, float knot[])
{
     float d1, d2, sum = 0.0;

     if (m == 1)
           return (knot[k] < u &&  u <= knot[k + 1]);   //1 or 0

       //m larger than 1, so recurse
     d1 = knot[k + m - 1] - knot[k];
     if (d1 != 0)
           sum = (u - knot[k]) * bSpline(k, m - 1, u, knot) / d1;
     d2 = knot[k + m] - knot[k + 1];
     if (d2 != 0)
           sum += (knot[k + m] - u) * bSpline(k + 1, m - 1, u, knot) /
d2;

     return sum;
}

//non uniform rational B-splines, n control points, order m, p[] is
the output point
void nurb(float control_points[][3], float u, float knot[], float p[])
{
     // sum the control points mulitplied by their respective blending
functions
```

```
    for (int i = 0; i < 3; ++i) {        //x, y, z components
        p[i] = 0;
        for (int k = 0; k < Npoints; ++k)
            p[i] += bSpline(k, m_order, u, knot) *
control_points[k][i];
    }
}


//polynomial interpretation for N points
float polyint(float  points[][3], float x, int N)
{
    float y;

    float num = 1.0, den = 1.0;
    float sum = 0.0;

    for (int i = 0; i < N; ++i) {
        num = den = 1.0;
        for (int j = 0; j < N; ++j) {
            if (j == i) continue;

            num = num * (x - points[j][0]);             //x - xj
        }
        for (int j = 0; j < N; ++j) {
            if (j == i) continue;
            den = den * (points[i][0] - points[j][0]);  //xi - xj
        }
        sum += num / den * points[i][1];
    }
    y = sum;

    return y;
}

float aLine(float x)
{
    return x + 2.5;
}

//cubic B-spline, a special case of NURB
void bspline(float  points[][3], float t, float out[])
{
    // the t value inverted
    float it = 1.0f - t;
```

```
      // calculate blending functions
      float b0 = it * it*it;
      float b1 = 3 * t*it*it;
      float b2 = 3 * t*t*it;
      float b3 = t * t*t;

      // sum the control points mulitplied by their respective blending
functions
      out[0] = b0 * points[0][0] + b1 * points[1][0] + b2 *
points[2][0] + b3 * points[3][0];       //x
      out[1] = b0 * points[0][1] + b1 * points[1][1] + b2 *
points[2][1] + b3 * points[3][1];       //y
      out[2] = b0 * points[0][2] + b1 * points[1][2] + b2 *
points[2][2] + b3 * points[3][2];       //z
}

void testing()
{
      int n = Npoints, m = m_order;
      float knot[n + m];

      buildKnots(m, n, knot);

      for (int i = 0; i < n + m; i++)
            printf("%4.2f,", knot[i]);

      printf("\n");
}


void pawn(int nx, int ntheta, float startx, float endx)
{
      const int n = Npoints, m = m_order;    //n control points, degree
m NURB
      float knot[n + m];

      const float dx = (endx - startx) / nx;//x step size
      const float dtheta = 2 * PI / ntheta; //angular step size
      float theta = PI / 2.0;          //from pi/2 to3pi/2
      buildKnots(m, n, knot);

      int i, j;
      float x, y, z, r;                //current coordinates
      float x1, y1, z1, r1;      //next coordinates
      float t, v[3];
      float va[3], vb[3], vc[3], normal[3];
```

```
    int nturn = 0;
    x = startx;
    nurb(ctrlpoints, 0, knot, v);
    x = v[0];
    r = v[1];
    bool first_point = true;
    for (int k = m - 1; k < n; ++k) {      //step through the knots
        float dknot = knot[k + 1] - knot[k];
        if (dknot == 0) continue;

        theta = 0; //PI / 2.0;
        int start = 0, nn = 60, end = nn;
        //  if ( k == n - 1 ) end = nn;
        for (i = start; i <= end; i++) {
            t = knot[k] + dknot * (float)i / nn;
            nurb(ctrlpoints, t, knot, v);
            if (first_point) {
                v[0] = ctrlpoints[0][0];
                v[1] = ctrlpoints[0][1];
                first_point = false;
            }
            x1 = v[0];
            r1 = v[1];

            //draw the surface composed of quadrilaterals by 
sweeping theta
            glBegin(GL_QUAD_STRIP);
            for (j = 0; j <= ntheta; ++j) {
                theta += dtheta;
                double cosa = cos(theta);
                double sina = sin(theta);
                y = r * cosa;   y1 = r1 * cosa;   //current and 
next y
                z = r * sina;     z1 = r1 * sina; //current and 
next z
                if (nturn == 0) {
                    va[0] = x; va[1] = y;       va[2] = z;
                    vb[0] = x1;     vb[1] = y1;     vb[2] = 
z1;
                    nturn++;
                }
                else {
                    nturn = 0;
                    vc[0] = x; vc[1] = y;       vc[2] = z;
                    //vector_normal(normal, va, vb, vc);
                    vector_normal()
                    glNormal3f(normal[0], normal[1],
normal[2]);
                }
                //edge from point at x to point at next x
                glVertex3f(x, y, z);
                glVertex3f(x1, y1, z1);
                //forms quad with next pair of points with
incremented theta value
            }
            glEnd();
            x = x1;
            r = r1;
        }
    } //for k
}

//revolve about y-axis
void display(void)
{

    glClear(GL_COLOR_BUFFER_BIT);
    glColor3f(0.0, 1.0, 1.0);
    const float startx = 0, endx = 3.5;
    const int nx = 32;              //number of slices along x-
direction
    const int ntheta = 64;          //number of angular slices

    glPushMatrix();
    glRotatef(anglex, 1.0, 0.0, 0.0);    //rotate the object about
x-axis
    glRotatef(angley, 0.0, 1.0, 0.0);    //rotate about y-axis
    glRotatef(anglez, 0.0, 0.0, 1.0);    //rotate about z-axis

    glEnable(GL_LIGHTING);

    glCallList(thePawn);
    /* The following code displays the control points as dots. */

    glDisable(GL_LIGHTING);
    glPointSize(5.0);
    glColor3f(1.0, 0.0, 1.0);
    glBegin(GL_POINTS);
    for (int i = 0; i < Npoints; i++)
        glVertex3fv(&ctrlpoints[i][0]);
    glEnd();
    glPopMatrix();
    glFlush();
}


void reshape(int w, int h)
{
    glViewport(0, 0, (GLsizei)w, (GLsizei)h);
    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    if (w <= h)
        glOrtho(-5.0, 5.0, -5.0*(GLfloat)h / (GLfloat)w,
            5.0*(GLfloat)h / (GLfloat)w, -5.0, 5.0);
    else
        glOrtho(-5.0*(GLfloat)w / (GLfloat)h,
            5.0*(GLfloat)w / (GLfloat)h, -5.0, 5.0, -5.0, 5.0);
    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity();
}

void keyboard(unsigned char key, int x, int y)
{
    switch (key) {
    case 'x':
        anglex = (anglex + 3) % 360;
        break;
    case 'X':
        anglex = (anglex - 3) % 360;
        break;
    case 'y':
        angley = (angley + 3) % 360;
        break;
    case 'Y':
        angley = (angley - 3) % 360;
        break;
    case 'z':
        anglez = (anglez + 3) % 360;
        break;
    case 'Z':
        anglez = (anglez - 3) % 360;
        break;
    case 'r':                           //reset
        anglez = angley = anglex = 0;
        glLoadIdentity();
        break;
    case 27: /* escape */
```

```
        glutDestroyWindow(window);
        exit(0);
    }
    glutPostRedisplay();
}

int main(int argc, char** argv)
{
    glutInit(&argc, argv);
    glutInitDisplayMode(GLUT_SINGLE | GLUT_RGB);
    glutInitWindowSize(800, 800);
    glutInitWindowPosition(100, 100);
    window = glutCreateWindow(argv[0]);
    init();
    glutDisplayFunc(display);
    glutReshapeFunc(reshape);
    glutKeyboardFunc(keyboard);
    glutMainLoop();
    return 0;
}
```

Part 4 (success):

```
#include <stdlib.h>
#include <string.h>
#include <iostream>
#include <vector>
#include <algorithm>
#include "LinearR4.h"
#include <SDL/SDL.h>
#include <GL/glut.h>

using namespace std;

int anglex = 0, angley = 0, anglez = 0;          //rotation angles
int window;

float a = 1;
float b = 0.5;
float p = 1;
float q = 7;
```

```
//float dC[4] = (-p * (q + b * cos(q*t)) * sin(p*t) - b * q * sin(q*t)
* cos(p*t), p * (a + b * cos(q*t)) * cos(p*t) - b * q * sin(q*t) *
sin(p*t), b * q * cos(q*t), 0);
//float dC[3];
//float ddC[3];

void init(void)
{
     glClearColor(1.0, 1.0, 1.0, 1.0);
     glEnable(GL_DEPTH_TEST);
     glMatrixMode(GL_PROJECTION);
     glLoadIdentity();
     glOrtho(-3.0, 3.0, -3.0, 3.0, 0.1, 100);
     glMatrixMode(GL_MODELVIEW); // position and aim the camera
     glLoadIdentity();
     gluLookAt(0, 0, 10.0, 0.0, 0.0, 0.0, 0.0, 1.0, 0.0);
}

//v1[], v2[] are two vectors
//out[] holds the crossproduct v1 x v2
void crossprod(float v1[3], float v2[3], float out[3])
{
     out[0] = v1[1] * v2[2] - v1[2] * v2[1];
     out[1] = v1[2] * v2[0] - v1[0] * v2[2];
     out[2] = v1[0] * v2[1] - v1[1] * v2[0];
}

//helix curve
void get_C(float C[4], float t, float b)
{
     C[0] = (a + b * cos(q * t)) * cos(p * t);
     C[1] = (a + b * cos(q * t)) * sin(p * t);
     C[2] = b * sin(q * t);
     C[3] = 1;
}

//Matrix for transforming to Frenet frame
//void setM(LinearMapR4 &M, float t, float b)
void setM(LinearMapR4 &M, float t)
{

     float c = 1.0 / sqrt(1 + b * b);
     M.SetColumn1((7 * sin(t) * sin(7 * t)) + cos(t) * (-25 * cos(7 *
t) - 1),
                      (-25.5 * sin(t) * cos(7 * t)) - (10.5 * sin(7 *
t) * cos(t)),
                      -24.5 * sin(7 * t),
                      0);        //Normal    N(t)
     M.SetColumn2((-89.25 * pow(cos(7*t),2) * sin(t)) + (24.5 * cos(t)
* sin(7*t)) - (24.5 * cos(t) * cos(7*t) * sin(7*t)) - (85.75 * sin(t)
* pow(sin(7*t), 2))*c,
                      (3.5 * cos(t) * cos(7*t)) + (87.5 * cos(t) *
pow(cos(7*t), 2)) + (24.5 * sin(t) * sin(7*t)) - (12.25 * cos(7*t) *
sin(t) * sin(7*t)) + (85.75 * cos(t) * pow(sin(7*t), 2)) *c,
                      (-pow(cos(t), 2)) - (25.5 * pow(cos(t), 2) *
cos(7*t)) - (12.5 * pow(cos(t), 2) * pow(cos(7*t), 2)) - (25.5 *
cos(7*t) * pow(sin(t), 2)) - (12.75 * pow(cos(7*t), 2) * pow(sin(t),
2)) - (3.5 * cos(t) * cos(7*t) * sin(t) * sin(7*t)) - (36.75 *
pow(cos(t), 2) * pow(sin(7*t), 2)) - (24.5 * pow(sin(t), 2) *
pow(sin(7*t), 2)),
                      0);   //Binormal  B(t)
     M.SetColumn3(sin(t) * (-0.5 * Cos(7 * t) - 1) - (3.5 * sin(7 * t)
* cos(t)) * c,
                      (-3.5 * sin(t) *  sin(7 * t)) + (0.5 * cos(7 *t)
* cos(t)) + cos(t) * c,
                      (3.5 * cos(7 * t)) * c,
                      0);   //Tangent   T(t)
     M.SetColumn4((1 + 0.5 * cos(7 * t)) * cos(t),
                      (1 + 0.5 * cos(7 * t)) * sin(t),
                      0.5 * sin(7 * t),
                      1);        //The curve C(t)

     float tangent[3];

     tangent[0] = (-p * (q + b * cos(q*t)) * sin(p*t) - b * q *
sin(q*t) * cos(p*t); //dx
     tangent[1] = p * (a + b * cos(q*t)) * cos(p*t) - b * q * sin(q*t)
* sin(p*t); //dy
     tangent[2] = b * q * cos(q*t); //dz

     float deriveTan[3];

     deriveTan[0] = (-p * p * (a + b * cos(q*t)) * cos(p*t) - b * q *
sin(q*t) * sin(p*t)) + b * q * (p * sin(q*t) * sin(p*t) - q * cos(q*t)
* cos(p*t)); //ddx
     deriveTan[1] = (p * (-p * (q + b * cos(q*t)) * sin(p*t) - b * q *
sin(q*t) * cos(p*t)) - b * q * (p * sin(q*t) * cos(p*t) + q * cos(q*t)
* sin(p*t)); //ddy
     deriveTan[2] = (-q * -q) * b * sin(q*t); //ddz

     float binormal[3];
     crossprod(tangent, deriveTan, binormal);
     float normal[3];
     crossprod(binormal, tangent, normal);

     M.SetColumn1(normal[0], normal[1], normal[2], 0);     //Normal
N(t)
     M.SetColumn2(binormal[0], binormal[1], binormal[2], 0);
     //Binormal  B(t)
     M.SetColumn3(-p * (q + b * cos(q*t)) * sin(p*t) - b * q *
sin(q*t) * cos(p*t), p * (a + b * cos(q*t)) * cos(p*t) - b * q *
sin(q*t) * sin(p*t), b * q * cos(q*t), 0);  //Tangent   T(t)
     M.SetColumn4((a + b * cos(q * t)) * cos(p * t), (a + b * cos(q *
t)) * sin(p * t), b * sin(q * t), 1);           //The curve C(t)
}

void print_M(LinearMapR4 &M)
{
     cout << "(" << M.m11 << ",\t" << M.m12 << ",\t" << M.m13 << ",\t"
<< M.m14 << ")" << endl;
     cout << "(" << M.m21 << ",\t" << M.m22 << ",\t" << M.m23 << ",\t"
<< M.m24 << ")" << endl;
     cout << "(" << M.m31 << ",\t" << M.m32 << ",\t" << M.m33 << ",\t"
<< M.m34 << ")" << endl;
     cout << "(" << M.m41 << ",\t" << M.m42 << ",\t" << M.m43 << ",\t"
<< M.m44 << ")" << endl;
}

class Cfloat3 {      //Note: array is copyable; e.g. int a[8],b[8]; "a
= b;" won't work
public:
     float p3[3];
};

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

     const float b = 0.1;       //constant of Helix curve
     double H = 6.0;
     LinearMapR4 M;       //Transformation matrix
     const int N = 4;     //number of vertices in base


     vector<Cfloat3>vp0(N), vp1(N);
     VectorR4 p_1;              //transformed point
```

```
    //4 vertices of a quad
    //float p[4][3]= { {-0.2,-0.2,0}, {0.2,-0.2,0}, {0.2,0.2, 0},{-
0.2,0.2,0} };
    //homogeneous coordinates of the four vertices of a quad
    VectorR4 points[4];        //define four points
    points[0] = VectorR4(-0.1, -0.1, 0, 1);     //x, y, z, w
    points[1] = VectorR4(0.1, -0.1, 0, 1);//x, y, z, w
    points[2] = VectorR4(0.1, 0.1, 0, 1); //x, y, z, w
    points[3] = VectorR4(-0.1, 0.1, 0, 1);//x, y, z, w

    glColor3f(0.1, 1.0, 0);
    glPushMatrix();
    glRotatef(anglex, 1.0, 0.0, 0.0);   //rotate the object about x-
axis
    glRotatef(angley, 0.0, 1.0, 0.0);   //rotate about y-axis
    glRotatef(anglez, 0.0, 0.0, 1.0);   //rotate about z-axis
    float C[4];
    glLineWidth(3);
    glPolygonMode(GL_FRONT, GL_LINE);
    glPolygonMode(GL_BACK, GL_LINE);

    glPolygonMode(GL_FRONT, GL_FILL);
    glPolygonMode(GL_BACK, GL_FILL);
    //The curve
    glBegin(GL_LINE_STRIP);
    for (float t = 0; t <= 26; t += 0.2) {
        get_C(C, t, b);
        glVertex4fv(C);
    }
    glColor3f(1.0, 0.1, 0);
    glEnd();

    float p3[3];          //3-D point, (x, y, z)
    //starting
    //setM(M, 0, b);//t = 0
    setM(M, 0);
    for (int i = 0; i < 4; ++i) {
        p_1 = M * points[i];  //transform the point
        p_1.Dump(vp0[i].p3);  //put (x, y, z) in vp0[i].p3[]
    }
    glBegin(GL_QUADS);         //a side has four points
    for (float t = 0.2; t <= 26; t += 0.2) {
        //setM(M, t, b);
        setM(M, t);
        for (int i = 0; i < N; ++i) {
            p_1 = M * points[i];  //transform the point
            p_1.Dump(vp1[i].p3);  //put (x, y, z) in vp1[i].p3[]
        }
        for (int i = 0; i < N; ++i) { //draw the N sides of tube
between 'base' and 'cap'
            int j = (i + 1) % N;
            glVertex3fv(vp0[i].p3);
            glVertex3fv(vp0[j].p3);
            glVertex3fv(vp1[j].p3);
            glVertex3fv(vp1[i].p3);
        }
        copy(vp1.begin(), vp1.end(), vp0.begin());  //copy vp1 to
vp0
    }  //for t
    glEnd();
    glPopMatrix();
    glFlush();
}

void keyboard(unsigned char key, int x, int y)
{
    switch (key) {
    case 27:
        glutDestroyWindow(window);
        exit(0);
    case 'x':
        anglex = (anglex + 3) % 360;
        break;
    case 'X':
        anglex = (anglex - 3) % 360;
        break;
    case 'y':
        angley = (angley + 3) % 360;
        break;
    case 'Y':
        angley = (angley - 3) % 360;
        break;
    case 'z':
        anglez = (anglez + 3) % 360;
        break;
    case 'Z':
        anglez = (anglez - 3) % 360;
        break;
    case 'r':                                   //reset
        anglez = angley = anglex = 0;
        break;
    }
    glutPostRedisplay();
}


int main(int argc, char *argv[])
{
    glutInit(&argc, argv);
    glutInitDisplayMode(GLUT_SINGLE | GLUT_RGB | GLUT_DEPTH);
    glutInitWindowSize(500, 500);
    glutInitWindowPosition(100, 100);
    window = glutCreateWindow("Mesh ");
    glutDisplayFunc(display);
    glutKeyboardFunc(keyboard);
    glClearColor(1.0f, 1.0f, 1.0f, 0.0f); //white background
    glViewport(0, 0, 500, 500);
    init();

    glutMainLoop();

    return 0;
}
```

Summary:

For this assignment we had multiple tasks. The first task was to write a program to print out the standard knot vector user provided number of control points and degree of the spline. It then prints out the knot vector to the screen. The next task was to make a program that plots the blending functions for degree 3. Next was to find the point at u=0.8 using the given four control points. The fourth assignment was to use a B-Spline generated by a set of given control points and then use surface of revolution to generate a chess piece. Finally, the last part was to make tube using the Frenet frame of a toroidal spiral with the given x, y, z functions. Overall each program compiled and ran successfully per the requirements of each task, however I am missing the screenshot for the last part of the assignment due to being unable to get to the computer lab to grab a screenshot of the program before the due date and I believe I earned 65 points for the assignment.