Assignment 1 : Geometric Modeling

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1 INTRODUCTION

In this technical report, i construct triangle meshes based on BÃľzier surfaces and then shade them with Ground lighting.

Also, i implement the methods supporting camera controling (also rotation and translation) and texturing.

Besides, i enabled the control points editing visually, and the surface will be automatically re-evaluated and re-meshed.

Finally, i implement a 2D Delaunay triangulation in triangle.h, but finally found it is not suitable for 3d cases and i post that on piazza.

Thus i just do basic triangulation. When i consider delaunay property, as long as two triangles are not on the plane, they satisfy delaunay property. Since the bezier surface is curved, delaunay property always holds.

2 IMPLEMENTATION DETAILS

2.1 Bezier Surface generation

To draw a bezier surface , we start with control points and evaluate bezier curves twice to get a bezier point.(first u then v).

2.1.1 Eval Bezier Curve . x

First i complete the last interploration of bezier curve

```
inline glm::vec3 mlBezier::derivBezier(const glm::vec3 *
    P, const float & t)
{
return (1 - t)*P[0] + t*P[1];
}
```

Then i do bezier interploration recursively,starting from controlpoints.

```
glm::vec3 mlBezier::mlEvalBezierCurve(const glm::vec3 * P
    , const float & t ,int input_length,bool getTagent)
{
if (input_length == 2) {
        if (getTagent==true) {
                return glm::normalize(P[0] - P[1]);

        }else {
                return derivBezier(P,t);
        }
}else {
        glm::vec3 * out_Points = new glm::vec3[
            input_length - 1];
        glm::vec3 P1, P2;
        for (int i = 0; i < input_length-1; i++) {
                P1 = P[i]; P2 = P[i + 1];
        out_Points[i] = (1 - t)*P1 + t*P2;
        }
        return mlEvalBezierCurve(out_Points, t,
            input_length-1,getTagent);
}
}
```

getTagent is a flag to return the tagent vector on that point instead of returning that point.

input_length is the number of points in P.

At each iteration, the point numbers will decrease by one.With this function, we can get a point or its tagent vector.

```
glm::vec3 mlBezier::mlEvalBezierPatch(const glm::vec3 *
    controlPoints, const float & u, const float & v)
{
        glm::vec3 Pu[4];
        for (int i = 0; i < 4;i++) {
                glm::vec3 curveP[4];
                curveP[0] = controlPoints[i * 4];
                curveP[1] = controlPoints[i * 4+1];
                curveP[2] = controlPoints[i * 4+2];
                curveP[3] = controlPoints[i * 4+3];
                Pu[i] = mlEvalBezierCurve(curveP, u,4,
                    false);
        }
        return mlEvalBezierCurve(Pu, v,4,false);
}
```

To get tagent vector. Calculate from tagent vecors on the controlPoints.And interplorate it from the nearst two tagent vector.

```
glm::vec3 mlBezier::dUBezier(const glm::vec3 *
    controlPoints, const float & u, const float & v)
{
        glm::vec3 Pu[4];
        for (int i = 0; i < 4; i++) {
                glm::vec3 curveP[4];
                curveP[0] = controlPoints[i * 4];
                curveP[1] = controlPoints[i * 4 + 1];
                curveP[2] = controlPoints[i * 4 + 2];
                curveP[3] = controlPoints[i * 4 + 3];
                Pu[i] = mlEvalBezierCurve(curveP, u, 4,
                    true);
        }
        int pre = floor(v * 4);
        float t = v * 4 - pre;
        int next = ceil(v * 4);
        return Pu[pre] * (1 - t) + t*Pu[next];
}
```

Now that we can eval bezier points smoothly.To generate the mesh, we should specify (u,v) to generate a point with normal and st.

Normal is generating by cross product from two tagent vector.

```
void mlBezier::mlCreateBeizermesh()
{
        P.clear(); N.clear(); st.clear();
        float step = 1/sqrt(divs);
        for (float v = 0; v <= 1; v += step) {
                for (float u = 0; u <= 1; u += step) {
                        glm::vec3 p = mlEvalBezierPatch(
                            controlPoints, u, v);
                        P.push_back(p);
                        N.push_back(
                        glm::normalize(
```

```
                        glm::cross(dUBezier(controlPoints
                            , u, v), dVBezier(
                            controlPoints, u, v))
                        )
                        );
                        st.push_back(glm::vec2(u, v));

                }
        }
}
```

to draw the surface out.

```
void mlBezier::mlTriangularization()
{
        indicesofControlpoints.clear();
        for (int j = 0; j < 3; j++)
        {
                for (int i = 0; i < 3; i++)
                {
                        int ind = j * 4 + i;
                        indicesofControlpoints.push_back(
                            ind);
                        indicesofControlpoints.push_back(
                            ind + 1);
                        indicesofControlpoints.push_back(
                            ind + 5);
                        indicesofControlpoints.push_back(
                            ind + 4);
                }
        }
        indicesofP.clear();
        int div = sqrt(divs);
        indicesofP.clear();
        for (int j = 0; j < div; j++)
        {
                for (int i = 0; i < div; i++)
                {
                        int ind = j * (div+1) + i;
                        indicesofP.push_back(ind);
                        indicesofP.push_back(ind + 1);
                        indicesofP.push_back(ind + (div +
                              1));

                        indicesofP.push_back(ind + 1);
                        indicesofP.push_back(ind + (div +
                              2));
                        indicesofP.push_back(ind + (div +
                              1));
                }
        }
}
```

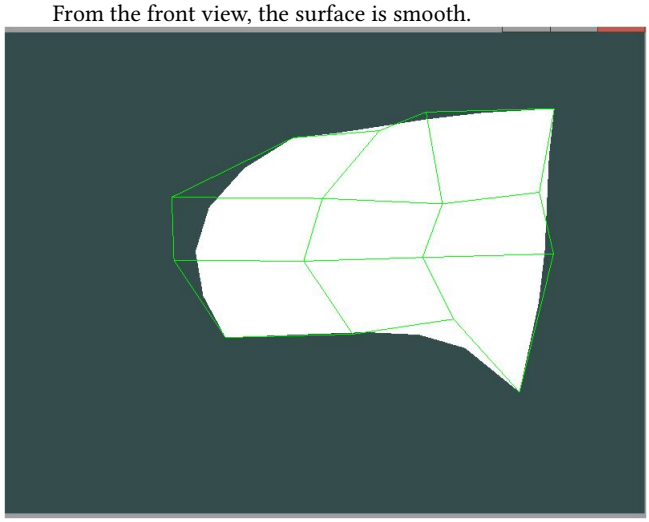
```
void drawBezierSurface(mlBezier &mlbezier)
{
        glm::vec3 points_pos[3], points_norm[3];glm::vec2
             points_tex[3];
        for (size_t i = 0; i < mlbezier.indicesofP.size()
            ; i += 3) {
                points_pos[0] = mlbezier.P[mlbezier.
                    indicesofP[i]];
                points_norm[0] = mlbezier.N[mlbezier.
                    indicesofP[i]];
                points_tex[0] = mlbezier.st[mlbezier.
                    indicesofP[i]];

                glColor3f(1, 1, 1);
                glBegin(GL_TRIANGLES);
                glNormal3f(points_norm[0].x, points_norm
                    [0].y, points_norm[0].z);
                glTexCoord2f(points_tex[0].x, points_tex
                    [0].y);
                glVertex3f(points_pos[0].x, points_pos
                    [0].y, points_pos[0].z);
                glEnd();
                ...
        }
}
```

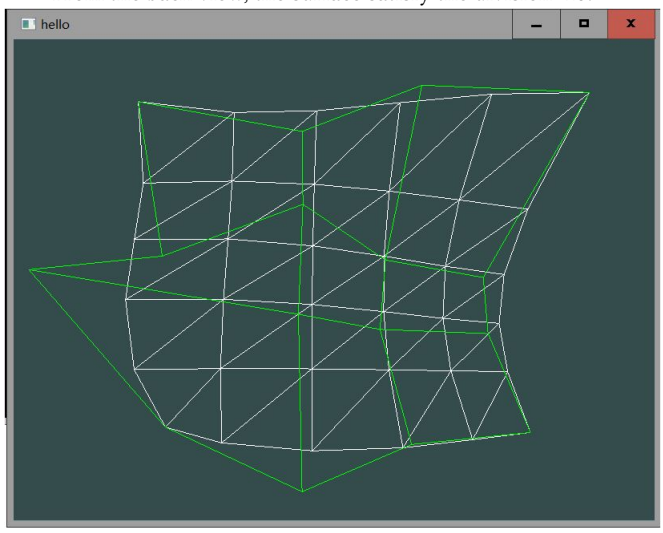
This function setting up the points based on the division ,for example 6x6 or 9x9. it suits all.

2.1.2 *curve result.* x

From the front view, the surface is smooth.



From the back view, the surface satisfy the division=25.



2.2 Camera movement

I defined several global variables.

```
//Setting up camera
// for translating the camera
glm::vec3 cameraPos = glm::vec3(0.0f, 0.0f, 3.0f);
glm::vec3 cameraFront = glm::vec3(0.0f, 0.0f, -1.0f);
glm::vec3 cameraUp = glm::vec3(0.0f, 1.0f, 0.0f);

glm::mat4 model ,view, projection;
// fo smoothing
float deltaTime = 0;
float lastFrame = 0;
// for rotating the camera
float pitch = 0;
float yaw = -90.0f;
```

```
// for mouse input
float lastX = 400, lastY = 300;
bool firstMouse = true;
// for scene scaling
float fov = 45.0f;
glm::vec3 lightPos(1.2f, 1.0f, 2.0f);
```

also two global functions

```
void initPMV()
{
        glMatrixMode(GL_PROJECTION);
        glLoadIdentity();

        gluPerspective(60, SCR_WINDTH / SCR_HEIGHT, 0.1,
             100);

        glMatrixMode(GL_MODELVIEW);
        glLoadIdentity();
        gluLookAt
        (0, 0, 7.5,
        0, 0, 0,
        0, 1, 0
        );
}
void changePMV() {
        glMatrixMode(GL_PROJECTION);
        glLoadIdentity();
        gluPerspective(fov, SCR_WINDTH / SCR_HEIGHT, 0.1,
              100);
        glMatrixMode(GL_MODELVIEW);
        glLoadIdentity();
        gluLookAt
        (cameraPos.x,cameraPos.y,cameraPos.z,
        cameraPos.x+cameraFront.x, cameraPos.y +
             cameraFront.y, cameraPos.z + cameraFront.z,
        cameraUp.x,cameraUp.y,cameraUp.z
        );
        view = glm::lookAt(cameraPos, cameraPos +
             cameraFront, cameraUp);
        projection = glm::perspective(glm::radians(fov),
             (float)(SCR_WINDTH / SCR_HEIGHT), 0.1f, 100.0
             f);
}
```

Fill in the void processInput(Window * window)

```


void processInput(GLFWwindow *window)
{

float cameraSpeed = 2.5f* deltaTime; // adjust
     accordingly
if (glfwGetKey(window, GLFW_KEY_ESCAPE) == GLFW_PRESS)
glfwSetWindowShouldClose(window, true);
if (glfwGetKey(window, GLFW_KEY_W) == GLFW_PRESS)
cameraPos += cameraSpeed * cameraFront;
if (glfwGetKey(window, GLFW_KEY_S) == GLFW_PRESS)
cameraPos -= cameraSpeed * cameraFront;
if (glfwGetKey(window, GLFW_KEY_A) == GLFW_PRESS)
cameraPos -= glm::normalize(glm::cross(cameraFront,
     cameraUp)) * cameraSpeed;
if (glfwGetKey(window, GLFW_KEY_D) == GLFW_PRESS)
cameraPos += glm::normalize(glm::cross(cameraFront,
     cameraUp)) * cameraSpeed;

}
```

Now press WASD to translate the camera, indeed it's changing the view matrix.

To support camera rotating.

```
void mouse_callback(GLFWwindow* window, double xpos,
     double ypos)
{
if (firstMouse) // Initialization
{
        lastX = xpos;
        lastY = ypos;
        firstMouse = false;
}
// calculate the mouse movement
float xoffset = xpos - lastX;
float yoffset = lastY - ypos;
lastX = xpos;
lastY = ypos;

float sensitivity = 0.05f;
xoffset *= sensitivity;
yoffset *= sensitivity;

yaw += xoffset;
pitch += yoffset;
\\restrict the camera not to rotate to backwards
if (pitch > 89.0f)
pitch = 89.0f;
if (pitch < -89.0f)
pitch = -89.0f;

glm::vec3 front;
front.x = cos(glm::radians(pitch)) * cos(glm::radians(yaw
     ));
front.y = sin(glm::radians(pitch));
front.z = cos(glm::radians(pitch)) * sin(glm::radians(yaw
     ));
\\set the camera front
cameraFront = glm::normalize(front);
}
```

In this function, i calculate the relative mouse movement and change the yaw/pitch of the camera. To further support scaling , use mouse scroll event to change the fov of camera.

```
glfwSetScrollCallback(window, scroll_callback);
void scroll_callback(GLFWwindow* window, double xoffset,
     double yoffset) {
        if (fov >= 1.0f && fov <= 45.0f)
                fov -= yoffset;
        if (fov <= 1.0f)
                fov = 1.0f;
        if (fov >= 45.0f)
                fov = 45.0f;
}
```

2.3 Gourand Lighting with OpenGL

First specify material of light source and obect.

```
GLfloat sun_light_position[] = { 0.0f, 0.0f, 12.0f, 0.0f
     };
GLfloat sun_light_ambient[] = { 0.0f, 0.0f, 0.0f, 1.0f };
GLfloat sun_light_diffuse[] = { 1.0f,  0.0f, 1.0f, 1.0f
     };
GLfloat sun_light_specular[] = { 1.0f, 1.0f, 0.0f, 1.0f
     };

GLfloat earth_mat_ambient[] = { 1.0f, 1.0f, 1.0f, 1.0f };
GLfloat earth_mat_diffuse[] = { 0.0f, 0.0f, 0.5f, 1.0f };
GLfloat earth_mat_specular[] = { 1.0f, 0.0f, 0.0f, 1.0f
     };
GLfloat earth_mat_emission[] = { 0.0f, 0.0f, 0.0f, 1.0f
     };
GLfloat earth_mat_shininess = 30.0f;
```

Add following codes into drawBezierSurface()

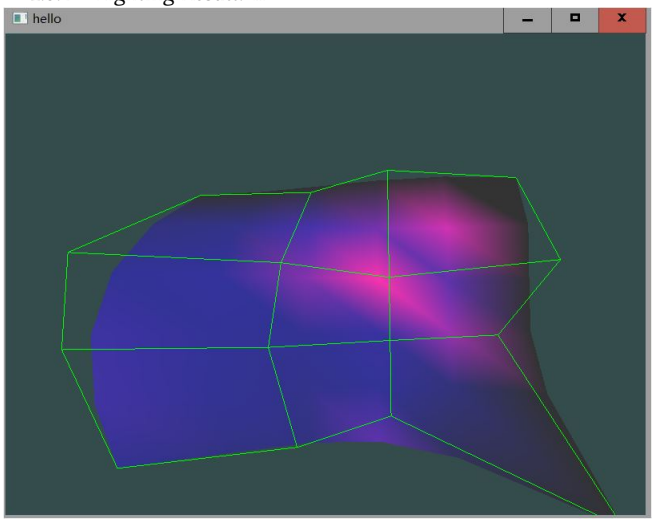
```
glMaterialfv(GL_FRONT, GL_AMBIENT, earth_mat_ambient);
glMaterialfv(GL_FRONT, GL_DIFFUSE, earth_mat_diffuse);
glMaterialfv(GL_FRONT, GL_SPECULAR, earth_mat_specular);
glMaterialfv(GL_FRONT, GL_EMISSION, earth_mat_emission);
```

```
glMaterialf(GL_FRONT, GL_SHININESS, earth_mat_shininess);
```

in AddLight(), turn on lighting.

```
void AddLight(mlBezier &mlbezier)
{
        glLightfv(GL_LIGHT0, GL_POSITION,
             sun_light_position);
        glLightfv(GL_LIGHT0, GL_AMBIENT,
             sun_light_ambient);
        glLightfv(GL_LIGHT0, GL_DIFFUSE,
             sun_light_diffuse);
        glLightfv(GL_LIGHT0, GL_SPECULAR,
             sun_light_specular);
        glEnable(GL_LIGHTING);
        glEnable(GL_LIGHT0);
}
```

2.3.1 *Lighting Result.* x



the purple part is specular part, the basis diffuse is blue.

2.4 Texturing

Initialize the texuture and set parameters.

```
void initTexture(unsigned int &texture)
{
        int width, height, nrChannels;
        unsigned char *data = stbi_load("resource/
             textures/container.jpg", &width, &height, &
             nrChannels, 0);
        //bind it to texture
        glEnable(GL_TEXTURE_2D);
        glGenTextures(1, &texture);
        glBindTexture(GL_TEXTURE_2D, texture);
        // set the active texture
        glTexImage2D(GL_TEXTURE_2D, 0, GL_RGB, width,
             height, 0, GL_RGB, GL_UNSIGNED_BYTE, data);
        // sample: specify texture parameters
        glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_S,
              GL_REPEAT);
        glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_T,
              GL_REPEAT);
        glTexParameteri(GL_TEXTURE_2D,
             GL_TEXTURE_MAG_FILTER, GL_LINEAR);
        glTexParameteri(GL_TEXTURE_2D,
             GL_TEXTURE_MIN_FILTER, GL_LINEAR);
        stbi_image_free(data);
}
```

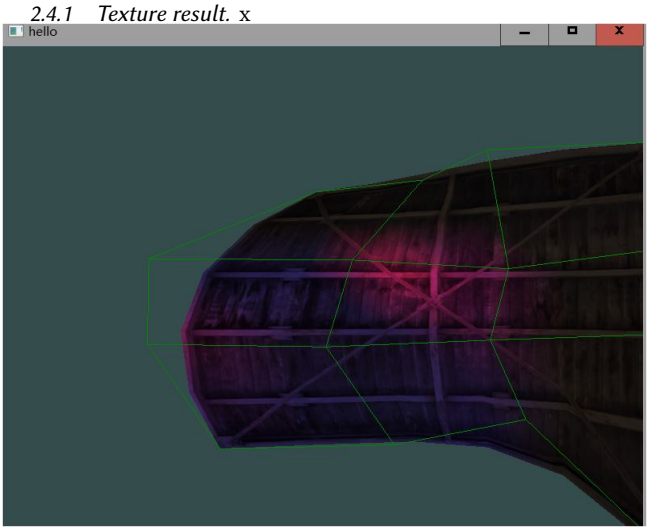
Since st is already setted in drawBezierSurface()

```
glTexCoord2f(points_tex[0].x, points_tex[0].y);
```

Bind Texture before drawing, then all should work as expected.
Add following code into drawBezierSurface()

```
glBindTexture(GL_TEXTURE_2D, texture);
```

2.4.1 *Texture result.* x



2.5 Editing ControlPoints

The main idea is to project all current 3d points back to screen space and select a point closest to the cursor position under certain threshold.

Then estiamte mouse movement until mouse release. Then get a estimated screen space point, and we projected it back to set the 3d controlPoints.

First, we register the mouse_button_callback()

```
void mouse_button_callback(GLFWwindow* window, int button
     , int action, int mods);
glfwSetMouseButtonCallback(window, mouse_button_callback)
     ;
```

Use drag_start and drag_end to estimate the mouse movement during dragging.
Use dragFlag to specify whether is on the process of dragging.

```
void mouse_button_callback(GLFWwindow* window, int button
     , int action, int mods)
{
        double xpos, ypos;
        glm::vec4 viewport = glm::vec4(0, 0, SCR_WINDTH,
             SCR_HEIGHT);
        glfwGetCursorPos(window, &xpos, &ypos);
        if (action == GLFW_PRESS) switch (button)
        {
                case GLFW_MOUSE_BUTTON_LEFT:
                if (dragFlag == false) {
                        int ind = mlbezier.
                             getSelectedControlPointIndice
                             (xpos, ypos, view, projection
                             , viewport);
                        if (ind != -1) {
                                dragFlag = true;
                                drag_start = glm::vec2(
                                     xpos,viewport[3]-
                                     ypos);
```

```
                                selected_index = ind;
                        }
                }
                break;
                default:
                return;
        }

        if (action == GLFW_RELEASE) switch (button)
        {
                case GLFW_MOUSE_BUTTON_LEFT:
                if (dragFlag ==true&&selected_index!=-1)
                     {
                        drag_end = glm::vec2(xpos,
                             viewport[3] - ypos);
                        mlbezier.
                             updateControlPointPosition(
                             selected_index, (drag_end -
                             drag_start),view,projection,
                             viewport);
                        mlbezier.mlCreateBeizermesh();//
                             Recreate mesh and
                             triangularization
                        mlbezier.mlTriangularization();
                        selected_index = -1;
                        dragFlag = false;
                }
                break;
                default:
                return;
        }
        return;
}
```

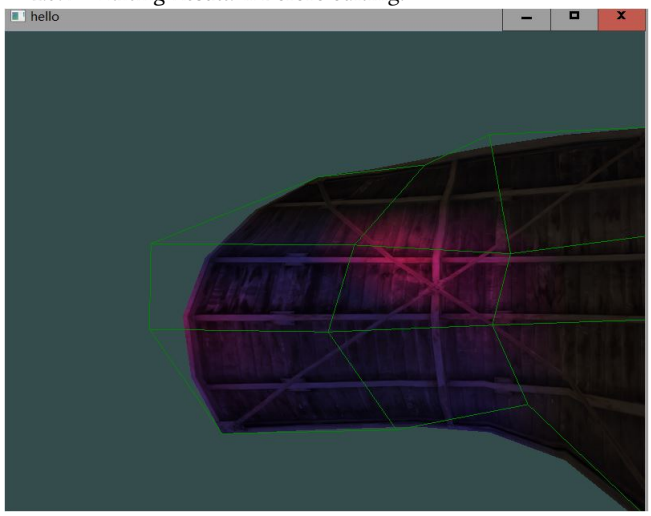
Note that due to the windows screen coordinate is upside down of opengl screen coordiante,we should do 'Height - ypos' to convert to opengl coordiante.
Then we can use glm::project and glm::unproject currently.

```
int mlBezier::getSelectedControlPointIndice(int posX, int
      posY,glm::mat4 view,glm::mat4 projection,glm::vec4
     viewport)
{
        float minDistance = 65536;
        int ind = -1;
        float thres = 20;
        for (int i = 0; i < controlPointsNums; i++) {
                glm::vec3 pos = glm::project(
                     controlPoints[i], view, projection,
                     viewport);
                float distance =glm::distance(glm::vec2(
                     posX, viewport[3] - posY), glm::vec2(
                     pos.x,pos.y));
                if (distance < minDistance && distance<
                     thres) {
                        minDistance = distance;
                        ind = i;
                }
        }
        return ind;
}
```

```
void mlBezier::updateControlPointPosition(int selectedInd
     ,glm::vec2 moveDistance,glm::mat4 view, glm::mat4
     projection, glm::vec4 viewport)
{
        glm::vec3 pos = glm::project(controlPoints[
             selectedInd], view, projection, viewport);
        glm::vec3 newprojected = glm::vec3(pos.x +
             moveDistance.x, pos.y + moveDistance.y, pos.z
             );
        this->controlPoints[selectedInd] = glm::unProject
             (newprojected,view, projection, viewport);
}
```

Thus the controlpoints editing should work.

2.5.1 Editing Result. x Before editing.



After editing.