CS6060- Final

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Overview

The goal of this project was to render a 3D model of my head. A screenshot of the end result is shown below.

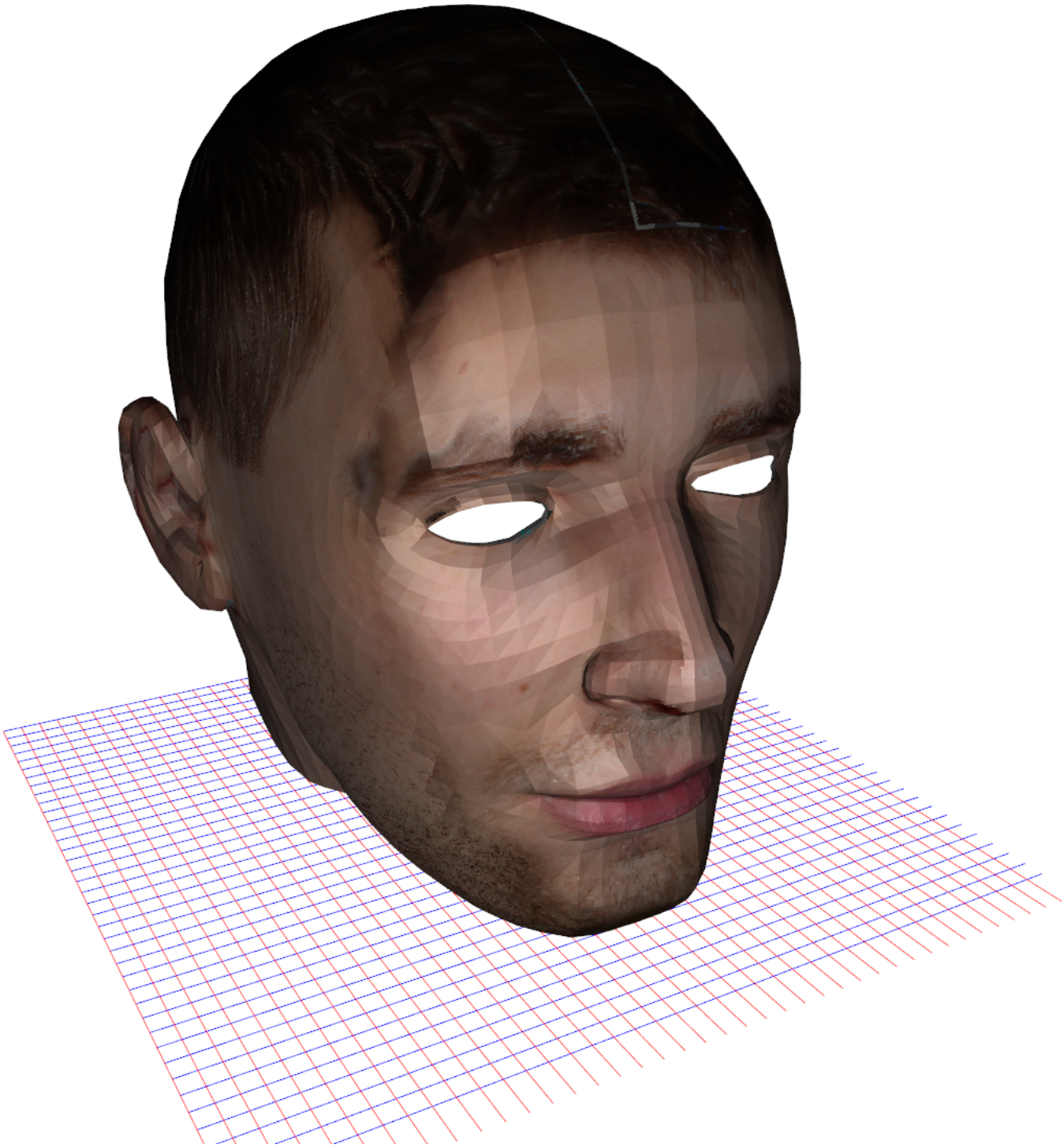


Figure 1: Program Screenshot

A video demonstation can be found here: `http://youtu.be/1Sn57Y0Xirw`

All code and resources can be found here: `https://github.com/bear24rw/CS6060/tree/master/final`

Head Model

The first step in this project was to model my head. I didn't have the time or experience to construct the model from scratch so I found a generic head online which is shown below.

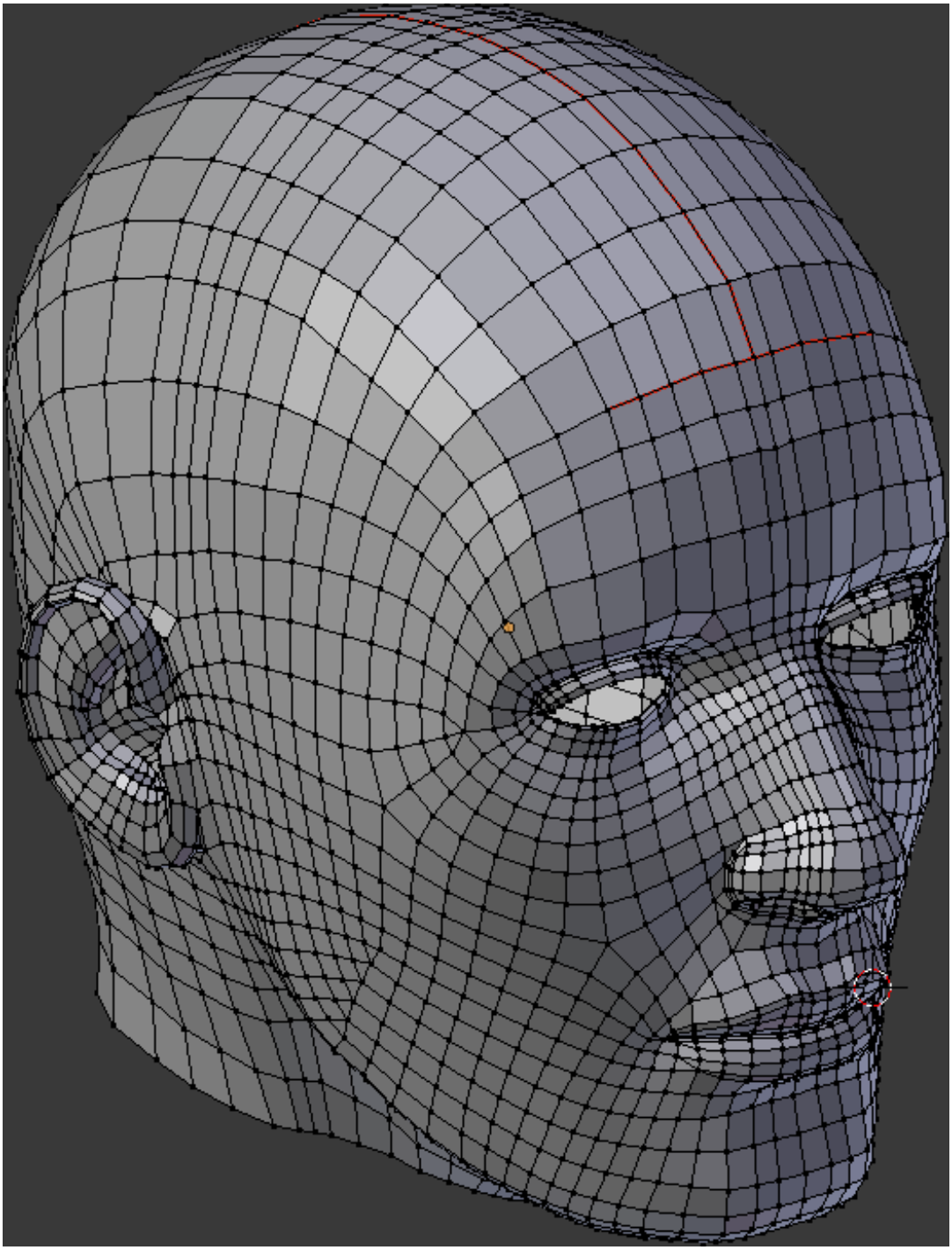
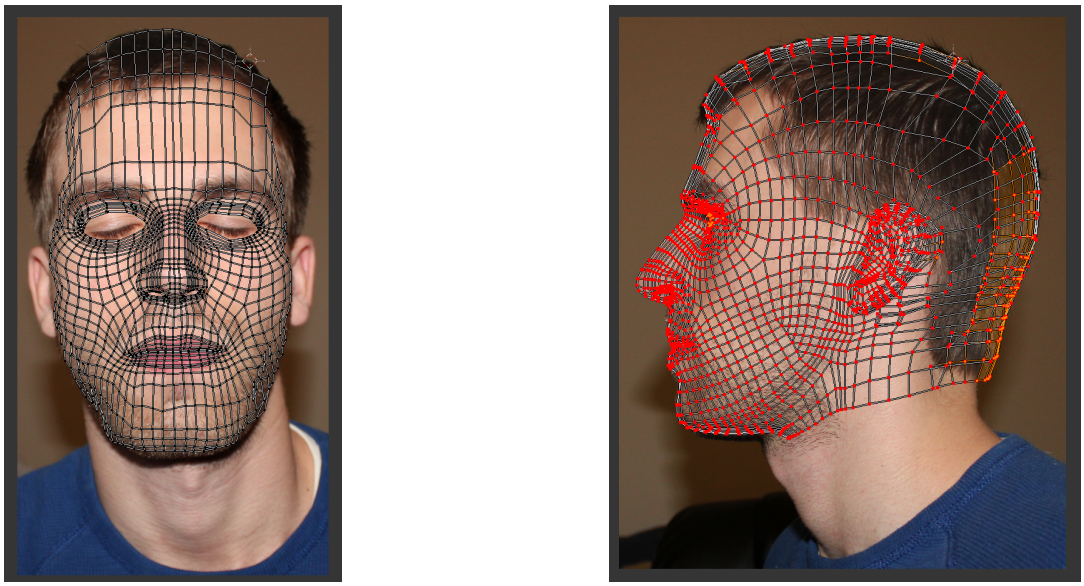


Figure 2: Generic 3D Head Model

In order to texture it I first took a front and side image of my head and then projection mapped them onto the model in Blender.



(a) Front Projection Map **(b)** Side Projection Map

Figure 3: Projection Texture Mapping

The resulting mapping isn't totally perfect since the head model I used doesn't exactly match my face and I also only used a front and side image of my face. The images below show the model pre and post texturing.

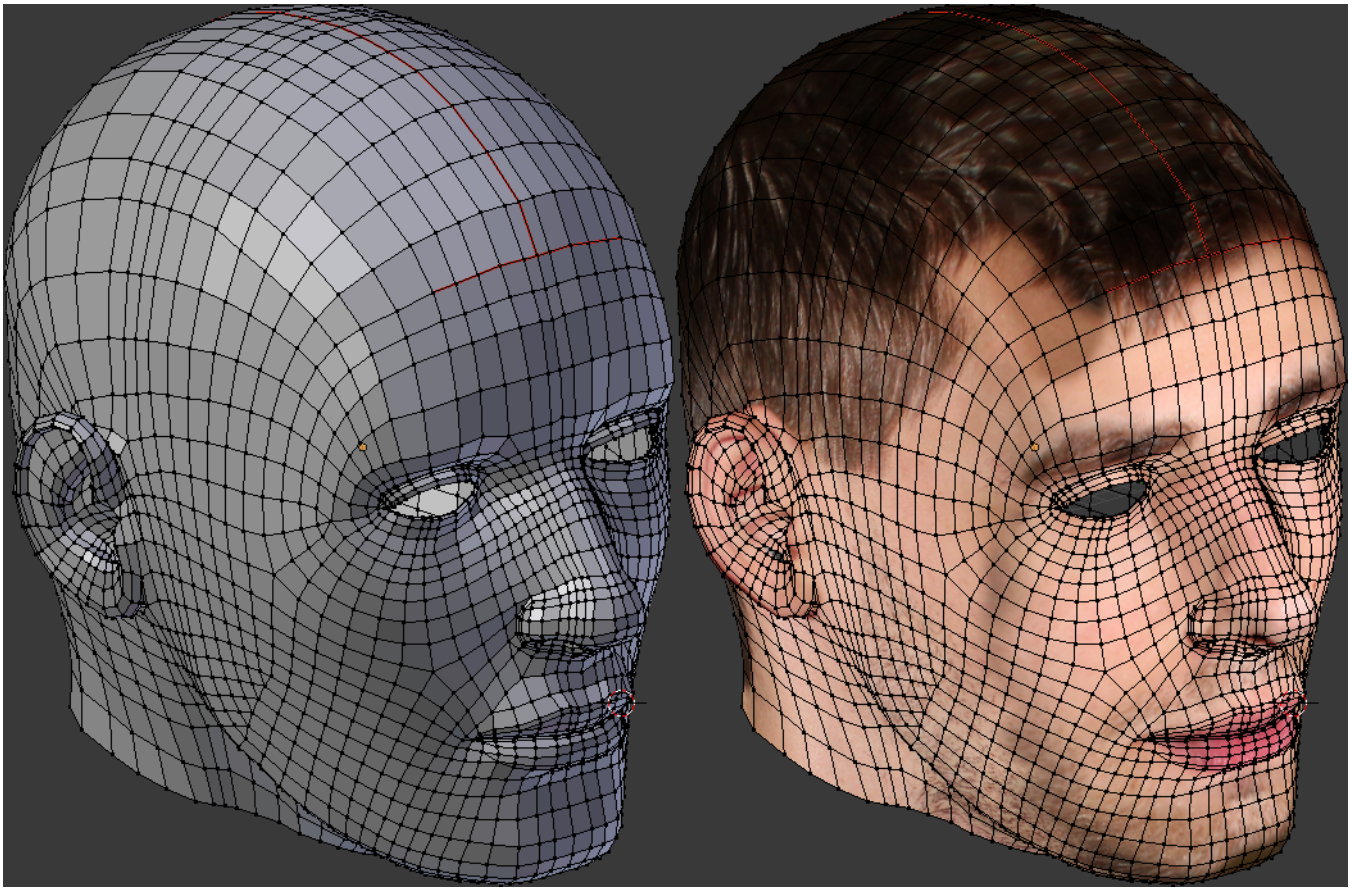


Figure 4: Untextured Model

Figure 5: Textured Model

I then exported the model as an OBJ file and exported the texture as a PNG. The final texture is shown below.

Figure 6: Final Texture

Head Rendering

In order to render the head we first load the shaders and get IDs for all the uniforms that we will be manipulating.

```
21      shader_id = LoadShaders("head_vert.glsl", "head_frag.glsl");
23
23      model_id = glGetUniformLocation(shader_id, "M");
24      view_id  = glGetUniformLocation(shader_id, "V");
25      proj_id  = glGetUniformLocation(shader_id, "P");
26      light_id = glGetUniformLocation(shader_id, "light_pos_world");
27      texture_id = glGetUniformLocation(shader_id, "tex");
```

Listing 1: Load Shader (`../code/head.cpp`)

For loading the texture we take a shortcut and use the texture functionality provided by SFML. Since we are just loading a simple 2D texture there is no need to manually load and bind the texture with raw opengl calls.

```
29      texture.loadFromFile("../assets/uvmap.png");
```

Listing 2: Load Texture (`../code/head.cpp`)

We then create some vectors to hold the vertices, normals, and texture coordinates for our model and call a helper function to populate them.

```
32      std::vector<glm::vec3> indexed_vertices;
33      std::vector<glm::vec2> indexed_uvs;
34      std::vector<glm::vec3> indexed_normals;
35      load_obj("../assets/head.obj", indices, indexed_vertices, indexed_uvs, indexed_normals);
```

Listing 3: Read OBJ (`../code/head.cpp`)

In order to parse the OBJ file I used the Open Asset Import Library (Assimp). Assimp takes care of all the dirty work required to parse the OBJ and provides us with simple lists for the vertices, normals, and uv coordinates. The following code shows the body of the function which is responsible for opening the OBJ file with Assimp and populating vectors of GLM objects.

```
23      Assimp::Importer importer;
25
25      const aiScene* scene = importer.ReadFile(path, 0/*aiProcess_JoinIdenticalVertices | aiProcess_SortByPType*/);
26      if( !scene) {
27          fprintf( stderr, importer.GetErrorString());
28          getchar();
29          return false;
30      }
31      const aiMesh* mesh = scene->mMeshes[0]; // In this simple example code we always use the 1rst mesh (in OBJ files there is often only one anyway)
33
33      // Fill vertices positions
34      printf("[assimp] filling vertice positions\n");
35      vertices.reserve(mesh->mNumVertices);
36      for(unsigned int i=0; i<mesh->mNumVertices; i++){
37          aiVector3D pos = mesh->mVertices[i];
38          vertices.push_back(glm::vec3(pos.x, pos.y, pos.z));
39      }
41
41      // Fill vertices texture coordinates
42      printf("[assimp] filling vertice tex coords\n");
43      uvs.reserve(mesh->mNumVertices);
44      for(unsigned int i=0; i<mesh->mNumVertices; i++){
45          aiVector3D UVW = mesh->mTextureCoords[0][i]; // Assume only 1 set of UV coords; AssImp supports 8 UV sets.
46          uvs.push_back(glm::vec2(UVW.x, UVW.y));
47      }
49
49      // Fill vertices normals
50      printf("[assimp] filling vertice normals\n");
51      normals.reserve(mesh->mNumVertices);
52      for(unsigned int i=0; i<mesh->mNumVertices; i++){
53          aiVector3D n = mesh->mNormals[i];
54          normals.push_back(glm::vec3(n.x, n.y, n.z));
55      }
57
57      // Fill face indices
58      printf("[assimp] filling face indices\n");
59      indices.reserve(3*mesh->mNumFaces);
60      for (unsigned int i=0; i<mesh->mNumFaces; i++){
61          // Assume the model has only triangles.
62          indices.push_back(mesh->mFaces[i].mIndices[0]);
63          indices.push_back(mesh->mFaces[i].mIndices[1]);
64          indices.push_back(mesh->mFaces[i].mIndices[2]);
65      }
```

Listing 4: OBJ Loading (`../code/objloader.cpp`)

Next we want to be able to place the bottom of the model at Y=0 and also center the camera target to the middle of the model. To do this we simply loop through each vertices of the model and keep track of the lowest one. We will use this offset later in the render function. The camera is targeted to three fourths of the way up the model which was determined experimentally to be a nice position.

```
32      std::vector<glm::vec3> indexed_vertices;
33      std::vector<glm::vec2> indexed_uvs;
34      std::vector<glm::vec3> indexed_normals;
35      load_obj("../assets/head.obj", indices, indexed_vertices, indexed_uvs, indexed_normals);
36
37      offset = 0.0f;
38      for (glm::vec3 i : indexed_vertices) {
39          if (i.y < offset) offset = i.y;
40      }
41
42      cam->target.y = -offset * 0.75f;
```

Listing 5: Calculate model offset (`../code/head.cpp`)

We then get the shader attribute locations for the vertices, normals, and texture. We then create a Vertex Array Object (VAO) which will keep track of all the bindings and attribute parameters we are about to set. Then, for each attribute, we generate a vertex buffer, bind it, upload the data for it with `glBufferData`, set the parameters for the data with `glVertexAttribPointer`, and finally enable the attribute. We also bind the texture after this.

```
46      GLuint posAttrib = glGetAttribLocation(shader_id, "vert_pos_model");
47      GLuint norAttrib = glGetAttribLocation(shader_id, "vert_nor_model");
48      GLuint texAttrib = glGetAttribLocation(shader_id, "vert_tex");
49
50      glGenVertexArrays(1, &vao);
51      glBindVertexArray(vao);
52
53      glGenBuffers(1, &vertexbuffer);
54      glBindBuffer(GL_ARRAY_BUFFER, vertexbuffer);
55      glBufferData(GL_ARRAY_BUFFER, indexed_vertices.size() * sizeof(glm::vec3), &indexed_vertices[0], GL_STATIC_DRAW);
56      glVertexAttribPointer(posAttrib, 3, GL_FLOAT, GL_FALSE, 0, (void*)0);
57      glEnableVertexAttribArray(posAttrib);
58
59      glGenBuffers(1, &normalbuffer);
60      glBindBuffer(GL_ARRAY_BUFFER, normalbuffer);
61      glBufferData(GL_ARRAY_BUFFER, indexed_normals.size() * sizeof(glm::vec3), &indexed_normals[0], GL_STATIC_DRAW);
62      glVertexAttribPointer(norAttrib, 3, GL_FLOAT, GL_FALSE, 0, (void*)0);
63      glEnableVertexAttribArray(norAttrib);
64
65      glGenBuffers(1, &uvbuffer);
66      glBindBuffer(GL_ARRAY_BUFFER, uvbuffer);
67      glBufferData(GL_ARRAY_BUFFER, indexed_uvs.size() * sizeof(glm::vec2), &indexed_uvs[0], GL_STATIC_DRAW);
68      glVertexAttribPointer(texAttrib, 2, GL_FLOAT, GL_FALSE, 0, (void*)0);
69      glEnableVertexAttribArray(texAttrib);
70
71      glGenBuffers(1, &elementbuffer);
72      glBindBuffer(GL_ELEMENT_ARRAY_BUFFER, elementbuffer);
73      glBufferData(GL_ELEMENT_ARRAY_BUFFER, indices.size() * sizeof(unsigned short), &indices[0] , GL_STATIC_DRAW);
74
75      sf::Texture::bind(&texture);
```

Listing 6: Setup Bind and Load Buffers (`../code/head.cpp`)

The rendering function is extremely simple. We first activate the shader responsible for rendering the head. We then create an identity model matrix which is first rotated and then translated to achieve the animation and place the head on the 'ground'. We then send the updated matrices to the shader using `glUniformMatrix4fv`. We also update the position of the light to the position of the camera. Finally we bind our VAO and draw all the elements of our model.

```
80  void Head::render()
81  {
82      glUseProgram(shader_id);
83
84      glm::mat4 model = glm::mat4(1.0f);
85      model = glm::rotate(model, rotation, glm::vec3(0,1,0));
86      model = glm::translate(model, glm::vec3(0.0f, -offset, 0.0f));
87
88      glUniformMatrix4fv(proj_id, 1, GL_FALSE, glm::value_ptr(cam->proj_mat()));
89      glUniformMatrix4fv(view_id, 1, GL_FALSE, glm::value_ptr(cam->view_mat()));
90      glUniformMatrix4fv(model_id, 1, GL_FALSE, glm::value_ptr(model));
91
92      glUniform3f(light_id, cam->position.x, cam->position.y, cam->position.z);
93
94      glBindVertexArray(vao);
95      glDrawElements(GL_TRIANGLES, indices.size(), GL_UNSIGNED_SHORT, (void*)0);
96  }
```

Listing 7: Render Function (`../code/head.cpp`)

Animation

A simple rotation animation is achieved by keeping track of total rotation angle. In the main render loop the `rotation` instance variable is incremented at a rate of 10 degrees per second. `delta` is the lapsed time since the last loop.

```
113         if (rotate_mode)
114             head.rotation += 10.0f * delta.asSeconds();
```

Listing 8: Rotation (`../code/main.cpp`)

The head rendering function, discussed in the previous section, then simply rotates the model matrix by the number of degrees accumulated in the `rotation` variable.

```
84      glm::mat4 model = glm::mat4(1.0f);
85      model = glm::rotate(model, rotation, glm::vec3(0,1,0));
```

Listing 9: Model Matrix Rotation (`../code/head.cpp`)

Lighting

Lighting is achieved through the combination of diffuse, ambient, and specular components.

The ambient component simply bumps up the brightness of each fragment to simulate a global indirect light source.

The diffuse component takes into account the distance of the fragment to the light source and angle of the income light and the fragments normal.

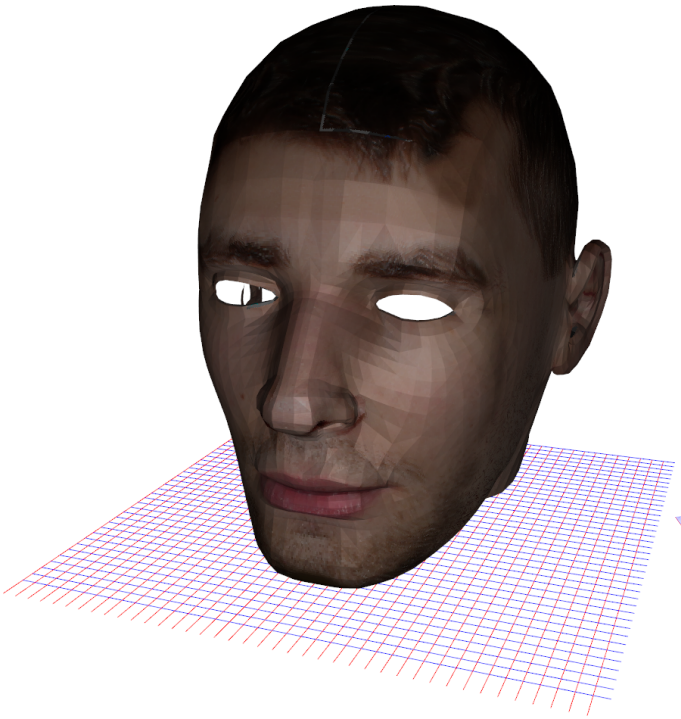
The specular component accounts for the fact that there will be more light reflecting in the direction that the light intersected the surface.

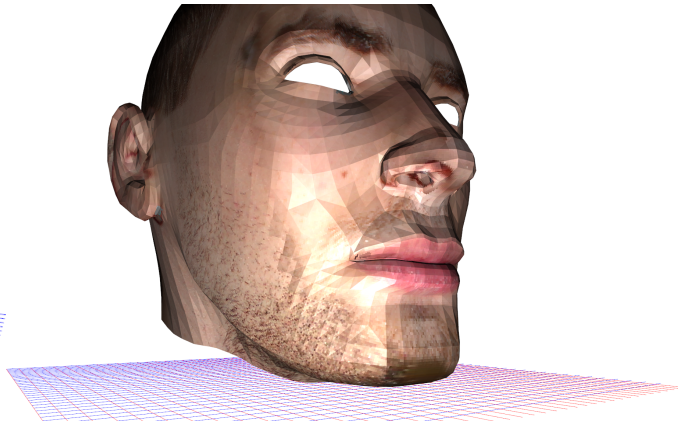
```
18  void main(){
19
20          // Light emission properties
21          vec3 light_color = vec3(1,1,1);
22          float light_power = 1500.0f;
23
24          // Material properties
25          vec3 diffuse_color = texture2D(tex, UV).rgb;
26          vec3 ambient_color = vec3(0.1,0.1,0.1) * diffuse_color;
27          vec3 specular_color = vec3(0.3,0.3,0.3);
28
29          // Distance to the light
30          float distance = length(light_pos_world - vert_pos_world);
31
32          vec3 n = normalize( vert_nor_cam );
33          vec3 l = normalize( light_dir_cam );
34          float cosTheta = clamp( dot( n,l ), 0,1 );
35
36          vec3 E = normalize(eye_dir_cam);
37          vec3 R = reflect(-l,n);
38          float cosAlpha = clamp( dot( E,R ), 0,1 );
39
40          color = ambient_color +
41              diffuse_color * light_color * light_power * cosTheta / (distance*distance) +
42              specular_color * light_color * light_power * pow(cosAlpha,5) / (distance*distance);
43
44  }
```

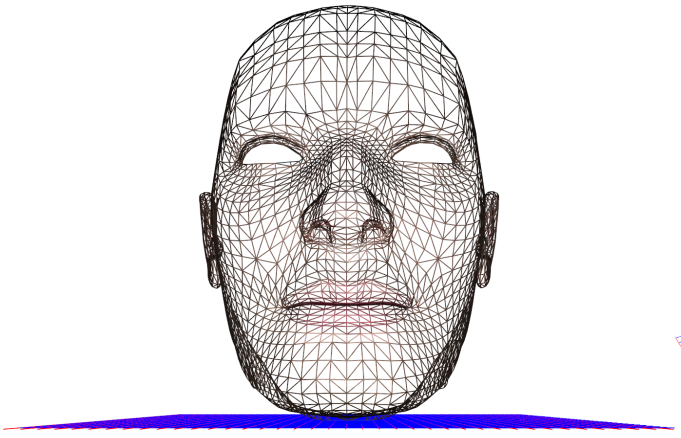
Listing 10: Head Fragment Shader (`../code/head_frag.glsl`)

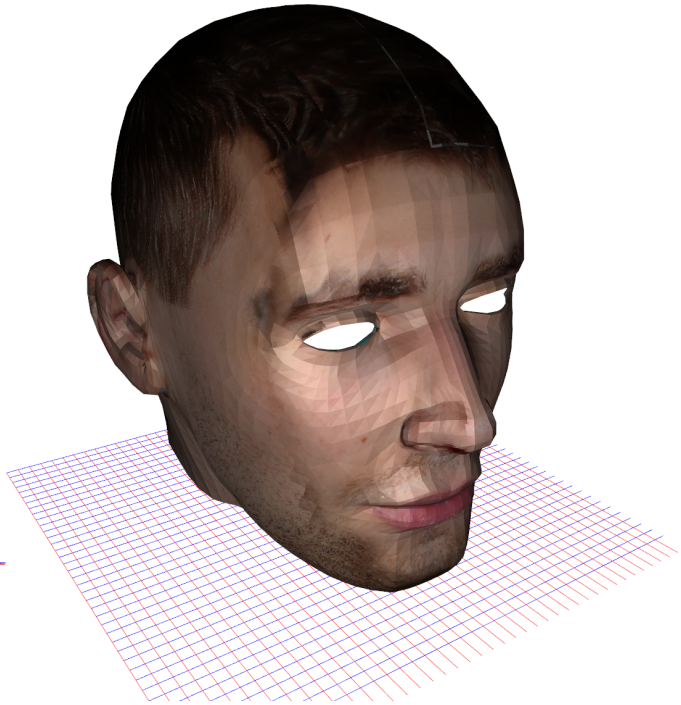
The shader code to achieve these effects was heavily lifted from this tutorial:
`http://www.opengl-tutorial.org/beginners-tutorials/tutorial-8-basic-shading/`

Screenshots









Code

```
#define GLEW_STATIC
#include <vector>
#include <GL/glew.h>
#include <SFML/Graphics.hpp>
#include <SFML/OpenGL.hpp>
#include <iostream>
#include <ctime>
#include <glm/glm.hpp>
#include <glm/gtc/matrix_transform.hpp>
#include <glm/gtx/rotate_vector.hpp>
#include <glm/gtc/type_ptr.hpp>
#include "camera.h"
#include "grid.h"
#include "head.h"

int main()
{
    sf::ContextSettings contextSettings;
    contextSettings.depthBits = 32;
    contextSettings.antialiasingLevel = 8;

    sf::RenderWindow window(sf::VideoMode(800, 800), "Test 1", sf::Style::Default, contextSettings);
    window.setVerticalSyncEnabled(true);

    window.setActive();

    glewExperimental = GL_TRUE;
    glewInit();

    Camera cam;
    Grid grid(&cam);
    Head head(&cam);

    int mouse_down = 0;
    int last_mouse_x = 0;
    int last_mouse_y = 0;

    int poly_mode = 0;
    int rotate_mode = 0;

    sf::Clock clock;

    printf("Starting render loop\n");
    while (window.isOpen())
    {
        sf::Time delta = clock.restart();

        sf::Event event;
        while (window.pollEvent(event))
        {
            if (event.type == sf::Event::Closed)
                window.close();

            if (event.type == sf::Event::KeyPressed) {
                switch(event.key.code) {
                    case sf::Keyboard::Escape:
                        window.close();
                        break;
                    case sf::Keyboard::P:
                        poly_mode = !poly_mode;
                        break;
                    case sf::Keyboard::Space:
                        rotate_mode = !rotate_mode;
                        break;
                }
            }
            if (event.type == sf::Event::MouseButtonPressed) {
                if (event.mouseButton.button == sf::Mouse::Left)
                    mouse_down = 1;
            }
            if (event.type == sf::Event::MouseButtonReleased) {
                if (event.mouseButton.button == sf::Mouse::Left)
                    mouse_down = 0;
            }
            if (event.type == sf::Event::MouseMoved) {
                int dx = event.mouseMove.x - last_mouse_x;
                int dy = event.mouseMove.y - last_mouse_y;

                if (mouse_down){
                    cam.increase_angle_v((float)dy * delta.asSeconds() * 0.2f);
                    cam.increase_angle_h((float)dx * delta.asSeconds() * 0.2f * -1.0f);
                }

                last_mouse_x = event.mouseMove.x;
                last_mouse_y = event.mouseMove.y;

            }
            if (event.type == sf::Event::MouseWheelMoved) {
                cam.increase_distance(-event.mouseWheel.delta);
            }
            if (event.type == sf::Event::Resized) {
                glViewport(0, 0, event.size.width, event.size.height);
                cam.set_size(event.size.width, event.size.height);
            }

        }

        glEnable(GL_DEPTH_TEST);
        glDepthFunc(GL_LESS);
        glEnable(GL_CULL_FACE);

        glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
        glClearColor(1.0, 1.0, 1.0, 0.0);
```

```
105
105             if (poly_mode) {
106                 glPolygonMode(GL_FRONT_AND_BACK, GL_LINE);
107                 glLineWidth(2);
108             } else {
109                 glPolygonMode(GL_FRONT_AND_BACK, GL_FILL);
110                 glLineWidth(1);
111             }
113
113             if (rotate_mode)
114                 head.rotation += 10.0f * delta.asSeconds();
116
116             grid.render();
117             head.render();
119
119             window.display();
120         }
122
122         return 0;
123     }
```

Listing 11: main (`../code/main.cpp`)

```
1   #include <GL/glew.h>
2   #include <SFML/Graphics.hpp>
3   #include <SFML/OpenGL.hpp>
4   #include <glm/glm.hpp>
5   #include <glm/gtc/noise.hpp>
6   #include <glm/gtc/matrix_transform.hpp>
7   #include <glm/gtc/type_ptr.hpp>
8   #include "camera.h"
9   #include "shader.h"
10  #include "objloader.h"
11  #include "head.h"
13
13  Head::Head() {}
15
15  Head::Head(Camera *_cam)
16  {
17      cam = _cam;
19
19      rotation = 0.0f;
21
21      shader_id = LoadShaders("head_vert.glsl", "head_frag.glsl");
23
23      model_id = glGetUniformLocation(shader_id, "M");
24      view_id  = glGetUniformLocation(shader_id, "V");
25      proj_id  = glGetUniformLocation(shader_id, "P");
26      light_id = glGetUniformLocation(shader_id, "light_pos_world");
27      texture_id = glGetUniformLocation(shader_id, "tex");
29
29      texture.loadFromFile("../assets/uvmap.png");
31
31      // read the obj file
32      std::vector<glm::vec3> indexed_vertices;
33      std::vector<glm::vec2> indexed_uvs;
34      std::vector<glm::vec3> indexed_normals;
35      load_obj("../assets/head.obj", indices, indexed_vertices, indexed_uvs, indexed_normals);
37
37      offset = 0.0f;
38      for (glm::vec3 i : indexed_vertices) {
39          if (i.y < offset) offset = i.y;
40      }
42
42      cam->target.y = -offset * 0.75f;
44
44      printf("[head] offset: %f\n", offset);
46
46      GLuint posAttrib = glGetAttribLocation(shader_id, "vert_pos_model");
47      GLuint norAttrib = glGetAttribLocation(shader_id, "vert_nor_model");
48      GLuint texAttrib = glGetAttribLocation(shader_id, "vert_tex");
50
50      glGenVertexArrays(1, &vao);
51      glBindVertexArray(vao);
53
53      glGenBuffers(1, &vertexbuffer);
54      glBindBuffer(GL_ARRAY_BUFFER, vertexbuffer);
55      glBufferData(GL_ARRAY_BUFFER, indexed_vertices.size() * sizeof(glm::vec3), &indexed_vertices[0], GL_STATIC_DRAW);
56      glVertexAttribPointer(posAttrib, 3, GL_FLOAT, GL_FALSE, 0, (void*)0);
57      glEnableVertexAttribArray(posAttrib);
59
59      glGenBuffers(1, &normalbuffer);
60      glBindBuffer(GL_ARRAY_BUFFER, normalbuffer);
61      glBufferData(GL_ARRAY_BUFFER, indexed_normals.size() * sizeof(glm::vec3), &indexed_normals[0], GL_STATIC_DRAW);
62      glVertexAttribPointer(norAttrib, 3, GL_FLOAT, GL_FALSE, 0, (void*)0);
63      glEnableVertexAttribArray(norAttrib);
65
65      glGenBuffers(1, &uvbuffer);
66      glBindBuffer(GL_ARRAY_BUFFER, uvbuffer);
67      glBufferData(GL_ARRAY_BUFFER, indexed_uvs.size() * sizeof(glm::vec2), &indexed_uvs[0], GL_STATIC_DRAW);
68      glVertexAttribPointer(texAttrib, 2, GL_FLOAT, GL_FALSE, 0, (void*)0);
69      glEnableVertexAttribArray(texAttrib);
71
71      glGenBuffers(1, &elementbuffer);
72      glBindBuffer(GL_ELEMENT_ARRAY_BUFFER, elementbuffer);
73      glBufferData(GL_ELEMENT_ARRAY_BUFFER, indices.size() * sizeof(unsigned short), &indices[0] , GL_STATIC_DRAW);
75
75      sf::Texture::bind(&texture);
77
77      glBindVertexArray(0);
78  }
80
80  void Head::render()
81  {
82      glUseProgram(shader_id);
```

```
84
84      glm::mat4 model = glm::mat4(1.0f);
85      model = glm::rotate(model, rotation, glm::vec3(0,1,0));
86      model = glm::translate(model, glm::vec3(0.0f, -offset, 0.0f));
88
88      glUniformMatrix4fv(proj_id, 1, GL_FALSE, glm::value_ptr(cam->proj_mat()));
89      glUniformMatrix4fv(view_id, 1, GL_FALSE, glm::value_ptr(cam->view_mat()));
90      glUniformMatrix4fv(model_id, 1, GL_FALSE, glm::value_ptr(model));
92
92      glUniform3f(light_id, cam->position.x, cam->position.y, cam->position.z);
94
94      glBindVertexArray(vao);
95      glDrawElements(GL_TRIANGLES, indices.size(), GL_UNSIGNED_SHORT, (void*)0);
96  }
```

Listing 12: head (`../code/head.cpp`)

```
1   #pragma once
2   #include <SFML/Graphics.hpp>
3   #include <SFML/OpenGL.hpp>
4   #include <vector>
5   #include "camera.h"
7
7   class Head {
8       public:
9           Head();
10          Head(Camera*);
11          void render();
12          float rotation;
13      private:
14          std::vector<unsigned short> indices;
15          GLuint vao;
16          GLuint vertexbuffer;
17          GLuint uvbuffer;
18          GLuint normalbuffer;
19          GLuint elementbuffer;
20          GLuint shader_id;
21          GLuint model_id;
22          GLuint view_id;
23          GLuint proj_id;
24          GLuint texture_id;
25          sf::Texture texture;
26          GLuint light_id;
27          Camera *cam;
28          float offset;
29  };
```

Listing 13: head (`../code/head.h`)

```
1   #include <GL/glew.h>
2   #include <SFML/Graphics.hpp>
3   #include <SFML/OpenGL.hpp>
4   #include <glm/glm.hpp>
5   #include <glm/gtc/noise.hpp>
6   #include <glm/gtc/matrix_transform.hpp>
7   #include <glm/gtc/type_ptr.hpp>
8   #include "camera.h"
9   #include "shader.h"
10  #include "grid.h"
12
12  Grid::Grid() {}
14
14  Grid::Grid(Camera *_cam)
15  {
16      cam = _cam;
18
18      #define GRID_SIZE   20
20
20      for(int k = -GRID_SIZE; k<GRID_SIZE; k++) {
21          // start of x line / color / end of x line / color
22          verts.push_back(k); verts.push_back(0); verts.push_back(-GRID_SIZE);
23          verts.push_back(1); verts.push_back(0); verts.push_back(0);
24          verts.push_back(k); verts.push_back(0); verts.push_back(GRID_SIZE);
25          verts.push_back(1); verts.push_back(0); verts.push_back(0);
26          // start of z line / color / end of z line / color
27          verts.push_back(-GRID_SIZE); verts.push_back(0); verts.push_back(k);
28          verts.push_back(0); verts.push_back(0); verts.push_back(1);
29          verts.push_back(GRID_SIZE); verts.push_back(0); verts.push_back(k);
30          verts.push_back(0); verts.push_back(0); verts.push_back(1);
31      }
33
33      glGenVertexArrays(1, &vao);
34      glBindVertexArray(vao);
36
36      glGenBuffers(1, &vbo);
37      glBindBuffer(GL_ARRAY_BUFFER, vbo);
38      glBufferData(GL_ARRAY_BUFFER, verts.size()*sizeof(float), verts.data(), GL_STATIC_DRAW);
40
40      printf("[grid] Loading shaders\n");
41      shader_id = LoadShaders("grid_vert.glsl", "grid_frag.glsl");
43
43      mvp_id = glGetUniformLocation(shader_id, "mvp");
44      GLint posAttrib = glGetAttribLocation(shader_id, "position");
45      GLint colAttrib = glGetAttribLocation(shader_id, "color");
46      printf("[grid] %d %d\n", posAttrib, colAttrib);
47      glEnableVertexAttribArray(posAttrib);
48      glEnableVertexAttribArray(colAttrib);
49      glVertexAttribPointer(posAttrib, 3, GL_FLOAT, GL_FALSE, 6*sizeof(GLfloat), 0);
50      glVertexAttribPointer(colAttrib, 3, GL_FLOAT, GL_FALSE, 6*sizeof(GLfloat), (void*)(3*sizeof(GLfloat)));
52
52  }
```

```
54
54  void Grid::render()
55  {
56      glUseProgram(shader_id);
58
58      glm::mat4 mvp = cam->proj_mat() * cam->view_mat() * glm::mat4(1.0f);
59      glUniformMatrix4fv(mvp_id, 1, GL_FALSE, glm::value_ptr(mvp));
61
61      glBindVertexArray(vao);
62      glDrawArrays(GL_LINES, 0, verts.size()/6-2);
63  }
```

Listing 14: grid (../code/grid.cpp)

```
1   #pragma once
2   #include <SFML/Graphics.hpp>
3   #include <SFML/OpenGL.hpp>
4   #include <vector>
5   #include "camera.h"
7
7   class Grid {
8       public:
9           Grid();
10          Grid(Camera*);
11          void render();
12      private:
13          Camera *cam;
14          std::vector<float> verts;
15          GLuint vao;
16          GLuint vbo;
17          GLuint shader_id;
18          GLuint mvp_id;
19  };
```

Listing 15: grid (../code/grid.h)

```
1   #include <glm/glm.hpp>
2   #include <glm/gtc/matrix_transform.hpp>
4
4   #include "camera.h"
6
6   Camera::Camera()
7   {
8       distance = 50.0f;
9       target = glm::vec3(0.0f);
10      angle_horz = 45.0f;
11      angle_vert = 20.0f;
12      fov = 45.0f;
13      _width = 800;
14      _height = 600;
15      update_vectors();
16  }
18
18  void Camera::increase_angle_v(float angle)
19  {
20      angle_vert += angle;
21      update_vectors();
22  }
24
24  void Camera::increase_angle_h(float angle)
25  {
26      angle_horz += angle;
27      update_vectors();
28  }
30
30  void Camera::increase_distance(float dist)
31  {
32      distance += dist;
33      update_vectors();
34  }
36
36  void Camera::update_vectors()
37  {
38      direction = glm::vec3(
39              cos(angle_vert) * sin(angle_horz),
40              sin(angle_vert),
41              cos(angle_vert) * cos(angle_horz)
42              );
44
44      right = glm::vec3(
45              sin(angle_horz - 3.14f/2.0f),
46              0,
47              cos(angle_horz - 3.14f/2.0f)
48              );
50
50      up = glm::cross(right, direction);
52
52      position = distance * direction;
53  }
55
55  glm::mat4 Camera::view_mat(void)
56  {
57      return glm::lookAt(
58              target + (distance * direction),
59              target,
60              up);
61  }
63
63  glm::mat4 Camera::proj_mat(void)
64  {
65      return glm::perspective(fov, (float)_width/(float)_height, 0.01f, 10000.0f);
```

```
}

void Camera::set_size(int width, int height)
{
    _width = width;
    _height = height;
}
```

Listing 16: camera (`../code/camera.cpp`)

```
#pragma once

#include <glm/glm.hpp>

class Camera
{
    public:
        Camera();
        glm::vec3 position;
        glm::vec3 direction;
        glm::vec3 right;
        glm::vec3 up;
        glm::vec3 target;
        glm::mat4 proj_mat(void);
        glm::mat4 view_mat(void);
        void increase_angle_v(float);
        void increase_angle_h(float);
        void increase_distance(float);
        void set_size(int, int);
        float distance;
        float angle_horz;
        float angle_vert;
        float fov;
    private:
        void update_vectors(void);
        int _width;
        int _height;
};
```

Listing 17: camera (`../code/camera.h`)

```
#include <vector>
#include <stdio.h>
#include <string>
#include <cstring>

#include <glm/glm.hpp>

#include "objloader.h"

// Include AssImp
#include <assimp/Importer.hpp>      // C++ importer interface
#include <assimp/scene.h>           // Output data structure
#include <assimp/postprocess.h>     // Post processing flags

bool load_obj(
    const char * path,
    std::vector<unsigned short> & indices,
    std::vector<glm::vec3> & vertices,
    std::vector<glm::vec2> & uvs,
    std::vector<glm::vec3> & normals
){

    Assimp::Importer importer;

    const aiScene* scene = importer.ReadFile(path, 0/*aiProcess_JoinIdenticalVertices | aiProcess_SortByPType*/);
    if( !scene) {
        fprintf( stderr, importer.GetErrorString());
        getchar();
        return false;
    }
    const aiMesh* mesh = scene->mMeshes[0]; // In this simple example code we always use the 1rst mesh (in OBJ files there is often only one anyway)

    // Fill vertices positions
    printf("[assimp] filling vertice positions\n");
    vertices.reserve(mesh->mNumVertices);
    for(unsigned int i=0; i<mesh->mNumVertices; i++){
        aiVector3D pos = mesh->mVertices[i];
        vertices.push_back(glm::vec3(pos.x, pos.y, pos.z));
    }

    // Fill vertices texture coordinates
    printf("[assimp] filling vertice tex coords\n");
    uvs.reserve(mesh->mNumVertices);
    for(unsigned int i=0; i<mesh->mNumVertices; i++){
        aiVector3D UVW = mesh->mTextureCoords[0][i]; // Assume only 1 set of UV coords; AssImp supports 8 UV sets.
        uvs.push_back(glm::vec2(UVW.x, UVW.y));
    }

    // Fill vertices normals
    printf("[assimp] filling vertice normals\n");
    normals.reserve(mesh->mNumVertices);
    for(unsigned int i=0; i<mesh->mNumVertices; i++){
        aiVector3D n = mesh->mNormals[i];
        normals.push_back(glm::vec3(n.x, n.y, n.z));
    }

    // Fill face indices
    printf("[assimp] filling face indices\n");
    indices.reserve(3*mesh->mNumFaces);
    for (unsigned int i=0; i<mesh->mNumFaces; i++){
```

```
61            // Assume the model has only triangles.
62            indices.push_back(mesh->mFaces[i].mIndices[0]);
63            indices.push_back(mesh->mFaces[i].mIndices[1]);
64            indices.push_back(mesh->mFaces[i].mIndices[2]);
65        }
66
67        // The "scene" pointer will be deleted automatically by "importer"
68        return true;
69    }
```

Listing 18: objloader (`../code/objloader.cpp`)

```
1   #ifndef OBJLOADER_H
2   #define OBJLOADER_H
3
4   bool load_obj(
5       const char * path,
6       std::vector<unsigned short> & indices,
7       std::vector<glm::vec3> & vertices,
8       std::vector<glm::vec2> & uvs,
9       std::vector<glm::vec3> & normals
10  );
11
12  #endif
```

Listing 19: objloader (`../code/objloader.h`)

```
1   #include <stdio.h>
2   #include <string>
3   #include <vector>
4   #include <iostream>
5   #include <fstream>
6   #include <algorithm>
7   using namespace std;
8
9   #include <stdlib.h>
10  #include <string.h>
11
12  #include <GL/glew.h>
13
14  #include "shader.h"
15
16  GLuint LoadShaders(const char * vertex_file_path,const char * fragment_file_path){
17
18      // Create the shaders
19      GLuint VertexShaderID = glCreateShader(GL_VERTEX_SHADER);
20      GLuint FragmentShaderID = glCreateShader(GL_FRAGMENT_SHADER);
21
22      // Read the Vertex Shader code from the file
23      std::string VertexShaderCode;
24      std::ifstream VertexShaderStream(vertex_file_path, std::ios::in);
25      if(VertexShaderStream.is_open()){
26          std::string Line = "";
27          while(getline(VertexShaderStream, Line))
28              VertexShaderCode += "\n" + Line;
29          VertexShaderStream.close();
30      }else{
31          printf("Impossible to open %s. Are you in the right directory ? Don't forget to read the FAQ !\n", vertex_file_path);
32          return 0;
33      }
34
35      // Read the Fragment Shader code from the file
36      std::string FragmentShaderCode;
37      std::ifstream FragmentShaderStream(fragment_file_path, std::ios::in);
38      if(FragmentShaderStream.is_open()){
39          std::string Line = "";
40          while(getline(FragmentShaderStream, Line))
41              FragmentShaderCode += "\n" + Line;
42          FragmentShaderStream.close();
43      }
44
45      GLint Result = GL_FALSE;
46      int InfoLogLength;
47
48      // Compile Vertex Shader
49      printf("Compiling shader : %s\n", vertex_file_path);
50      char const * VertexSourcePointer = VertexShaderCode.c_str();
51      glShaderSource(VertexShaderID, 1, &VertexSourcePointer , NULL);
52      glCompileShader(VertexShaderID);
53
54      // Check Vertex Shader
55      glGetShaderiv(VertexShaderID, GL_COMPILE_STATUS, &Result);
56      glGetShaderiv(VertexShaderID, GL_INFO_LOG_LENGTH, &InfoLogLength);
57      if ( InfoLogLength > 0 ){
58          std::vector<char> VertexShaderErrorMessage(InfoLogLength+1);
59          glGetShaderInfoLog(VertexShaderID, InfoLogLength, NULL, &VertexShaderErrorMessage[0]);
60          printf("%s\n", &VertexShaderErrorMessage[0]);
61      }
62
63      // Compile Fragment Shader
64      printf("Compiling shader : %s\n", fragment_file_path);
65      char const * FragmentSourcePointer = FragmentShaderCode.c_str();
66      glShaderSource(FragmentShaderID, 1, &FragmentSourcePointer , NULL);
67      glCompileShader(FragmentShaderID);
68
69      // Check Fragment Shader
70      glGetShaderiv(FragmentShaderID, GL_COMPILE_STATUS, &Result);
71      glGetShaderiv(FragmentShaderID, GL_INFO_LOG_LENGTH, &InfoLogLength);
72      if ( InfoLogLength > 0 ){
73          std::vector<char> FragmentShaderErrorMessage(InfoLogLength+1);
74          glGetShaderInfoLog(FragmentShaderID, InfoLogLength, NULL, &FragmentShaderErrorMessage[0]);
```

```
75          printf("%s\n", &FragmentShaderErrorMessage[0]);
76      }
78      // Link the program
79      printf("Linking program\n");
80      GLuint ProgramID = glCreateProgram();
81      glAttachShader(ProgramID, VertexShaderID);
82      glAttachShader(ProgramID, FragmentShaderID);
83      glLinkProgram(ProgramID);
85      // Check the program
86      glGetProgramiv(ProgramID, GL_LINK_STATUS, &Result);
87      glGetProgramiv(ProgramID, GL_INFO_LOG_LENGTH, &InfoLogLength);
88      if ( InfoLogLength > 0 ){
89          std::vector<char> ProgramErrorMessage(InfoLogLength+1);
90          glGetProgramInfoLog(ProgramID, InfoLogLength, NULL, &ProgramErrorMessage[0]);
91          printf("%s\n", &ProgramErrorMessage[0]);
92      }
94      glDeleteShader(VertexShaderID);
95      glDeleteShader(FragmentShaderID);
97      return ProgramID;
98  }
```

Listing 20: shader (`../code/shader.cpp`)

```
1  #pragma once
2  GLuint LoadShaders(const char * vertex_file_path,const char * fragment_file_path);
```

Listing 21: shader (`../code/shader.h`)

```
1  #version 330 core
3  // Input vertex data, different for all executions of this shader.
4  in vec3 vert_pos_model;
5  in vec3 vert_nor_model;
6  in vec2 vert_tex;
8  // Output data ; will be interpolated for each fragment.
9  out vec2 UV;
10 out vec3 vert_pos_world;
11 out vec3 vert_nor_cam;
12 out vec3 eye_dir_cam;
13 out vec3 light_dir_cam;
15 // Values that stay constant for the whole mesh.
16 uniform mat4 M;
17 uniform mat4 V;
18 uniform mat4 P;
19 uniform vec3 light_pos_world;
21 void main(){
23          // Output position of the vertex, in clip space : MVP * position
24          gl_Position =  P * V * M * vec4(vert_pos_model,1);
26          // Position of the vertex, in worldspace : M * position
27          vert_pos_world = (M * vec4(vert_pos_model,1)).xyz;
29          // Vector that goes from the vertex to the camera, in camera space.
30          // In camera space, the camera is at the origin (0,0,0).
31          vec3 vert_pos_cam = ( V * M * vec4(vert_pos_model,1)).xyz;
32          eye_dir_cam = vec3(0,0,0) - vert_pos_cam;
34          // Vector that goes from the vertex to the light, in camera space. M is ommited because it's identity.
35          vec3 light_pos_cam = ( V * vec4(light_pos_world,1)).xyz;
36          light_dir_cam = light_pos_cam + eye_dir_cam;
38          // Normal of the the vertex, in camera space
39          vert_nor_cam = ( V * M * vec4(vert_nor_model,0)).xyz; // Only correct if ModelMatrix does not scale the model ! Use its inverse transpose if not.
41          // UV of the vertex. No special space for this one.
42          UV = vert_tex;
43 }
```

Listing 22: head vertex shader (`../code/head_vert.glsl`)

```
1  #version 330 core
3  // Interpolated values from the fragex shaders
4  in vec2 UV;
5  in vec3 vert_pos_world;
6  in vec3 vert_nor_cam;
7  in vec3 eye_dir_cam;
8  in vec3 light_dir_cam;
10 // Ouput data
11 out vec3 color;
13 // Values that stay constant for the whole mesh.
14 uniform sampler2D tex;
15 uniform mat4 MV;
16 uniform vec3 light_pos_world;
18 void main(){
20
```

```
20          // Light emission properties
21          vec3 light_color = vec3(1,1,1);
22          float light_power = 1500.0f;
23
24          // Material properties
25          vec3 diffuse_color = texture2D(tex, UV ).rgb;
26          vec3 ambient_color = vec3(0.1,0.1,0.1) * diffuse_color;
27          vec3 specular_color = vec3(0.3,0.3,0.3);
28
29          // Distance to the light
30          float distance = length(light_pos_world - vert_pos_world );
31
32          vec3 n = normalize( vert_nor_cam );
33          vec3 l = normalize( light_dir_cam );
34          float cosTheta = clamp( dot( n,l ), 0,1 );
35
36          vec3 E = normalize(eye_dir_cam);
37          vec3 R = reflect(-l,n);
38          float cosAlpha = clamp( dot( E,R ), 0,1 );
39
40          color = ambient_color +
41              diffuse_color * light_color * light_power * cosTheta / (distance*distance) +
42              specular_color * light_color * light_power * pow(cosAlpha,5) / (distance*distance);
43
44  }
```

Listing 23: head fragment shader (`../code/head_frag.glsl`)

```
1   #version 150
2
3   in vec3 position;
4   in vec3 color;
5
6   uniform mat4 mvp;
7
8   out vec3 Color;
9
10  void main()
11  {
12      Color = color;
13      gl_Position = mvp * vec4(position, 1);
14  }
```

Listing 24: grid vertex shader (`../code/grid_vert.glsl`)

```
1   #version 150
2
3   in vec3 Color;
4   out vec4 out_color;
5
6   void main()
7   {
8       out_color = vec4(Color, 1.0);
9   }
```

Listing 25: grid fragment shader (`../code/grid_frag.glsl`)