# CS171 Assignment1: Exploring OpenGL Programming

## Introduction

In this assignment, you are required to create a basic graphics program using OpenGL. As you have learned during class and tutorial, to start up your graphics program, you will need to use GLFW to create a window. By default, GLFW will create a window with double buffering enabled. Then, you can use the basic OpenGL calls to draw 3D objects on the window as well as manipulate the camera to navigate through the virtual scene. To reduce aliasing artifacts, you can also enable antialiasing in OpenGL by multi-sampling.

In the following, we will give you the specifics about what you need to accomplish, as well as some related guidelines to assist your programming.

## Note

Before doing the assignment, it is recommended for you to read the materials on OpenGL programming at OpenGL Tutorial, OpenGL tutorials and notes. You can also read Learn OpenGL which conducts OpenGL rendering based on OpenGL Mathematics (GLM) library.

## Programming Requirements

- **[must]** You are required to load mesh objects from files and draw the meshes. (40%)
- **[must]** You are required to render objects with a Phong lighting model. (30%)
- **[must]** You are required to manipulate the camera and use the keyboard to control the camera: you can use the keyboard to translate and rotate the camera so that you can walk in the virtual scene. (30%)
- **[optional]** You can support multiple lights in the fragment shader (10%).
- **[optional]** You can add a skybox to the scene to make the scene more realistic (10%).
- **[optional]** You can use a geometry shader to modify the vertex data to make some animation (10%).
- **[optional]** You can support multiple objects in the scene (10%).

## Demonstration Requirements

In addition to programming, you will also need to demonstrate your code to TAs on site.

Things you should prepare:

- Explain how you load and draw objects, show related code fragments, and demonstrate the result.
- Explain how you render 3D objects with Phong lighting model, show related code fragments, and demonstrate the result.
- Explain your implementation of camera navigation, show related code fragments, and demonstrate the result.
- For the optional parts, explain your implementation and show it!

Additional Notification:

- You should try your best to present your ideas as clearly as possible.
- If you do not follow the above requirements, your score will be deduced by 10% of the entire assignment score.

## Submission

You are required to submit the following things through the GitHub repository:

- Project scripts and an executable program in the Coding folder.
- A PDF-formatted report which describes what you have done in the Report folder.

Submission deadline: **22:00, Oct 24, 2024**

## Grading rules

- You can choose to do the **[optional]** items, and if you choose to do them, you will get additional scores based on the additional work you have done. But the maximum additional score will not exceed 15% of the entire score of this assignment.
- **NO CHEATING**! If found, your score for the assignment is zero. You are required to work **INDEPENDENTLY**. We fully understand that implementations could be similar somewhere, but they cannot be identical. To avoid being evaluated inappropriately, please show your understanding of your code to TAs.
- Late submission of your assignment will be subject to score deduction based on the rule on the course webpage.

## Skeleton Project/ Report Template

The skeleton program and report template will be provided once you accept the assignment link of GitHub classroom which will be given below. If you accept the assignment through the link properly, a repository that contains the skeleton project and the report template will be created under your GitHub account. Please follow the template to prepare your report.

You should complete your assignment submission to your repository through GitHub before the deadline.

## Implementation Guide

### Git Classroom

Accept the assignment through this link or download the zip file to start your assignment.

### 1. Environment Setup

You will need CMake to build your code. To build the project, firstly you need to download CMake if you do not have one. Then run command

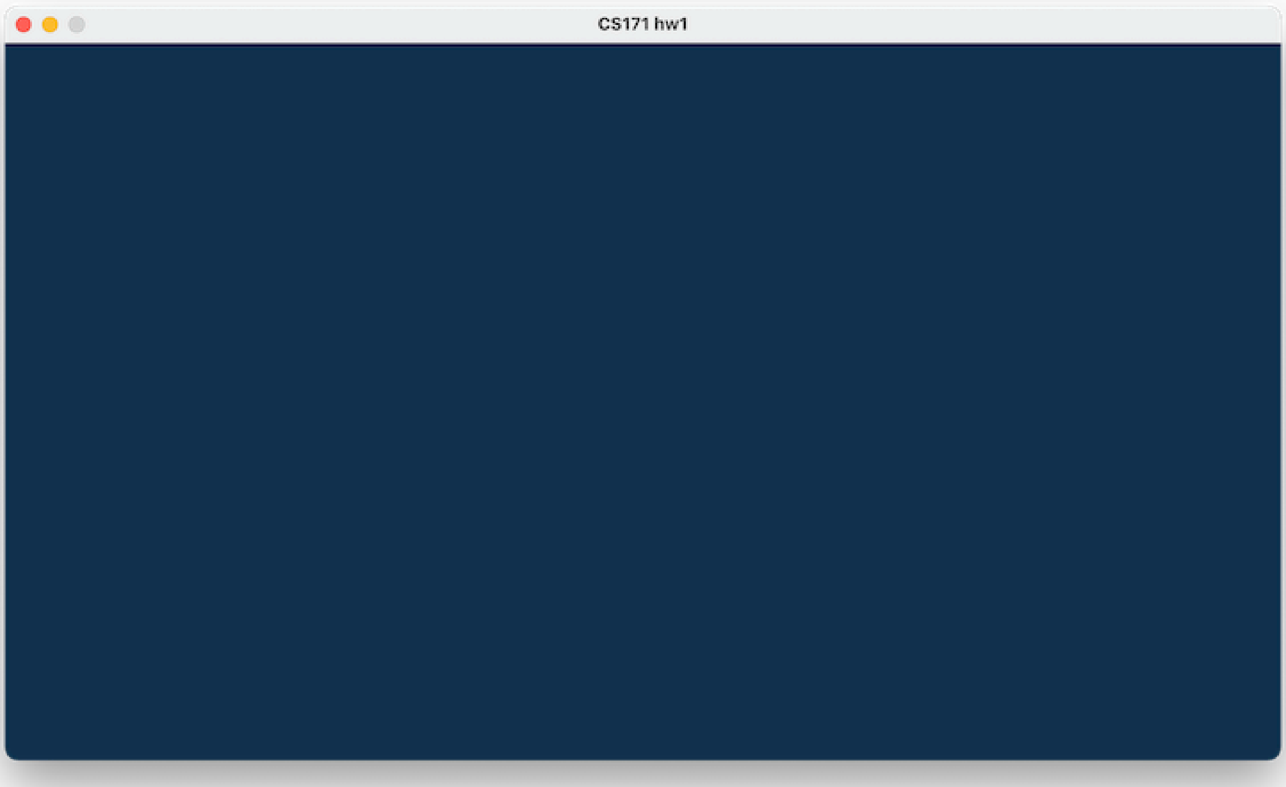
```
mkdir build
cd build
cmake ..
cmake --build .
```

These commands first make a directory whose name is "build" After that, it uses CMake to configure the project and builds the project.

Besides, we recommend using Visual Studio on Windows and Visual Studio Code on Linux. Both of them can build the CMake-based projects automatically (maybe with help of some plugins). If you are already an experienced developer, you can choose whatever you like. (You are encouraged to use clang+clangd+llvm+ninja on linux or windows. To generate the compile_commands.json file, which can help you manage your code through vscode, you can use the following command: cmake -Bbuild build/ -DCMAKE_EXPORT_COMPILE_COMMANDS=True -G Ninja, then you can use the following command to build your project: cmake --build build/ -j)

### 2. Creating the window program using GLFW

We have already created a blank window for you to start your drawing. You should expect the following result.



## 3. Loading object

We define a simple mesh file that can represent 3D mesh objects with vertices, normals, and triangle face indices. We provide three object files in assets directory, ("bunny", "plane" and "sphere) that require you to load by yourself with the following format:

```
int int int

float float float
...
float float float

float float float
...
float float float

int int int int int int
```

To be more specific, the first line contains 3 integers, namely the vertex count, normal count, and face count. Then, there follows as many lines as the vertex count, where each line contains 3 floats representing the position of a vertex. For the next lines with the line count equal to the normal count, where each line contains 3 floats representing the normal of a vertex. And according to the face count, there are extra corresponding lines. Each line contains 6 integers v0, n0, v1, n1, v2, n2, where v0, n0 means the vertex index and normal index of the first vertex, v1, n1 means the vertex index and normal index of the second vertex and v2, n2 means the vertex index and normal index of the third vertex.

Here, we give an example of a plane mesh file as below.

```
4 1 2

-1.0 1.0 -1.0
1.0 1.0 -1.0
1.0 -1.0 -1.0
-1.0 -1.0 -1.0

0.0 0.0 1.0

0 0 1 0 3 0
1 0 2 0 3 0
```

You need to implement the function `loadDataFromFile()` in "mesh.cpp" to load all the data of the mesh from this simplified mesh file. You can organize the data with the provided vertex structure in "mesh.h" and save the vertices into the `Mesh` object for rendering:

```
struct Vertex {
  vec3 position;
  vec3 normal;
};
```

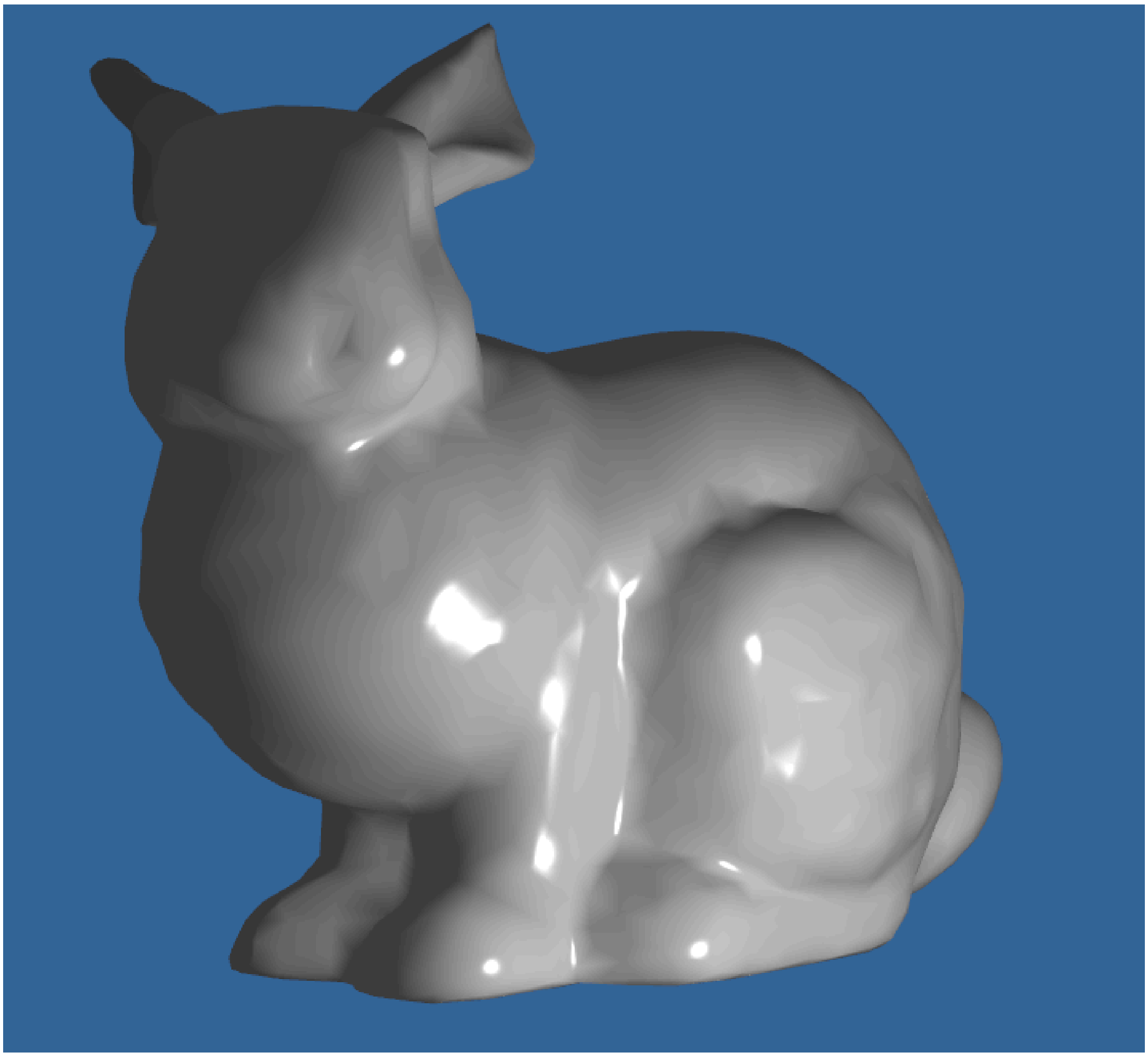
## 4. Rendering 3D objects with Phong lighting model

You will find that a drawn mesh does not appear to be 3D if it is filled with one color. The reason is that you do not have a lighting model applied to give the appropriate shading on its appearance.

Phong lighting model is an approximation of the lighting in the real world, which is easy and efficient to implement.

The OpenGL lighting model considers the lighting to be divided into three independent components: ambient, diffuse, and specular. All these components are computed independently and then added up together. For a more comprehensive description, please follow the link above. After implementing this light model, the rendering effect will be much more exciting!

Here we provide an example rendering result of the bunny object.



## 5. Manipulating camera

To navigate in your virtual scene, you need to change your camera from time to time.

**Navigate in the virtual world**

We only have to specify a camera position, a target position, and a vector that represents the up vector in the world space (the up vector we used for calculating the camera/view coordinate system), and the OpenGL will help you construct the view matrix by `gluLookAt(...)`.

If we want to achieve the pitch and yaw of the camera, we only need to change the target position that the camera looks at in `gluLookAt(...)`. If we want to roll the camera, we will need to change the up vector in `gluLookAt(...)`. To move the camera, we change the camera position in `gluLookAt(...)`.

**Walk around using keyboard input**

As described above, we can define the camera view matrix through `gluLookAt(...)`. By changing the camera position in this matrix, camera translation can be achieved.

As you have learned in class, the camera coordinate system can be described by 3 vectors: up vector, forward vector, and the right vector. To move the camera forward and backward, you should calculate the movement increment along the forward vector (positive or negative) based on your keyboard input, and then update the camera position using this increment. To move the camera left and right, you should calculate the movement along the right vector based on your keyboard input and update the camera position using this delta movement vector.

To respond to the keyboard input, you should implement a function to process the input like below:

```
void processInput(GLFWwindow *window)
{
  ...
  float cameraSpeed = 0.05f; /* adjust accordingly */
  if (glfwGetKey(window, GLFW_KEY_W) == GLFW_PRESS)
      cameraPos += cameraSpeed * cameraFront;
  ...
}
```

And you may need to call this function to update the coordinate inside the render loop.

**Look around using mouse input**

To be able to change the viewing angle, we need to change the camera's forward vector based on the mouse input. The yaw and pitch values are obtained from mouse (or controller/joystick) movement where horizontal mouse movement affects the yaw and vertical mouse movement affects the pitch. To capture and process mouse input, first, we have to tell GLFW that it should hide the cursor and capture it:

```
glfwSetInputMode(window, GLFW_CURSOR, GLFW_CURSOR_DISABLED);
```

Then, we should define mouse input callbacks:

```
void mouse_callback(GLFWwindow* window, double xpos, double ypos)
{
  ...
  // Here is how you process mouse inputs
  ...
};
```

Then, you should register it to OpenGL:

```
glfwSetCursorPosCallback(window, mouse_callback);
```

When handling mouse input for a camera, there are several steps we have to take before eventually retrieving the direction vector:

1. Calculate the offset of the mouse at the current frame compared to the previous frame.
2. Add the mapping of the offset values to the camera's yaw and pitch values and add to them.
3. Add some constraints to the maximum/minimum yaw/pitch values.
4. Calculate the direction vector.

Check more from this site for OpenGL camera transformation.

Looking forward to your exciting work!

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