COSC422 Advanced Computer Graphics
Programming Exercise 01

This exercise introduces the structure of OpenGL-4 programs that use buffer objects and shaders (vertex and fragment shaders) for developing applications for the programmable pipeline.

I. TorusDraw.cpp:

The program `TorusDraw.cpp` provides the code for displaying the mesh model of a torus. The structure of the application is shown below (Fig. (a)).

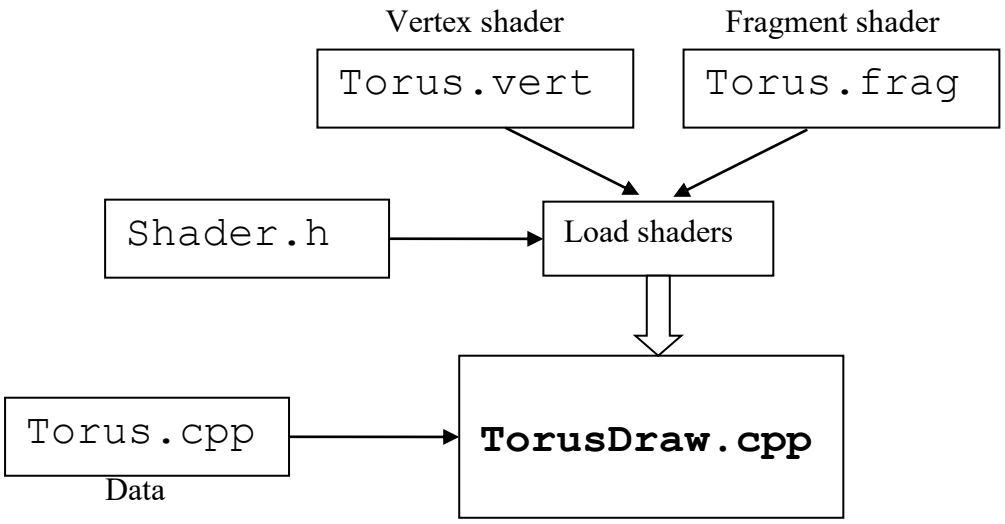


Fig. (a)

- The "main()" function in `TorusDraw.cpp` initializes the rendering context with OpenGL 4.2 core profile. The "initialize()" function calls the "createShaderProg()" function of `shader.h` to load the shaders `Torus.vert` and `Torus.frag`. It also gets the locations of uniform variables defined in the vertex shader. The "display()" function creates the matrices required for model, view and projection transformations, passes the values to the vertex shader, and calls the "render()" function of the Torus class. The angle of rotation of the torus model is continuously incremented using a timer callback.

- The constructor of the "Torus" class (see `Torus.cpp`) generates the vertex buffer objects and the vertex array object for the mesh model. It also includes a `render()` function to generate the display of the model using the reference to the vertex array object.

- The vertex shader (`Torus.vert`) contains code for lighting calculations and the transformation of vertex coordinates to the clip coordinate space.

- The fragment shader (`Torus.frag`) outputs a single colour value for every fragment, and causes the torus to appear as shown in Fig. (b).

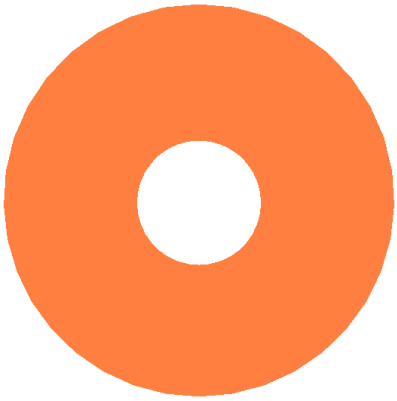


Fig. (b)

1. The fragment shader has a built-in variable `gl_FragCoord`. Its z-component, `gl_FragCoord.z` gives the depth of the fragment in the range [0, 1]. Modify the fragment shader to output a colour value whose r, g, b components all have the depth value of the fragment. You will then get the depth-map of the torus, with points close to the near-plane having a dark colour and points farther away from the camera having lighter colours (Fig. (c)).

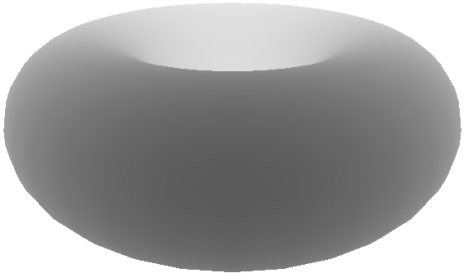


Fig. (c).

2. Edit the vertex shader (`Torus.vert`) to pass the result of the lighting calculations (sum of ambient, diffuse and specular reflections at a vertex) to the fragment shader. The fragment shader (`Torus.frag`) should declare the same variable with storage qualifer "in", so that it will receive the interpolated

values of colour for each fragment. Assign this interpolated value to the output of the fragment shader (gl_FragColor) to get the output shown in Fig.(d).

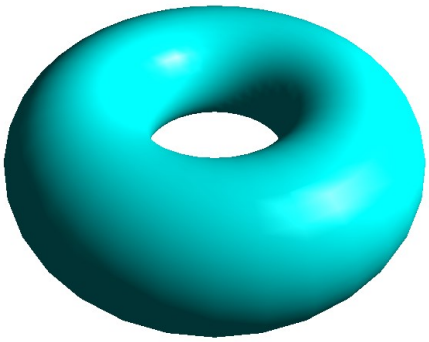
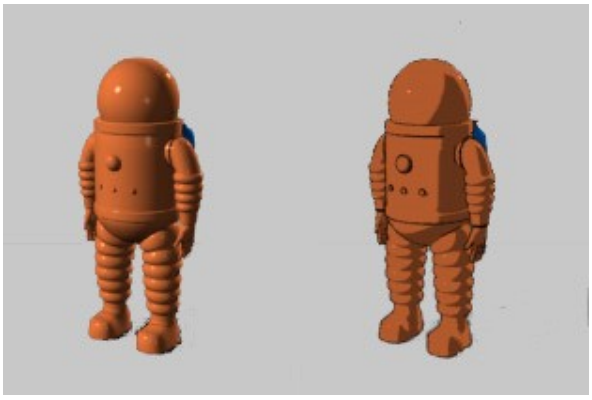


Fig. (d)

II. Non-Photorealistic Rendering:

Non-photorealistic rendering refers to the process of generating displays with expressive or artistic styles. This rendering paradigm is also known by other names such as toon-shading, cel-shading, sketch-based rendering etc. An example from Wikipedia (http://en.wikipedia.org/wiki/Non-photorealistic_rendering) is shown in Fig. (e).



A robot model rendered using Gouraud shading and 2-tone shading.

Source: Wikipedia

Fig. (e).

1. A two-tone shading of a model as seen in the above figure is generated by replacing the continuous variation of shades on a surface with just two colour values. This is done by using a threshold for the diffuse term $\boldsymbol{n \bullet l}$. (Note: the brightness is proportional to this term). In the following, we will create a two-tone shading of the torus model.

2. For two-tone shading, we require the value of $\boldsymbol{n \bullet l}$ for each fragment. This value is computed in the vertex shader. Declare this variable as an "out" variable inside the vertex shader, and also as an "in" variable inside the fragment shader. The interpolated values of $\boldsymbol{n \bullet l}$ will then be become

available in the fragment shader. Modify `Torus.frag` to output a colour based on the following rule:

if $\boldsymbol{n} \bullet \boldsymbol{l}$ is less than 0.1, output one colour, otherwise output another colour.

A sample output is shown below in Fig. (f):

Fig. (f)

3. To further enhance the quality of the two-tone shading, it is necessary to highlight the silhouette edges of the model. Such edges can be clearly seen in the robot model in Fig. (e). A fragment belongs to a silhouette edge if $\boldsymbol{n} \bullet \boldsymbol{v} = 0$, where $\boldsymbol{v}$ is the view vector (Fig. (g)).

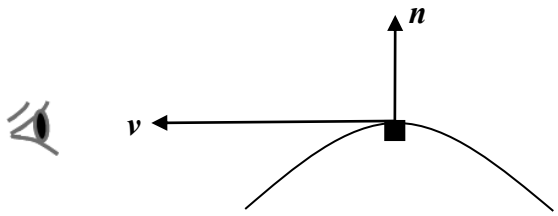


Fig.(g)

4. Compute the value of $\boldsymbol{n} \bullet \boldsymbol{v}$ inside the vertex shader and pass the value to the fragment shader. Modify the output of the fragment shader as follows:

   If $|\boldsymbol{n} \bullet \boldsymbol{v}| < 0.2$, output black colour.

   The above condition, if properly implemented, will cause some of the silhouette edges to become visible on the torus model as shown in Fig. (h).

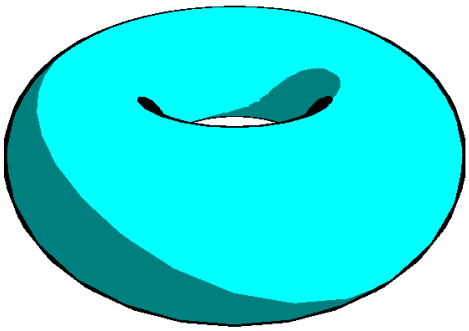


Fig. (h)