COSC363 Computer Graphics
Lab03: Illumination and Texturing

Aim:

This lab provides an introduction to the OpenGL illumination model and different forms of lighting that could be used in rendering a scene. The lab also gives a few examples of texture mapping.

I. Train.cpp:

1. The program **`train.cpp`** displays a scene consisting of circular rail tracks, and the model of a toy locomotive (Fig. (1)). A description of the functions included in the program is given below.

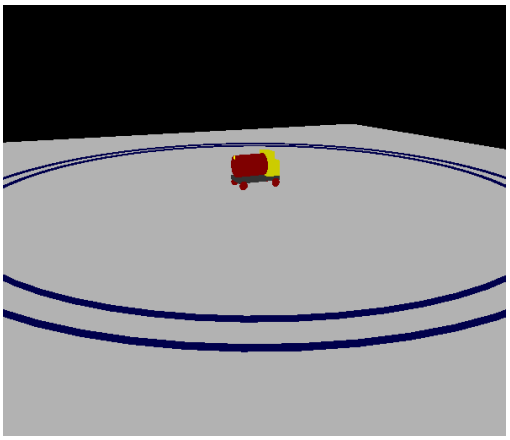


Fig. (1)

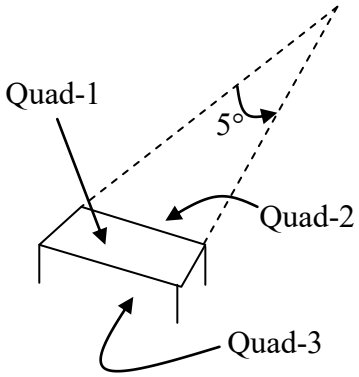


Fig. (2)

`floor()`: The floor plane is *not* modeled as a single quad. Instead, it is an array of 200x200 tiny quads laid out on the *xz*-plane. This form of subdivision of the floor plane is useful for proper lighting of the scene.

`track()`: This function creates the model of a circular rail track of specified radius using 72 small segments, each segment subtending 5 degs at the centre (Fig (2)). Each segment is modeled as a set of 3 quads. The tracks have a height of 1 unit, and a separation of 10 units (Fig. (3)).

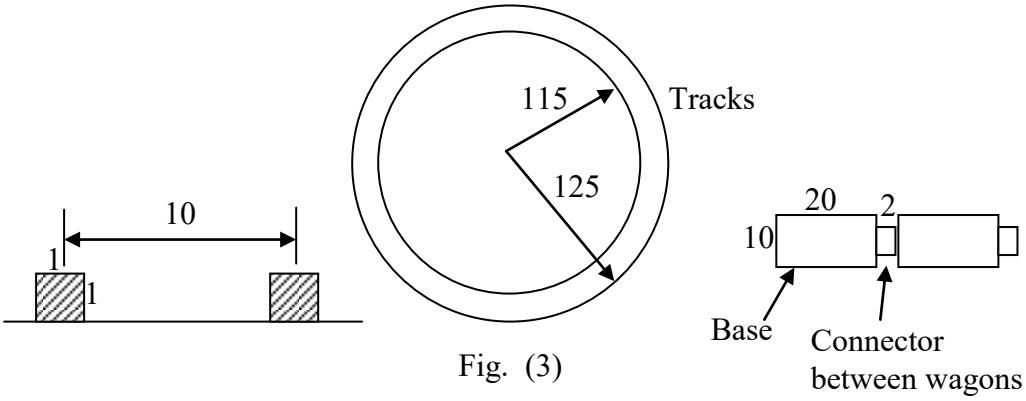


Fig. (3)

`base()`: The locomotive and the wagons of the train have a common base to which 4 wheels are attached (See Figs. (3)-(5)). Each base has a size 20x10 units. A connector of size 2 units is also attached to the base.

`engine()`: This function creates the model of the locomotive including the base, a boiler and the cab (Fig. (4)).

`wagon()`: This function models a wagon as a combination of the base and a cube (Fig. (5)).

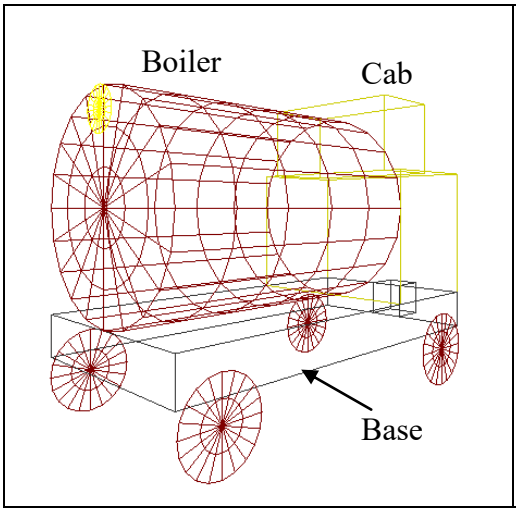


Fig. (4)

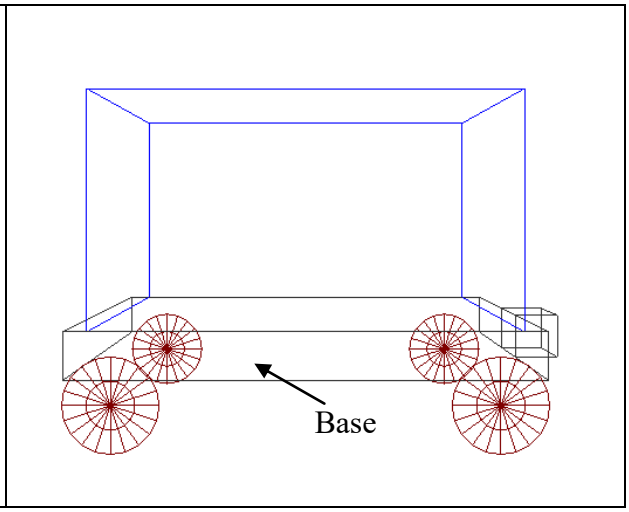


Fig. (5)

2. Lighting is currently disabled. Surfaces are rendered using only constant colour values specified by the glColor3f() function, and therefore appear flat. Enable lighting by un-commenting the statement glEnable(GL_LIGHTING) in the initialize() function. The scene is now illuminated with a light source GL_LIGHT0 positioned at (0, 50, 0) directly above the origin. However, OpenGL has ignored all surface colour values that were defined using glColor3f() (Fig. (6)).

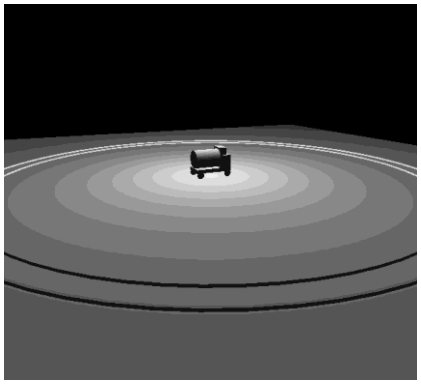


Fig. (6)

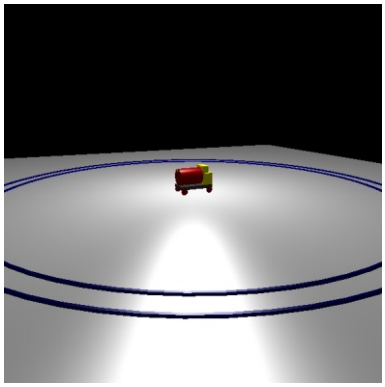


Fig. (7)

3. When lighting is enabled, OpenGL expects the material properties for each surface to be defined using three calls to the glMaterial3fv() function with ambient, diffuse and specular colour values. The ambient and diffuse colours are usually the surface colour already defined using glColor3f(). OpenGL can

use this colour value, instead of ignoring it, as the ambient and diffuse properties if the following state is enabled:

```
glColorMaterial(GL_FRONT, GL_AMBIENT_AND_DIFFUSE);
glEnable(GL_COLOR_MATERIAL);
```

The common specular colour and the shininess term for all materials need be set only once:

```
glMaterialfv(GL_FRONT, GL_SPECULAR, white);
glMaterialf(GL_FRONT, GL_SHININESS, 50);
```

Include the above statements in initialize(), and the display should change to that given in Fig. (7). Notice the bright specular highlight on the floor plane.

4. Floors are generally diffuse surfaces. We can suppress specular reflections from the floor by temporarily setting the specular colour to black. Include the following statement in the `floor()` function before the glBegin() statement:
   ```
   glMaterialfv(GL_FRONT, GL_SPECULAR, black);
   ```
   Reset the specular property to white after the glEnd() statement:
   ```
   glMaterialfv(GL_FRONT, GL_SPECULAR, white);
   ```
   The floor plane should now be displayed as a diffusely reflecting surface (Fig. 8)

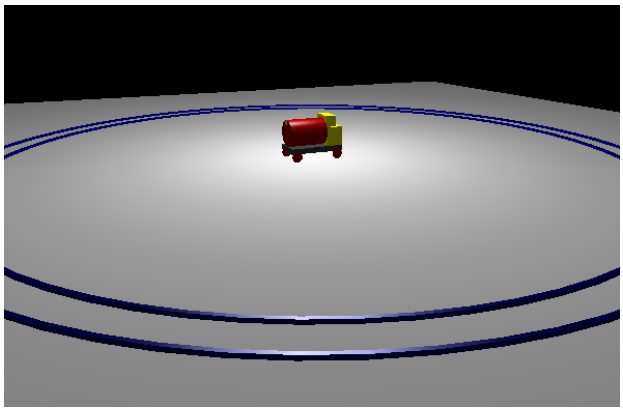


Fig. (8)

5. We will now implement a series of transformations to construct a toy train and to make it move along the tracks! Move the rail engine from its current position at the origin to the position (0, 1, –120). The *y*-value 1 corresponds to the track height, and the *z* value 120 corresponds to the mean radius of the tracks (see Fig. (9)). Please make sure to include the transformation within a `glpushMatrix()-glPopMatrix()` block so that it will not affect other objects in the scene.

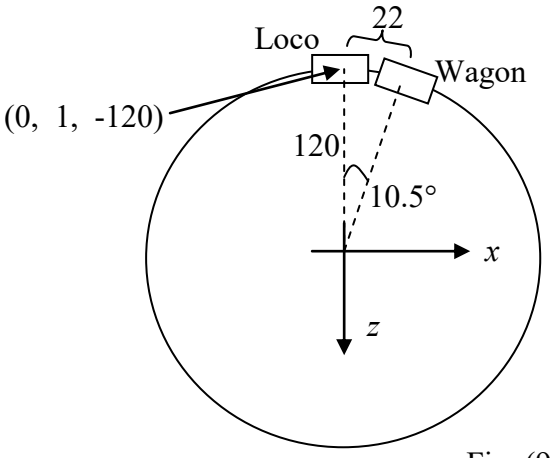


Fig. (9)

6. Generate the display of a wagon by calling the function wagon(). Translate it from the origin to (0, 1, −120) and then rotate it about the *y*-axis by 10.5 degrees (positive or negative?) to position it correctly as shown in Fig (9). (How was the separation angle 10.5 degs obtained?). Add a few more wagons to the train (Fig.(10)). Use a timer call back to move the entire train along the track by applying a continuous rotation about the *y*-axis. Adjust the timer delay and angle step size to get a smooth animation. Note that the program uses double-buffered animation to eliminate screen flicker. This is done by specifying GLUT_DOUBLE in `glutInitDisplayMode()` function, and by calling `glutSwapBuffers()` after drawing the scene.

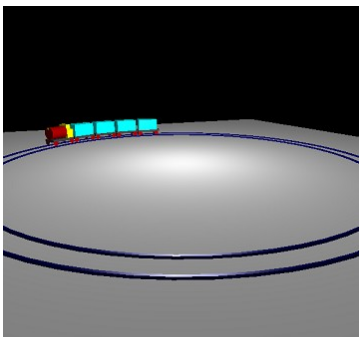


Fig. (10)

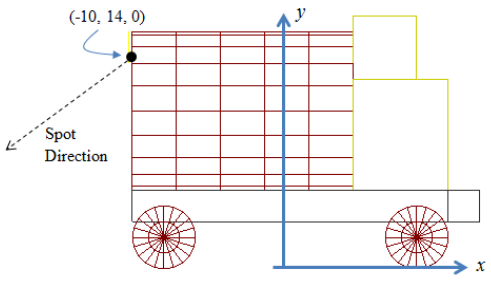


Fig. (11)

7. Create a new light source GL_LIGHT1 with the same parameters as GL_LIGHT0. Convert it to a spotlight with cutoff angle 30 degs by adding the following statements (see slide[3]-13):

```
glLightf(GL_LIGHT1, GL_SPOT_CUTOFF, 30.0);
glLightf(GL_LIGHT1, GL_SPOT_EXPONENT,0.01);
```

Inside `display()` function, specify the spotlight's position as (-10, 14, 0). This corresponds to the headlight position on the locomotive (Fig (11)). Also specify the direction of the spotlight such that it is oriented towards the floor. All transformations applied to the locomotive must also be applied to the spotlight's position and direction, so that it moves as if attached to the engine (Fig. (12)).

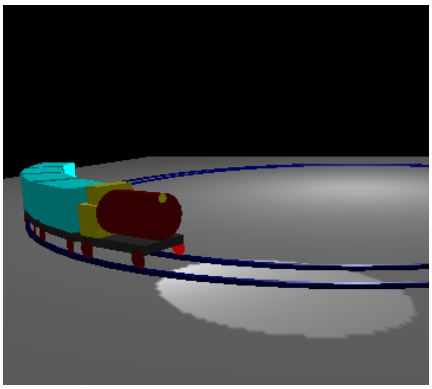


Fig. (12)

8. Move the camera backwards (towards the viewer) by changing its *z*-position in gluLookAt() from 180 to 250.

II. Yard.cpp:

1. The program displays five polygons (four "walls" and one "floor") forming a rectangular yard (Fig. (13)). The camera is placed at the center of the yard. The arrow keys can be used to change the view direction and position.

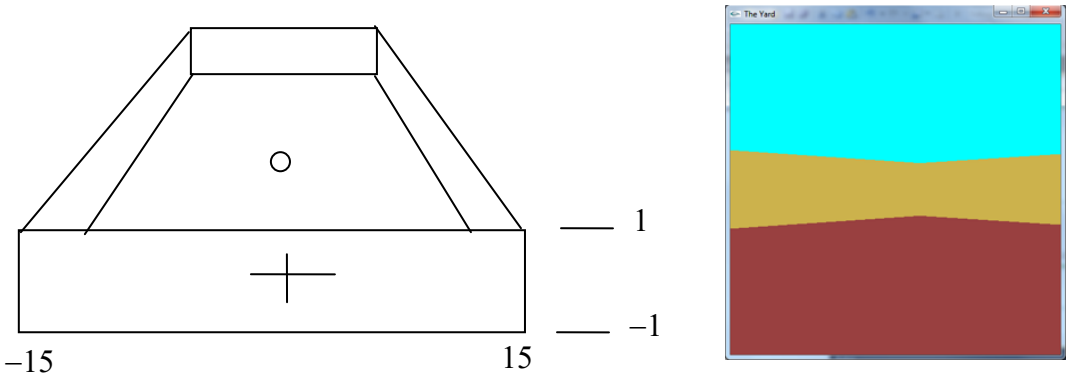
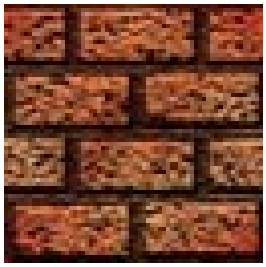


Fig. (13)

2. Two textures "Wall.tga" and "Floor.tga" are provided (Fig. (14)). The textures have a special property that they can be seamlessly tiled any number of times along both *s*, *t* directions without any visible discontinuities at boundary pixels. The program contains the necessary function definition to load both these textures. Note also that GL_REPEAT is the default wrapping mode for textures. Load the two textures and enable texture mapping by un-commenting the first two statements inside the `initialise()` function. The program uses the header file `loadTGA.h` to read tga files.


Wall.tga

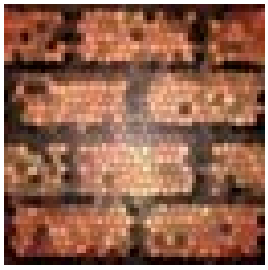
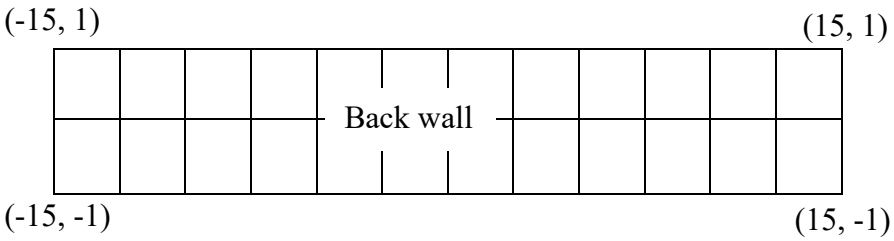

Floor.tga

Fig. (14)

3. Using the image "Wall.tga", texture the first quad (in the function wall()) as given below. The texture must be repeated 12 times in the horizontal direction, and twice along the vertical direction.




```
glTexCoord2f(0.0,  2.0);      glVertex3f(-15, 1, -15);
glTexCoord2f(0.0,  0.0);      glVertex3f(-15, -1, -15);
glTexCoord2f(12.0, 0.0);      glVertex3f(15, -1, -15);
glTexCoord2f(12.0, 2.0);      glVertex3f(15, 1, -15);
```

Texture the remaining 3 quads also the same way.

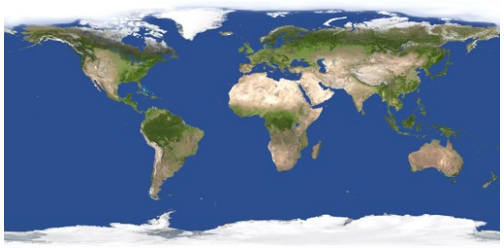
4. Similarly, texture map the floor using the second texture image "Floor.tga", with a repetition count of 16 along both directions. The final output is shown in Fig. (15).


Fig. (15)

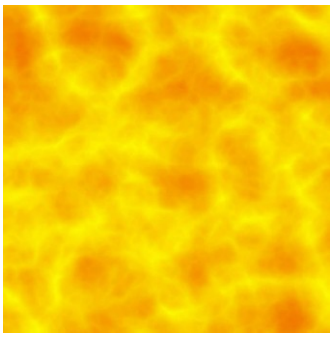
5. The program implements an "interactive walk-through" mode of the camera, where the up (down) arrow key moves the camera forward (backward), and the left and right arrow keys change the direction of movement.
   Take-home exercise: Implement a simple collision detection algorithm so that the camera would always remain within the four walls of the yard.

III. Earth.cpp

The program "Earth.cpp", uses the header file `loadBMP.h` to load two texture images in BMP format (Fig (16)). The program gives an example of texturing spheres defined as quadric surfaces using implicitly generated texture coordinates.



Earth.bmp



Sun.bmp

Fig. (16)

There exists a one-to-one mapping of points on a quadric surface and points on a two-dimensional image. Texture coordinates for such surfaces can be automatically generated and assigned to vertex coordinates by specifying the auto texture mapping mode using the function call

```
gluQuadricTexture (q, GL_TRUE);
```

This mode is already enabled inside the function initialise().

The program generates a display shown in Fig. (17). The sphere representing the Sun is positioned at the origin, and the Earth at a distance of 20 units along the x-axis. Please note how the Earth is first rotated about its axis and then translated to (20, 0).

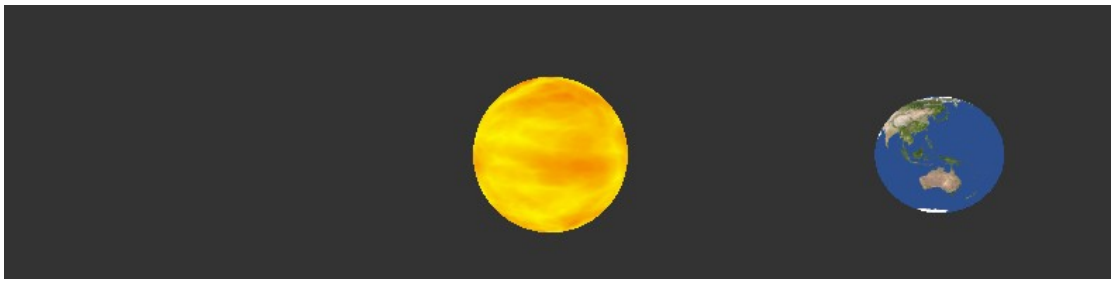


Fig. (17)

Specify a light source at the origin (position of the Sun). Light parameters have already been defined inside the `initialise()` function. Modify the environment parameter of the Earth texture to GL_MODULATE in the display() function, so that shadows are made visible on Earth's textured surface:

```
glTexEnvi(GL_TEXTURE_ENV, GL_TEXTURE_ENV_MODE, GL_MODULATE);
```

Finally, revolve the Earth around the Sun (Fig. (18)).

Fig. (18)

IV. (Take-home exercise) Skybox.cpp

A skybox is a large cube-shaped structure placed in a scene to which a set of textures is mapped to generate the appearance of a natural surrounding environment. The camera usually has a fixed position at the centre of the scene, and can only rotate to give different views of the environment. Six textures corresponding to the six sides of a cube as shown in Fig. (19) are provided.

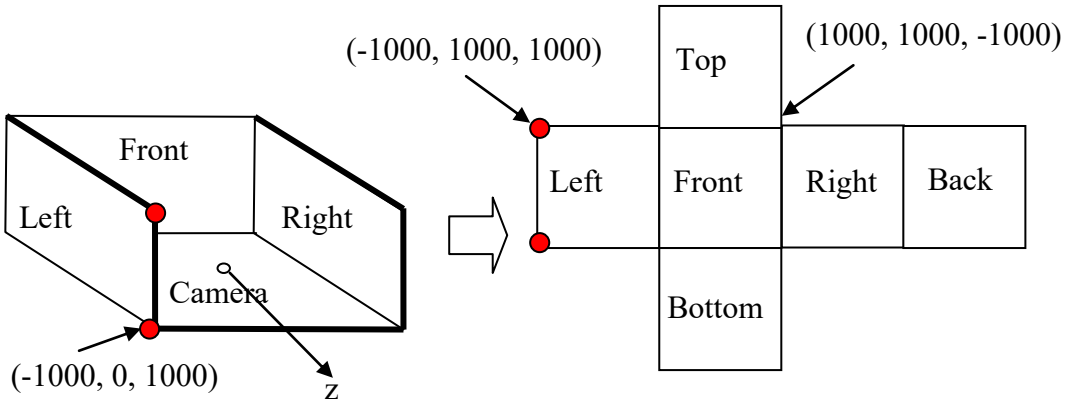
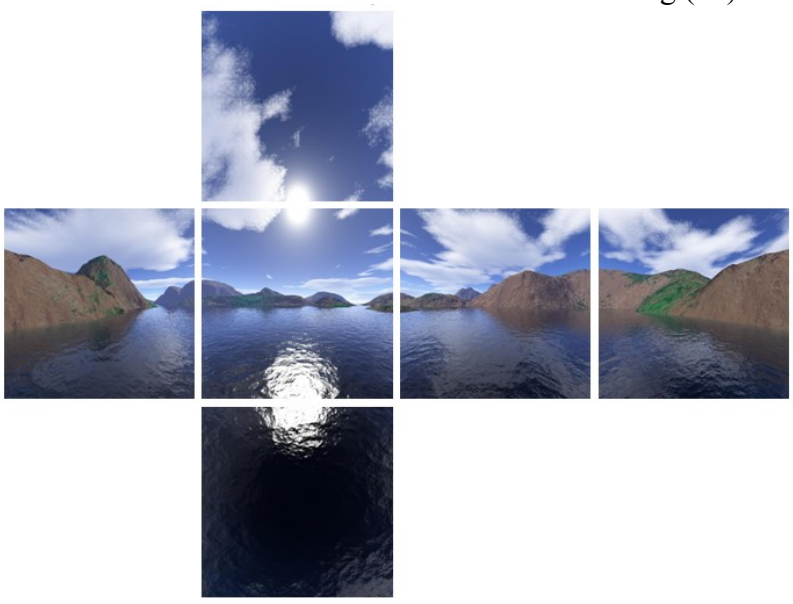


Fig (19)



The program `Skybox.cpp` displays the six sides of a cube with the camera positioned at the origin. The camera can be rotated using left/right arrow keys. The program already includes functions to load the textures and to set up texture parameters. You only need to assign texture coordinates using the function `glTexCoord2f( , )` to each vertex of each of the cubes to generate the display of a skybox as shown below (Fig. (k)). Please check (by rotating the camera) if all sides of the cube are properly mapped with seamless tiling and continuity of images across the edges.

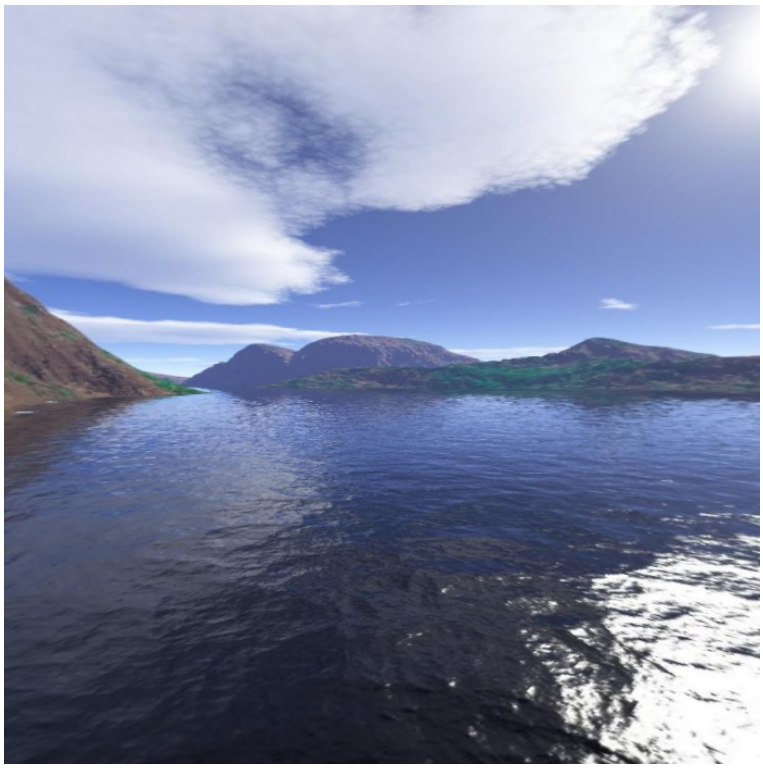


Fig (20)

NOTE:

Texture images must have the following properties in order to be loaded correctly using the functions defined in loadBMP.h, loadTGA.h:
BMP files: Windows bitmap, 24 bits, Width and height must be a power of 2.
TGA files: Uncompressed TGA, 24 bits, Width and height must be a power of 2.

V. Quiz-03

The quiz will remain open until **5pm, 23-Mar-2018**.

A quiz can be attempted only once. A question within a quiz may be attempted multiple times. However, a fraction of the marks (25%) will be deducted for each incorrect answer.