VISVESVARAYA TECHNOLOGICAL UNIVERSITY

JNANASANGAMA, BELAGAVI - 590018

Computer Graphics Mini Project Report

On

SNOW CITY

Submitted in partial fulfillment for the award of degree of

Bachelor of Engineering

in

Computer Science and Engineering

Submitted by

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Vidyayāmruthamashnuthe

B.N.M. Institute of Technology

Approved by AICTE, Affiliated to VTU, Accredited as grade A Institution by NAAC.
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Department of Computer Science and Engineering

2019 – 2020

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CERTIFICATE

Certified that the mini project entitled **SNOW CITY** carried out by **Mr.NAYAN SURYA N** USN **1BG18CS414** a bonafide student of VI Semester B.E., **B.N.M Institute of Technology** in partial fulfillment for the Bachelor of Engineering in COMPUTER SCIENCE AND ENGINEERING of the **Visvesvaraya Technological University**, Belagavi during the year 2019-20. It is certified that all corrections / suggestions indicated for internal Assessment have been incorporated in the report. The project report has been approved as it satisfies the academic requirements in respect of Computer Graphics Mini Project Laboratory prescribed for the said degree.

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Examiner 2:

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ABSTRACT

The main aim of this Mini Project is to illustrate the concepts and usage of pre-built functions in OpenGL. Creating Figures like Snowman and the surrounding environment using inbuilt functions provided by the glut library. The environment is built in -ve z-axis and translated to +ve Z-axis to make it look like the snowman is moving. We have used input devices like the mouse and keyboard to interact with the program. Primitives are defined by a group of one or more vertices. A vertex defines a point, an endpoint of a line, or a corner of a polygon where two edges meet. Data is associated with a vertex, and each vertex and its associated data are processed independently, in order, and in the same way. The type of clipping depends on which primitive the group of vertices represents.

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Chapter 1

INTRODUCTION

1.1 Overview

Interactive computer graphics provides us with the most natural means of communicating information through a computer. Over the years advancements in computer graphics have enabled us to not only make pictures of real-world objects but also visualize abstract, synthetic objects such as mathematical surfaces and of data that have no inherent geometry, such as survey results. Some topics in computer graphics include user interface design, sprite graphics, vector graphics, 3D modeling, shaders, GPU design, implicit surface visualization with ray tracing, and computer vision, among others. The overall methodology depends heavily on the underlying sciences of geometry, optics, and physics. The computer on receiving signals from the input device can modify the displayed picture appropriately. To the user it appears that the picture is changing instantaneously in response to his commands. He can give a series of commands, each one generating a graphical response from the computer. In this way he maintains a conversation, or dialogue, with the computer.

1.2 Problem Statement

The aim of this application is to show a basic implementation of prebuilt functions of OpenGL; The application will be implemented using the C++ programming language and the OpenGL API. The objective of the application is to demonstrate the simulation of objects like snowman and change in climate of the place using the principles of Computer Graphics. The application will also include user interaction through keyboard events; for changing the climate from day to night and navigation.

1.3 Motivation

Snow city is a simulation with added 3D functions which makes an ideal option for graphic designers and vfx experts to use in their solutions. The ability to visualize how the simulations works using rotation motion will give us a valuable insight on its working. The ability to develop this visualization using C++ programming and the OpenGL API serves as a motivation to develop this application.

1.4 Computer Graphics

Computer graphics and multimedia technologies are becoming widely used in educational applications because they facilitate non-linear, self-learning environments that particularly suited to abstract concepts and technical information.

Computer graphics are pictures and films created using computers. Usually, the term refers to computer-generated image data created with help from specialized graphical hardware and software. It is a vast and recent area in computer science. The phrase was coined in 1960, by computer graphics researchers Verne Hudson and William Fetter of Boeing. It is often abbreviated as CG, though sometimes erroneously referred to as CGI. Important topics in computer graphics include user interface design, sprite graphics, vector graphics, 3D modeling, shaders, GPU design, implicit surface visualization with ray tracing, and computer vision, among others.

The overall methodology depends heavily on the underlying sciences of geometry, optics, and physics. Computer graphics is responsible for displaying art and image data effectively and meaningfully to the user. It is also used for processing image data received from the physical world. Computer graphic development has had a significant impact on many types of media and has revolutionized animation, movies, advertising, video games, and graphic design generally.

1.5 OpenGL API

Open Graphics Library (OpenGL) is a cross-language, cross-platform application programming interface (API) for rendering 2D and 3D vector graphics. The API is typically used to interact with a graphics processing unit (GPU), to achieve hardware-accelerated rendering. Silicon Graphics Inc., (SGI) began developing OpenGL in 1991 and released it on June 30, 1992; applications use it extensively in the fields of computer-aided design (CAD), virtual reality, scientific visualization, information visualization, flight simulation, and video games. Since 2006 OpenGL has been managed by the non-profit technology consortium Khronos Group.

The OpenGL specification describes an abstract API for drawing 2D and 3D graphics. Although it is possible for the API to be implemented entirely in software, it is designed to be implemented mostly or entirely in hardware. The API is defined as a set of functions which may be called by the client program, alongside a set of named

integer constants. In addition to being language-independent, OpenGL is also cross-platform.

Given that creating an OpenGL context is quite a complex process, and given that it varies between operating systems, automatic OpenGL context creation has become a common feature of several game-development and user-interface libraries, including SDL, Allegro, SFML, FLTK, and Qt. A few libraries have been designed solely to produce an OpenGL-capable window. The first such library was OpenGL Utility Toolkit (GLUT), later superseded by freeglut. GLFW is a newer alternative.

1.5.1 OpenGL API Architecture

Display Lists:

All data, whether it describes geometry or pixels, can be saved in a display list for current or later use. When a display list is executed, the retained data is sent from the display list just as if it were sent by the application in immediate mode.

Evaluators:

All geometric primitives are eventually described by vertices. Parametric curves and surfaces may be initially described by control points and polynomial functions called basis functions.

Per Vertex Operations:

For vertex data, next is the "per-vertex operations" stage, which converts the vertices into primitives. Some vertex data are transformed by 4 x 4 floating-point matrices. Spatial coordinates are projected from a position in the 3D world to a position on your screen.

Primitive Assembly:

Clipping, a major part of primitive assembly, is the elimination of portions of geometry which fall outside a half space, defined by a plane.

Pixel Operation:

While geometric data takes one path through the OpenGL rendering pipeline, pixel data takes a different route. Pixels from an array in system memory are first unpacked from one of a variety of formats into the proper number of components. Next

the data is scaled, biased, and processed by a pixel map. The results are clamped and then either written into texture memory or sent to the rasterization step.

Rasterization:

Rasterization is the conversion of both geometric and pixel data into fragments. Each fragment square corresponds to a pixel in the frame buffer. Colour and depth values are assigned for each fragment square.

Fragment Operations:

Before values are actually stored into the framebuffer, a series of operations are performed that may alter or even throw out fragments. All these operations can be enabled or disabled.

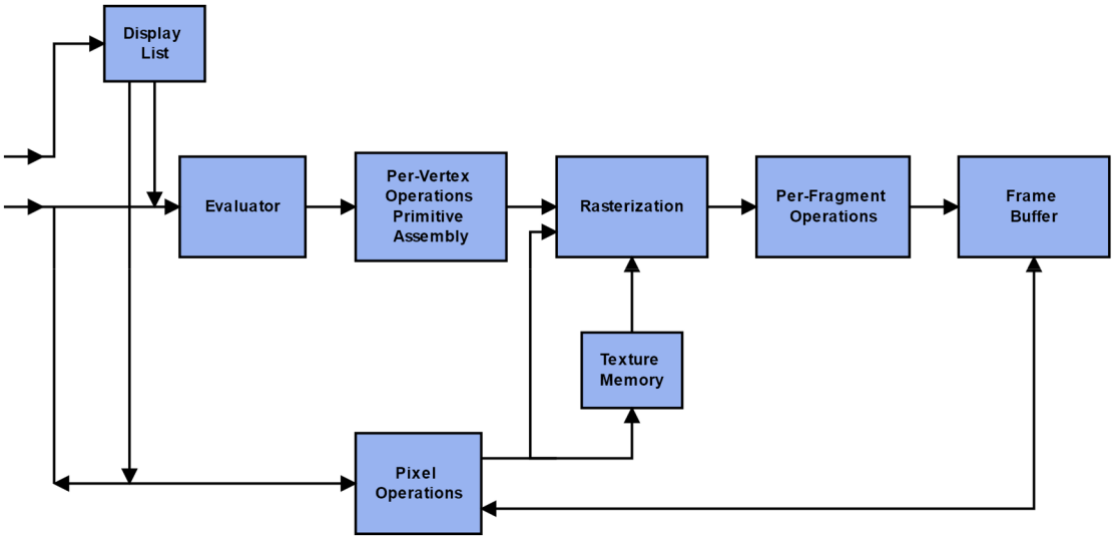

Fig 1.1 An illustration of the graphics pipeline process in OpenGL Architecture

1.6 Applications of Computer Graphics

Although many applications span two, three, or even all of these areas, the development of the field was based, for the most part, on separate work in each domain.

We can classify applications of computer graphics into four main areas:

1.6.1 Display of Information

Graphics has always been associated with the display of information. Examples of the use of orthographic projections to display floorplans of buildings can be found on 4000-year-old Babylonian stone tablets. Mechanical methods for creating perspective drawings were developed during the Renaissance. Countless engineering

students have become familiar with interpreting data plotted on log paper. More recently, software packages that allow interactive design of charts incorporating colour, multiple data sets, and alternate plotting methods have become the norm. In fields such as architecture and mechanical design, hand drafting is being replaced by computer-based drafting systems using plotters and workstations. Medical imaging uses computer graphics in a number of exciting ways.

1.6.2 Design

Professions such as engineering and architecture are concerned with design. Although their applications vary, most designers face similar difficulties and use similar methodologies. One of the principal characteristics of most design problems is the lack of a unique solution. Hence, the designer will examine a potential design and then will modify it, possibly many times, in an attempt to achieve a better solution. Computer graphics has become an indispensable element in this iterative process.

1.6.3 Simulation

Some of the most impressive and familiar uses of computer graphics can be classified as simulations. Video games demonstrate both the visual appeal of computer graphics and our ability to generate complex imagery in real time. Computer-generated images are also the heart of flight simulators, which have become the standard method for training pilots.

1.6.4 User Interfaces

The interface between the human and the computer has been radically altered by the use of computer graphics. Consider the electronic office. The figures in this book were produced through just such an interface. A secretary sits at a workstation, rather than at a desk equipped with a typewriter. This user has a pointing device, such as a mouse, that allows him to communicate with the workstation.

Chapter 2

LITERATURE SURVEY

2.1 History of Computer Graphics

The term “computer graphics” was coined in 1960 by William Fetter, a designer at Boeing, to describe his own job, the field can be said to have first arrived with the publication in 1963 of Ivan Sutherland’s Sketchpad program, as part of his Ph.D. thesis at MIT. Sketchpad, as its name suggests, was a drawing program. Beyond the interactive drawing of primitives such as lines and circles and their manipulation – in particular, copying, moving and constraining – with use of the then recently invented light pen, Sketchpad had the first fully-functional graphical user interface (GUI) and the first algorithms for geometric operations such as clip and zoom. Interesting, as well, is that Sketchpad’s innovation of an object-instance model to store data for geometric primitives foretold object-oriented programming. Coincidentally, on the hardware side, the year 1963 saw the invention by Douglas Engelbart at the Stanford Research Institute of the mouse, the humble device even today carrying so much of GUI on its thin shoulders.

Subsequent advances through the sixties came thick and fast: raster algorithms, the implementation of parametric surfaces, hidden-surface algorithms and the representation of points by homogeneous coordinates, the latter crucially presaging the foundational role of projective geometry in 3D graphics, to name a few. Flight simulators were the killer app of the day and companies such as General Electric and Evans & Sutherland, 6 co-founded by Douglas Evans and Ivan Sutherland, wrote simulators with real-time graphics.

The seventies, brought the Z-buffer for hidden surface removal, texture mapping, Phong’s lighting model – all crucial components of the OpenGL API (Application Programming Interface) we’ll be using soon – as well as keyframe-based animation. Photorealistic rendering of animated movie keyframes almost invariably deploys ray tracers, which were born in the seventies too.

Through the nineties, as well, the use of 3D effects in movies became pervasive. The Terminator and Star Wars series, and Jurassic Park, were among the early movies to set the standard for CGI. Toy Story from Pixar, 8 released in 1995, has special

importance in the history of 3D CGI as the first movie to be entirely computer-generated – no scene was ever pondered through a glass lens, nor any recorded on a photographic reel! It was cinema without film. Quake, released in 1996, the first of the hugely popular Quake series of games, was the first fully 3D game.

Another landmark from the nineties of particular relevance to us was the release in 1992 of OpenGL, the open-standard cross-platform and cross language 3D graphics API, by Silicon Graphics. OpenGL is actually a library of calls to perform 3D tasks, which can be accessed from programs written in various languages and running over various operating systems. That OpenGL was high-level (in that it frees the applications programmer from having to care about such low-level tasks as representing primitives like lines and triangles in the raster, or rendering them to the window) and easy to use (much more so than its predecessor 3D graphics API, PHIGS, standing for Programmer's Hierarchical Interactive Graphics System) first brought 3D graphics programming to the "masses". What till then had been the realm of a specialist was now open to a casual programmer following a fairly amicable learning curve.

Since its release OpenGL has been rapidly adopted throughout academia and industry. It's only among game developers that Microsoft's proprietary 3D API, Direct3D, which came soon after OpenGL bearing an odd similarity to it but optimized for Windows, is more popular.

The story of the past decade has been one of steady progress, rather than spectacular innovations in CG. Hardware continues to get faster, better, smaller and cheaper, continually pushing erstwhile high-end software down market, and raising the bar for new products. The almost complete displacement of CRT monitors by LCD and the emergence of high-definition television are familiar consequences of recent hardware evolution.

2.2 Related Work

- **Computer Aided Design (CAD):**

Most of engineering and Architecture students are concerned with Design. CAD is used to design various structures such as Computers, Aircrafts, Building, in almost all kinds of Industries. Its use in designing electronic systems is known as electronic design automation (EDA). In mechanical design it is known as mechanical design

automation (MDA) or computer-aided drafting (CAD), which includes the process of creating a technical drawing with the use of computer software.

- **Computer Simulation**

Computer simulation is the reproduction of the behaviour of a system using a computer to simulate the outcomes of a mathematical model associated with said system. Since they allow to check the reliability of chosen mathematical models, computer simulations have become a useful tool for the mathematical modeling of many natural systems in physics (computational physics), astrophysics, climatology, chemistry, biology and manufacturing, human systems in economics, psychology, social science, health care and engineering. Simulation of a system is represented as the running of the system's model. It can be used to explore and gain new insights into new technology and to estimate the performance of systems too complex for analytical solutions.

- **Digital Art**

Digital art is an artistic work or practice that uses digital technology as part of the creative or presentation process. Since the 1970s, various names have been used to describe the process, including computer art and multimedia art. Digital art is itself placed under the larger umbrella term new media art. With the rise of social media and the internet, digital art application of computer graphics. After some initial resistance, the impact of digital technology has transformed activities such as painting, drawing, sculpture and music/sound art, while new forms, such as net art, digital installation art, and virtual reality, have become recognized artistic practices. More generally the term digital artist is used to describe an artist who makes use of digital technologies in the production of art. In an expanded sense, "digital art" is contemporary art that uses the methods of mass production or digital media.

- **Virtual Reality**

Virtual reality (VR) is an experience taking place within a computer-generated reality of immersive environments can be similar to or completely different from the real world. Applications of virtual reality can include entertainment (i.e. gaming) and educational purposes (i.e. medical or military training). Other, distinct types of VR style technology include augmented reality and mixed reality. Currently standard virtual

reality systems use either virtual reality headsets or multi-projected environments to generate realistic images, sounds and other sensations that simulate a user's physical presence in a virtual environment. A person using virtual reality equipment is able to look around the artificial world, move around in it, and interact with virtual features or items. The effect is commonly created by VR headsets consisting of a head-mounted display with a small screen in front of the eyes, but can also be created through specially designed rooms with multiple large screens. Virtual reality typically incorporates auditory and video feedback, but may also allow other types of sensory and force feedback through haptic technology.

- **Video Games**

A video game is an electronic game that involves interaction with a user interface to generate visual feedback on a two- or three-dimensional video display device such as a TV screen, virtual reality headset or computer monitor. Since the 1980s, video games have become an increasingly important part of the entertainment industry, and whether they are also a form of art is a matter of dispute. The electronic systems used to play video games are called platforms. Video games are developed and released for one or several platforms and may not be available on others. Specialized platforms such as arcade games, which present the game in a large, typically coin-operated chassis, were common in the 1980s in video arcades, but declined in popularity as other, more affordable platforms became available. These include dedicated devices such as video game consoles, as well as general-purpose computers like a laptop, desktop or handheld computing devices.

Chapter 3

SYSTEM REQUIREMENTS

3.1 Software Requirements

Software requirements deal with defining software resource requirements and prerequisites that need to be installed on a computer to provide optimal functioning of an application.

The following are the software requirements for the application:

- Operating System: Windows 10
- Compiler: GNU C/C++ Compiler
- Development Environment: Visual Studio 2019 Community Edition
- API: OpenGL API & Win32 API for User Interface and Interaction

3.2 Hardware Requirements

The most common set of requirements defined by any operating system or software application is the physical computer resources, also known as hardware.

- CPU: Intel or AMD processor
- Cores: Dual-Core (Quad-Core recommended)
- RAM: minimum 4GB (>4GB recommended)
- Graphics: Intel Integrated Graphics or AMD Equivalent
- Secondary Storage: 250GB
- Display Resolution: 1366x768 (1920x1080 recommended)

Chapter 4

SYSTEM DESIGN

4.1 Proposed System

As a software interface for graphics hardware, OpenGL's main purpose is to render two- and three-dimensional objects into a frame buffer.
These objects are described as sequences of vertices or pixels.
OpenGL performs several processing steps on this data to convert it to pixels to form the final desired image in the frame buffer.

You can control modes independently of each other; that is, setting one mode doesn't affect whether other modes are set. Primitives are specified, modes are set, and other OpenGL operations are described by issuing commands in the form of function calls.
Primitives are defined by a group of one or more vertices. A vertex defines a point, an endpoint of a line, or a corner of a polygon where two edges meet. Data is associated with a vertex, and each vertex and its associated data are processed independently, in order, and in the same way. The type of clipping depends on which primitive the group of vertices represents.

The balance factor of the tree is defined as the difference of heights of the right and left subtrees of the tree. Commands are always processed in the order in which they are received, although there may be an indeterminate delay before a command takes effect.

This means that each primitive is drawn completely before any subsequent command takes effect. It also means that state-querying commands return data that's consistent with complete execution of all previously issue OpenGL commands.

4.2 Flowchart

A flowchart is a visual representation of the sequence of steps and decisions needed to perform a process. Each step in the sequence is noted within a diagram shape. Steps are linked by connecting lines and directional arrows.

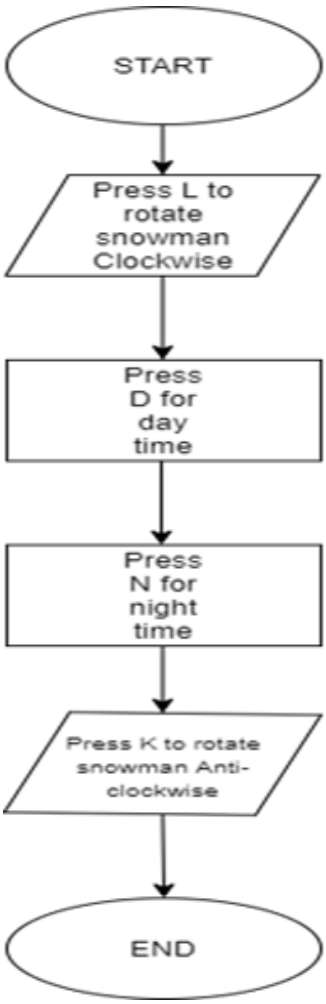

Figure 4.2 Flowchart of the Proposed System

Chapter 5

IMPLEMENTATION

5.1 Module Description

- **struct node**

This is a datatype created to store the nodes of the AVL Tree. It consists of 2 variables; the value of the node and the height of the node; along with 2 pointers to the left and right subtrees.

- **struct node* createNode (int key)**

This function creates a node with the value of the node set to key and initializing all the other node pointers and variables.

- **int height (struct node* N)**

This function returns the height of the node N passed as a parameter.

- **int getBalance (struct node*N)**

This function returns the balance factor of the node N passed as a parameter.

- **struct node* insert (struct node* node, int key)**

This is a recursive function is used to insert a new node into the tree pointed by node. It will recursively traverse the tree and insert the node at the appropriate position.

- **struct node* rightRotate (struct node* y)**

When a tree is *left-heavy* we have to perform a right rotate operation in order to maintain the balance in the tree; which is achieved in the application using this function.

- **struct node* leftRotate (struct node* y)**

When a tree is *right-heavy* we have to perform a left rotate operation in order to maintain the balance in the tree; which is achieved in the application using this function.

- **void drawCircle (float segments, float radius, float sx, float sy)**

This function is used to draw an individual node onto the screen using the x and y positions and the radius of the circle.

- **void drawText (char buffer, float x, float y)**

This function is used to print the value of the node on the screen using the x and y parameters. The character buffer stores the string.

- **void drawLine (float x1, float y1, float x2, float y2)**

This function is used to draw a line from point x1,y1 to point x2,y2. This function essentially draws the edge connecting the parent node to the child node.

- **void drawNode (struct node* root, float x1, float y1, int level)**

This is a recursive function draws the trees level incrementing the level by 1 for each child node. The tree recursively draws the left and right subtrees.

- **void keyboard (unsigned char key, int x, int y)**

This function is used to accept user input for navigation an inserting node into the tree.

- **void rightClickMenu (int ch)**

This is menu function which allows the user to clear the screen, by deleting all the node or allow the user to close the application.

5.2 High Level Code

5.2.1 Built-In Functions

- **void glClear(glEnum mode);**

Clears the buffers namely color buffer and depth buffer. mode refers to GL_COLOR_BUFFER_BIT or DEPTH_BUFFER_BIT.

- **void glTranslate[fd] (TYPE x, TYPE y, TYPE z);**

Alters the current matrix by displacement of (x, y, z), TYPE is either GLfloat or GLdouble.

- **void glutSwapBuffers();**

Swaps the front and back buffers.

- **void glMatrixMode(GLenum mode);**

Specifies which matrix will be affected by subsequent transformations, Mode can be GL_MODELVIEW or GL_PROJECTION.

- **void glLoadIdentity( );**

Sets the current transformation matrix to identity matrix.

- **void glEnable(GLenum feature);**

Enables an OpenGL feature. Feature can be GL_DEPTH_TEST (enables depth test for hidden surface removal), GL_LIGHTING (enables for lighting calculations), GL_LIGHTi (used to turn on the light for number i), etc.

- **void glPushMatrix() and void glPopMatrix();**

Pushes to and pops from the matrix stack corresponding to the current matrix mode.

- **void glutBitmapCharacter(void *font, int character);**

Without using any display lists, glutBitmapCharacter renders the character in the named bitmap font. The fonts used are GLUT_BITMAP_TIMES_ROMAN_24.

- **void glRasterPos[234][ifd](GLfloat x, GLfloat y, GLfloat z);**

This position, called the raster position, is used to position pixel and bitmap write operations.

- **void glutInit(int *argc, char **argv);**

Initializes GLUT; the arguments from main are passed in and can be used by the application.

- **void glutInitDisplayMode(unsigned int mode);**

Requests a display with the properties in the mode; the value of mode is determined by the logical OR of options including the color model (GLUT_RGB, GLUT_INDEX) and buffering (GLUT_SINGLE, GLUT_DOUBLE).

- **void glutCreateWindow(char *title);**

Creates a window on display; the string title can be used to label the window. The return value provides a reference to the window that can be used when there are multiple windows.

- **void glutMainLoop();**

Causes the program to enter an event-processing loop.

- **void glutDisplayFunc(void (*func)(void))**

Registers the display function func that is executed when the window needs to be redrawn.

- **void glutMouseFunc(void *f(int button, int state, int x, int y)**

Registers the mouse callback function f. The callback function returns the button (GLUT_LEFT_BUTTON,etc., the state of the button after the event (GLUT_DOWN), and the position of the mouse relative to the top-left corner of the window.

- **void glutKeyboardFunc(void *f(char key, int width, int height))**

Registers the keyboard callback function f. The callback function returns the ASCII code of the key pressed and the position of the mouse.

- **void glClearColor(GLclampf r, GLclampf g, GLclamp b, Glclamp a)**

Sets the present RGBA clear color used when clearing the color buffer. Variables of type GLclampf are floating point numbers between 0.0 and 1.0.

- **void glViewport(int x ,int y, GLsizei width, GLsizei height)**

Specifies the width*height viewport in pixels whose lower left corner is at (x,y) measured from the origin of the window.

- **void glColor3[b I f d ub us ui](TYPE r, TYPE g, TYPE b)**

Sets the present RGB colors. Valid types are bytes(b), int(i), float(f), double(d), unsigned byte(ub), unsigned short(us), and unsigned int(ui). The maximum and minimum value for floating point types are 1.0 and 0.0 respectively, whereas the maximum and minimum values of the discrete types are those of the type, for eg, 255 and 0 for unsigned bytes.

- **void glutInitWindowSize(int width, int height);**

Specifies the initial height and width of the window in pixels.

- **void glutReshapeFunc(void *f(int width, int height));**

Registers the reshape callback function f. the callback function returns the height and width of the new window. The reshape callback invokes the display callback.

- **void createMenu(void);**

This function is used to create menus which are used as options in program.

5.2.2 User Implementation

```
#include <iostream>
#include <stdlib.h>
#include <math.h>
#ifdef __APPLE__
#include <GLUT/glut.h>
#else
#include <GL/glut.h>
#endif
using namespace std;

GLfloat pos[] = {0, 0, 0, 1}, //light position
emission[] = {0, 0, 0, 1},
emission_default[] = {0, 0, 0, 1},
amb[] = {.4, .4, .4, 1.0}; //ambient intensity
GLfloat front_amb_diff[] = {.7, .5, .1, 1.0}; //front side property
GLfloat back_amb_diff[] = {.4, .7, .1, 1.0}; //back side property
GLfloat spe[] = {.2, .2, .2, 1.0}; //property for front and back
GLfloat dr = 0, moonHorizontal = 0, moonVertical = 0, snowmanMove = 0;

//dr=rotation angle for big snowman, moonHorizontal=tansition value for moon horizontally,

//moonVertical=transition value for moon vertically, snowmanMove = rotation value for small snowman idle annimation
bool rotateRight = false, rotateLeft = false, movement = true,
goDown = false, moon = true, snowmanMovement = true, sLeft = true,
sRight = false;
```

- **Function to make ground have snow**

```
void snow(void)
{
   glDisable(GL_LIGHTING);
   glDisable(GL_DEPTH_TEST);
   glBegin(GL_QUADS);
      glColor3f(.9, .9, .9);
       glVertex2f(-2.3, -.88);
       glVertex2f(2.3, -.88);
       glVertex2f(2.3, -2.3);
       glVertex2f(-2.3, -2.3);
   glEnd();
   glEnable(GL_LIGHTING);
   glEnable(GL_DEPTH_TEST);
}
```

- **Function to create a house**

```
  void house(void){
     glRotated(-20, 0, 1, 0);
     //house
     glColor3f(.871, .612, .416);
     glTranslated(0, -.38, 0);
     glutSolidCube(.73);
     //door
     glTranslated(-.2, -.355, .046);
     glScaled(.5, 1.1, 0);
     glutSolidCube(.23);
  }
```

- **Function to create a tree**

```
   void tree(void){
   //trunk
   glPushMatrix();
   glColor3f(.388, .2, .0039);
   GLUquadric* qobj = gluNewQuadric(); //cylinder trunk
   glRotated(90, 1, 0, 0);
   gluCylinder(qobj, .05, .05, .4, 30, 30);
   glPopMatrix();
   //tree leaves
   glColor3f(0, .415, .0156);
   glTranslated(0, -.23, 0);
}
```

```
glRotated(-90, 1, 0, 0);
glutSolidCone(.3, .3, 40, 40);
glTranslated(0, 0, .1);
glutSolidCone(.25, .3, 40, 40);
glTranslated(0, 0, .1);
glutSolidCone(.2, .3, 40, 40);
```

- **Function to create moon/sun**

```
void moonOrSun(void){
glTranslated(.05, 0, 0);
glLightfv(GL_LIGHT0, GL_POSITION, pos);
glMaterialfv(GL_FRONT, GL_EMISSION, emission);
glutSolidSphere(.4, 40, 40);
glMaterialfv(GL_FRONT, GL_EMISSION, emission_default);
glLightfv(GL_LIGHT0, GL_AMBIENT, amb);
glEnable(GL_LIGHTING);
glEnable(GL_LIGHT0);
}
```

- **Function to snowman**

```
void snowman(void){
//hat
glTranslated(-.05, 0, 0);
glPushMatrix();
glColor3f(1, 1,  1);
glTranslated(0, .7, 0);
glutSolidSphere(.04, 40, 40);
glColor3f(1, 0, 0);
glTranslated(0, -.30, 0);
glRotated(-90, 1, 0, 0);
glutSolidCone(.1, .3, 40, 40);
glColor3f(1, 1, 1);
glTranslated(0, 0, -.015);
glutSolidTorus(.05, .07, 10, 10);
glPopMatrix();
```

```
    //body
    glPushMatrix();
    glColor3f(1, 1,  1);
    glTranslated(0, .2, 0);
    glutSolidSphere(.19, 40, 40);
    glTranslated(0.0, -.45, 0);
    glutSolidSphere(.3, 40, 40);
    glTranslated(0.0, -.6, 0);
    glutSolidSphere(.4, 40, 40);
    glPopMatrix();
  //mouth
  glColor3f(0, 0, 0);
  glTranslated(-.06, -.08, 0);
  glutSolidSphere(.014, 40, 40);
  glTranslated(.03, -.015, 0);
  glutSolidSphere(.014, 40, 40);
  glTranslated(.03, -.001, 0);
  glutSolidSphere(.014, 40, 40);
  glTranslated(.03, .001, 0);
  glutSolidSphere(.014, 40, 40);
  glTranslated(.03, .015, 0);
  glutSolidSphere(.014, 40, 40);
  glPopMatrix(); //pop face objects
  //arms
  glPushMatrix();
  glColor3f(.388, .2, .0039);
  GLUquadric* qobj = gluNewQuadric(); //create cylinder object
  glRotated(45, 0, 0, 1);
  glRotated(90, 0, 1, 0);
  glTranslated(-.04, -.3, 0);
  gluCylinder(qobj, .02, .02, .3, 30, 30);
  glRotated(-90, 1, 0, 0);
  glTranslated(0, .3, .3);
  gluCylinder(qobj, .02, .02, .3, 30, 30);
  glPopMatrix();
}
```

- **Display function**

```
void display(void){
   glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
   snow(); //snow on the ground

   //key command animations
  if(rotateRight){
     glRotated(dr, 0, 1, 0);
  }
  else if(rotateLeft){
     glRotated(dr, 0, 1, 0);
  }
  snowman();
  glPopMatrix();
          //idle animation
  if(snowmanMovement){
     glRotated(snowmanMove, 0, 0, 1);
  }
  snowman();
  glPopMatrix();

   glPushMatrix();
   glTranslated(1.1, -1, -.6);
   glScaled(.5, .5, .5);
   if(snowmanMovement){
      glRotated(-snowmanMove, 0, 0, 1);
   }
   snowman();
   glPopMatrix();

  void keyboard(unsigned char key, int x, int y){
     switch (key){
        case 'k':
           //rotate big snowman counter-clockwise
           rotateRight = true;
           rotateLeft = false;
                          break;
  case 'l':
           //rotate big snowman clockwise
           rotateLeft = true;
```

```
rotateRight = false;
    break;
case 'n':
    //night time
    moon = true;
    glClearColor(0.03, 0.02, 0.7, 0.0);
    break;
case 'd':
    //day time
    moon = false;
    glClearColor(.165, .553, .812, 0);
    break;
       }
       glutPostRedisplay();
    }
    int main(int argc, char** argv){
     glutInit(&argc, argv);
     glutInitDisplayMode(GLUT_DOUBLE | GLUT_RGB | GLUT_DEPTH);
     glutInitWindowSize(800, 700);
     glutInitWindowPosition(200, 100);
     glutCreateWindow("Snowman World");
     glClearColor(0.03, 0.02, 0.7, 0.0);
     glEnable(GL_DEPTH_TEST);
     glMatrixMode(GL_PROJECTION);
     glLoadIdentity();
     gluPerspective(45, 1.0, 2, 8);
     glColorMaterial(GL_FRONT_AND_BACK, GL_AMBIENT_AND_DIFFUSE);
     glMaterialfv(GL_FRONT, GL_AMBIENT_AND_DIFFUSE, front_amb_diff);
     glMaterialfv(GL_BACK, GL_AMBIENT_AND_DIFFUSE, back_amb_diff);
     glMaterialfv(GL_FRONT_AND_BACK, GL_SPECULAR, spe);
     glMaterialf(GL_FRONT_AND_BACK, GL_SHININESS, 30);
     glLightModeli(GL_LIGHT_MODEL_TWO_SIDE, GL_TRUE);
     glMatrixMode(GL_MODELVIEW);
     glLoadIdentity();
     glTranslated(0, 0, -5); //translate object (& light) into view volume
     glEnable(GL_COLOR_MATERIAL);
     glEnable (GL_NORMALIZE); //for scaling down objects
     commandInfo(); //display key command information
     glutKeyboardFunc(keyboard);
     glutDisplayFunc(display);
     glutIdleFunc(idle);
     glutMainLoop();
  }
```

Chapter 6

RESULTS

- **Start Page**

  The starting page of the application, shows the snowman's rotating using Keyboard interaction.

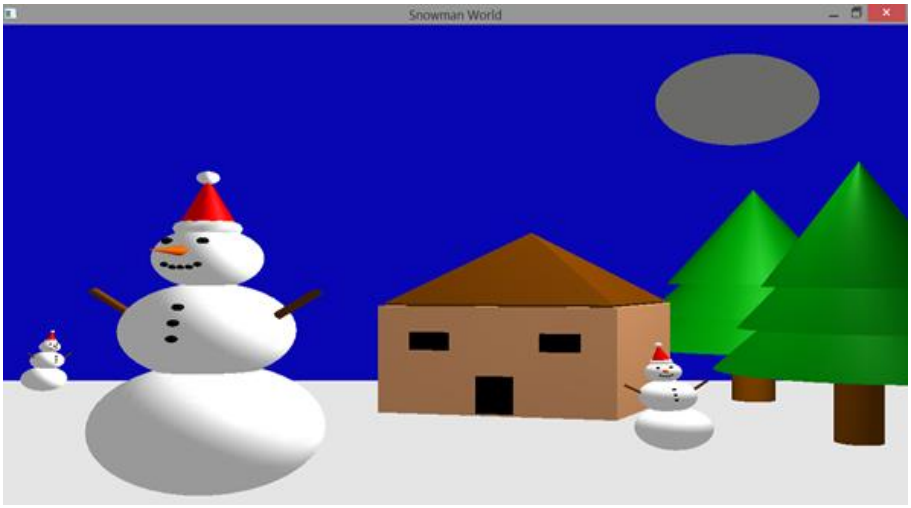

Figure 6.1 Start page(simulation)

- **Night time Page**

  The daytime page shows the simulation of moon along with the snowman's.

Figure 6.2 Night time page

- **Day time Page**

In this page the user is allowed to change the climate from night to day using keyboard interactions.

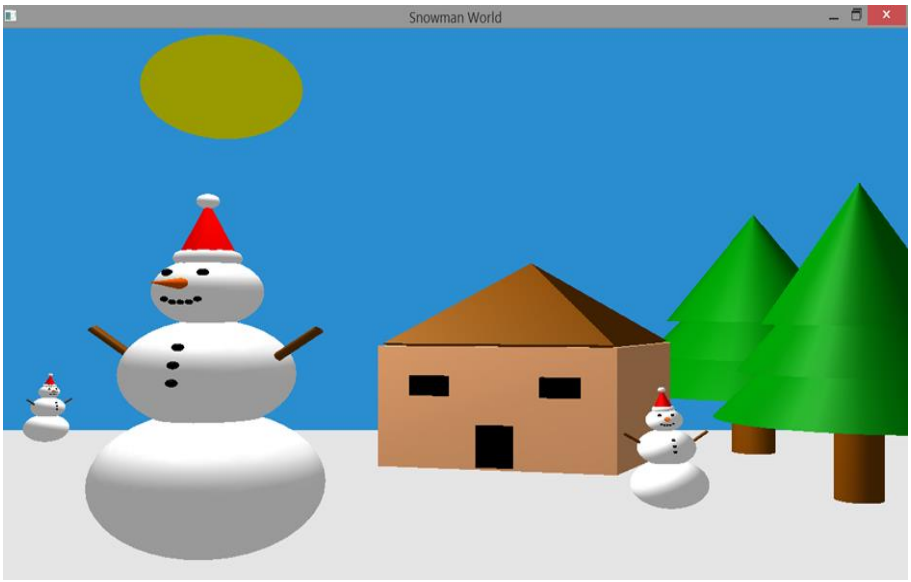

Figure 6.3 Day time Page

Chapter 7

CONCLUSION AND FUTURE ENHANCEMENTS

The project “Snow city” clearly demonstrates the functions provided by OpenGL library for creating figures and translating them by using interactive keyboard and mouse functions.

Finally, we conclude that this program clearly illustrates the usage of OpenGL library and has been completed successfully and is ready to be demonstrated.

In the future this application can be further enhanced by adding more functionality to show more operations on 3D functions and simulations of the objects.

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