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A Mini Project Report 18CSL67
on

Tower of Hanoi Visualization

A mini project report submitted in partial fulfillment of the requirement for the award of the degree of

Bachelor of Engineering
in
Computer Science & Engineering

Submitted by
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Certificate

Certified that the Computer Graphics Mini Project entitled **"Tower of Hanoi Visualization"** is a bonafide work carried out by **Mr. Bikram Biswas (1AY18CS028)** in partial fulfillment for the award of degree of **Bachelor of Engineering in Computer Science & Engineering of the Visvesvaraya Technological University**, Belgaum during the academic year **2020-2021.** It is certified that all corrections/ suggestions indicated for internal assessments have been incorporated in the Report deposited in the departmental library. The Mini project report has been approved as it satisfies the academic requirements in respect of Mini Project work prescribed for the **Bachelor of Engineering Degree**.

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1.

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ABSTRACT

This paper describes an automated approach to generating abstractions for the Tower of Hanoi and analyzes the use of these abstractions for problem solving using OpenGL. The analysis shows that the learned abstractions produce an exponential reduction in the size of the search space. Since few problem solvers actually explore the entire search space, the paper also presents an empirical analysis of the speedup provided by abstraction when a heuristic searchisemployed. The empirical analysis shows that the benefit of abstraction is largely determined by the portion of the base-level search space explored. Thus, using breadth-first search, which searches the entire space, abstraction provides an exponential reduction in search. However, using a depth-first search, the search reduction is smaller and depends on the amount of backtracking required to solve the problem. Abstractions, 1990 1 Introduction The Tower of Hanoi puzzle has be studied extensively in the problem-solving.In this paper , visualization is made by using OpenGL and OpenGL libraries.

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Chapter 1

INTRODUCTION

1.1 Computer Graphics

1.1.1 About Computer Graphics:

Computer graphics is one of the most exciting and rapidly growing computer field and computer. It is also an extremely effective medium for communication between men.The human can understand the information content of a displayed diagram or perceptive view much faster than it can understand a table of numbers.

There is a lot of development in hardware and software required to generate images, and now-a-days the cost of such hardware and software is also dropping rapidly. Due to this the interactive computer graphics is becoming available to more and more people.

Computer graphics today is largely interactive. The user controls the contents, structure and appearance of the objects and of their displayed images by using input devices, such as keyboard, mouse or touch sensitive panel on the screen. Because of the close relationship between the input devices and display, the handling of such devices is included in the study of computer graphics.

This is a subfield of geometry which studies the representation of three-dimensional objects in a discrete digital setting. Because the appearance of an object depends largely on its exterior, boundary representation are most commonly used. Two dimensional surface are a good representation for most objects, though they may be non-manifold. Since surfaces are not finite, discrete digital approximations are used. Polygonal Meshes are by far the most common representation, although point-based representations have become more popular recently. These representations are Lagrangian meaning the spatial locations of the samples are independent. Recently, *Eulerian* surface descriptions (i.e., where spatial samples are fixed) such as level sets have been developed into a useful representation for deforming surfaces which undergo many topological changes.

1.1.2 Applications of computer graphics:

User interface:

It is now a well-established fact that graphical interfaces provide an alternative and easy interaction between users and computers the built in graphics provided with user interfaces use the control items.

In industry, business government and education organization's computer graphics is mostcommonly used to create 2D and 3D graphs of mathematical, physical and economic functions inthe form of histograms, bars and pie charts which are very useful in decision making.

Computer aided drafting and design:

The computer aided drafting uses the graphics to components and systems. Electrical, mechanical and electronic devices such as automobile bodies, structure of airplane, ships, buildings.

Simulation and animation for scientific visualization and environment:

Use of graphics in simulation makes mathematical models and mechanical systems more realistic and easy to study. The interactive graphics supported by animation software proved theiruse in production of animated movies and cartoon films.

1.2 OpenGL

1.2.1 Introduction to OpenGL

OpenGL is a software interface to graphics hardware. This interface consists of about 150 distinctcommands that you use to specify the objects and operations needed to produce interactive three-dimensional applications.

OpenGL is designed as a streamlined, hardware-independent interface to be implemented on many different hardware platforms. To achieve these qualities, no commands for performing windowingtasks or obtaining user input are included in OpenGL; instead, you must work through whatever windowing system controls the particular hardware you're using. Similarly, OpenGL doesn't provide high-level commands for describing models of three-dimensional objects. Such commands might allow you to specify relatively complicated shapes such as automobiles, parts ofthe body, airplanes, or molecules. With OpenGL, you must build up your desired model from a small set of *geometric primitives* - points, lines, and polygons.

A sophisticated library that provides these features could certainly be built on top of OpenGL. TheOpenGL Utility Library (GLU) provides many of the modeling features, such as quadric surfacesand NURBS (Non-Uniform Rational B-Splines) curves and surfaces. GLU is a standard part of every OpenGL implementation. Also, there is a higher-level, object-oriented toolkit, Open Inventor, which is built atop OpenGL, and is available separately for many implementations of OpenGL.

1.2.2 Uses of OpenGL

Basically for anything related to graphics. There is a good chance your favorite mobile game is using OpenGL. If I'm not mistaken, most of the iPhone animations also use OpenGL.

Most games on your PC use OpenGL.

1.2.3 Applications of OpenGL

OpenGL is commonly associated with video games because of its widespread use in 3D gaming. It provides developers with an easy way to create crossplatform games or port a game from one platform to another. OpenGL is also used as the graphics library for many CAD applications, such as AutoCAD and Blender. Even Apple uses OpenGL as the foundation of the macOS Core Animation, Core Image, and Quartz Extreme graphics libraries.

1.2.4 OpenGL Related Libraries

OpenGL provides a powerful but primitive set of rendering commands, and all higher-level drawing must be done in terms of these commands. Also, OpenGL programs have to use the underlying mechanisms of the windowing system. A number of libraries exist to allow you to simplify your programming tasks, including the following:

• The OpenGL Utility Library (GLU) contains several routines that use lower-level OpenGL commands to perform such tasks as setting up matrices for specific viewing orientations and projections, performing polygon tessellation, and rendering surfaces. This library is provided as part of every OpenGL implementation. GLU routines use the prefix glu.

• For every window system, there is a library that extends the functionality of that window system to support OpenGL rendering. For machines that use the X Window System, the OpenGL Extension to the X Window System (GLX) is provided as an adjunct to OpenGL. GLX routines use the prefix glX. For Microsoft Windows, the WGL routines provide the Windows to OpenGL interface. All WGL routines use the prefix wgl. For IBM OS/2, the PGL is the Presentation Manager to OpenGL interface, and its routines use the prefix pgl.

• The OpenGL Utility Toolkit (GLUT) is a window system-independent toolkit, written by Mark Kilgard, to hide the complexities of differing window system APIs. GLUT routines use the prefix glut.

• Open Inventor is an object-oriented toolkit based on OpenGL which provides objects and methods for creating interactive three-dimensional graphics applications. Open Inventor, which is written in C++, provides prebuilt objects and a built-in event model for user interaction, high-level application components for creating and editing three-dimensional scenes, and the ability to print objects and exchange data in other graphics formats. Open Inventor is separate from OpenGL.

1.2.5 How to make your first OpenGL Program:

The first thing to do is chose a programming language. It could be C, C++, C#, Visual Basic, Pascal, Perl, Java, Ada, x86 assembly, etc. As long as a language has an OpenGL binding for your chosen language, you may use it.

The second thing is to choose a compiler. It could be MS Visual C++, Code::Blocks, Delphi, Masm, etc. Remember that OpenGL is an API, so as long as you have the language bindings for your compiler, you can do OpenGL programming.

Typically, a compiler comes with the binding files. For example, if you have a C++ compiler, it will come with gl.h and opengl32.lib. It may even come with glu.h and glu32.lib, glut.h and glut32.lib.

If you don't have your binding files, you will need to figure out where to download them from. Microsoft releases their Windows Platform SDK which contains these files and most likely you don't need it because your compiler came with the files.

You might want to use SDL, GLUT, freeGLUT, or some other wrapper that takes care of creating a GL window for you and destroying for you. It makes it easier for someone who just wants to learn the OpenGL API syntax.

Assuming you know how to program in your language of choice, now all you need it to learn OpenGL. There are many online tutorials. Just search for opengl+tutorial in your favorite search engine or visit some of the tutorials listed here.

1.2.6 OpenGL Viewers:

These are programs that you install and run, and they give you information specific to the OpenGL API your system implements, like the version offered by your system, the vendor, the renderer, the extension list, supported viewport size, line size, point size, plus many other details. Some might include a benchmark. Some are standalone benchmarks.

GPU Caps Viewer (Windows XP, Vista 32)

OpenGL Extension Viewer (Windows, Windows x64 and MacOS X) OpenGL ES benchmark tool (Linux, Symbian, Windows Mobile) Fur rendering benchmark (Windows)

Futuremark's GL ES benchmark.

CHAPTER-2

SYSTEM REQUIREMENT

Chapter 2

SYSTEM REQUIREMENTS

2.1 Hardware requirements:

- Pentium or higher processor.
- 512 MB or more RAM
- A standard keyboard, compatible mouse and a VGA monitor

2.2 Software requirements:

This graphics package has been designed in Ubuntu platform by using the virtualization technology of Oracle VM Virtual Machine.

- OS : Ubuntu 20.04 LTS
- Development Tool : Notepad
- Language : C

2.3 Functional requirements:

- This software offers the users to calculate any type of problem by using Tower of Hanoi Method.
- In the introduction page there will be a option for inserting the disk number for solving the problem and user can enter no. of disks with his/her wish.
- Then there will be a option for enter into the main screen where there will be option for Lighting,Move Camera,Animation,Background-color,Solve Completely and Restart .
- User can choose any and for solving the problem he/she should choose ‘solve completely’ option.
- Moving of disks among the three towers(suppose a,b,c are the three towers) means how the plates are moved among the towers should shown in the screen.
- User can restart the problem by choosing ‘restart’ option.

CHAPTER-3
ABOUT THE PROJECT

Chapter 3

ABOUT THE PROJECT

3.1 Introduction

3.1.1 Tower of Hanoi Introduction:

The Tower of Hanoi is a mathematical game or puzzle. It consists of three rods, and a number of disks of different sizes which can slide onto any rod. The puzzle starts with the disks in a neat stack in ascending order of size on one rod, the smallest at the top, thus making a conical shape.

The objective of the puzzle is to move the entire stack to another rod, obeying the following simple rules:

1. Only one disk can be moved at a time.

2. Each move consists of taking the upper disk from one of the stacks and placing it on top of another stack i.e. a disk can only be moved if it is the uppermost disk on a stack.

3. No disk may be placed on top of a smaller disk.

With three disks, the puzzle can be solved in seven moves. The minimum number of moves required to solve a Tower of Hanoi puzzle is 2n - 1, where n is the number of disks.

3.1.2 Recursive Solution:

A key to solving this puzzle is to recognize that it can be solved by breaking the problem down into a collection of smaller problems and further breaking those problems down into even smaller problems until a solution is reached. For example:

- label the pegs A,B,C.
- let *n* be the total number of discs
- number the discs from 1(smallest, topmost) to n(largest,bottommost)

To move n discs from peg A to C:

1. moves n-1 discs from A to B.This leaves disc n alone on peg A
2. move disc n from A to C
3. Moves n-1 discs from B to C so they sit on disc n.

The above is a recursive algorithm, to carry out steps 1 and 3, apply the same algorithm again for n−1. The entire procedure is a finite number of steps, since at some point the algorithm will be required for n = 1. This step, moving a single disc from peg A to peg C, is trivial. This approach can be given a rigorous mathematical formalism with the theory of dynamic programming and is often used as an example of recursion when teaching programming.

3.2 Objectives:

This is a mini project on Tower of Hanoi based on OPENGL API for Computer graphics and visualization laboratory (18CSL67). The project simulates the optimal solution of the

Tower of Hanoi problem given a number of disk. The project implements various geometric transformations like Translation, Rotation, and Scaling. The basic model consists of three poles, source, auxiliary and destination. The disks initially resting on the source pole reaches the destination. The poles are drawn using the GLUT library function glutSolidCone(), and the disks are drawn using glutSolidTorus().Initially the user is presented with an introduction scene which has a menu to choose the number of disks.

On pressing the Enter key the actual simulation scene is loaded. The user can use the mouse wheel to advance through the simulation. An optional animation has been implemented, which shows the movement of the disks from pole to pole. The viewing model used is an Orthogonal Projection. The moves to be performed as per the optimal solution are displayed on the top left of the screen is a raster text using the function glutBitmapCharacter(). Lighting has been implemented by the inbuilt OPENGL lighting functions. Menus have been provided to modify various features such as Lighting, Move camera, animation, change background color, to automatically simulate the complete solution, restart the simulation and to exit the program. The movement of the camera is only along the Y axis, and is implemented using the gluLookAt() function.

3.3 Built-in Functions & User Defined Function:

Include Files

For all OpenGL applications, you want to include the gl.h header file in every file. Almost all OpenGL applications use GLU, the aforementioned OpenGL Utility Library, which requires inclusion of the glu.h header file. So almost every OpenGL source file begins with

#include <GL/gl.h> #include <GL/glu.h>

If you are directly accessing a window interface library to support OpenGL, such as GLX, AGL, PGL, or WGL, you must include additional header files. For example, if you are calling GLX, you may need to add these lines to your code

#include <X11/Xlib.h> #include <GL/glx.h>

If you are using GLUT for managing your window manager tasks, you should include #include <GL/glut.h>

Note that glut.h includes gl.h, glu.h, and glx.h automatically, so including all three files is redundant. GLUT for Microsoft Windows includes the appropriate header file to access WGL.

GLUT, the OpenGL Utility Toolkit:

As you know, OpenGL contains rendering commands but is designed to be independent of any window system or operating system. Consequently, it contains no commands for opening windows or reading events from the keyboard or mouse. Unfortunately, it's impossible to write a complete graphics program without at least opening a window, and most interesting programs require a bit of user input or other services from the operating system or window system.

In addition, since OpenGL drawing commands are limited to those that generate simple geometric primitives (points, lines, and polygons), GLUT includes several routines that create more complicated three-dimensional objects such as a sphere, a torus, and a teapot. This way, snapshots of program output can be interesting to look at. (Note that the OpenGL Utility

Library, GLU, also has quadrics routines that create some of the same three-dimensional objects as GLUT, such as a sphere, cylinder, or cone.)

Important features of OpenGL Utility Toolkit (GLUT)

- Provides functionality common to all window systems.
- Open a window.
- Get input from mouse and keyboard.
- Menus.
- Event-driven.
- Code is portable but GLUT lacks the functionality of a good toolkit for a specific platform.
- No slide bars.
- OpenGL is not object oriented so that there are multiple functions for a given logical function :

- glVertex3f
    i. glVertex2i
    ii. glVertex3dv

- Underlying storage mode is the same easy to create overloaded functions in C++ but issue is efficiency.

- **OpenGL Interface**
    - GL (OpenGL in Windows)
    - GLU (graphics utility library) uses only GL functions, creates common objects (such as spheres)
    - GLUT (GL Utility Toolkit) interfaces with the window system

- GLX: glue between OpenGL and Xwindow, used by GLUT

Window Management

Five routines perform tasks necessary to initialize a window.

- glutInit(int *argc, char **argv) initializes GLUT and processes any command line arguments (for X, this would be options like -display and -geometry). glutInit() should be called before any other GLUT routine.
- glutInitDisplayMode(unsigned int mode) specifies whether to use an RGBA or color- index color model. You can also specify whether you want a single- or double-buffered window. (If you're working in color-index mode, you'll want to load certain colors into the color map; use glutSetColor() to do this.) Finally, you can use this routine to indicate that you want the window to have an associated depth, stencil, and/or accumulation buffer. For example, if you want a window with double buffering, the RGBA color model, and a depth buffer, you might call **glutInitDisplayMode**(GLUT_DOUBLE | GLUT_RGB | GLUT_DEPTH).
- **glutInitWindowPosition**(int x, int y) specifies the screen location for the upper-left corner of your window.
- **glutInitWindowSize**(int width, int size) specifies the size, in pixels, of your window.
- int **glutCreateWindow**(char *string) creates a window with an OpenGL context. It returns a unique identifier for the new window. Be warned: Until **glutMainLoop()** is called (see next section), the window is not yet displayed.

The Display Callback

glutDisplayFunc(void (*func)(void)) is the first and most important event callback function you will see. Whenever GLUT determines the contents of the window need to be redisplayed, the callback function registered by **glutDisplayFunc()** is executed. Therefore, you should put all the routines you need to redraw the scene in the display callback function.

If your program changes the contents of the window, sometimes you will have to call **glutPostRedisplay(void)**, which gives **glutMainLoop()** a nudge to call the registered display callback at its next opportunity.

Running the Program

The very last thing you must do is call **glutMainLoop**(void). All windows that have been created are now shown, and rendering to those windows is now effective. Event processing begins, and the registered display callback is triggered. Once this loop is entered, it is never exited!

Graphics Functions

- Primitive Function:
  points, line segments, polygons, pixels, text, curves, surfaces
- Attribute Function:
  color, pattern, typeface

Some Primitive Attribute

glClearColor (red, green, blue, alpha); - Default = (0.0, 0.0, 0.0, 0.0) glColor3f (red, green, blue); - Default = (1.0, 1.0, 1.0)

glLineWidth (width); - Default = (1.0) glLineStipple (factor, pattern) - Default = (1, 0xffff) glEnable (GL_LINE_STIPPLE);

glPolygonMode (face, mode) - Default = (GL_FRONT_AND_BACK, GL_FILL) glPointSize (size); - Default = (1.0)

- Viewing functions:
  Position,orientation,clipping

- Transformation functions:
  Rotation,translation,scaling
- Input Functions:
  Keyboards,mice,data tablets
- Control functions:
  Communicate with windows,initialization,error handling
- Inquiry Functions:
  Number of colors,camera parameters/values

Matrix Mode

There are two matrices in OpenGL:

- Model-view: defines COP and orientation
- Projection: defines Projection Matrix

```
glMatrixMode(GL_PROJECTION);

glLoadIdentity();

gluOrtho2D(0.0, 500.0, 0.0, 500.0);

glMatrixMode(GL_MODELVIEW);
```

Control Functions

- OpenGL assumes origin is bottom left
- glutInit(int *argcp, char **argv);
- glutCreateWindow(char *title);
- glutInitDisplayMode(GLUT_RGB | GLUT_DEPTH | GLUT_DOUBLE);
- glutInitWindowSize(480,640);
- glutInitWindowPosition(0,0);
- OpenGL default: RGB color, no hidden-surface removal, single buffering.

Obtaining Values of OpenGL State Variables :

glGetBooleanv (paramname, *paramlist);

glGetDoublev (paramname, *paramlist);

glGetFloatv (paramname, *paramlist);

glGetIntegerv (paramname, *paramlist);

Saving and Restoring Attributes:

glPushAttrib (group);

glPopAttrib ( );

where group = GL_CURRENT_BIT, GL_ENABLE_BIT, GL_LINE_BIT, GL_POLYGON_BIT, etc

Projection Transformations

glMatrixMode (GL_PROJECTION);

glLoadIdentity ( );

glFrustum (left, right, bottom, top, near, far);

gluPerspective (fov, aspect, near, far);

glOrtho (left, right, bottom, top, near, far);

- Default = (-1.0, 1.0, -1.0, 1.0, -1.0, 1.0)

gluOrtho2D (left, right, bottom, top);

Modelview Transformations

glMatrixMode (GL_MODELVIEW);

glLoadIdentity ( );

gluLookAt (eye_x, eye_y, eye_z, at_x, at_y, at_z, up_x, up_y, up_z);

glTranslatef (dx, dy, dz);

glScalef (sx, sy, sz);

glRotatef (angle, axisx, axisy, axisz);

Writing Bitmapped Text:

glPixelStorei (GL_UNPACK_ALIGNMENT, 1);

glColor3f (red, green, blue);

glRasterPos2f (x, y); glutBitmapCharacter (font, character);

where font = GLUT_BITMAP_8_BY_13, GLUT_BITMAP_HELVETICA_10, etc.

Managing the Frame Buffer:

glutInit (&argc, argv);

glutInitDisplayMode (GLUT_RGB | mode);

glutInitWindowSize (width, height);

glutInitWindowPosition (x, y);

glutCreateWindow (label);

glClear (GL_COLOR_BUFFER_BIT);

glutSwapBuffers ( );

where mode = GLUT_SINGLE or GLUT_DOUBLE.

Registering Callbacks

glutDisplayFunc (callback);

glutReshapeFunc (callback);

glutDisplayFunc (callback);

glutMotionFunc (callback);

glutPassiveMotionFunc (callback);

glutMouseFunc (callback);

```
glutKeyboardFunc  (callback);

id = glutCreateMenu (callback);

glutMainLoop ( );
```

Display Lists

```
glNewList (number, GL_COMPILE);

glEndList ( );

glCallList (number);

glDeleteLists (number, 1);
```

Managing Menus

```
id = glutCreateMenu (callback);

glutDestroyMenu (id);

glutAddMenuEntry (label, number);

glutAttachMenu (button);

glutDetachMenu (button);
```

where button = GLUT_RIGHT_BUTTON or GLUT_LEFT_BUTTON.

3.4 Dataflow Diagram

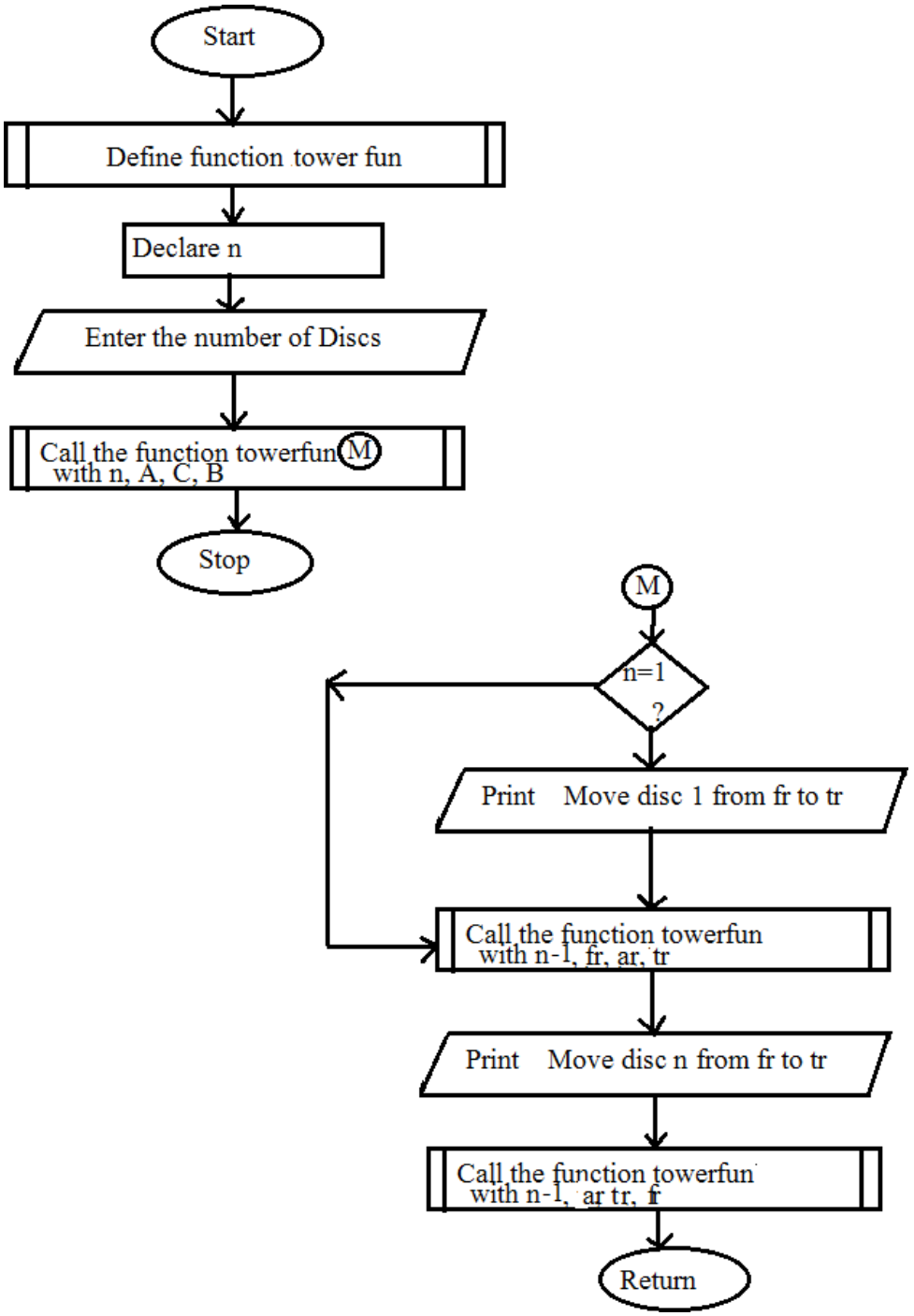


Fig-3.4

CHAPTER-4
IMPLEMENTATION

4.Implementation:

Complete Source Code of the Package:

```
#include<GL/glut.h>

#include<stdio.h>

#include<math.h>

#include<stdlib.h>

#include<string.h>

#include<unistd.h>

#define LIGHT_ON 0

#define LIGHT_OFF 1

int pos[16] = {10,15,20,25,30,35,40,45,50,55,60,65,70,75,80,85}; int peg[3] = {50,150,250};

int moves[10000][3]; int max_moves;

int POLES[3][10]; int top[3]={-1,-1,-1}; int NUM_DISKS=3;

int cnt,counter,speed=20; int line1=90,line2=85; float ycoordinate;

int lightflag=1,animationFlag=1,randomColorFlag=0;



void push(int p,int disk)

{

POLES[p][++top[p]] = disk;

}
```

```
void pop(int p)
{
top[p]--;
}
void tower(int n,int src,int temp,int dst)
{
if(n>0)
{
tower(n-1,src,dst,temp); moves[cnt][0] = n; moves[cnt][1] = src; moves[cnt][2] = dst; cnt++;
tower(n-1,temp,src,dst);
}
}
void drawPegs()
{
int i;
glColor3f(0.5,0.0,0.1); for(i=0;i<3;i++)
{
glPushMatrix();
glTranslatef(peg[i],5,0);
glRotatef(-90,1,0,0);
glutSolidCone(2,70,20,20);
glutSolidTorus(2,45, 20, 20);
glPopMatrix();
```

```
}

}

void drawSolved()

{

}

void display()

{

glColor3f(1,1,0);

glRasterPos3f(-60,87,0);

printString("Solved !!");

glColor3f(0.6,0.3,0.5);

glBegin(GL_POLYGON);

glVertex3f(-75,93,-5);

glVertex3f(-75,83,-5);

glVertex3f(10,83,-5);

glVertex3f(10,93,-5);

glEnd();

glColor3f(1,0,0);

glRasterPos3f(peg[0],70,0);
glutBitmapCharacter(GLUT_BITMAP_TIMES_ROMAN_24,'A');
glRasterPos3f(peg[1],70,0);
glutBitmapCharacter(GLUT_BITMAP_TIMES_ROMAN_24,'B');
glRasterPos3f(peg[2],70,0);
glutBitmapCharacter(GLUT_BITMAP_TIMES_ROMAN_24,'C');

int i,j,k; if(randomColorFlag)
```

```
glClearColor((rand()%100)/100.0,(rand()%100)/100.0,(rand()%100)/100.0,

glClear(GL_COLOR_BUFFER_BIT|GL_DEPTH_BUFFER_BIT);

if(lightflag)glEnable(GL_LIGHTING); glPushMatrix(); gluLookAt(0,ycoordinate,0,0,0,-
1,0,1,0); drawPegs();

for(i=0;i<3;i++)

{

k=0;

for(j=0;j<=top[i];j++)

{

glPushMatrix(); glTranslatef(peg[i],pos[k++],0); glRotatef(90,1,0,0);
glColor3f(0.1*POLES[i][j],0.2*POLES[i][j],0);

glutSolidTorus(2.0, 4*POLES[i][j], 20, 20); glPopMatrix();

}

}

glPopMatrix(); glDisable(GL_LIGHTING); if(counter==max_moves)

drawSolved(); else

drawText(); if(lightflag)glEnable(GL_LIGHTING); glutSwapBuffers();

}

void animate(int n,int src,int dest)

{

int i; if(speed<=0)speed=1;

for(i=pos[top[src]+1];i<90;i+=speed)

{

glPushMatrix(); glTranslatef(peg[src],i,0); glRotatef(85,1,0,0); glColor3f(0.1*n,0.2*n,0);
glutSolidTorus(2.0, 4*n, 20, 20); glPopMatrix(); glutSwapBuffers();
```

```
display();
}
if(peg[src]<peg[dest]) for(i=peg[src];i<=peg[dest];i+=speed)
{
glPushMatrix(); glTranslatef(i,90,0); glRotatef(85,1,0,0); glColor3f(0.1*n,0.2*n,0);
glutSolidTorus(2.0, 4*n, 20, 20); glPopMatrix(); glutSwapBuffers();
display();
}
else
for(i=peg[src];i>=peg[dest];i-=speed)
{
glPushMatrix(); glTranslatef(i,90,0); glRotatef(85,1,0,0); glColor3f(0.1*n,0.2*n,0);
glutSolidTorus(2.0, 4*n, 20, 20); glPopMatrix(); glutSwapBuffers();
display();
}
}
```

```
void mouse(int btn,int mode,int x,int y)
{
if(btn == 4 && mode == GLUT_DOWN)
{
if(counter<max_moves)
{
pop(moves[counter][1]); if(animationFlag)
```

```
animate(moves[counter][0],moves[counter][1],moves[counter][2]);
push(moves[counter][2],moves[counter][0]);
counter++;
}
}
if(btn == 3 && mode == GLUT_DOWN)
{
if(counter>0)
{
counter--; pop(moves[counter][2]); if(animationFlag)

animate(moves[counter][0],moves[counter][2],moves[counter][1]);
push(moves[counter][1],moves[counter][0]);
}
}
}
void restart()
{
glutPostRedisplay();
int i;
memset(POLES,0,sizeof(POLES));
memset(moves,0,sizeof(POLES));
memset(top,-1,sizeof(top));
cnt=0,counter=0;
```

```
ycoordinate=0.1;
max_moves = pow(2,NUM_DISKS)-1; for(i=NUM_DISKS;i>0;i--)
{
 push(0,i);
}
tower(NUM_DISKS,0,1,2);
}
void processMenuNumDisks(int option)
{
NUM_DISKS=option; restart(); glutPostRedisplay();
}
void strokeString(float x,float y,float sx,float sy,char *string,int width)
{
char *c; glLineWidth(width); glPushMatrix(); glTranslatef(x,y,0); glScalef(sx,sy,0);
for (c=string; *c != '\0'; c++) { glutStrokeCharacter(GLUT_STROKE_ROMAN, *c);
}
glPopMatrix();
}
void keyboard(unsigned char c, int x, int y)
{
switch(c)
{
case 13:
restart(); init();
```

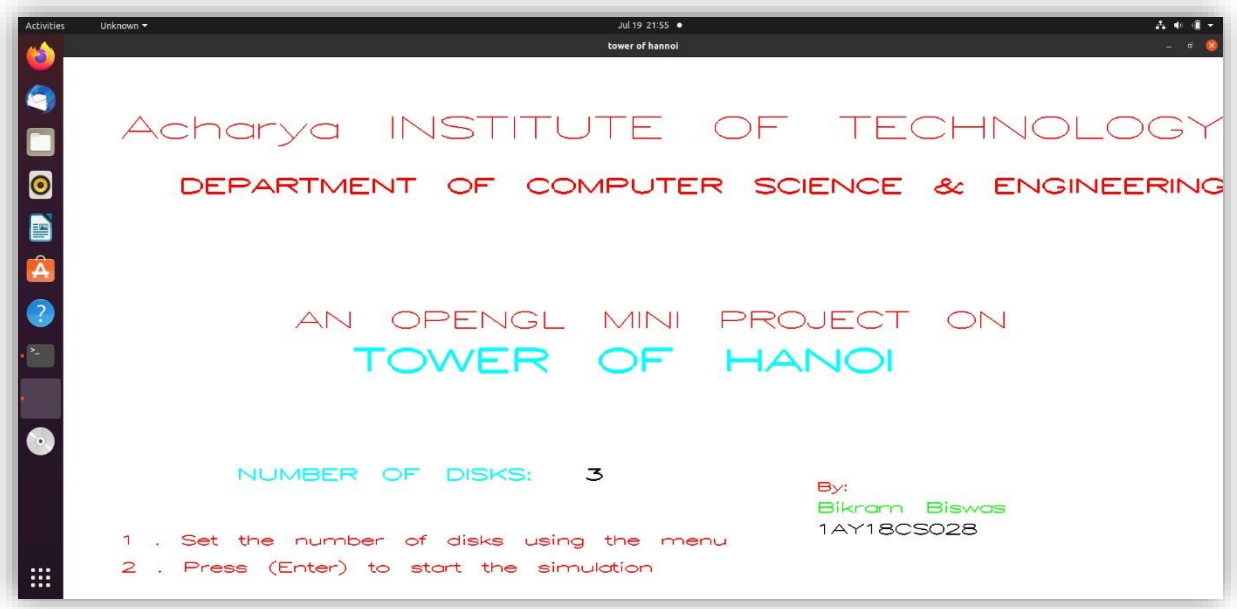
```
glutDisplayFunc(display); createGLUTMenus2();




break;

}


glutKeyboardFunc(keyboard2); glutMouseFunc(mouse);


glutPostRedisplay();

}

int main(int argc,char** argv)

{

glutInit(&argc,argv); glutInitDisplayMode(GLUT_DOUBLE|GLUT_RGB);
glutInitWindowSize(1024,720); glutInitWindowPosition(100,100);
glutCreateWindow("tower of hannoi");

initfirst(); glutDisplayFunc(first); createGLUTMenus1(); glutKeyboardFunc(keyboard);
glutMainLoop();

return 0;

}
```

Chapter-5

Results

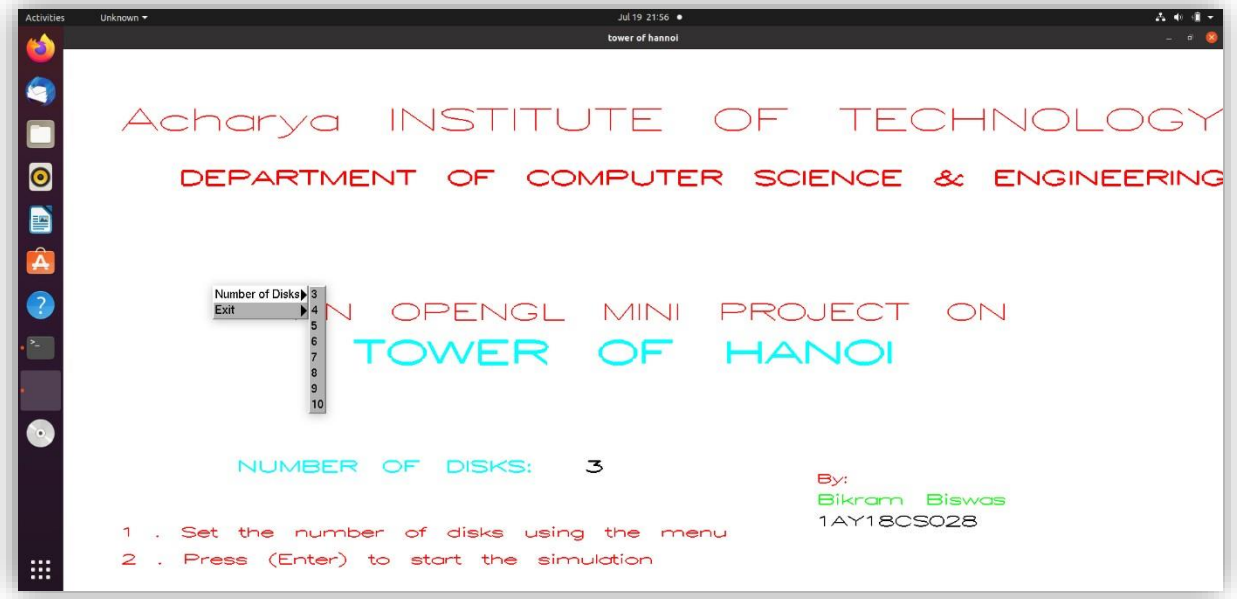
5. Results:

Figure 5.1



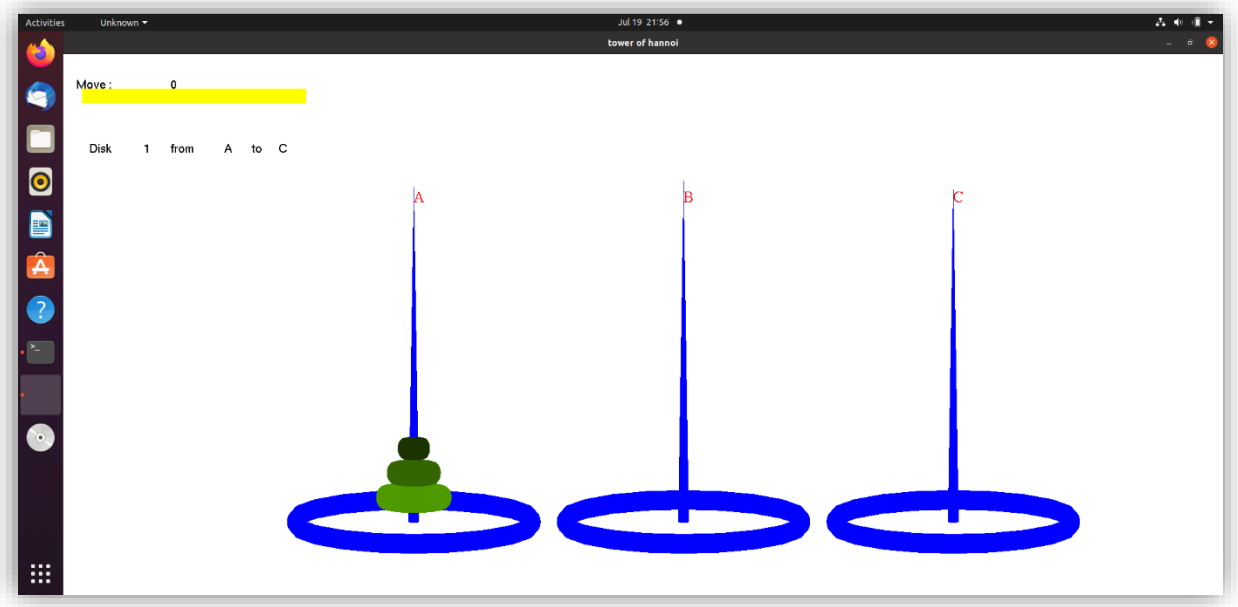
Front Page of Tower of Hanoi Visualization

Figure 5.2



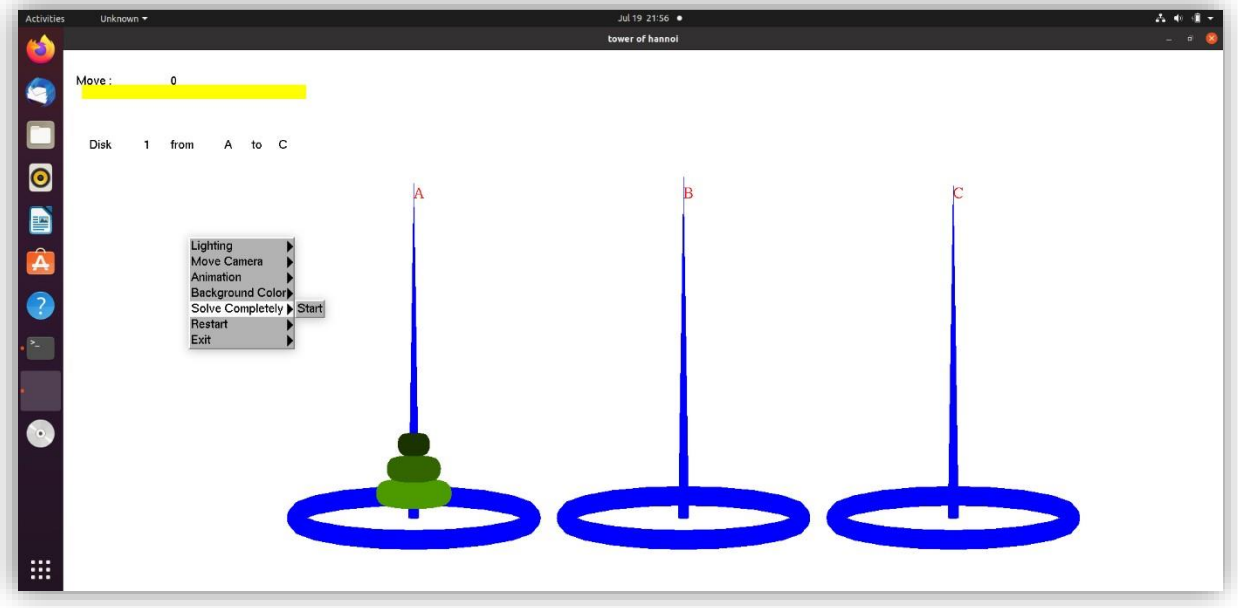
Front Page with Menu of Tower of Hanoi Visualization

Figure 5.3



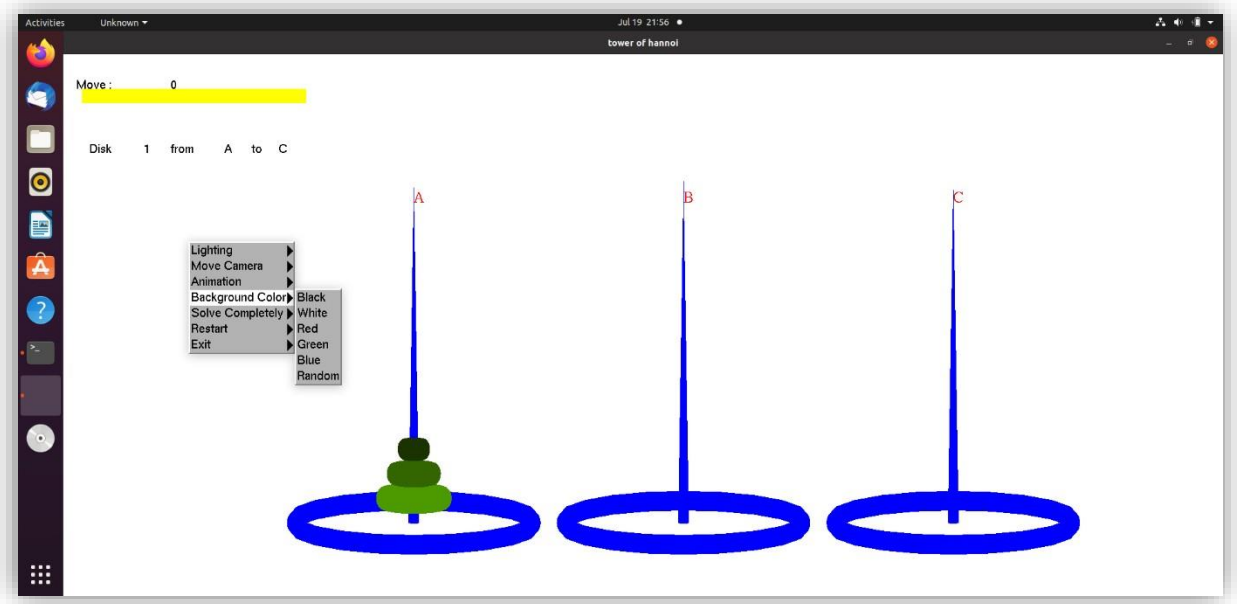
Initial Position of the Tower of Hanoi Visualization

Figure 5.4



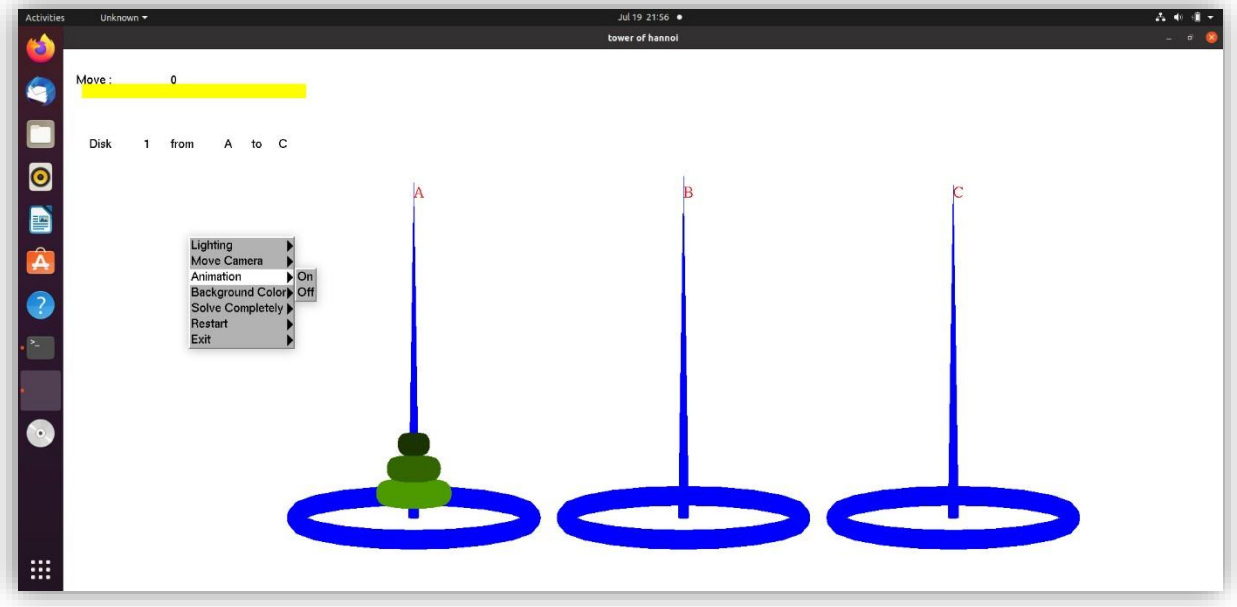
Initial Position of Tower of Hanoi Visualization with Menu

Figure 5.5



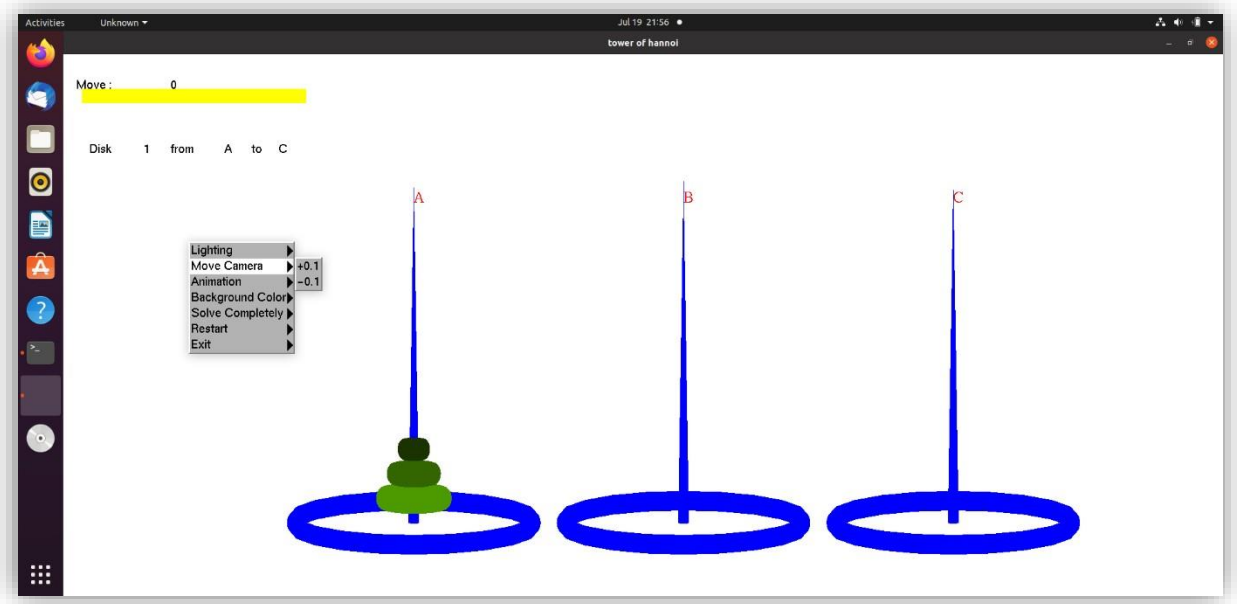
Background Color Changing Option for User

Figure 5.6



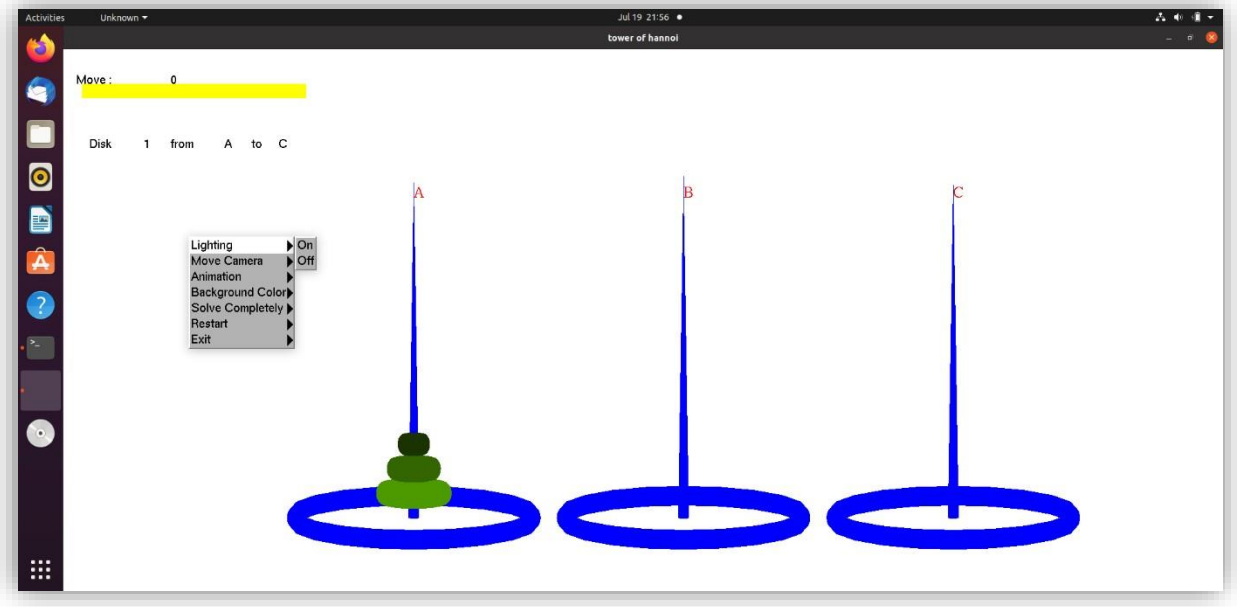
Animation Changing Menu for User

Figure 5.7



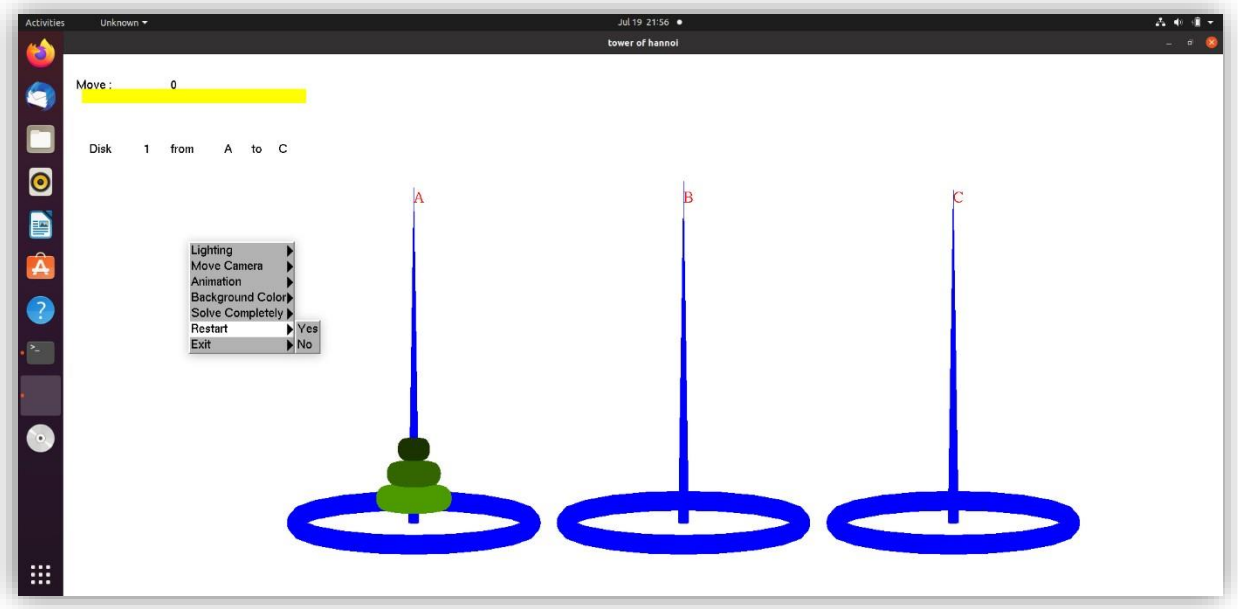
Move Camera Menu for User

Figure 5.8



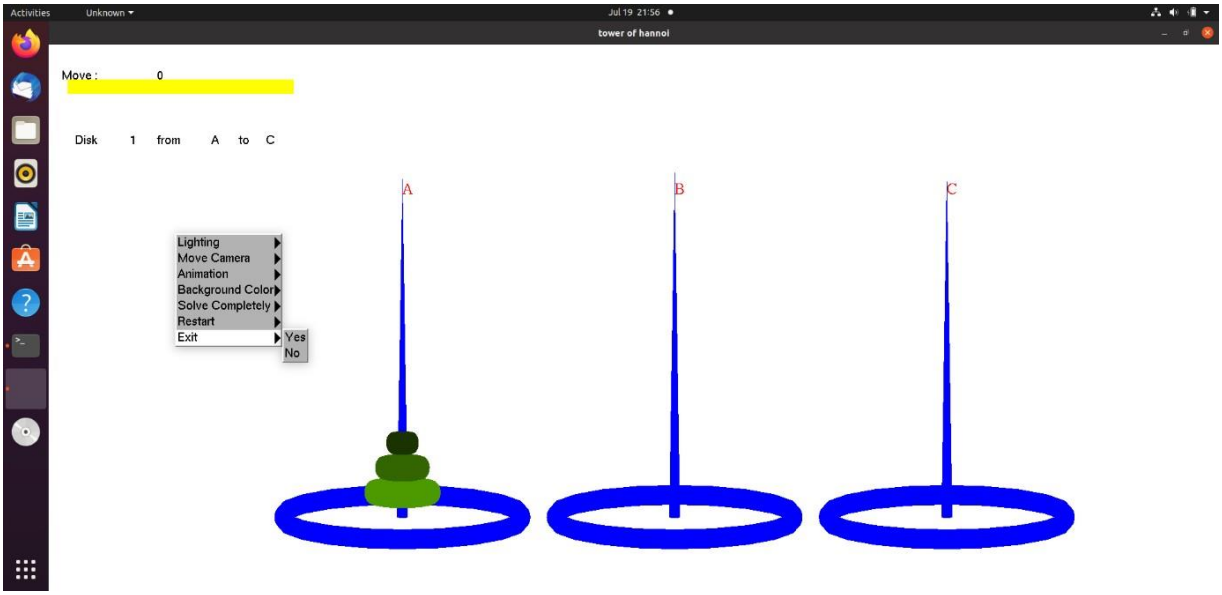
Lighting Menu for User

Figure 5.9



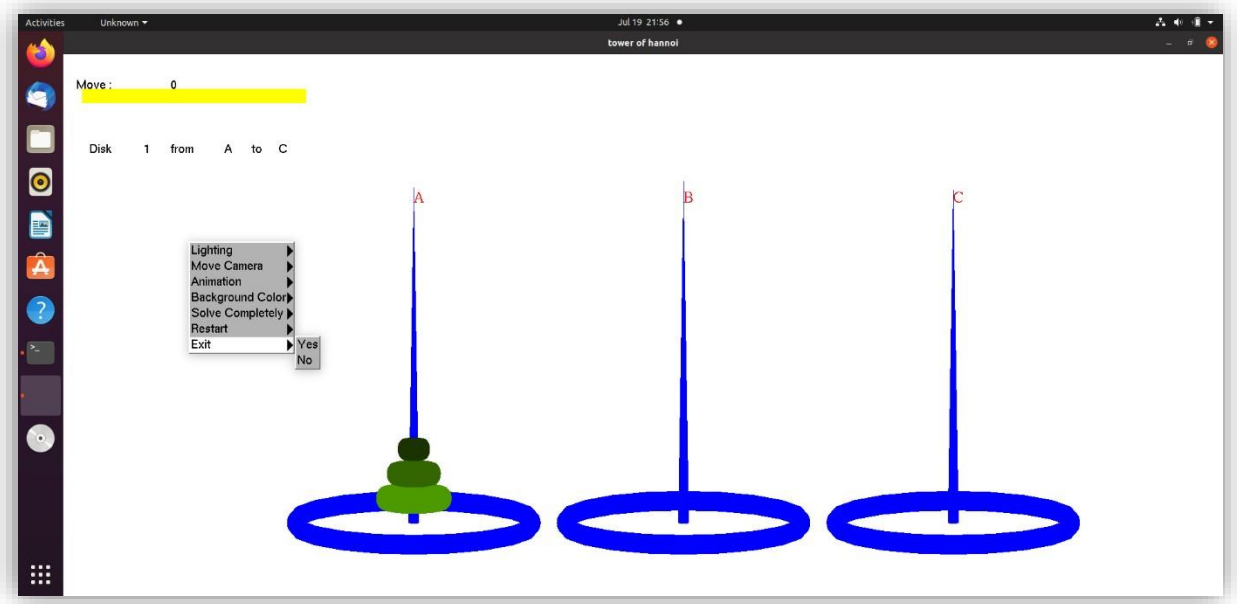
Restart Option for User

Figure 5.10



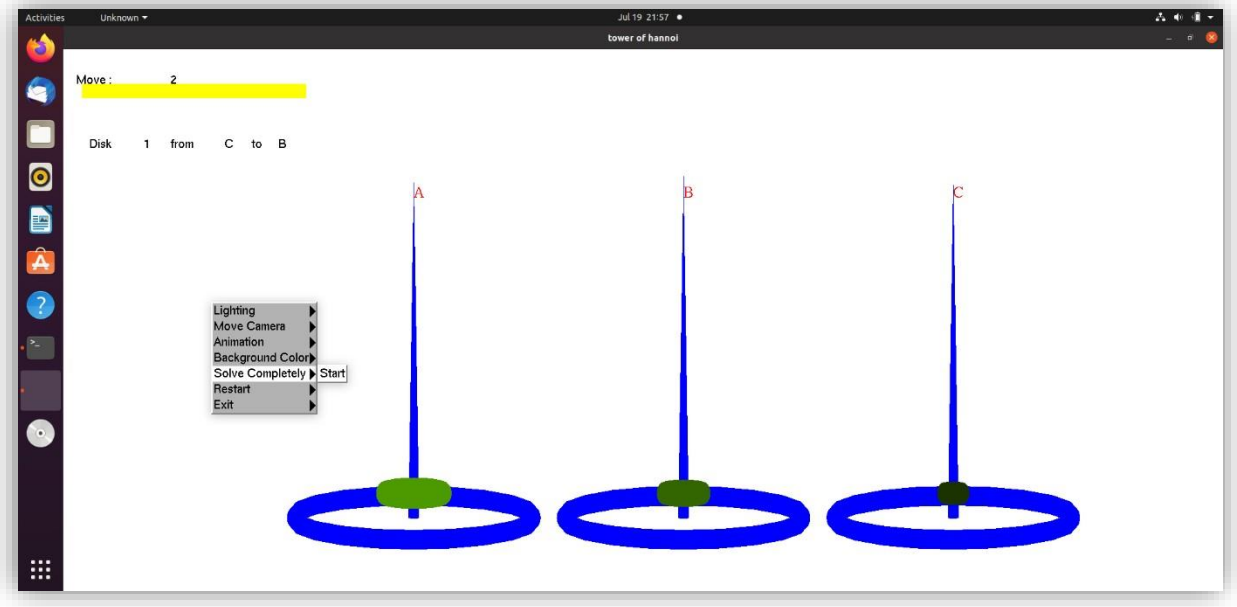
Exit Menu for User

Fig 5.11



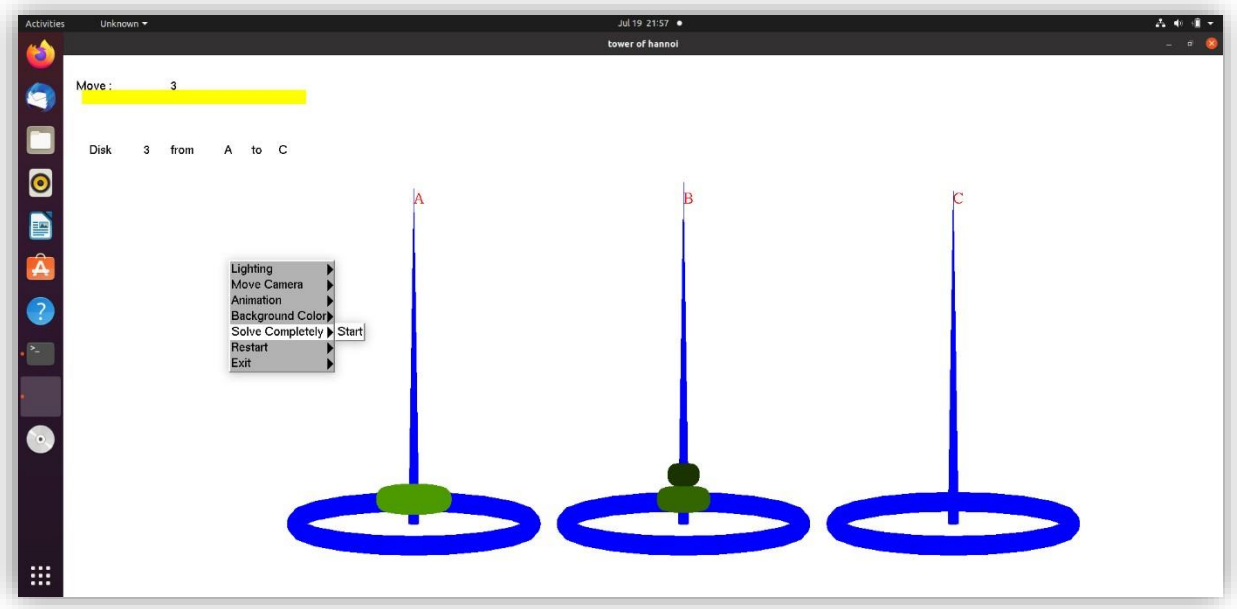
Solving Process

Fig 5.12



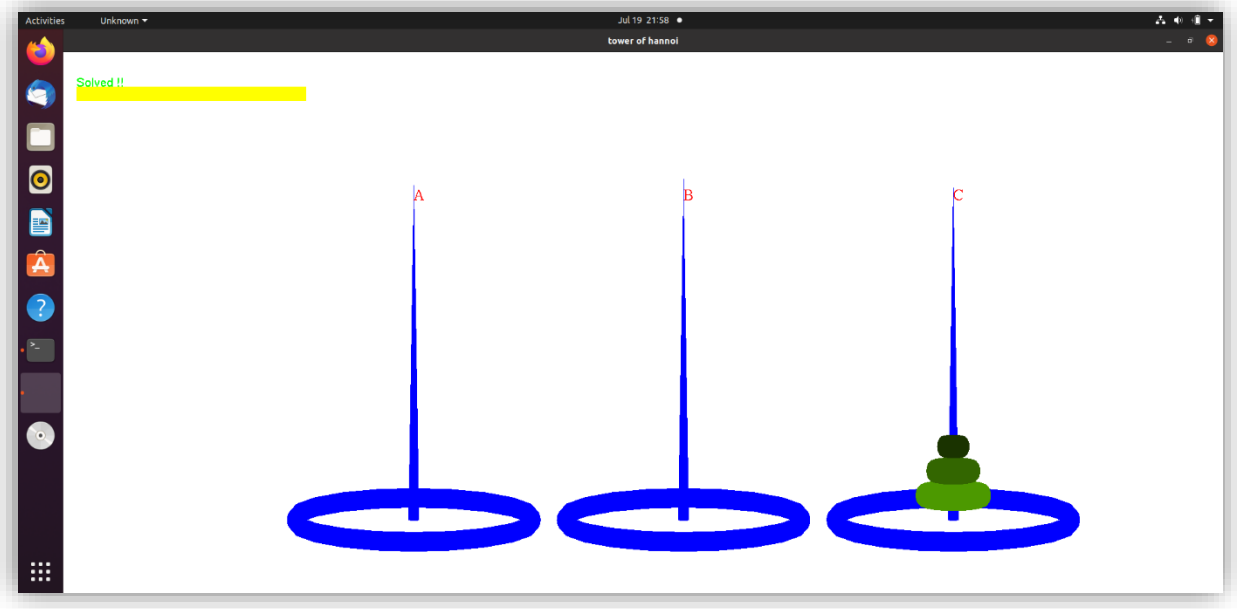
Solving Process

Fig 5.13



Solving Process

Fig 5.14



Completely Solved

CHAPTER-6

CONCLUSION & FUTURE WORK

Conclusion and Future Work

6.1 Conclusion

It was a wonderful learning experience for me working on this project. This project took me through various phases of project development and gave me real insight into the world of software engineering. The joy of working and the thrill involved while tackling the various problems and challenges gave me a feel of developers industry.

It was due to project that I came to know how professional software's are designed. I enjoyed each and every bit of work I had to put into this project.

6.2 Future Work

I just started learning OpenGL . I want to learn more on this topic as it is very interesting to learn .I want to develop different types of Airshows Games in future by the concepts of OpenGL. This is just the beginning ,I have just applied some of the things which I learnt now.It will be great to work in this domain.

CHAPTER-7

REFERENCES

REFERENCES

[1] Donald Hearn & Pauline Baker: Computer Graphics with OpenGL Version,3rd / 4th Edition, Pearson Education,2011

[2] Edward Angel: Interactive Computer Graphics- A Top Down approach with OpenGL, 5 th edition. Pearson Education, 2008

[3] James D Foley, Andries Van Dam, Steven K Feiner, John F Huges Computer graphics with OpenGL: pearson education

[4] Xiang, Plastock : Computer Graphics , sham's outline series, 2nd edition, TMG

[5] https://www.opengl.org/

[6] https://learnopengl.com/Getting-started/OpenGL

[7] https://en.wikipedia.org/wiki/Computer_graphics