PROJECT BASED LEARNING REPORT
ON
DEMONSTRATION OF COLOR COMBINATION AND USAGE OF OPENGL LIBRARY

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Declaration

I hereby declare that the Project-Based Learning (PBL) report titled **"Demonstration of Color Combination and Usage of the OpenGL Library"** is an original work completed by me/us as a part of the **Computer Graphics (CG)** course requirements.
This report has not been submitted to any other institution or university for the award of any degree, diploma, or academic credit. The work presented here is based on my/our understanding, research, and implementation using the OpenGL graphics library.
we have duly acknowledged all sources of information used in this report, including books, research papers, online resources, and reference materials.

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TABLE OF CONTENTS

1. Aim

The aim of this Project-Based Learning activity is to **demonstrate the concepts of color combination** using the **RGB color model** and to implement various color effects such as blending, shading, gradients, and multi-color rendering using the **OpenGL graphics library**. The objective is to understand how OpenGL handles color processing and how graphical primitives can be displayed with different color combinations in real-time.

2. THEORY

2.1 Objectives

1. The main objectives of this project are:
2. To understand the RGB color model used in computer graphics.
3. To demonstrate primary, secondary, and gradient color combinations.
4. To learn how the OpenGL library is used for drawing shapes and applying colors.
5. To implement smooth color transitions using vertex-based color interpolation.
6. To develop a simple OpenGL program that displays different color effects.

2.2 Methodology

1. The project was carried out using the following steps:
2. **Study of Color Theory:**
   Understanding RGB values, primary colors, and mixing techniques.
3. **Learning OpenGL Basics:**
   Learning functions such as glBegin(), glEnd(), glColor3f(), glVertex2f(), glClearColor(), etc.
4. **Designing the Output:**
   Planning shapes (triangles and rectangles) to demonstrate both solid colors and gradients.
5. **Coding in OpenGL:**
   Writing a C/OpenGL program to draw shapes while assigning different colors to each vertex.
6. **Testing and Improvement:**
   Running the code, observing output, adjusting color values, and verifying gradient effects.

7. **Documentation:**
   Preparing a structured PBL report based on observations and results.

2.3 Mathematical Background

RGB Color Values

1. OpenGL uses the **RGB color model**, where each color is represented as:

$$(R, G, B)$$

Each component ranges from **0.0 to 1.0**.

Examples:

- Red = (1, 0, 0)
- Green = (0, 1, 0)
- Blue = (0, 0, 1)
- Yellow = (1, 1, 0)

Color Interpolation (Gradient Effect)

When different vertices of a shape have different colors, OpenGL blends them using **linear interpolation**:

$$C(t) = (1 - t)C_1 + tC_2, 0 \leq t \leq 1$$

This creates smooth color transitions between vertices.

Coordinate System in OpenGL

OpenGL uses a 2D coordinate system (after gluOrtho2D) where:

$$x \in [-1,1], y \in [-1,1]$$

Vertices like (-0.5, 0.3) represent exact positions on the screen.

Basic Matrix Transformations (Conceptual)

OpenGL internally uses matrices for operations like translation, scaling, and rotation, although this project mainly focuses on color demonstration.

2.4 Applications of Color and OpenGL

- Game development
- UI design
- Data visualization
- Animation
- Virtual reality
- Lighting and shading
- Simulation modeling
- This project focuses on 2D rendering but the concepts apply to 3D as well.

2.5 OpenGL Architecture

OpenGL follows a pipeline-based architecture that processes graphical data step by step. The major stages in the OpenGL pipeline are:

Vertex Processing

Each vertex is transformed using coordinate transformations. Colors assigned to vertices are also passed to the next stage.

Primitive Assembly

Vertices are grouped into shapes such as triangles, quads, and polygons.

Rasterization

Converts shapes into pixels. Each pixel is assigned a color, depth, and other properties.

Fragment Processing

Colors are modified, blended, or interpolated to form smooth gradients or shading.

Output to Framebuffer

The final colored image appears on the screen.

This architecture helps OpenGL render complex scenes quickly and efficiently.

2.6 Shading in OpenGL

- OpenGL provides two main shading models:

2.6.1 Flat Shading

- The color of the entire polygon is determined by a single vertex. There is no smooth transition between colors.

2.6.2 Smooth Shading (Gouraud Shading)

- Colors at vertices are interpolated across the polygon. This produces soft, blended color transitions, which we use in this project.
- OpenGL performs smooth shading automatically when different colors are assigned to each vertex.

2.7 Importance of Color in Computer Graphics

Color plays a key role in:

- **User Interface design**

  Buttons, themes, icons depend on color clarity.

- **Animation & Visual Effects**

  Gradients and shading give depth and realism.

- **Games & Simulation**

  Colors help differentiate characters, environments, and lighting.

- **Data Visualization**

  Color-coded charts make data easier to understand.

- **Scene Realism**

  Correct color representation enhances immersion.

OpenGL gives developers full control over color intensity and blending.

2.8 Working of glColor3f()

- The function **glColor3f(R, G, B)** assigns color to the next vertices:
- R → Red intensity
- G → Green intensity
- B → Blue intensity
- Example:
  glColor3f(1.0, 0.5, 0.0);

This produces an **orange** color (Red + partial Green).

- OpenGL stores this color and applies it to all subsequent vertices until a new color is specified.

2.9 Color Gradients in OpenGL

- Gradients are formed when:
- Each vertex of a polygon has a different color
- OpenGL automatically blends the colors between vertices
- This blending occurs in fragment processing, using a mathematical formula:

$$Color_{final} = (1 - t)C_1 + tC_2$$

- Thus, gradients are smooth and visually appealing.

2.10 2D vs 3D Color Rendering

In 2D:

- Colors are applied directly to shapes
- There is no depth or lighting calculation
- Output depends only on vertex color

In 3D:

- Colors depend on:

  ✓ lighting

  ✓ material

✓ shading model

✓ camera angle

- Since our project is 2D, color demonstration is simpler and clearer.

3. PROGRAM CODE

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

void display() {
    glClear(GL_COLOR_BUFFER_BIT);

    // Primary Colors - Red, Green, Blue Triangles
    glBegin(GL_TRIANGLES);

    // Red Triangle
    glColor3f(1.0, 0.0, 0.0);
    glVertex2f(-0.8, 0.2);
    glVertex2f(-0.4, 0.2);
    glVertex2f(-0.6, 0.6);

    // Green Triangle
    glColor3f(0.0, 1.0, 0.0);
    glVertex2f(-0.2, 0.2);
    glVertex2f(0.2, 0.2);
    glVertex2f(0.0, 0.6);

    // Blue Triangle
    glColor3f(0.0, 0.0, 1.0);
    glVertex2f(0.4, 0.2);
    glVertex2f(0.8, 0.2);
    glVertex2f(0.6, 0.6);

    glEnd();

    // Gradient Demonstration Rectangle
    glBegin(GL_QUADS);

    glColor3f(1.0, 0.0, 0.0);  // Red
    glVertex2f(-0.5, -0.2);

    glColor3f(0.0, 1.0, 0.0);  // Green
    glVertex2f(0.5, -0.2);

    glColor3f(0.0, 0.0, 1.0);  // Blue
    glVertex2f(0.5, -0.8);

    glColor3f(1.0, 1.0, 0.0);  // Yellow
    glVertex2f(-0.5, -0.8);

    glEnd();

    glFlush();
}

void init() {
    glClearColor(1.0, 1.0, 1.0, 1.0);
    glMatrixMode(GL_PROJECTION);
    gluOrtho2D(-1, 1, -1, 1);
}

int main(int argc, char** argv) {
    glutInit(&argc, argv);
    glutCreateWindow("Color Combination using OpenGL");
    glutInitWindowSize(800, 600);

    init();
    glutDisplayFunc(display);
    glutMainLoop();

    return 0;
}
```

4. RESULT

The OpenGL program runs successfully and produces the following visual output:

4.1 Primary Color Triangles

- A **red triangle**, **green triangle**, and **blue triangle** are drawn side-by-side.
- These help visualize how primary colors look on screen.

4.2 Gradient Rectangle

- A multi-colored rectangle is drawn with different colors on each vertex.
- OpenGL automatically blends these colors, creating a smooth gradient.
- The gradient demonstrates:
    - **Color interpolation**
    - **Smooth shading**
    - **Color blending**

4.3 Observations

- Colors with higher intensity values appear brighter.
- Smooth shading (GL_SMOOTH) creates natural gradients.
- Changing RGB values reflects instantly in the displayed output.
- The scene renders with no flicker, showing the efficiency of OpenGL.

4.4 Learning Outcomes

Students learned:

- How RGB values determine color intensity.
- How OpenGL processes vertices and colors.
- How to draw shapes with multiple colors.
- How gradients work through interpolation.
- How OpenGL’s rendering pipeline handles shading.

5. CONCLUSION

The Project-Based Learning activity on **"Demonstration of Color Combination and Usage of the OpenGL Library"** successfully achieved all the intended objectives. Through this project, the RGB color model was clearly understood and implemented using OpenGL functions. By applying different RGB values to vertices, the project demonstrated how **primary, secondary, and gradient color combinations** can be rendered visually on the screen.

Using OpenGL, we learned how to draw 2D shapes such as triangles and rectangles, apply distinct colors to each vertex, and observe how OpenGL automatically performs **color interpolation** to produce smooth shading effects. The project also provided practical exposure to the OpenGL rendering pipeline, including vertex processing, rasterization, and fragment coloring.

Overall, the project enhanced our understanding of **color theory**, **graphics programming**, and **OpenGL functionalities**, while strengthening our ability to design and develop simple graphical applications. This foundational knowledge will be useful for future work in areas like 3D graphics, game development, simulations, and UI/UX design

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