МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ

«КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ імені ІГОРЯ СІКОРСЬКОГО»

ФАКУЛЬТЕТ ІНФОРМАТИКИ ТА ОБЧИСЛЮВАЛЬНОЇ ТЕХНІКИ

Кафедра інформатики та програмної інженерії

Звіт

З лабораторної роботи № 4 з дисципліни
«Програмування комп'ютерної графіки»

«Моделювання освітлення»

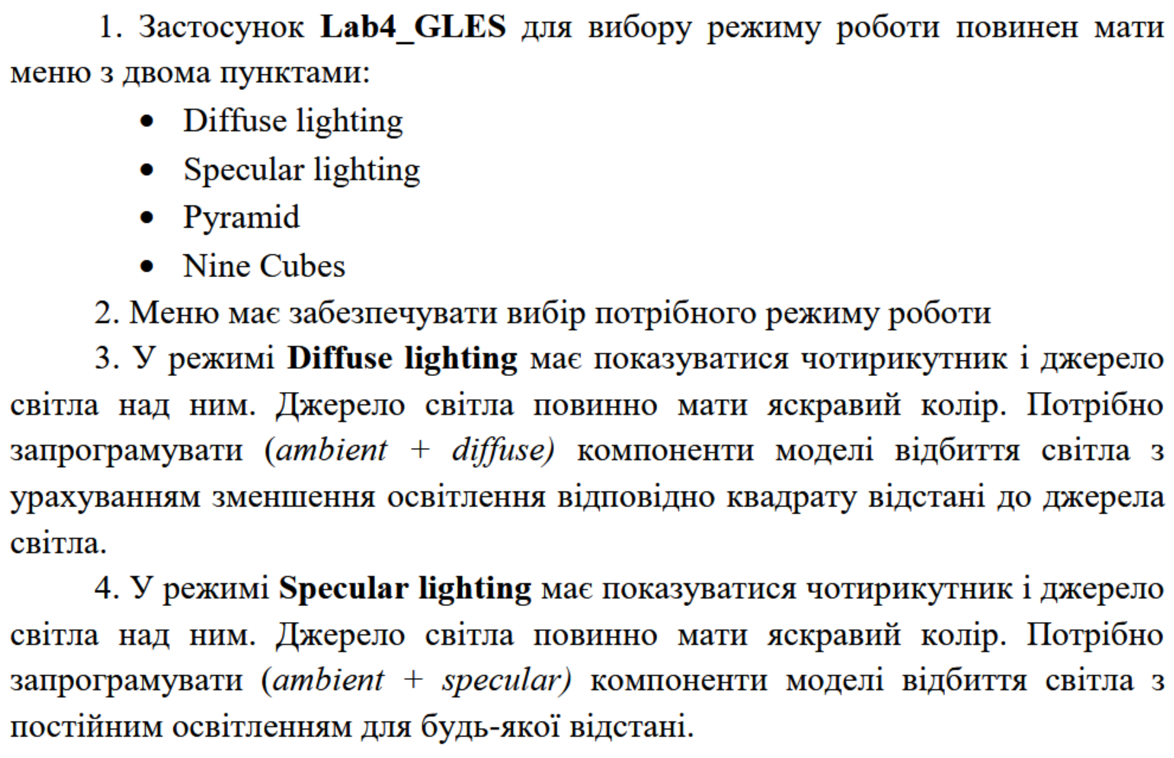
Виконав(ла)	*ІП-13 Бабіч Денис*	
	(шифр, прізвище, ім'я, по батькові)	
Перевірив(ла)	*Порєв В. М.*	
	(посада, прізвище, ім'я, по батькові)	

Київ 2025

ОСНОВНА ЧАСТИНА

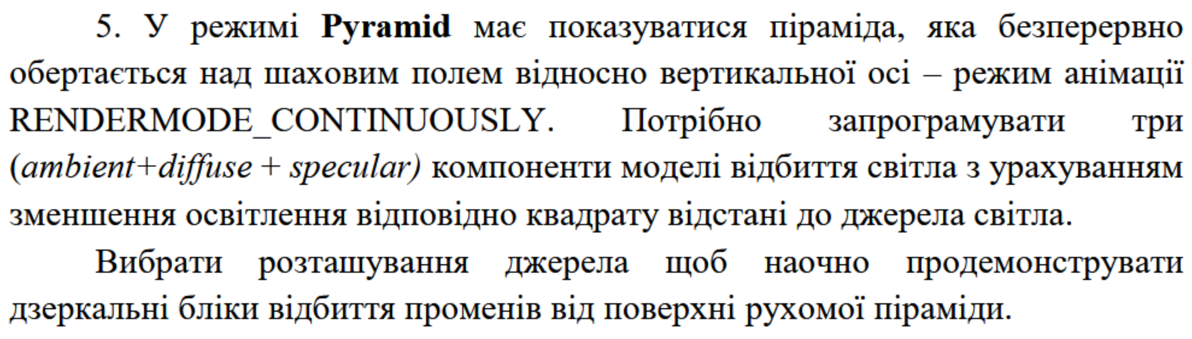
Мета роботи: Отримати навички програмування освітлення тривимірних об'єктів засобами графіки OpenGL ES.

Завдання:



1. Застосунок **Lab4_GLES** для вибору режиму роботи повинен мати меню з двома пунктами:
   - Diffuse lighting
   - Specular lighting
   - Pyramid
   - Nine Cubes
2. Меню має забезпечувати вибір потрібного режиму роботи
3. У режимі **Diffuse lighting** має показуватися чотирикутник і джерело світла над ним. Джерело світла повинно мати яскравий колір. Потрібно запрограмувати (*ambient + diffuse)* компоненти моделі відбиття світла з урахуванням зменшення освітлення відповідно квадрату відстані до джерела світла.
4. У режимі **Specular lighting** має показуватися чотирикутник і джерело світла над ним. Джерело світла повинно мати яскравий колір. Потрібно запрограмувати (*ambient + specular)* компоненти моделі відбиття світла з постійним освітленням для будь-якої відстані.

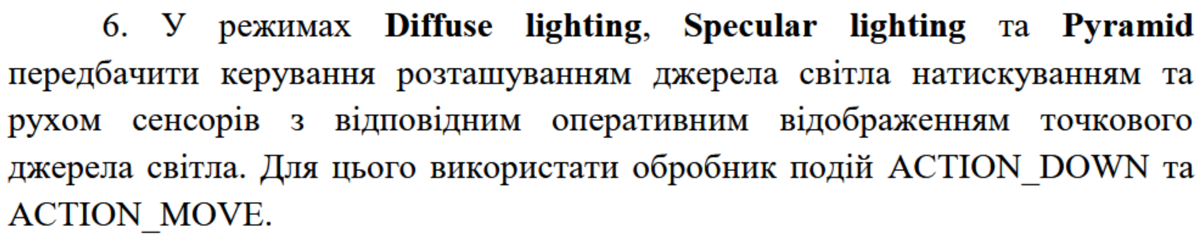
Рисунок 1.1 – Завдання лабораторної роботи



5. У режимі **Pyramid** має показуватися піраміда, яка безперервно обертається над шаховим полем відносно вертикальної осі – режим анімації RENDERMODE_CONTINUOUSLY. Потрібно запрограмувати три (*ambient+diffuse + specular)* компоненти моделі відбиття світла з урахуванням зменшення освітлення відповідно квадрату відстані до джерела світла.

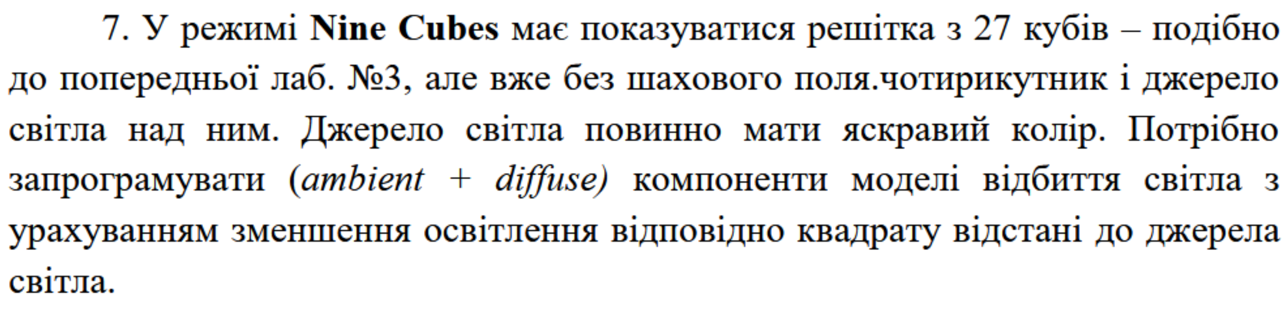
Вибрати розташування джерела щоб наочно продемонструвати дзеркальні бліки відбиття променів від поверхні рухомої піраміди.

Рисунок 1.2 – Завдання лабораторного практикуму



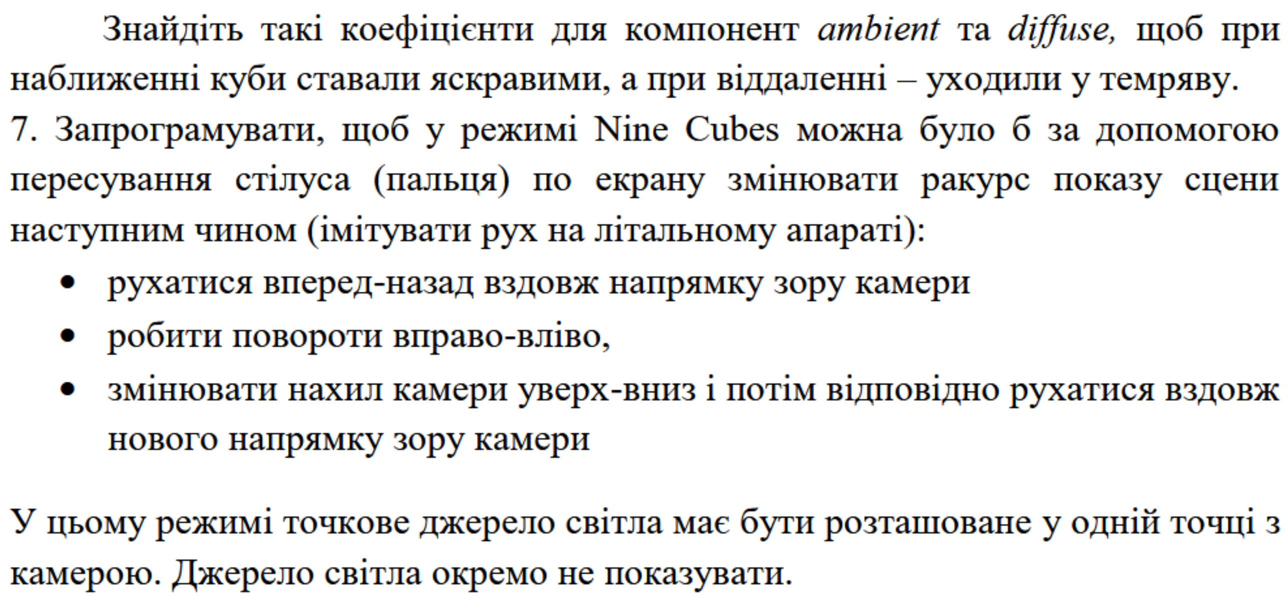
6. У режимах **Diffuse lighting**, **Specular lighting** та **Pyramid** передбачити керування розташуванням джерела світла натискуванням та рухом сенсорів з відповідним оперативним відображенням точкового джерела світла. Для цього використати обробник подій ACTION_DOWN та ACTION_MOVE.

Рисунок 1.3 – Завдання лабораторного практикуму



7. У режимі **Nine Cubes** має показуватися решітка з 27 кубів – подібно до попередньої лаб. №3, але вже без шахового поля.чотирикутник і джерело світла над ним. Джерело світла повинно мати яскравий колір. Потрібно запрограмувати (*ambient + diffuse)* компоненти моделі відбиття світла з урахуванням зменшення освітлення відповідно квадрату відстані до джерела світла.

Рисунок 1.4 – Завдання лабораторного практикуму



Знайдіть такі коефіцієнти для компонент *ambient* та *diffuse,* щоб при наближенні куби ставали яскравими, а при віддаленні – уходили у темряву.
7. Запрограмувати, щоб у режимі Nine Cubes можна було б за допомогою пересування стілуса (пальця) по екрану змінювати ракурс показу сцени наступним чином (імітувати рух на літальному апараті):

- рухатися вперед-назад вздовж напрямку зору камери
- робити повороти вправо-вліво,
- змінювати нахил камери уверх-вниз і потім відповідно рухатися вздовж нового напрямку зору камери

У цьому режимі точкове джерело світла має бути розташоване у одній точці з камерою. Джерело світла окремо не показувати.

Рисунок 1.5 – Завдання лабораторного практикуму

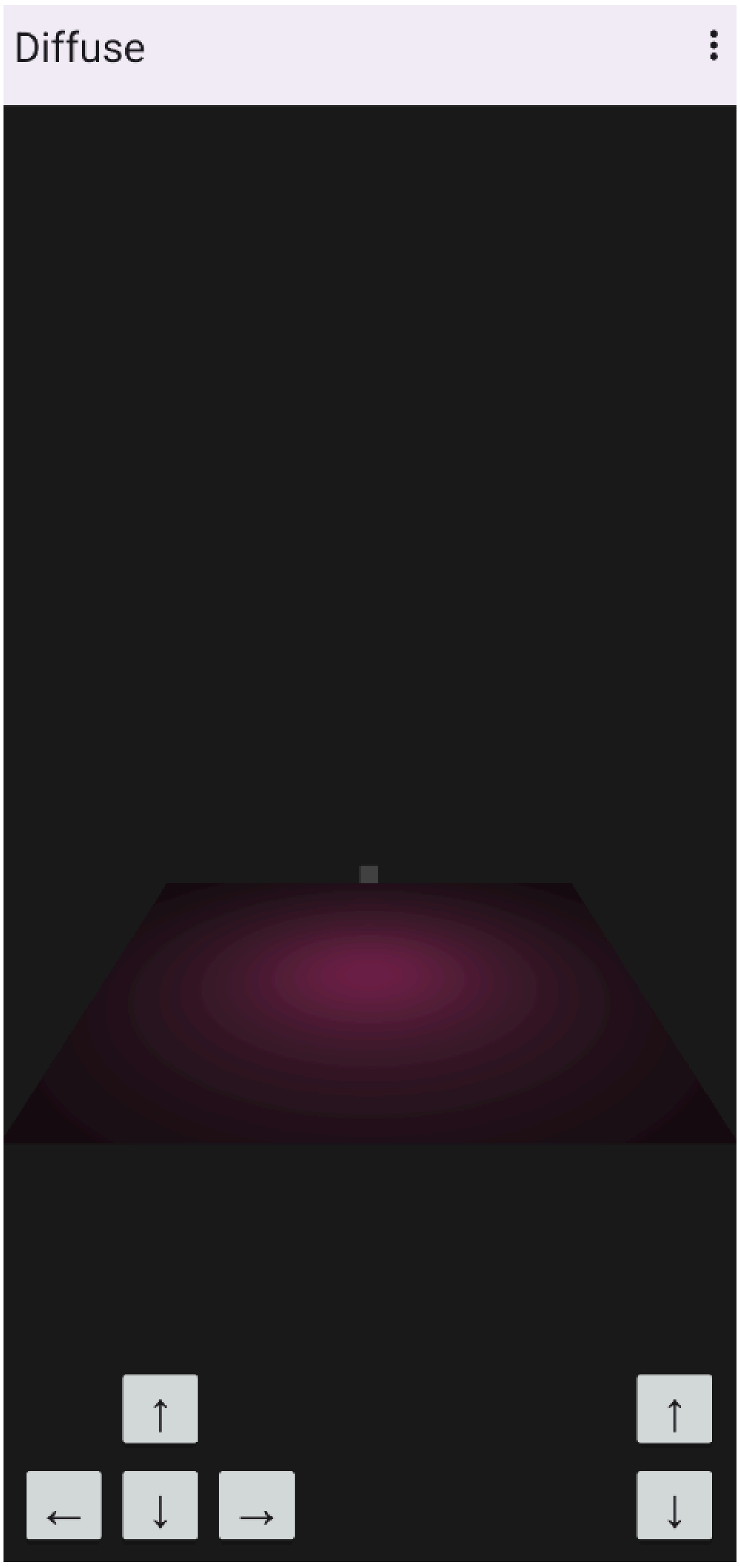


Рисунок 1.6 – Приклад сцени з дифузним світлом

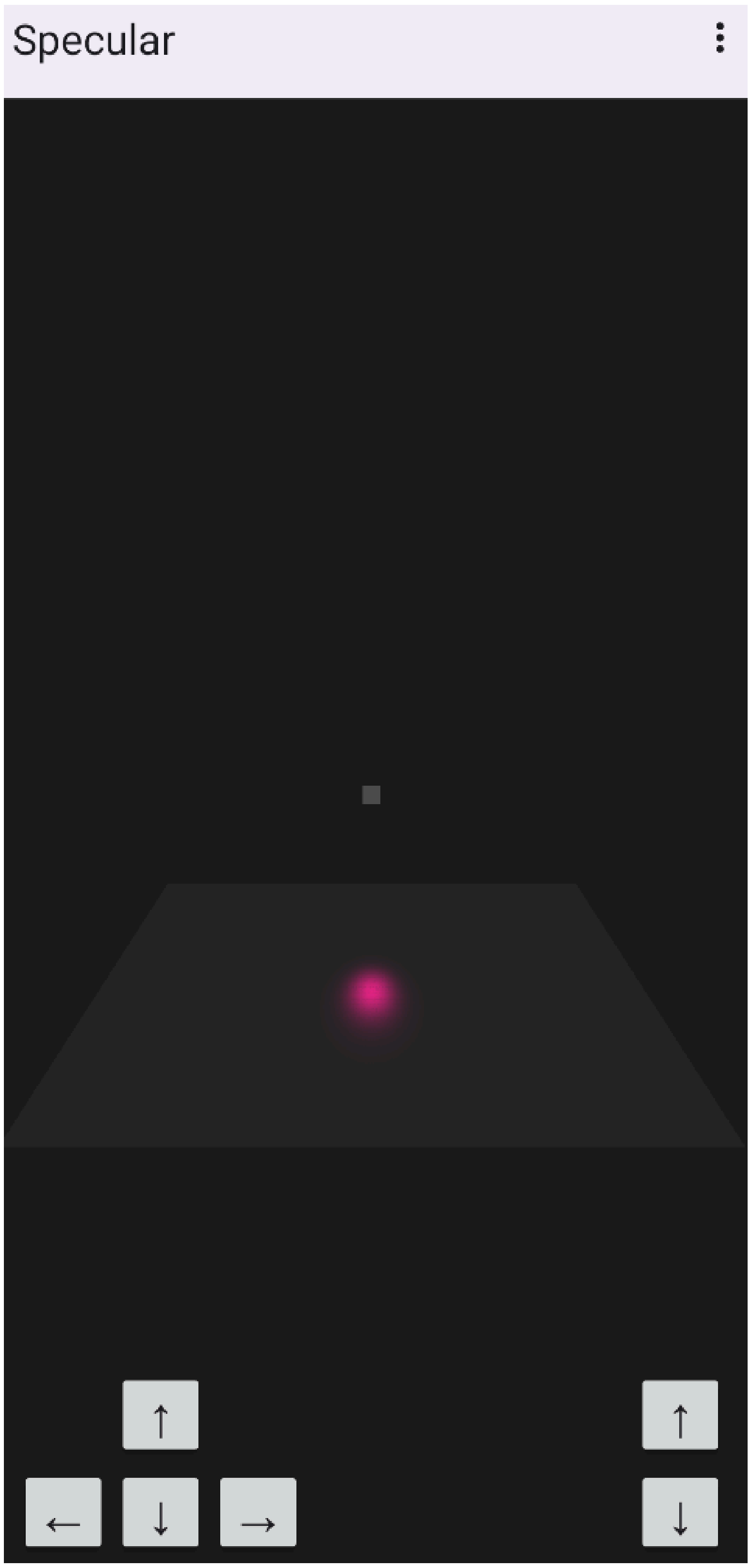


Рисунок 1.7 – Приклад сцени зі спекулярним світлом

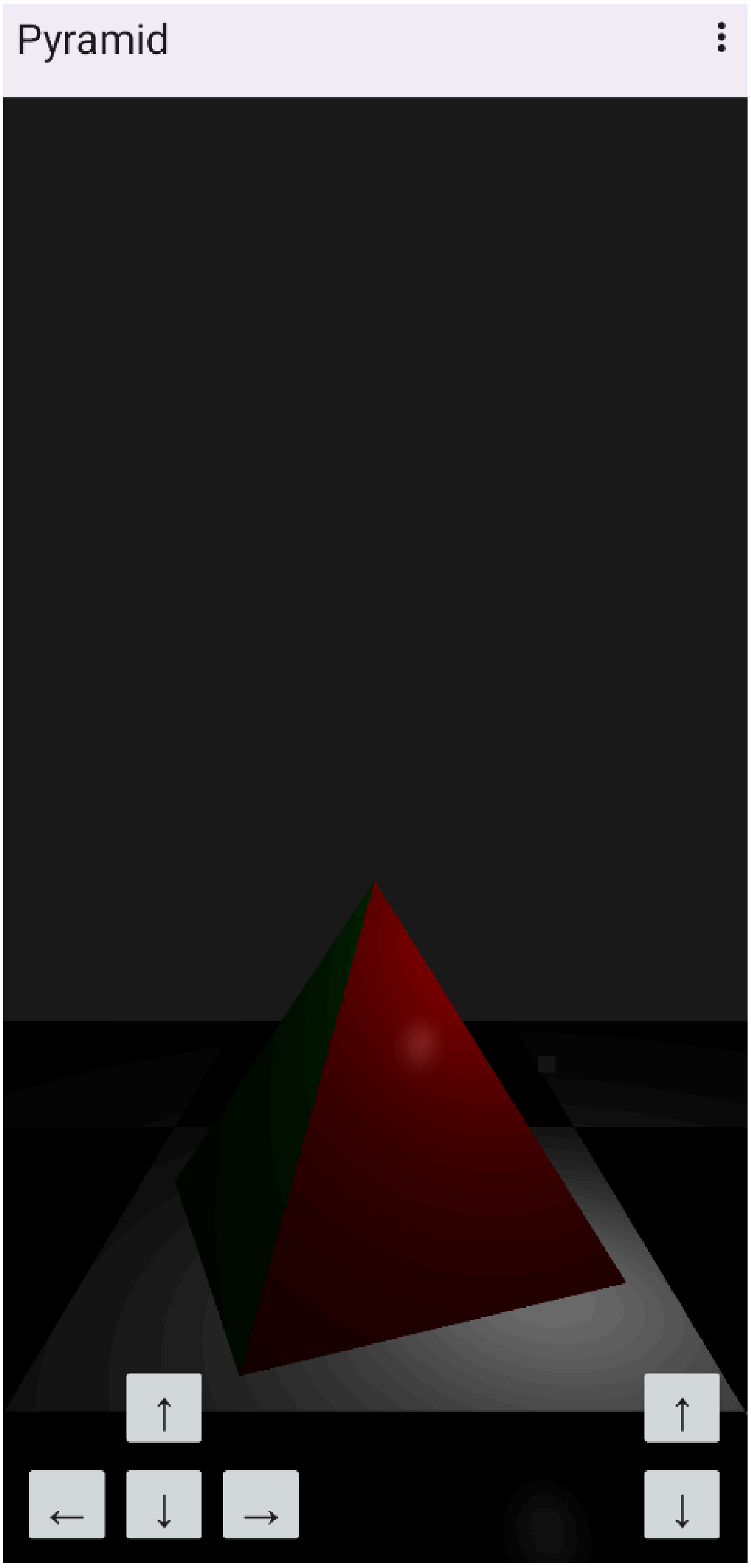


Рисунок 1.8 – Сцена з пірамідою та освітленням

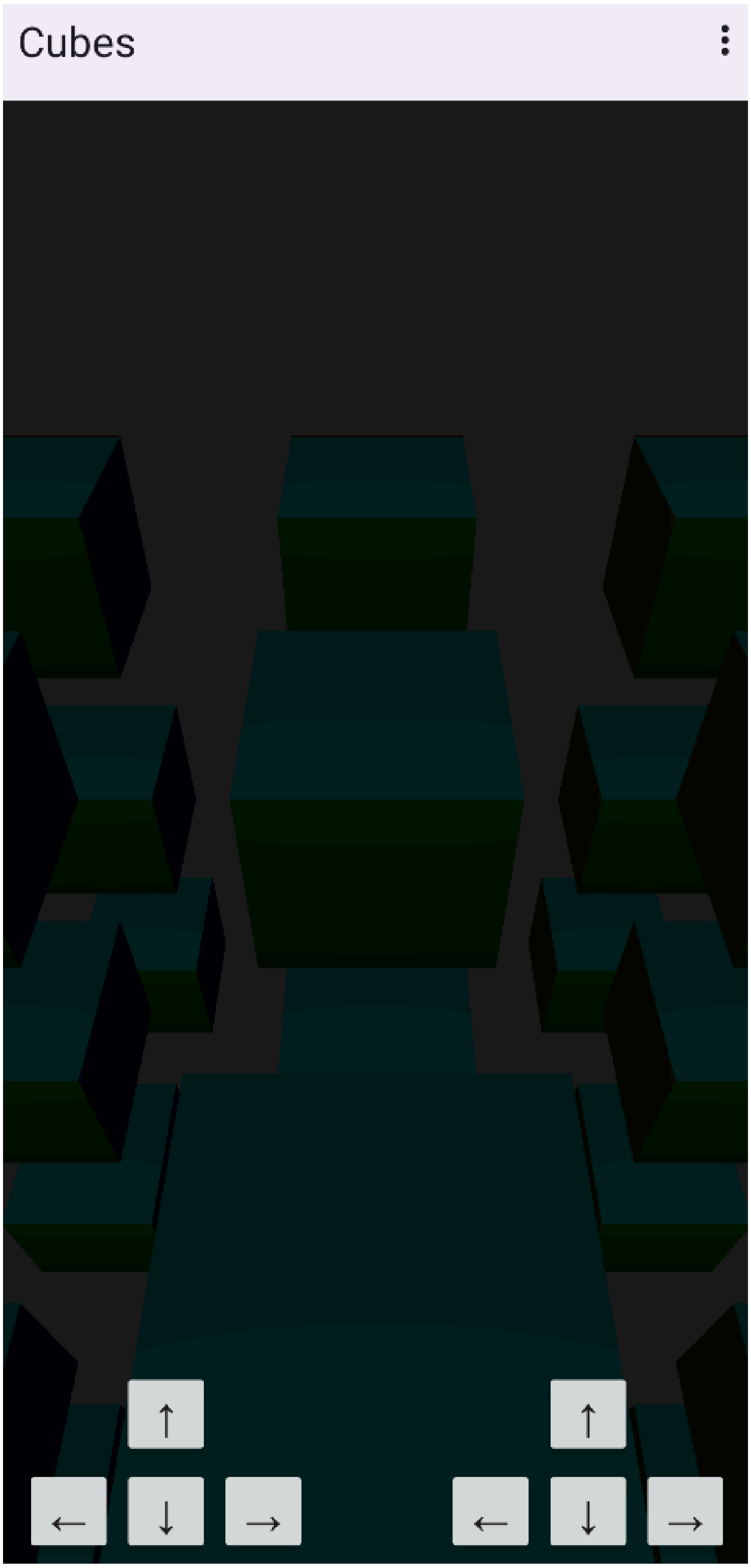


Рисунок 1.9 – Сцена з кубами

Component.java

```
package com.labwork.texturesexample.core.components.common;

import com.labwork.texturesexample.core.general.Entity;

public class Component {
    private static int nextId;

    private final int id;
    private final Entity entity;

    private boolean isActive;

    public Component(Entity entity) {
        this.entity = entity;
        this.id = ++Component.nextId;
    }

    public int getId() {
        return this.id;
    }

    public Entity getEntity() {
        return this.entity;
    }

    public boolean getIsActive() {
        return this.isActive;
    }
```

```
  public void setIsActive(boolean value) {
    this.isActive = value;
  }

  public void onStart() {}

  public void onUpdate(float deltaTime) {}

  public void onDestroy() {}
}
```

CameraComponent.java

```
package com.labwork.texturesexample.core.components.concrete;

import android.opengl.Matrix;
import com.labwork.texturesexample.core.general.Color;
import com.labwork.texturesexample.core.general.Entity;
import com.labwork.texturesexample.core.components.common.Component;

public class CameraComponent extends Component {

  private static final int MATRIX_DIMENSIONS_COUNT = 16;

  protected final float[] matrixView;
  protected final float[] matrixProjection;

  protected Color backgroundColor;
  protected float farClippingPlane;
  protected float nearClippingPlane;
  public CameraComponent(Entity entity, Color color, float nearClippingPlane, float farClippingPlane) {
    super(entity);
    this.backgroundColor = color;
    this.farClippingPlane = farClippingPlane;
    this.nearClippingPlane = nearClippingPlane;
    this.matrixView = new float[CameraComponent.MATRIX_DIMENSIONS_COUNT];
    this.matrixProjection = new float[CameraComponent.MATRIX_DIMENSIONS_COUNT];
    Matrix.setIdentityM(this.matrixView, 0);
    Matrix.setIdentityM(this.matrixProjection, 0);
  }

  public float[] getMatrixView() {
    return this.matrixView;
  }

  public float[] getMatrixProjection() {
    return this.matrixProjection;
  }

  public Color getBackgroundColor() {
    return this.backgroundColor;
  }

  public void setBackgroundColor(Color value) {
    this.backgroundColor = value;
  }

  public float getFarClippingPlane() {
     return this.farClippingPlane;
  }

  public void setFarClippingPlane(float value) {
     this.farClippingPlane = value;
  }

  public float getNearClippingPlane() {
     return this.nearClippingPlane;
  }

  public void setNearClippingPlane(float value) {
     this.nearClippingPlane = value;
  }
}
```

CameraPerspectiveComponent.java

```
package com.labwork.texturesexample.core.components.concrete;

import android.opengl.GLES32;
import android.opengl.Matrix;
import android.opengl.GLSurfaceView;
import com.labwork.texturesexample.runtime.Framework;
import com.labwork.texturesexample.core.general.Color;
import com.labwork.texturesexample.core.general.Entity;
import com.labwork.texturesexample.core.general.Vector3;
```

```
public final class CameraPerspectiveComponent extends CameraComponent {
  private final Vector3 target;
  private final GLSurfaceView viewport;

  private Vector3 up;
  private Vector3 position;
  private float aspectRatio;
  private float fieldOfView;
  private TransformComponent transform;

        public CameraPerspectiveComponent(Entity entity, Color color, float
nearClippingPlane, float farClippingPlane, float aspectRatio, float fieldOfView) {
    super(entity, color, nearClippingPlane, farClippingPlane);
    this.viewport = Framework.getInstance().getSurfaceView();
    this.fieldOfView = fieldOfView;
    this.aspectRatio = aspectRatio;
    this.up = new Vector3(0.0f, 1.0f, 0.0f);
    this.target = new Vector3(0.0f, 0.0f, 1.0f);
    this.position = new Vector3(0.0f, 0.0f, 0.0f);
  }

  public float getAspectRatio() {
    return this.aspectRatio;
  }

  public void setAspectRatio(float value) {
    this.aspectRatio = value;
  }
```

```
    public float getFieldOfView() {
        return this.fieldOfView;
    }

    public void setFieldOfView(float value) {
        this.fieldOfView = value;
    }

    @Override
    public void onStart() {
        this.transform = super.getEntity().getComponent(TransformComponent.class);
        this.up = this.transform.getUp();
        this.position = this.transform.getPosition();
    }

    @Override
    public void onUpdate(float deltaTime) {
        this.setAspectRatio((float)this.viewport.getWidth() / this.viewport.getHeight());
                        GLES32.glClearColor(super.backgroundColor.getRNormalized(),
super.backgroundColor.getGNormalized(),
super.backgroundColor.getBNormalized(),
super.backgroundColor.getANormalized());

                    Vector3.add(this.transform.getPosition(),   this.transform.getForward(),
this.target);
                      Matrix.perspectiveM(super.matrixProjection,   0,   this.fieldOfView,
this.aspectRatio, super.nearClippingPlane, super.farClippingPlane);
```

```
                    Matrix.setLookAtM(super.matrixView, 0, this.position.getX(), this.position.getY(), this.position.getZ(), this.target.getX(), this.target.getY(), this.target.getZ(), this.up.getX(), this.up.getY(), this.up.getZ());
  }
}
```

LightComponent.java

```
package com.labwork.illuminationexample.core.components.concrete;

import android.opengl.GLES32;
import com.labwork.illuminationexample.core.general.Color;
import com.labwork.illuminationexample.core.general.Entity;
import com.labwork.illuminationexample.core.general.Shader;
import com.labwork.illuminationexample.core.general.Vector3;
import com.labwork.illuminationexample.core.components.common.Component;

public final class LightComponent extends Component {
  private Color color;
  private Shader shader;
  private float intensity;
  private boolean isDistanceDependent;
  private TransformComponent transform;

    public LightComponent(Entity entity, Shader shader, Color color, float intensity, boolean isDistanceDependent) {
      super(entity);
      this.color = color;
      this.shader = shader;
      this.intensity = intensity;
      this.isDistanceDependent = isDistanceDependent;
  }

  public Color getColor() {
    return this.color;
  }

  public void setColor(Color value) {
    this.color = value;
  }

  public float getIntensity() {
    return this.intensity;
  }

  public void setIntensity(float value) {
    this.intensity = value;
  }

  @Override
  public void onStart() {
    this.transform = super.getEntity().getComponent(TransformComponent.class);
  }

  public void render() {

GLES32.glUniform1f(this.shader.getVariableHandler("uLightPropertyIntensity"),
this.intensity);
      GLES32.glUniform1i(this.shader.getVariableHandler("uIsDistanceDependent"),
this.isDistanceDependent ? 1 : 0);
```

```
GLES32.glUniform4f(this.shader.getVariableHandler("uLightPropertyColorRGBA"),
this.color.getRNormalized(),                          this.color.getGNormalized(),
this.color.getBNormalized(), this.color.getANormalized());

      Vector3 position = this.transform.getPosition();

GLES32.glUniform3f(this.shader.getVariableHandler("uTransformLightPositionGlob
al"), position.getX(), position.getY(), position.getZ());
  }
}
```

OpaqueRenderingComponent.java

```
package com.labwork.texturesexample.core.components.concrete;

import android.opengl.GLES32;
import com.labwork.texturesexample.core.general.Mesh;
import com.labwork.texturesexample.core.general.Color;
import com.labwork.texturesexample.core.general.Entity;
import com.labwork.texturesexample.core.general.Shader;
import com.labwork.texturesexample.core.general.Material;
import com.labwork.texturesexample.core.components.common.Component;

public final class OpaqueRenderingComponent extends Component {
  private static final int TEXTURE_UNIT_INDEX_OPAQUE = 0;

  private Mesh mesh;
  private Material material;
  private TransformComponent transform;
```

```
public OpaqueRenderingComponent(Entity entity, Mesh mesh, Material material) {
   super(entity);
   this.mesh = mesh;
   this.material = material;
}

public Mesh getMesh() {
   return this.mesh;
}

public void setMesh(Mesh value) {
   this.mesh = value;
}

public Material getMaterial() {
   return this.material;
}

public void setMaterial(Material value) {
   this.material = value;
}

@Override
public void onStart() {
   this.transform = super.getEntity().getComponent(TransformComponent.class);
}

public void render() {
   Shader shader = this.material.getShader();
```

```
        GLES32.glUniformMatrix4fv(shader.getVariableHandler("uMatrixModel"), 1, false, this.transform.getMatrixModel(), 0);

      Color color = this.material.getColor();
        GLES32.glUniform4f(shader.getVariableHandler("uMaterialColorRGBA"), color.getRNormalized(), color.getGNormalized(), color.getBNormalized(), color.getANormalized());

        GLES32.glBindTexture(GLES32.GL_TEXTURE_2D, this.material.getTextureAlbedo().getId());
        GLES32.glUniform1i(shader.getVariableHandler("uTextureAlbedo"), OpaqueRenderingComponent.TEXTURE_UNIT_INDEX_OPAQUE);

      this.mesh.draw();
  }
}
```

TransformComponent.java

```
package com.labwork.texturesexample.core.components.concrete;

import android.opengl.Matrix;
import com.labwork.texturesexample.core.general.Axis;
import com.labwork.texturesexample.core.general.Entity;
import com.labwork.texturesexample.core.general.Vector3;
import com.labwork.texturesexample.core.components.common.Component;

public final class TransformComponent extends Component {

  private static final int MATRIX_OUTPUT_DIMENSIONS_COUNT = 16;
  private static final int MATRIX_INTERMEDIATE_DIMENSIONS_COUNT = 4;

  private static final float[] MATRIX_VECTOR_UP = { 0.0f, 1.0f, 0.0f, 0.0f };
  private static final float[] MATRIX_VECTOR_RIGHT = { 1.0f, 0.0f, 0.0f, 0.0f };
  private static final float[] MATRIX_VECTOR_FORWARD = { 0.0f, 0.0f, 1.0f, 0.0f
};

  private final Vector3 scale;
  private final Vector3 rotation;
  private final Vector3 position;
  private final Vector3 vectorUp;
  private final Vector3 vectorRight;
  private final Vector3 vectorForward;

  private final float[] matrixModel;
  private final float[] matrixRotation;
  private final float[] matrixRotationOutput;

  public TransformComponent(Entity entity) {
    super(entity);
                                        this.matrixModel     =     new
float[TransformComponent.MATRIX_OUTPUT_DIMENSIONS_COUNT];
                                      this.matrixRotation     =     new
float[TransformComponent.MATRIX_OUTPUT_DIMENSIONS_COUNT];
                                  this.matrixRotationOutput     =     new
float[TransformComponent.MATRIX_INTERMEDIATE_DIMENSIONS_COUNT];
    this.scale = new Vector3(1.0f, 1.0f, 1.0f);
    this.rotation = new Vector3(0.0f, 0.0f, 0.0f);
    this.position = new Vector3(0.0f, 0.0f, 0.0f);
    this.vectorUp = new Vector3(0.0f, 0.0f, 0.0f);
    this.vectorRight = new Vector3(0.0f, 0.0f, 0.0f);
    this.vectorForward = new Vector3(0.0f, 0.0f, 0.0f);
}

public Vector3 getScale() {
    return this.scale;
}

public void setScale(Vector3 value) {
    this.scale.setX(value.getX());
    this.scale.setY(value.getY());
    this.scale.setZ(value.getZ());
}

public Vector3 getRotation() {
    return this.rotation;
}

public void setRotation(Vector3 value) {
    this.rotation.setX(value.getX());
    this.rotation.setY(value.getY());
    this.rotation.setZ(value.getZ());
}

public Vector3 getPosition() {
    return this.position;
}
```

```
  public void setPosition(Vector3 value) {
    this.position.setX(value.getX());
    this.position.setY(value.getY());
    this.position.setZ(value.getZ());
  }

  public float[] getMatrixModel() {
    Matrix.setIdentityM(this.matrixModel, 0);
            Matrix.scaleM(this.matrixModel,  0,  this.scale.getX(),  this.scale.getY(),
this.scale.getZ());
    Matrix.rotateM(this.matrixModel, 0, this.rotation.getZ(), 0.0f, 0.0f, 1.0f);
    Matrix.rotateM(this.matrixModel, 0, this.rotation.getY(), 0.0f, 1.0f, 0.0f);
    Matrix.rotateM(this.matrixModel, 0, this.rotation.getX(), 1.0f, 0.0f, 0.0f);
     Matrix.translateM(this.matrixModel, 0, this.position.getX(), this.position.getY(),
this.position.getZ());
    return this.matrixModel;
  }

  public Vector3 getUp() {
       Matrix.multiplyMV(this.matrixRotationOutput, 0, this.getRotationMatrix(), 0,
TransformComponent.MATRIX_VECTOR_UP, 0);
    this.vectorUp.setX(this.matrixRotationOutput[Axis.X.ordinal()]);
    this.vectorUp.setY(this.matrixRotationOutput[Axis.Y.ordinal()]);
    this.vectorUp.setZ(this.matrixRotationOutput[Axis.Z.ordinal()]);
    Vector3.normalize(this.vectorUp, this.vectorUp);
    return this.vectorUp;
  }

  public Vector3 getRight() {
        Matrix.multiplyMV(this.matrixRotationOutput, 0, this.getRotationMatrix(), 0,
TransformComponent.MATRIX_VECTOR_RIGHT, 0);
        this.vectorRight.setX(this.matrixRotationOutput[Axis.X.ordinal()]);
        this.vectorRight.setY(this.matrixRotationOutput[Axis.Y.ordinal()]);
        this.vectorRight.setZ(this.matrixRotationOutput[Axis.Z.ordinal()]);
        Vector3.normalize(this.vectorRight, this.vectorRight);
        return this.vectorRight;
    }

    public Vector3 getForward() {
        Matrix.multiplyMV(this.matrixRotationOutput, 0, this.getRotationMatrix(), 0,
TransformComponent.MATRIX_VECTOR_FORWARD, 0);
        this.vectorForward.setX(this.matrixRotationOutput[Axis.X.ordinal()]);
        this.vectorForward.setY(this.matrixRotationOutput[Axis.Y.ordinal()]);
        this.vectorForward.setZ(this.matrixRotationOutput[Axis.Z.ordinal()]);
        Vector3.normalize(this.vectorForward, this.vectorForward);
        return this.vectorForward;
    }

    private float[] getRotationMatrix() {
        Matrix.setIdentityM(this.matrixRotation, 0);
        Matrix.rotateM(this.matrixRotation, 0, this.rotation.getZ(), 0.0f, 0.0f, 1.0f);
        Matrix.rotateM(this.matrixRotation, 0, this.rotation.getY(), 0.0f, 1.0f, 0.0f);
        Matrix.rotateM(this.matrixRotation, 0, this.rotation.getX(), 1.0f, 0.0f, 0.0f);
        return this.matrixRotation;
    }
}
```

Axis.java

```
package com.labwork.texturesexample.core.general;
```

```
public enum Axis {
  X,
  Y,
  Z,
}
```

Color.java

```
package com.labwork.texturesexample.core.general;

public final class Color {
  private static final float MAX_CHANNEL_VALUE = 255.0f;

  private int r, g, b, a;
  private float rNormalized, gNormalized, bNormalized, aNormalized;

  public Color(int r, int g, int b, int a) {
    this.r = r;
    this.g = g;
    this.b = b;
    this.a = a;
    this.rNormalized = r / Color.MAX_CHANNEL_VALUE;
    this.gNormalized = g / Color.MAX_CHANNEL_VALUE;
    this.bNormalized = b / Color.MAX_CHANNEL_VALUE;
    this.aNormalized = a / Color.MAX_CHANNEL_VALUE;
  }

  public int getR() {
    return this.r;
  }
```

```
public void setR(int value) {
   this.r = value;
   this.rNormalized = value / Color.MAX_CHANNEL_VALUE;
}

public float getRNormalized() {
   return this.rNormalized;
}

public int getG() {
   return this.g;
}

public void setG(int value) {
   this.g = value;
   this.gNormalized = value / Color.MAX_CHANNEL_VALUE;
}

public float getGNormalized() {
   return this.gNormalized;
}

public int getB() {
   return this.b;
}

public void setB(int value) {
   this.b = value;
```

```
        this.bNormalized = value / Color.MAX_CHANNEL_VALUE;
    }

    public float getBNormalized() {
        return this.bNormalized;
    }

    public int getA() {
        return this.a;
    }

    public void setA(int value) {
        this.a = value;
        this.aNormalized = value / Color.MAX_CHANNEL_VALUE;
    }

    public float getANormalized() {
        return this.aNormalized;
    }
}
```

Entity.java

```
package com.labwork.texturesexample.core.general;

import java.util.Map;
import java.util.HashMap;
import java.util.Collection;
import com.labwork.texturesexample.core.components.common.Component;

public class Entity {
```

```
private static int nextId;

private final int id;
private final Map<Class<?>, Component> components;

private boolean isActive;

public Entity() {
    this.isActive = true;
    this.id = ++Entity.nextId;
    this.components = new HashMap<>();
}

public int getId() {
    return this.id;
}

public boolean getIsActive() {
    return this.isActive;
}

public void setIsActive(boolean value) {
    this.isActive = value;
}

public Collection<Component> getComponents() {
    return this.components.values();
}
```

```
  public void addComponent(Component component) {
    if (this.components.containsKey(component.getClass()))
                throw new IllegalArgumentException("Component of type " +
component.getClass().getName() + " already exists.");

    this.components.put(component.getClass(), component);
  }

  public boolean hasComponent(Class<?> component) {
    return this.components.containsKey(component);
  }

  @SuppressWarnings("unchecked")
  public <T extends Component> T getComponent(Class<T> component) {
    return (T) this.components.getOrDefault(component, null);
  }

  public void onStart() {
    for (Component component : this.components.values())
      component.onStart();
  }

  public void onUpdate(float deltaTime) {
    for (Component component : this.components.values())
      component.onUpdate(deltaTime);
  }

  public void onDestroy() {
    for (Component component : this.components.values())
```

```
            component.onDestroy();
        }
    }
```

Material.java

```
package com.labwork.illuminationexample.core.general;

public final class Material {
    private Shader shader;
    private Color colorAlbedo;
    private float propertyAmbient;
    private float propertyDiffuse;
    private float propertySpecular;

    public Material(Shader shader, Color colorAlbedo, float propertyAmbient, float
propertyDiffuse, float propertySpecular) {
        this.shader = shader;
        this.colorAlbedo = colorAlbedo;
        this.propertyAmbient = propertyAmbient;
        this.propertyDiffuse = propertyDiffuse;
        this.propertySpecular = propertySpecular;
    }

    public Shader getShader() {
        return this.shader;
    }

    public void setShader(Shader value) {
        this.shader = value;
    }
```

```
public Color getColorAlbedo() {
   return this.colorAlbedo;
}

public void setColorAlbedo(Color value) {
   this.colorAlbedo= value;
}

public float getPropertyAmbient() {
   return this.propertyAmbient;
}

public void setPropertyAmbient(float value) {
   this.propertyAmbient = value;
}

public float getPropertyDiffuse() {
   return this.propertyDiffuse;
}

public void setPropertyDiffuse(float value) {
   this.propertyDiffuse = value;
}

public float getPropertySpecular() {
   return this.propertySpecular;
}
```

```
  public void setPropertySpecular(float value) {
    this.propertySpecular = value;
  }
}
```

Mesh.java

```
package com.labwork.illuminationexample.core.general;

import java.nio.ByteOrder;
import java.nio.ByteBuffer;
import java.nio.FloatBuffer;
import android.opengl.GLES32;

public final class Mesh {

  private static int HANDLERS_COUNT = 2;
  private static int HANDLER_INDEX_VAO = 0;
  private static int HANDLER_INDEX_VBO = 1;

  public static final int PAYLOAD_POSITION_SIZE = 3;
  public static final int PAYLOAD_POSITION_INDEX = 0;
  public static final int PAYLOAD_POSITION_OFFSET = 0;

  public static final int PAYLOAD_COLOR_SIZE = 4;
  public static final int PAYLOAD_COLOR_INDEX = 1;
  public static final int PAYLOAD_COLOR_OFFSET = Mesh.PAYLOAD_POSITION_SIZE * Float.BYTES;

  public static final int PAYLOAD_NORMAL_SIZE = 3;
  public static final int PAYLOAD_NORMAL_INDEX = 2;
```

```
    public static final int PAYLOAD_NORMAL_OFFSET = (Mesh.PAYLOAD_POSITION_SIZE + Mesh.PAYLOAD_COLOR_SIZE) * Float.BYTES;

    public static final int PAYLOAD_STRIDE = (Mesh.PAYLOAD_POSITION_SIZE + Mesh.PAYLOAD_COLOR_SIZE + Mesh.PAYLOAD_NORMAL_SIZE) * Float.BYTES;

    private final int drawingMode;
    private final int verticesCount;
    private final float[] verticesData;
    private final int[] bindingHandlers;

    public Mesh(float[] verticesData, int drawingMode) {
        this.drawingMode = drawingMode;
        this.verticesData = verticesData;
        this.bindingHandlers = new int[Mesh.HANDLERS_COUNT];
        this.verticesCount = verticesData.length / (Mesh.PAYLOAD_POSITION_SIZE + Mesh.PAYLOAD_COLOR_SIZE);

        FloatBuffer vertexBuffer = ByteBuffer.allocateDirect(this.verticesData.length * Float.BYTES).order(ByteOrder.nativeOrder()).asFloatBuffer();
        vertexBuffer.put(this.verticesData).position(0);

        GLES32.glGenVertexArrays(1, this.bindingHandlers, Mesh.HANDLER_INDEX_VAO);
        GLES32.glGenBuffers(1, this.bindingHandlers, Mesh.HANDLER_INDEX_VBO);
```

```
GLES32.glBindVertexArray(this.bindingHandlers[Mesh.HANDLER_INDEX_VAO]
);
                         GLES32.glBindBuffer(GLES32.GL_ARRAY_BUFFER,
this.bindingHandlers[Mesh.HANDLER_INDEX_VBO]);
    GLES32.glBufferData(GLES32.GL_ARRAY_BUFFER, this.verticesData.length
* Float.BYTES, vertexBuffer, GLES32.GL_STATIC_DRAW);

             GLES32.glVertexAttribPointer(Mesh.PAYLOAD_POSITION_INDEX,
Mesh.PAYLOAD_POSITION_SIZE,        GLES32.GL_FLOAT,        false,
Mesh.PAYLOAD_STRIDE, Mesh.PAYLOAD_POSITION_OFFSET);
    GLES32.glEnableVertexAttribArray(Mesh.PAYLOAD_POSITION_INDEX);

               GLES32.glVertexAttribPointer(Mesh.PAYLOAD_COLOR_INDEX,
Mesh.PAYLOAD_COLOR_SIZE,        GLES32.GL_FLOAT,        false,
Mesh.PAYLOAD_STRIDE, Mesh.PAYLOAD_COLOR_OFFSET);
    GLES32.glEnableVertexAttribArray(Mesh.PAYLOAD_COLOR_INDEX);

             GLES32.glVertexAttribPointer(Mesh.PAYLOAD_NORMAL_INDEX,
Mesh.PAYLOAD_NORMAL_SIZE,        GLES32.GL_FLOAT,        false,
Mesh.PAYLOAD_STRIDE, Mesh.PAYLOAD_NORMAL_OFFSET);
    GLES32.glEnableVertexAttribArray(Mesh.PAYLOAD_NORMAL_INDEX);

    GLES32.glBindVertexArray(0);
    GLES32.glEnableVertexAttribArray(0);
    GLES32.glBindBuffer(GLES32.GL_ARRAY_BUFFER, 0);
  }

  public void draw() {
```

```
GLES32.glBindVertexArray(this.bindingHandlers[Mesh.HANDLER_INDEX_VAO]
);
      GLES32.glDrawArrays(this.drawingMode, 0, this.verticesCount);
      GLES32.glBindVertexArray(0);
   }

   public void delete() {
      GLES32.glDeleteBuffers(this.bindingHandlers.length, this.bindingHandlers, 0);
   }
}
```

Scene.java

```
package com.labwork.texturesexample.core.general;

import java.util.List;
import java.util.ArrayList;
import java.util.Collection;
import com.labwork.texturesexample.core.components.common.Component;
import com.labwork.texturesexample.core.components.concrete.CameraComponent;
import
com.labwork.texturesexample.core.components.concrete.SkyboxRenderingCompone
nt;

public final class Scene {
   private final List<Entity> entities;

   private CameraComponent camera;
   private SkyboxRenderingComponent skybox;
```

```
public Scene() {
   this.entities = new ArrayList<>();
}

public List<Entity> getEntities() {
   return this.entities;
}

public CameraComponent getCamera() {
   return this.camera;
}

public SkyboxRenderingComponent getSkybox() {
   return this.skybox;
}

public void addEntity(Entity entity) {
   this.entities.add(entity);

   Collection<Component> components = entity.getComponents();

   for (Component component : components) {
      if (component instanceof CameraComponent) {
         this.camera = (CameraComponent) component;
      }
      if (component instanceof SkyboxRenderingComponent) {
         this.skybox = (SkyboxRenderingComponent) component;
      }
   }
```

```
  }

  public void onUnloaded() {
    for (Entity entity: this.entities)
      entity.onDestroy();
  }
}
```

Shader.java

```
package com.labwork.texturesexample.core.general;

import android.opengl.GLES32;

public final class Shader {
  private final int vertId;
  private final int fragId;
  private final int programId;
  private final Class<?> renderFeature;

  public Shader(Class<?> renderFeature, String sourceVert, String sourceFrag) {
    this.renderFeature = renderFeature;
    this.programId = GLES32.glCreateProgram();

    this.vertId = GLES32.glCreateShader(GLES32.GL_VERTEX_SHADER);
    GLES32.glShaderSource(this.vertId, sourceVert);

    this.fragId = GLES32.glCreateShader(GLES32.GL_FRAGMENT_SHADER);
    GLES32.glShaderSource(this.fragId, sourceFrag);

    GLES32.glCompileShader(this.vertId);
    GLES32.glCompileShader(this.fragId);

    GLES32.glAttachShader(this.programId, this.vertId);
    GLES32.glAttachShader(this.programId, this.fragId);

                                        GLES32.glBindAttribLocation(this.programId,
Mesh.PAYLOAD_COLOR_INDEX, "aVertexColorRGB");
                                        GLES32.glBindAttribLocation(this.programId,
Mesh.PAYLOAD_NORMAL_INDEX, "aVertexNormalLocal");
                                        GLES32.glBindAttribLocation(this.programId,
Mesh.PAYLOAD_POSITION_INDEX, "aVertexPositionLocal");
                                        GLES32.glBindAttribLocation(this.programId,
Mesh.PAYLOAD_TEXTURE_INDEX, "aVertexTextureCoordinate");

    GLES32.glLinkProgram(this.programId);
  }

  public int getId() {
    return this.programId;
  }

  public Class<?> getRenderFeature() {
    return this.renderFeature;
  }

  public int getVariableHandler(String identifier) {
    return GLES32.glGetUniformLocation(this.programId, identifier);
  }
  public void delete() {
    GLES32.glDetachShader(this.programId, this.vertId);
    GLES32.glDetachShader(this.programId, this.fragId);
    GLES32.glDeleteShader(this.vertId);
    GLES32.glDeleteShader(this.fragId);
    GLES32.glDeleteProgram(this.programId);
  }
}
```

Vector3.java

```
package com.labwork.texturesexample.core.general;

public final class Vector3 {
  private float x;
  private float y;
  private float z;

  public Vector3(float x, float y, float z) {
     this.x = x;
     this.y = y;
     this.z = z;
  }

  public float getX() {
     return this.x;
  }
  public void setX(float value) {
     this.x = value;
  }
```

```
public float getY() {
   return this.y;
}
public void setY(float value) {
   this.y = value;
}

public float getZ() {
   return this.z;
}

public void setZ(float value) {
   this.z = value;
}

public void setXYZ(float x, float y, float z) {
   this.x = x;
   this.y = y;
   this.z = z;
}

public float getMagnitude() {
   return (float) Math.sqrt(this.x * this.x + this.y * this.y + this.z * this.z);
}

public static float dot(Vector3 a, Vector3 b) {
   return a.x * b.x + a.y * b.y + a.z * b.z;
}
```

```
public static void add(Vector3 a, Vector3 b, Vector3 output) {
    output.x = a.x + b.x;
    output.y = a.y + b.y;
    output.z = a.z + b.z;
}

public static void subtract(Vector3 a, Vector3 b, Vector3 output) {
    output.x = a.x - b.x;
    output.y = a.y - b.y;
    output.z = a.z - b.z;
}

public static void multiply(Vector3 a, float scalar, Vector3 output) {
    output.x = a.x * scalar;
    output.y = a.y * scalar;
    output.z = a.z * scalar;
}

public static void cross(Vector3 a, Vector3 b, Vector3 output) {
    output.x = a.y * b.z - a.z * b.y;
    output.y = a.z * b.x - a.x * b.z;
    output.z = a.x * b.y - a.y * b.x;
}

public static void normalize(Vector3 a, Vector3 output) {
    float magnitude = (float) Math.sqrt(a.x * a.x + a.y * a.y + a.z * a.z);

    if (magnitude == 0) {
        output.x = 0;
```

```
            output.y = 0;
            output.z = 0;
        } else {
            output.x = a.x / magnitude;
            output.y = a.y / magnitude;
            output.z = a.z / magnitude;
        }
    }
}
```

DynamicLightControllerComponent.java

```
package com.labwork.texturesexample.demo.components;

import android.view.View;
import android.view.MotionEvent;
import android.widget.Button;
import android.widget.RelativeLayout;
import android.widget.RelativeLayout.LayoutParams;
import com.labwork.texturesexample.runtime.Framework;
import com.labwork.texturesexample.core.general.Entity;
import com.labwork.texturesexample.core.general.Vector3;
import com.labwork.texturesexample.core.components.common.Component;
import
com.labwork.texturesexample.core.components.concrete.TransformComponent;

public final class DynamicLightControllerComponent extends Component {
  private static final float MOVEMENT_SPEED = 1.0f;

  private TransformComponent transform;
  private boolean isMovingLeft;
  private boolean isMovingRight;
  private boolean isMovingForward;
  private boolean isMovingBackward;
  private boolean isMovingUp;
  private boolean isMovingDown;

  private final Button buttonMoveLeft;
  private final Button buttonMoveRight;
  private final Button buttonMoveForward;
  private final Button buttonMoveBackward;
  private final Button buttonMoveUp;
  private final Button buttonMoveDown;

  public DynamicLightControllerComponent(Entity entity, Button buttonMoveForward, Button buttonMoveBackward, Button buttonMoveLeft, Button buttonMoveRight, Button buttonMoveUp, Button buttonMoveDown) {
    super(entity);

    int spacing = 10;
    int leftOffset = 50;
    int rightOffset = 50;
    int buttonSize = 125;
    int bottomOffset = 150;
    float textSize = 30.0f;

    buttonMoveLeft.setVisibility(View.INVISIBLE);
    buttonMoveRight.setVisibility(View.INVISIBLE);
    buttonMoveForward.setVisibility(View.INVISIBLE);
    buttonMoveBackward.setVisibility(View.INVISIBLE);
    buttonMoveUp.setVisibility(View.INVISIBLE);
    buttonMoveDown.setVisibility(View.INVISIBLE);

    this.buttonMoveLeft = buttonMoveLeft;
    buttonMoveLeft.setId(View.generateViewId());
    buttonMoveLeft.setPadding(0, 0, 0, 0);
    buttonMoveLeft.setText("←");
    buttonMoveLeft.setTextSize(textSize);
    LayoutParams paramsMoveLeft = new LayoutParams(buttonSize, buttonSize);
    paramsMoveLeft.addRule(RelativeLayout.ALIGN_PARENT_BOTTOM);
    paramsMoveLeft.addRule(RelativeLayout.ALIGN_PARENT_LEFT);
    paramsMoveLeft.leftMargin = leftOffset;
    paramsMoveLeft.bottomMargin = bottomOffset;
    buttonMoveLeft.setLayoutParams(paramsMoveLeft);
    buttonMoveLeft.setOnTouchListener(this::handleMoveLeftButtonTouch);

    this.buttonMoveBackward = buttonMoveBackward;
    buttonMoveBackward.setId(View.generateViewId());
    buttonMoveBackward.setPadding(0, 0, 0, 0);
    buttonMoveBackward.setText("↓");
    buttonMoveBackward.setTextSize(textSize);
    LayoutParams paramsMoveDown = new LayoutParams(buttonSize, buttonSize);
                    paramsMoveDown.addRule(RelativeLayout.RIGHT_OF,
buttonMoveLeft.getId());
    paramsMoveDown.addRule(RelativeLayout.ALIGN_PARENT_BOTTOM);
    paramsMoveDown.leftMargin = spacing;
    paramsMoveDown.bottomMargin = bottomOffset;
    buttonMoveBackward.setLayoutParams(paramsMoveDown);
buttonMoveBackward.setOnTouchListener(this::handleMoveBackwardButtonTouch)
;

    this.buttonMoveForward = buttonMoveForward;
    buttonMoveForward.setId(View.generateViewId());
    buttonMoveForward.setPadding(0, 0, 0, 0);
    buttonMoveForward.setText("↑");
    buttonMoveForward.setTextSize(textSize);
    LayoutParams paramsMoveUp = new LayoutParams(buttonSize, buttonSize);
                                    paramsMoveUp.addRule(RelativeLayout.ABOVE,
buttonMoveBackward.getId());
                                   paramsMoveUp.addRule(RelativeLayout.ALIGN_LEFT,
buttonMoveBackward.getId());
    paramsMoveUp.bottomMargin = spacing;
    buttonMoveForward.setLayoutParams(paramsMoveUp);

buttonMoveForward.setOnTouchListener(this::handleMoveForwardButtonTouch);

    this.buttonMoveRight = buttonMoveRight;
    buttonMoveRight.setId(View.generateViewId());
    buttonMoveRight.setPadding(0, 0, 0, 0);
    buttonMoveRight.setText("→");
    buttonMoveRight.setTextSize(textSize);
    LayoutParams paramsMoveRight = new LayoutParams(buttonSize, buttonSize);
                                   paramsMoveRight.addRule(RelativeLayout.RIGHT_OF,
buttonMoveBackward.getId());
                                  paramsMoveRight.addRule(RelativeLayout.ALIGN_TOP,
buttonMoveBackward.getId());
```

```
    paramsMoveRight.leftMargin = spacing;
    buttonMoveRight.setLayoutParams(paramsMoveRight);
    buttonMoveRight.setOnTouchListener(this::handleMoveRightButtonTouch);

    this.buttonMoveDown = buttonMoveDown;
    buttonMoveDown.setId(View.generateViewId());
    buttonMoveDown.setPadding(0, 0, 0, 0);
    buttonMoveDown.setText("↓");
    buttonMoveDown.setTextSize(textSize);
        LayoutParams paramsMoveDownRight = new LayoutParams(buttonSize,
buttonSize);

paramsMoveDownRight.addRule(RelativeLayout.ALIGN_PARENT_BOTTOM);
    paramsMoveDownRight.addRule(RelativeLayout.ALIGN_PARENT_RIGHT);
    paramsMoveDownRight.rightMargin = rightOffset;
    paramsMoveDownRight.bottomMargin = bottomOffset;
    buttonMoveDown.setLayoutParams(paramsMoveDownRight);
    buttonMoveDown.setOnTouchListener(this::handleMoveDownButtonTouch);

    this.buttonMoveUp = buttonMoveUp;
    buttonMoveUp.setId(View.generateViewId());
    buttonMoveUp.setPadding(0, 0, 0, 0);
    buttonMoveUp.setText("↑");
    buttonMoveUp.setTextSize(textSize);
        LayoutParams paramsMoveUpRight = new LayoutParams(buttonSize,
buttonSize);
                    paramsMoveUpRight.addRule(RelativeLayout.ABOVE,
buttonMoveDown.getId());
```

```
                        paramsMoveUpRight.addRule(RelativeLayout.ALIGN_LEFT,
buttonMoveDown.getId());
    paramsMoveUpRight.bottomMargin = spacing;
    buttonMoveUp.setLayoutParams(paramsMoveUpRight);
    buttonMoveUp.setOnTouchListener(this::handleMoveUpButtonTouch);

    Framework.getInstance().getViewport().register(buttonMoveLeft);
    Framework.getInstance().getViewport().register(buttonMoveRight);
    Framework.getInstance().getViewport().register(buttonMoveForward);
    Framework.getInstance().getViewport().register(buttonMoveBackward);
    Framework.getInstance().getViewport().register(buttonMoveUp);
    Framework.getInstance().getViewport().register(buttonMoveDown);
  }

  private boolean handleMoveForwardButtonTouch(View view, MotionEvent event)
{
    switch (event.getAction()) {
      case MotionEvent.ACTION_DOWN:
        this.isMovingForward = true;
        return true;
      case MotionEvent.ACTION_UP:
      case MotionEvent.ACTION_CANCEL:
        this.isMovingForward = false;
        return true;
      default:
        return false;
    }
  }
  private boolean handleMoveBackwardButtonTouch(View view, MotionEvent
event) {
    switch (event.getAction()) {
      case MotionEvent.ACTION_DOWN:
        this.isMovingBackward = true;
        return true;
      case MotionEvent.ACTION_UP:
      case MotionEvent.ACTION_CANCEL:
        this.isMovingBackward = false;
        return true;
      default:
        return false;
    }
  }

  private boolean handleMoveLeftButtonTouch(View view, MotionEvent event) {
    switch (event.getAction()) {
      case MotionEvent.ACTION_DOWN:
        this.isMovingLeft = true;
        return true;
      case MotionEvent.ACTION_UP:
      case MotionEvent.ACTION_CANCEL:
        this.isMovingLeft = false;
        return true;
      default:
        return false;
    }
  }
```

```
private boolean handleMoveRightButtonTouch(View view, MotionEvent event) {
    switch (event.getAction()) {
        case MotionEvent.ACTION_DOWN:
            this.isMovingRight = true;
            return true;
        case MotionEvent.ACTION_UP:
        case MotionEvent.ACTION_CANCEL:
            this.isMovingRight = false;
            return true;
        default:
            return false;
    }
}

private boolean handleMoveUpButtonTouch(View view, MotionEvent event) {
    switch (event.getAction()) {
        case MotionEvent.ACTION_DOWN:
            this.isMovingUp = true;
            return true;
        case MotionEvent.ACTION_UP:
        case MotionEvent.ACTION_CANCEL:
            this.isMovingUp = false;
            return true;
        default:
            return false;
    }
}

private boolean handleMoveDownButtonTouch(View view, MotionEvent event) {
        switch (event.getAction()) {
            case MotionEvent.ACTION_DOWN:
                this.isMovingDown = true;
                return true;
            case MotionEvent.ACTION_UP:
            case MotionEvent.ACTION_CANCEL:
                this.isMovingDown = false;
                return true;
            default:
                return false;
        }
    }

    @Override
    public void onStart() {
        this.buttonMoveLeft.setVisibility(View.VISIBLE);
        this.buttonMoveRight.setVisibility(View.VISIBLE);
        this.buttonMoveForward.setVisibility(View.VISIBLE);
        this.buttonMoveBackward.setVisibility(View.VISIBLE);
        this.buttonMoveUp.setVisibility(View.VISIBLE);
        this.buttonMoveDown.setVisibility(View.VISIBLE);

        this.transform = super.getEntity().getComponent(TransformComponent.class);
    }

    @Override
    public void onUpdate(float deltaTime) {
        Vector3 position = this.transform.getPosition();
```

```
      float moveSpeed = DynamicLightControllerComponent.MOVEMENT_SPEED
* deltaTime;

    if (this.isMovingForward) {
      position.setZ(position.getZ() + moveSpeed);
    }
    if (this.isMovingBackward) {
      position.setZ(position.getZ() - moveSpeed);
    }
    if (this.isMovingLeft) {
      position.setX(position.getX() + moveSpeed);
    }
    if (this.isMovingRight) {
      position.setX(position.getX() - moveSpeed);
    }
    if (this.isMovingUp) {
      position.setY(position.getY() + moveSpeed);
    }
    if (this.isMovingDown) {
      position.setY(position.getY() - moveSpeed);
    }
  }

  @Override
  public void onDestroy() {
    this.buttonMoveLeft.setVisibility(View.INVISIBLE);
    this.buttonMoveRight.setVisibility(View.INVISIBLE);
    this.buttonMoveForward.setVisibility(View.INVISIBLE);
    this.buttonMoveBackward.setVisibility(View.INVISIBLE);
```

```
      this.buttonMoveUp.setVisibility(View.INVISIBLE);
      this.buttonMoveDown.setVisibility(View.INVISIBLE);
  }
}
```

NoClipControllerComponent.java

```
package com.labwork.texturesexample.demo.components;

import android.view.View;
import android.view.MotionEvent;
import android.widget.Button;
import android.widget.RelativeLayout;
import android.widget.RelativeLayout.LayoutParams;
import com.labwork.texturesexample.runtime.Framework;
import com.labwork.texturesexample.core.general.Entity;
import com.labwork.texturesexample.core.general.Vector3;
import com.labwork.texturesexample.core.components.common.Component;
import
com.labwork.texturesexample.core.components.concrete.TransformComponent;

public final class NoClipControllerComponent extends Component {
  private static final float MOVEMENT_SPEED = 1.0f;
  private static final float ROTATION_SPEED = 45.0f;

  private final Button buttonMoveLeft;
  private final Button buttonMoveRight;
  private final Button buttonMoveForward;
  private final Button buttonMoveBackward;
  private final Button buttonRotateUp;
  private final Button buttonRotateDown;
  private final Button buttonRotateLeft;
  private final Button buttonRotateRight;

  private final Vector3 tempVector = new Vector3(0, 0, 0);
  private final Vector3 moveDirection = new Vector3(0, 0, 0);

  private TransformComponent transform;

  private boolean isMovingLeft;
  private boolean isMovingRight;
  private boolean isMovingForward;
  private boolean isMovingBackward;
  private boolean isRotatingUp;
  private boolean isRotatingDown;
  private boolean isRotatingLeft;
  private boolean isRotatingRight;

    public NoClipControllerComponent(Entity entity, Button buttonMoveForward,
Button buttonMoveBackward, Button buttonMoveLeft, Button buttonMoveRight,
Button buttonRotateUp, Button buttonRotateDown, Button buttonRotateLeft, Button
buttonRotateRight) {
     super(entity);

     int spacing = 10;
     int leftOffset = 50;
     int rightOffset = 50;
     int buttonSize = 125;
     int bottomOffset = 150;
     float textSize = 30.0f;
```

```
buttonMoveLeft.setVisibility(View.INVISIBLE);
buttonMoveRight.setVisibility(View.INVISIBLE);
buttonMoveForward.setVisibility(View.INVISIBLE);
buttonMoveBackward.setVisibility(View.INVISIBLE);
buttonRotateUp.setVisibility(View.INVISIBLE);
buttonRotateDown.setVisibility(View.INVISIBLE);
buttonRotateLeft.setVisibility(View.INVISIBLE);
buttonRotateRight.setVisibility(View.INVISIBLE);

this.buttonMoveLeft = buttonMoveLeft;
buttonMoveLeft.setId(View.generateViewId());
buttonMoveLeft.setPadding(0, 0, 0, 0);
buttonMoveLeft.setText("←");
buttonMoveLeft.setTextSize(textSize);
LayoutParams paramsMoveLeft = new LayoutParams(buttonSize, buttonSize);
paramsMoveLeft.addRule(RelativeLayout.ALIGN_PARENT_BOTTOM);
paramsMoveLeft.addRule(RelativeLayout.ALIGN_PARENT_LEFT);
paramsMoveLeft.leftMargin = leftOffset;
paramsMoveLeft.bottomMargin = bottomOffset;
buttonMoveLeft.setLayoutParams(paramsMoveLeft);
buttonMoveLeft.setOnTouchListener(this::handleMoveLeftButtonTouch);

this.buttonMoveBackward = buttonMoveBackward;
buttonMoveBackward.setId(View.generateViewId());
buttonMoveBackward.setPadding(0, 0, 0, 0);
buttonMoveBackward.setText("↓");
buttonMoveBackward.setTextSize(textSize);
LayoutParams paramsMoveDown = new LayoutParams(buttonSize, buttonSize);
```

```
                        paramsMoveDown.addRule(RelativeLayout.RIGHT_OF,
buttonMoveLeft.getId());
    paramsMoveDown.addRule(RelativeLayout.ALIGN_PARENT_BOTTOM);
    paramsMoveDown.leftMargin = spacing;
    paramsMoveDown.bottomMargin = bottomOffset;
    buttonMoveBackward.setLayoutParams(paramsMoveDown);

buttonMoveBackward.setOnTouchListener(this::handleMoveBackwardButtonTouch)
;

    this.buttonMoveForward = buttonMoveForward;
    buttonMoveForward.setId(View.generateViewId());
    buttonMoveForward.setPadding(0, 0, 0, 0);
    buttonMoveForward.setText("↑");
    buttonMoveForward.setTextSize(textSize);
    LayoutParams paramsMoveUp = new LayoutParams(buttonSize, buttonSize);
                            paramsMoveUp.addRule(RelativeLayout.ABOVE,
buttonMoveBackward.getId());
                        paramsMoveUp.addRule(RelativeLayout.ALIGN_LEFT,
buttonMoveBackward.getId());
    paramsMoveUp.bottomMargin = spacing;
    buttonMoveForward.setLayoutParams(paramsMoveUp);

buttonMoveForward.setOnTouchListener(this::handleMoveForwardButtonTouch);

    this.buttonMoveRight = buttonMoveRight;
    buttonMoveRight.setId(View.generateViewId());
    buttonMoveRight.setPadding(0, 0, 0, 0);
    buttonMoveRight.setText("→");
    buttonMoveRight.setTextSize(textSize);
    LayoutParams paramsMoveRight = new LayoutParams(buttonSize, buttonSize);
                    paramsMoveRight.addRule(RelativeLayout.RIGHT_OF,
buttonMoveBackward.getId());
                    paramsMoveRight.addRule(RelativeLayout.ALIGN_TOP,
buttonMoveBackward.getId());
    paramsMoveRight.leftMargin = spacing;
    buttonMoveRight.setLayoutParams(paramsMoveRight);
    buttonMoveRight.setOnTouchListener(this::handleMoveRightButtonTouch);

    this.buttonRotateRight = buttonRotateRight;
    buttonRotateRight.setId(View.generateViewId());
    buttonRotateRight.setPadding(0, 0, 0, 0);
    buttonRotateRight.setText("→");
    buttonRotateRight.setTextSize(textSize);
    LayoutParams paramsRotateRight = new LayoutParams(buttonSize, buttonSize);
    paramsRotateRight.addRule(RelativeLayout.ALIGN_PARENT_BOTTOM);
    paramsRotateRight.addRule(RelativeLayout.ALIGN_PARENT_RIGHT);
    paramsRotateRight.rightMargin = rightOffset;
    paramsRotateRight.bottomMargin = bottomOffset;
    buttonRotateRight.setLayoutParams(paramsRotateRight);
    buttonRotateRight.setOnTouchListener(this::handleRotateRightButtonTouch);

    this.buttonRotateDown = buttonRotateDown;
    buttonRotateDown.setId(View.generateViewId());
    buttonRotateDown.setPadding(0, 0, 0, 0);
    buttonRotateDown.setText("↓");
    buttonRotateDown.setTextSize(textSize);
```

```
        LayoutParams paramsRotateDown = new LayoutParams(buttonSize,
buttonSize);
                    paramsRotateDown.addRule(RelativeLayout.LEFT_OF,
buttonRotateRight.getId());
    paramsRotateDown.addRule(RelativeLayout.ALIGN_PARENT_BOTTOM);
    paramsRotateDown.rightMargin = spacing;
    paramsRotateDown.bottomMargin = bottomOffset;
    buttonRotateDown.setLayoutParams(paramsRotateDown);
    buttonRotateDown.setOnTouchListener(this::handleRotateDownButtonTouch);

    this.buttonRotateLeft = buttonRotateLeft;
    buttonRotateLeft.setId(View.generateViewId());
    buttonRotateLeft.setPadding(0, 0, 0, 0);
    buttonRotateLeft.setText("←");
    buttonRotateLeft.setTextSize(textSize);
    LayoutParams paramsRotateLeft = new LayoutParams(buttonSize, buttonSize);
                    paramsRotateLeft.addRule(RelativeLayout.LEFT_OF,
buttonRotateDown.getId());
                    paramsRotateLeft.addRule(RelativeLayout.ALIGN_TOP,
buttonRotateDown.getId());
    paramsRotateLeft.rightMargin = spacing;
    buttonRotateLeft.setLayoutParams(paramsRotateLeft);
    buttonRotateLeft.setOnTouchListener(this::handleRotateLeftButtonTouch);

    this.buttonRotateUp = buttonRotateUp;
    buttonRotateUp.setId(View.generateViewId());
    buttonRotateUp.setPadding(0, 0, 0, 0);
    buttonRotateUp.setText("↑");
    buttonRotateUp.setTextSize(textSize);
```

```
        LayoutParams paramsRotateUp = new LayoutParams(buttonSize, buttonSize);
        paramsRotateUp.addRule(RelativeLayout.ABOVE, buttonRotateDown.getId());
        paramsRotateUp.addRule(RelativeLayout.ALIGN_LEFT, buttonRotateDown.getId());
        paramsRotateUp.bottomMargin = spacing;
        buttonRotateUp.setLayoutParams(paramsRotateUp);
        buttonRotateUp.setOnTouchListener(this::handleRotateUpButtonTouch);

        Framework.getInstance().getViewport().register(buttonMoveLeft);
        Framework.getInstance().getViewport().register(buttonMoveRight);
        Framework.getInstance().getViewport().register(buttonMoveForward);
        Framework.getInstance().getViewport().register(buttonMoveBackward);
        Framework.getInstance().getViewport().register(buttonRotateUp);
        Framework.getInstance().getViewport().register(buttonRotateDown);
        Framework.getInstance().getViewport().register(buttonRotateLeft);
        Framework.getInstance().getViewport().register(buttonRotateRight);
    }

    private boolean handleMoveForwardButtonTouch(View view, MotionEvent event) {
        switch (event.getAction()) {
            case MotionEvent.ACTION_DOWN:
                this.isMovingForward = true;
                return true;
            case MotionEvent.ACTION_UP:
            case MotionEvent.ACTION_CANCEL:
                this.isMovingForward = false;
                return true;
            default:
```

```
            return false;
        }
    }

        private boolean handleMoveBackwardButtonTouch(View view, MotionEvent
event) {
        switch (event.getAction()) {
            case MotionEvent.ACTION_DOWN:
                this.isMovingBackward = true;
                return true;
            case MotionEvent.ACTION_UP:
            case MotionEvent.ACTION_CANCEL:
                this.isMovingBackward = false;
                return true;
            default:
                return false;
        }
    }

    private boolean handleMoveLeftButtonTouch(View view, MotionEvent event) {
        switch (event.getAction()) {
            case MotionEvent.ACTION_DOWN:
                this.isMovingLeft = true;
                return true;
            case MotionEvent.ACTION_UP:
            case MotionEvent.ACTION_CANCEL:
                this.isMovingLeft = false;
                return true;
            default:
```

```
            return false;
    }
}

private boolean handleMoveRightButtonTouch(View view, MotionEvent event) {
    switch (event.getAction()) {
        case MotionEvent.ACTION_DOWN:
            this.isMovingRight = true;
            return true;
        case MotionEvent.ACTION_UP:
        case MotionEvent.ACTION_CANCEL:
            this.isMovingRight = false;
            return true;
        default:
            return false;
    }
}

private boolean handleRotateUpButtonTouch(View view, MotionEvent event) {
    switch (event.getAction()) {
        case MotionEvent.ACTION_DOWN:
            this.isRotatingUp = true;
            return true;
        case MotionEvent.ACTION_UP:
        case MotionEvent.ACTION_CANCEL:
            this.isRotatingUp = false;
            return true;
        default:
            return false;
    }
}

private boolean handleRotateDownButtonTouch(View view, MotionEvent event) {
    switch (event.getAction()) {
        case MotionEvent.ACTION_DOWN:
            this.isRotatingDown = true;
            return true;
        case MotionEvent.ACTION_UP:
        case MotionEvent.ACTION_CANCEL:
            this.isRotatingDown = false;
            return true;
        default:
            return false;
    }
}

private boolean handleRotateLeftButtonTouch(View view, MotionEvent event) {
    switch (event.getAction()) {
        case MotionEvent.ACTION_DOWN:
            this.isRotatingLeft = true;
            return true;
        case MotionEvent.ACTION_UP:
        case MotionEvent.ACTION_CANCEL:
            this.isRotatingLeft = false;
            return true;
        default:
            return false;
    }
```

```
}

private boolean handleRotateRightButtonTouch(View view, MotionEvent event) {
    switch (event.getAction()) {
        case MotionEvent.ACTION_DOWN:
            this.isRotatingRight = true;
            return true;
        case MotionEvent.ACTION_UP:
        case MotionEvent.ACTION_CANCEL:
            this.isRotatingRight = false;
            return true;
        default:
            return false;
    }
}

@Override
public void onStart() {
    this.buttonMoveLeft.setVisibility(View.VISIBLE);
    this.buttonMoveRight.setVisibility(View.VISIBLE);
    this.buttonMoveForward.setVisibility(View.VISIBLE);
    this.buttonMoveBackward.setVisibility(View.VISIBLE);
    this.buttonRotateUp.setVisibility(View.VISIBLE);
    this.buttonRotateDown.setVisibility(View.VISIBLE);
    this.buttonRotateLeft.setVisibility(View.VISIBLE);
    this.buttonRotateRight.setVisibility(View.VISIBLE);

    this.transform = super.getEntity().getComponent(TransformComponent.class);
}
```

```
  @Override
  public void onUpdate(float deltaTime) {
    Vector3 position = this.transform.getPosition();
    Vector3 rotation = this.transform.getRotation();
        float moveSpeed = NoClipControllerComponent.MOVEMENT_SPEED *
deltaTime;
         float rotateSpeed = NoClipControllerComponent.ROTATION_SPEED *
deltaTime;

    if (this.isRotatingUp) {
      rotation.setX(rotation.getX() - rotateSpeed);
    }
    if (this.isRotatingDown) {
      rotation.setX(rotation.getX() + rotateSpeed);
    }
    if (this.isRotatingLeft) {
      rotation.setY(rotation.getY() + rotateSpeed);
    }
    if (this.isRotatingRight) {
      rotation.setY(rotation.getY() - rotateSpeed);
    }

    this.moveDirection.setXYZ(0, 0, 0);

    if (this.isMovingLeft) {
                        Vector3.add(this.moveDirection, this.transform.getRight(),
this.moveDirection);
    }
```

```
      if (this.isMovingRight) {
                        Vector3.subtract(this.moveDirection,   this.transform.getRight(),
this.moveDirection);
      }
      if (this.isMovingForward) {
                        Vector3.add(this.moveDirection,   this.transform.getForward(),
this.moveDirection);
      }
      if (this.isMovingBackward) {
                    Vector3.subtract(this.moveDirection,   this.transform.getForward(),
this.moveDirection);
      }

      if (this.moveDirection.getMagnitude() > 0) {
        Vector3.normalize(this.moveDirection, this.tempVector);
        Vector3.multiply(this.tempVector, moveSpeed, this.moveDirection);
        position.setX(position.getX() + this.moveDirection.getX());
        position.setY(position.getY() + this.moveDirection.getY());
        position.setZ(position.getZ() + this.moveDirection.getZ());
      }
    }

    @Override
    public void onDestroy() {
      this.buttonMoveLeft.setVisibility(View.INVISIBLE);
      this.buttonMoveRight.setVisibility(View.INVISIBLE);
      this.buttonMoveForward.setVisibility(View.INVISIBLE);
      this.buttonMoveBackward.setVisibility(View.INVISIBLE);
      this.buttonRotateUp.setVisibility(View.INVISIBLE);
```

```
        this.buttonRotateDown.setVisibility(View.INVISIBLE);
        this.buttonRotateLeft.setVisibility(View.INVISIBLE);
        this.buttonRotateRight.setVisibility(View.INVISIBLE);
    }
}
```

Standalone.java

```
package com.labwork.illuminationexample.demo.shaders;

public final class Standalone {

    public static final String SHADER_VERT_SOURCE =
        "#version 300 es\n" +

        "in vec4 inVertexColorRGBA;\n" +
        "in vec3 inVertexNormalLocal;\n" +
        "in vec3 inVertexPositionLocal;\n" +

        "uniform mat4 uMatrixView;\n" +
        "uniform mat4 uMatrixModel;\n" +
        "uniform mat4 uMatrixProjection;\n" +
        "uniform vec3 uTransformLightPositionGlobal;\n" +
        "uniform vec3 uTransformCameraPositionGlobal;\n" +

        "out vec4 vVertexColorRGBA;\n" +
        "out vec3 vVertexPositionGlobal;\n" +
        "out vec3 vVertexNormalGlobalNormalized;\n" +
        "out vec3 vTransformLightPositionGlobal;\n" +
        "out vec3 vTransformCameraPositionGlobal;\n" +
        "void main() {\n" +
        "    gl_PointSize = 25.0f;\n" +
        "    gl_Position = uMatrixProjection * uMatrixView * uMatrixModel * vec4(inVertexPositionLocal, 1.0);\n" +

        "    vVertexPositionGlobal = mat3(uMatrixModel) * inVertexPositionLocal;\n" +
        "    vVertexNormalGlobalNormalized = normalize(mat3(uMatrixModel) * inVertexNormalLocal);\n" +

        "    vVertexColorRGBA = inVertexColorRGBA;\n" +
        "    vTransformLightPositionGlobal = uTransformLightPositionGlobal;\n" +
        "    vTransformCameraPositionGlobal = uTransformCameraPositionGlobal;\n" +
        "}\n";

    public static final String SHADER_FRAG_SOURCE =
        "#version 300 es\n" +
        "precision mediump float;\n" +

        "in vec4 vVertexColorRGBA;\n" +
        "in vec3 vVertexPositionGlobal;\n" +
        "in vec3 vVertexNormalGlobalNormalized;\n" +
        "in vec3 vTransformLightPositionGlobal;\n" +
        "in vec3 vTransformCameraPositionGlobal;\n" +

        "uniform bool uIsDistanceDependent;\n" +
        "uniform vec4 uLightPropertyColorRGBA;\n" +
        "uniform float uLightPropertyIntensity;\n" +
        "uniform vec4 uMaterialColorAlbedoRGBA;\n" +
        "uniform float uMaterialPropertyAmbient;\n" +
        "uniform float uMaterialPropertyDiffuse;\n" +
        "uniform float uMaterialPropertySpecular;\n" +

        "out vec4 outFragmentColorFinal;\n" +

        "void main() {\n" +
            "    vec3 fromVertexToLight = vTransformLightPositionGlobal -
    vVertexPositionGlobal;\n" +
        "    vec3 fromVertexToLightNormalized = normalize(fromVertexToLight);\n" +
        "    float fromVertexToLightLength = length(fromVertexToLight);\n" +
            "    vec3 lightReflectionDirectionNormalized =
    normalize(reflect(-fromVertexToLightNormalized,
    vVertexNormalGlobalNormalized));\n" +

            "    vec3 fromVertexToCamera = vTransformCameraPositionGlobal -
    vVertexPositionGlobal;\n" +
            "    vec3 fromVertexToCameraNormalized =
    normalize(fromVertexToCamera);\n" +

            "    vec4 mixedColorRGBA = mix(vVertexColorRGBA,
    uMaterialColorAlbedoRGBA, uMaterialColorAlbedoRGBA.a);\n" +

            "    vec4 ambientColorRGBA = uMaterialPropertyAmbient *
    mixedColorRGBA;\n" +

            "    float specular = max(dot(fromVertexToCameraNormalized,
    lightReflectionDirectionNormalized), 0.0);\n" +
            "    vec4 specularColorRGBA = uMaterialPropertySpecular *
    uLightPropertyColorRGBA * pow(specular, uLightPropertyIntensity);\n" +
        "        float diffuse = max(dot(vVertexNormalGlobalNormalized, fromVertexToLightNormalized), 0.0);\n" +
        "        vec4 diffuseColorRGBA = uMaterialPropertyDiffuse * diffuse * uLightPropertyColorRGBA * mixedColorRGBA;\n" +

        "    if (uIsDistanceDependent) {\n" +
        "        float attenuation = 1.0f / (1.0f + fromVertexToLightLength * fromVertexToLightLength);\n" +
        "        outFragmentColorFinal = vec4(attenuation * (ambientColorRGBA + diffuseColorRGBA + specularColorRGBA).rgb, mixedColorRGBA.a);\n" +
        "    } else {\n" +
            "        outFragmentColorFinal = vec4((ambientColorRGBA + diffuseColorRGBA + specularColorRGBA).rgb, mixedColorRGBA.a);\n" +
        "    }\n" +
        "}\n";
    }
```

RenderFeature.java

```
package com.labwork.texturesexample.rendering.features.common;

import java.util.List;
import com.labwork.texturesexample.core.general.Shader;
import com.labwork.texturesexample.core.general.Entity;

public abstract class RenderFeature {
  protected Shader shader;

  public RenderFeature(Shader shader) {
    this.shader = shader;
  }

  public abstract void execute(List<Entity> dispatchedEntities);
}
```

OpaqueRenderPass.java

```
package com.labwork.texturesexample.rendering.features.concrete;

import java.util.List;
import android.opengl.GLES32;
import com.labwork.texturesexample.runtime.Framework;
import com.labwork.texturesexample.core.general.Entity;
import com.labwork.texturesexample.core.general.Shader;
import com.labwork.texturesexample.rendering.features.common.RenderFeature;
import com.labwork.texturesexample.core.components.concrete.CameraComponent;
import
com.labwork.texturesexample.core.components.concrete.OpaqueRenderingCompone
nt;

public final class OpaqueRenderFeature extends RenderFeature {

  public OpaqueRenderFeature(Shader shader) {
     super(shader);
  }

  @Override
  public final void execute(List<Entity> dispatchedEntities) {
     GLES32.glEnable(GLES32.GL_DEPTH_TEST);

     GLES32.glUseProgram(super.shader.getId());
```

```
        GLES32.glActiveTexture(GLES32.GL_TEXTURE0);

        CameraComponent camera = Framework.getInstance().getScene().getCamera();
        GLES32.glUniformMatrix4fv(super.shader.getVariableHandler("uMatrixView"),
1, false, camera.getMatrixView(), 0);

GLES32.glUniformMatrix4fv(super.shader.getVariableHandler("uMatrixProjection"),
1, false, camera.getMatrixProjection(), 0);

        for (Entity entity: dispatchedEntities) {
                                OpaqueRenderingComponent rendering =
entity.getComponent(OpaqueRenderingComponent.class);

            if (rendering == null)
                continue;

                    if (rendering.getMaterial().getShader().getRenderFeature() ==
OpaqueRenderFeature.class) {
                rendering.render();
            }
        }

        GLES32.glUseProgram(0);

        GLES32.glDisable(GLES32.GL_DEPTH_TEST);
    }
}
```

SkyboxRednerFetature.java

```
package com.labwork.texturesexample.rendering.features.concrete;
```

```
import java.util.List;
import android.opengl.GLES32;
import com.labwork.texturesexample.runtime.Framework;
import com.labwork.texturesexample.core.general.Entity;
import com.labwork.texturesexample.core.general.Shader;
import com.labwork.texturesexample.rendering.features.common.RenderFeature;
import com.labwork.texturesexample.core.components.concrete.CameraComponent;
import
com.labwork.texturesexample.core.components.concrete.SkyboxRenderingCompone
nt;

public final class SkyboxRenderFeature extends RenderFeature {

  public SkyboxRenderFeature(Shader shader) {
     super(shader);
  }

  @Override
  public final void execute(List<Entity> dispatchedEntities) {
                              GLES32.glClear(GLES32.GL_COLOR_BUFFER_BIT      |
GLES32.GL_DEPTH_BUFFER_BIT);

     GLES32.glDepthMask(false);

     GLES32.glUseProgram(super.shader.getId());
     GLES32.glActiveTexture(GLES32.GL_TEXTURE0);

     CameraComponent camera = Framework.getInstance().getScene().getCamera();
```

```
    GLES32.glUniformMatrix4fv(super.shader.getVariableHandler("uMatrixView"),
1, false, camera.getMatrixView(), 0);

GLES32.glUniformMatrix4fv(super.shader.getVariableHandler("uMatrixProjection"),
1, false, camera.getMatrixProjection(), 0);

                    SkyboxRenderingComponent      skybox      =
Framework.getInstance().getScene().getSkybox();

    if (skybox != null) {
      skybox.render();
    }

    GLES32.glUseProgram(0);

    GLES32.glDepthMask(true);
  }
}
```

RenderProgrammable.java

```
package com.labwork.texturesexample.rendering.renderer.common;

import android.opengl.GLSurfaceView.Renderer;
import javax.microedition.khronos.egl.EGLConfig;
import javax.microedition.khronos.opengles.GL10;
import com.labwork.texturesexample.core.general.Scene;
import com.labwork.texturesexample.rendering.features.common.RenderFeature;

public interface RendererProgrammable extends Renderer {
  void onDrawFrame(GL10 unused);
  void onSurfaceCreated(GL10 unused, EGLConfig config);
  void onSurfaceChanged(GL10 unused, int width, int height);
  void loadScene(Scene scene);
  void registerRenderFeature(RenderFeature feature);
}
```

ForwardRenderer.java

```
package com.labwork.texturesexample.rendering.renderer.concrete;

import java.util.List;
import java.util.ArrayList;
import javax.microedition.khronos.egl.EGLConfig;
import javax.microedition.khronos.opengles.GL10;
import android.opengl.GLES32;
import com.labwork.texturesexample.runtime.Framework;
import com.labwork.texturesexample.core.general.Scene;
import com.labwork.texturesexample.core.general.Entity;
import com.labwork.texturesexample.rendering.features.common.RenderFeature;
import
com.labwork.texturesexample.rendering.renderer.common.RendererProgrammable;

public final class ForwardRenderer implements RendererProgrammable {
  private final List<RenderFeature> features;
  private final List<Entity> dispatchedEntities;
  private final Runnable initializationCallback;

  private float deltaTime;
  private float timestampCurrent;
  private float timestampPrevious;
  public ForwardRenderer(Runnable initializationCallback) {
    this.features = new ArrayList<>();
    this.dispatchedEntities = new ArrayList<>();
    this.initializationCallback = initializationCallback;
  }

  public void onDrawFrame(GL10 unused) {
    this.timestampCurrent = System.nanoTime();
          this.deltaTime = (this.timestampCurrent - this.timestampPrevious) /
1_000_000_000.0f;
    this.timestampPrevious = this.timestampCurrent;

    if (this.deltaTime > 0.95f) {
      this.deltaTime = 0.95f;
    }

    if (Framework.getInstance().getScene() == null)
      return;

    this.dispatchedEntities.clear();

    List<Entity> entities = Framework.getInstance().getScene().getEntities();

    for (Entity entity : entities) {
      if (entity.getIsActive()) {
        entity.onUpdate(this.deltaTime);
        this.dispatchedEntities.add(entity);
      }
    }
```

```
        for (RenderFeature feature : this.features)
            feature.execute(this.dispatchedEntities);
    }

    public void onSurfaceCreated(GL10 unused, EGLConfig config) {
        this.initializationCallback.run();
        this.timestampPrevious = System.nanoTime();
    }

    public void onSurfaceChanged(GL10 unused, int width, int height) {
        GLES32.glViewport(0, 0, width, height);
    }

    public void loadScene(Scene scene) {
        List<Entity> entities = Framework.getInstance().getScene().getEntities();

        for (Entity entity : entities)
            entity.onStart();
    }

    public void registerRenderFeature(RenderFeature feature) {
        this.features.add(feature);
    }
}
```

ViewportConfigurable.java

```
package com.labwork.texturesexample.rendering.viewport.common;

import android.view.View;
import android.widget.RelativeLayout;
import android.opengl.GLSurfaceView;
import
com.labwork.texturesexample.rendering.renderer.common.RendererProgrammable;

public interface ViewportConfigurable {
  RelativeLayout getLayout();
  GLSurfaceView getSurfaceView();
  void register(View view);
  void initialize(RendererProgrammable renderer);
}
```

Viewport.java

```
package com.labwork.texturesexample.rendering.viewport.concrete;

import android.content.Context;
import android.opengl.GLSurfaceView;
import android.view.View;
import android.widget.RelativeLayout;
import android.widget.RelativeLayout.LayoutParams;
import
com.labwork.texturesexample.rendering.renderer.common.RendererProgrammable;
import
com.labwork.texturesexample.rendering.viewport.common.ViewportConfigurable;

public final class Viewport extends GLSurfaceView implements
ViewportConfigurable {
  private final RelativeLayout layout;

  public Viewport(Context context) {
        super(context);
        super.setEGLContextClientVersion(3);
        this.layout = new RelativeLayout(context);
         this.layout.addView(this, new LayoutParams(LayoutParams.MATCH_PARENT,
LayoutParams.MATCH_PARENT));
    }

    public RelativeLayout getLayout() {
        return this.layout;
    }

    public GLSurfaceView getSurfaceView() {
        return this;
    }

    public void register(View view) {
        this.layout.post(() -> {
            this.layout.addView(view);
        });
    }

    public void initialize(RendererProgrammable renderer) {
        super.setFocusable(true);
        super.setRenderer(renderer);
        super.setFocusableInTouchMode(true);
        super.setRenderMode(GLSurfaceView.RENDERMODE_CONTINUOUSLY);
    }
}
```

Framework.java

```
package com.labwork.texturesexample.runtime;

import android.opengl.GLSurfaceView;
import com.labwork.texturesexample.core.general.Scene;
import
com.labwork.texturesexample.rendering.renderer.common.RendererProgrammable;
import
com.labwork.texturesexample.rendering.viewport.common.ViewportConfigurable;

public final class Framework {
  private static final Framework INSTANCE = new Framework();

  private Scene scene;
  private GLSurfaceView surfaceView;
  private ViewportConfigurable viewport;
  private RendererProgrammable renderer;

  private Framework() { }

  public static Framework getInstance() {
    return Framework.INSTANCE;
  }

  public Scene getScene() {
    return this.scene;
  }

  public GLSurfaceView getSurfaceView() {
    return this.surfaceView;
  }

  public ViewportConfigurable getViewport() {
    return this.viewport;
  }

  public RendererProgrammable getRenderer() {
    return this.renderer;
  }

  public void loadScene(Scene scene) {
    if (this.scene != null)
      this.scene.onUnloaded();

    this.scene = scene;
    this.renderer.loadScene(scene);
  }

    public void initialize(RendererProgrammable renderer, ViewportConfigurable
viewport) {
    viewport.initialize(renderer);
    this.renderer = renderer;
    this.viewport = viewport;
    this.surfaceView = viewport.getSurfaceView();
  }
}
```

MainActivity.java

```
package com.labwork.illuminationexample;
```

```
import android.os.Bundle;
import android.view.Menu;
import android.view.MenuItem;
import android.widget.Button;
import android.opengl.GLES32;
import androidx.appcompat.app.AppCompatActivity;
import com.labwork.illuminationexample.runtime.Framework;
import com.labwork.illuminationexample.core.general.Mesh;
import com.labwork.illuminationexample.core.general.Color;
import com.labwork.illuminationexample.core.general.Scene;
import com.labwork.illuminationexample.core.general.Entity;
import com.labwork.illuminationexample.core.general.Shader;
import com.labwork.illuminationexample.core.general.Material;
import
com.labwork.illuminationexample.core.components.concrete.LightComponent;
import
com.labwork.illuminationexample.core.components.concrete.TransformComponent;
import
com.labwork.illuminationexample.core.components.concrete.RenderingComponent;
import
com.labwork.illuminationexample.core.components.concrete.CameraPerspectiveCo
mponent;
import com.labwork.illuminationexample.demo.shaders.Standalone;
import com.labwork.illuminationexample.demo.components.RotationComponent;
import
com.labwork.illuminationexample.demo.components.NoClipControllerComponent;
import
com.labwork.illuminationexample.demo.components.DynamicLightControllerComp
onent;
```

```
import
com.labwork.illuminationexample.rendering.passes.concrete.OpaqueRenderPass;
import
com.labwork.illuminationexample.rendering.renderer.concrete.ForwardRenderer;
import
com.labwork.illuminationexample.rendering.renderer.common.RendererProgrammab
le;
import com.labwork.illuminationexample.rendering.viewport.concrete.Viewport;
import
com.labwork.illuminationexample.rendering.viewport.common.ViewportConfigurabl
e;

public class MainActivity extends AppCompatActivity {
  private static final int MENU_ITEM_SCENE_CUBES = 1;
  private static final int MENU_ITEM_SCENE_PYRAMID = 2;
  private static final int MENU_ITEM_SCENE_DIFFUSE = 3;
  private static final int MENU_ITEM_SCENE_SPECULAR = 4;

  private Shader shader;
  private Scene cubesScene;
  private Scene pyramidScene;
  private Scene diffuseScene;
  private Scene specularScene;

  @Override
  protected final void onCreate(Bundle savedInstanceState) {
    ViewportConfigurable viewport = new Viewport(this);
    RendererProgrammable renderer = new ForwardRenderer(this::initializeAssets);
```

```
        super.onCreate(savedInstanceState);
        super.setContentView(viewport.getLayout());
        Framework.getInstance().initialize(renderer, viewport);
    }

    private void initializeAssets() {
                                this.shader = new Shader(OpaqueRenderPass.class,
Standalone.SHADER_VERT_SOURCE, Standalone.SHADER_FRAG_SOURCE);
                            Framework.getInstance().getRenderer().registerRenderPass(new
OpaqueRenderPass(this.shader));
        this.specularScene = this.initializeSpecularScene();
        this.diffuseScene = this.initializeDiffuseScene();
        this.pyramidScene = this.initializePyramidScene();
        this.cubesScene = this.initializeCubesScene();
    }

    private Scene initializeCubesScene() {
        Scene scene = new Scene();
         Material material = new Material(this.shader, new Color(255, 255, 255, 0), 0.5f,
1.85f, 0.1f);

        float spacing = 2.0f;

        for (int x = 0; x < 3; x++) {
            for (int y = 0; y < 3; y++) {
                for (int z = 0; z < 3; z++) {
                    Entity cube = new Entity();
                    cube.addComponent(new TransformComponent(cube));
```

```
                        cube.addComponent(new RenderingComponent(cube, new
Mesh(this.generateCubeVertices(), GLES32.GL_TRIANGLES), material));

            float startOffset = -spacing;

cube.getComponent(TransformComponent.class).getPosition().setX(startOffset + x *
spacing);

cube.getComponent(TransformComponent.class).getPosition().setY(startOffset + y *
spacing);

cube.getComponent(TransformComponent.class).getPosition().setZ(startOffset + z *
spacing);

            scene.addEntity(cube);
          }
        }
      }

    Entity light = new Entity();
    light.addComponent(new TransformComponent(light));
      light.addComponent(new LightComponent(light, this.shader, new Color(255,
255, 255, 255), 200.0f, true));
    scene.addEntity(light);

    Entity camera = new Entity();
    camera.addComponent(new TransformComponent(camera));
            camera.addComponent(new LightComponent(camera, this.shader, new
Color(255, 255, 255, 255), 200.0f, true));
```

```
        camera.addComponent(new CameraPerspectiveComponent(camera, new Color(27, 27, 27, 255), 0.001f, 100.0f, 90.0f, 90.0f));
        camera.addComponent(new NoClipControllerComponent(camera, new Button(this), new Button(this), new Button(this), new Button(this), new Button(this), new Button(this), new Button(this), new Button(this), light));
        scene.addEntity(camera);

        camera.getComponent(TransformComponent.class).getPosition().setZ(-3.5f);
        camera.getComponent(TransformComponent.class).getPosition().setY(5.5f);
        camera.getComponent(TransformComponent.class).getRotation().setX(45.0f);

        return scene;
    }

    private Scene initializePyramidScene() {
        Scene scene = new Scene();
        Material material = new Material(this.shader, new Color(255, 255, 255, 0), 0.3f, 0.7f, 0.3f);

        Entity pyramid = new Entity();
        pyramid.addComponent(new RotationComponent(pyramid));
        pyramid.addComponent(new TransformComponent(pyramid));
        Mesh pyramidMesh = new Mesh(this.generatePyramidVertices(), GLES32.GL_TRIANGLES);
        pyramid.addComponent(new RenderingComponent(pyramid, pyramidMesh, material));
        scene.addEntity(pyramid);

        pyramid.getComponent(TransformComponent.class).getPosition().setY(1.0f);
        Entity plain = new Entity();
        plain.addComponent(new TransformComponent(plain));
        Mesh plainMesh = new Mesh(this.generateChessboardVertices(),
GLES32.GL_TRIANGLES);
        plain.addComponent(new RenderingComponent(plain, plainMesh, material));
        scene.addEntity(plain);

        plain.getComponent(TransformComponent.class).getScale().setX(3.0f);
        plain.getComponent(TransformComponent.class).getScale().setZ(3.0f);

        Entity light = new Entity();
        light.addComponent(new TransformComponent(light));
        Mesh lightMesh = new Mesh(this.generateLightMesh(), GLES32.GL_POINTS);
        light.addComponent(new RenderingComponent(light, lightMesh, material));
          light.addComponent(new LightComponent(light, this.shader, new Color(255,
255, 255, 255), 200.0f, true));
    light.addComponent(new DynamicLightControllerComponent(light, new
Button(this), new Button(this), new Button(this), new Button(this), new Button(this),
new Button(this)));
        scene.addEntity(light);

        light.getComponent(TransformComponent.class).getPosition().setY(2.5f);

        Entity camera = new Entity();
        camera.addComponent(new TransformComponent(camera));
    camera.addComponent(new CameraPerspectiveComponent(camera, new
Color(27, 27, 27, 255), 0.001f, 100.0f, 90.0f, 90.0f));
        scene.addEntity(camera);
        camera.getComponent(TransformComponent.class).getPosition().setY(2.5f);
        camera.getComponent(TransformComponent.class).getPosition().setZ(-5.0f);

        return scene;
      }

      private Scene initializeDiffuseScene() {
        Scene scene = new Scene();
         Material material = new Material(this.shader, new Color(255, 255, 255, 0), 0.3f,
0.7f, 0.0f);

        Entity rectangle = new Entity();
        rectangle.addComponent(new TransformComponent(rectangle));
                  Mesh rectangleMesh = new Mesh(this.generateRectangleVertices(),
GLES32.GL_TRIANGLES);
      rectangle.addComponent(new RenderingComponent(rectangle, rectangleMesh,
material));
        scene.addEntity(rectangle);

        Entity light = new Entity();
        light.addComponent(new TransformComponent(light));
        Mesh lightMesh = new Mesh(this.generateLightMesh(), GLES32.GL_POINTS);
        light.addComponent(new RenderingComponent(light, lightMesh, material));
         light.addComponent(new LightComponent(light, this.shader, new Color(255, 0,
127, 255), 200.0f, true));
             light.addComponent(new DynamicLightControllerComponent(light, new
Button(this), new Button(this), new Button(this), new Button(this), new Button(this),
new Button(this)));
```

```
    scene.addEntity(light);

    Entity camera = new Entity();
    camera.addComponent(new TransformComponent(camera));
        camera.addComponent(new CameraPerspectiveComponent(camera, new
Color(27, 27, 27, 255), 0.001f, 100.0f, 90.0f, 90.0f));
    scene.addEntity(camera);

    camera.getComponent(TransformComponent.class).getPosition().setY(1.5f);
    camera.getComponent(TransformComponent.class).getPosition().setZ(-3.0f);
    camera.getComponent(TransformComponent.class).getRotation().setX(15.0f);

    return scene;
  }

  private Scene initializeSpecularScene() {
    Scene scene = new Scene();
     Material material = new Material(this.shader, new Color(255, 255, 255, 0), 0.3f,
0.0f, 0.7f);

    Entity rectangle = new Entity();
    rectangle.addComponent(new TransformComponent(rectangle));
         Mesh rectangleMesh = new Mesh(this.generateRectangleVertices(),
GLES32.GL_TRIANGLES);
     rectangle.addComponent(new RenderingComponent(rectangle, rectangleMesh,
material));
    scene.addEntity(rectangle);

    Entity light = new Entity();
```

```
        light.addComponent(new TransformComponent(light));
        Mesh lightMesh = new Mesh(this.generateLightMesh(), GLES32.GL_POINTS);
        light.addComponent(new RenderingComponent(light, lightMesh, material));
        light.addComponent(new LightComponent(light, this.shader, new Color(255, 0,
127, 255), 200.0f, false));
        light.addComponent(new DynamicLightControllerComponent(light, new
Button(this), new Button(this), new Button(this), new Button(this), new Button(this),
new Button(this)));
        scene.addEntity(light);

        Entity camera = new Entity();
        camera.addComponent(new TransformComponent(camera));
        camera.addComponent(new CameraPerspectiveComponent(camera, new
Color(27, 27, 27, 255), 0.001f, 100.0f, 90.0f, 90.0f));
        scene.addEntity(camera);

        camera.getComponent(TransformComponent.class).getPosition().setY(1.5f);
        camera.getComponent(TransformComponent.class).getPosition().setZ(-3.0f);
        camera.getComponent(TransformComponent.class).getRotation().setX(15.0f);

        return scene;
    }

    private float[] generateLightMesh() {
        return new float[] {
            0.0f, 0.0f, 0.0f, 1.0f, 1.0f, 1.0f, 1.0f, 0.0f, 0.0f, 1.0f
        };
    }
```

```
private float[] generateCubeVertices() {
   return new float[] {
         -0.5f, -0.5f,  0.5f, 1.0f, 0.0f, 0.0f, 1.0f, 0.0f, 0.0f, 1.0f,
         0.5f, -0.5f,  0.5f, 1.0f, 0.0f, 0.0f, 1.0f, 0.0f, 0.0f, 1.0f,
         0.5f,  0.5f,  0.5f, 1.0f, 0.0f, 0.0f, 1.0f, 0.0f, 0.0f, 1.0f,
         0.5f,  0.5f,  0.5f, 1.0f, 0.0f, 0.0f, 1.0f, 0.0f, 0.0f, 1.0f,
         -0.5f,  0.5f,  0.5f, 1.0f, 0.0f, 0.0f, 1.0f, 0.0f, 0.0f, 1.0f,
         -0.5f, -0.5f,  0.5f, 1.0f, 0.0f, 0.0f, 1.0f, 0.0f, 0.0f, 1.0f,

         -0.5f, -0.5f, -0.5f, 0.0f, 1.0f, 0.0f, 1.0f, 0.0f, 0.0f, -1.0f,
         0.5f, -0.5f, -0.5f, 0.0f, 1.0f, 0.0f, 1.0f, 0.0f, 0.0f, -1.0f,
         0.5f,  0.5f, -0.5f, 0.0f, 1.0f, 0.0f, 1.0f, 0.0f, 0.0f, -1.0f,
         0.5f,  0.5f, -0.5f, 0.0f, 1.0f, 0.0f, 1.0f, 0.0f, 0.0f, -1.0f,
         -0.5f,  0.5f, -0.5f, 0.0f, 1.0f, 0.0f, 1.0f, 0.0f, 0.0f, -1.0f,
         -0.5f, -0.5f, -0.5f, 0.0f, 1.0f, 0.0f, 1.0f, 0.0f, 0.0f, -1.0f,

         -0.5f, -0.5f, -0.5f, 0.0f, 0.0f, 1.0f, 1.0f, -1.0f, 0.0f, 0.0f,
         -0.5f, -0.5f,  0.5f, 0.0f, 0.0f, 1.0f, 1.0f, -1.0f, 0.0f, 0.0f,
         -0.5f,  0.5f,  0.5f, 0.0f, 0.0f, 1.0f, 1.0f, -1.0f, 0.0f, 0.0f,
         -0.5f,  0.5f,  0.5f, 0.0f, 0.0f, 1.0f, 1.0f, -1.0f, 0.0f, 0.0f,
         -0.5f,  0.5f, -0.5f, 0.0f, 0.0f, 1.0f, 1.0f, -1.0f, 0.0f, 0.0f,
         -0.5f, -0.5f, -0.5f, 0.0f, 0.0f, 1.0f, 1.0f, -1.0f, 0.0f, 0.0f,

         0.5f, -0.5f, -0.5f, 1.0f, 1.0f, 0.0f, 1.0f, 1.0f, 0.0f, 0.0f,
         0.5f, -0.5f,  0.5f, 1.0f, 1.0f, 0.0f, 1.0f, 1.0f, 0.0f, 0.0f,
         0.5f,  0.5f,  0.5f, 1.0f, 1.0f, 0.0f, 1.0f, 1.0f, 0.0f, 0.0f,
         0.5f,  0.5f,  0.5f, 1.0f, 1.0f, 0.0f, 1.0f, 1.0f, 0.0f, 0.0f,
         0.5f,  0.5f, -0.5f, 1.0f, 1.0f, 0.0f, 1.0f, 1.0f, 0.0f, 0.0f,
         0.5f, -0.5f, -0.5f, 1.0f, 1.0f, 0.0f, 1.0f, 1.0f, 0.0f, 0.0f,
            -0.5f,  0.5f, -0.5f, 0.0f, 1.0f, 1.0f, 1.0f, 0.0f, 1.0f, 0.0f,
            0.5f,  0.5f, -0.5f, 0.0f, 1.0f, 1.0f, 1.0f, 0.0f, 1.0f, 0.0f,
            0.5f,  0.5f,  0.5f, 0.0f, 1.0f, 1.0f, 1.0f, 0.0f, 1.0f, 0.0f,
            0.5f,  0.5f,  0.5f, 0.0f, 1.0f, 1.0f, 1.0f, 0.0f, 1.0f, 0.0f,
            -0.5f,  0.5f,  0.5f, 0.0f, 1.0f, 1.0f, 1.0f, 0.0f, 1.0f, 0.0f,
            -0.5f,  0.5f, -0.5f, 0.0f, 1.0f, 1.0f, 1.0f, 0.0f, 1.0f, 0.0f,

            -0.5f, -0.5f, -0.5f, 1.0f, 0.0f, 1.0f, 1.0f, 0.0f, -1.0f, 0.0f,
            0.5f, -0.5f, -0.5f, 1.0f, 0.0f, 1.0f, 1.0f, 0.0f, -1.0f, 0.0f,
            0.5f, -0.5f,  0.5f, 1.0f, 0.0f, 1.0f, 1.0f, 0.0f, -1.0f, 0.0f,
            0.5f, -0.5f,  0.5f, 1.0f, 0.0f, 1.0f, 1.0f, 0.0f, -1.0f, 0.0f,
            -0.5f, -0.5f,  0.5f, 1.0f, 0.0f, 1.0f, 1.0f, 0.0f, -1.0f, 0.0f,
            -0.5f, -0.5f, -0.5f, 1.0f, 0.0f, 1.0f, 1.0f, 0.0f, -1.0f, 0.0f
    };
}

private float[] generatePyramidVertices() {
    return new float[] {
            -1.0f, -1.0f, -1.0f, 1.0f, 0.0f, 0.0f, 1.0f, 0.0f, -1.0f, 0.0f,
            1.0f, -1.0f, -1.0f, 1.0f, 0.0f, 0.0f, 1.0f, 0.0f, -1.0f, 0.0f,
            1.0f, -1.0f,  1.0f, 1.0f, 0.0f, 0.0f, 1.0f, 0.0f, -1.0f, 0.0f,
            1.0f, -1.0f,  1.0f, 1.0f, 0.0f, 0.0f, 1.0f, 0.0f, -1.0f, 0.0f,
            -1.0f, -1.0f,  1.0f, 1.0f, 0.0f, 0.0f, 1.0f, 0.0f, -1.0f, 0.0f,
            -1.0f, -1.0f, -1.0f, 1.0f, 0.0f, 0.0f, 1.0f, 0.0f, -1.0f, 0.0f,

            -1.0f, -1.0f, -1.0f, 0.0f, 1.0f, 0.0f, 1.0f, 0.0f, 0.0f, -1.0f,
            1.0f, -1.0f, -1.0f, 0.0f, 1.0f, 0.0f, 1.0f, 0.0f, 0.0f, -1.0f,
            0.0f,  1.0f,  0.0f, 0.0f, 1.0f, 0.0f, 1.0f, 0.0f, 0.0f, -1.0f,
            1.0f, -1.0f, -1.0f, 0.0f, 0.0f, 1.0f, 1.0f, 0.7071f, 0.7071f, 0.0f,
            1.0f, -1.0f,  1.0f, 0.0f, 0.0f, 1.0f, 1.0f, 0.7071f, 0.7071f, 0.0f,
            0.0f,  1.0f,  0.0f, 0.0f, 0.0f, 1.0f, 1.0f, 0.7071f, 0.7071f, 0.0f,

            1.0f, -1.0f,  1.0f, 1.0f, 1.0f, 0.0f, 1.0f, 0.0f, 0.0f, 1.0f,
            -1.0f, -1.0f,  1.0f, 1.0f, 1.0f, 0.0f, 1.0f, 0.0f, 0.0f, 1.0f,
            0.0f,  1.0f,  0.0f, 1.0f, 1.0f, 0.0f, 1.0f, 0.0f, 0.0f, 1.0f,

            -1.0f, -1.0f,  1.0f, 1.0f, 0.0f, 0.0f, 1.0f, -0.7071f, 0.7071f, 0.0f,
            -1.0f, -1.0f, -1.0f, 1.0f, 0.0f, 0.0f, 1.0f, -0.7071f, 0.7071f, 0.0f,
            0.0f,  1.0f,  0.0f, 1.0f, 0.0f, 0.0f, 1.0f, -0.7071f, 0.7071f, 0.0f
    };
}

private float[] generateRectangleVertices() {
    return new float[] {
            -1.0f, 0.0f, -1.0f, 0.5f, 0.5f, 0.5f, 1.0f, 0.0f, 1.0f, 0.0f,  // Bottom-left
            1.0f, 0.0f, -1.0f, 0.5f, 0.5f, 0.5f, 1.0f, 0.0f, 1.0f, 0.0f,   // Bottom-right
            1.0f, 0.0f,  1.0f, 0.5f, 0.5f, 0.5f, 1.0f, 0.0f, 1.0f, 0.0f,   // Top-right

            1.0f, 0.0f,  1.0f, 0.5f, 0.5f, 0.5f, 1.0f, 0.0f, 1.0f, 0.0f,   // Top-right
            -1.0f, 0.0f,  1.0f, 0.5f, 0.5f, 0.5f, 1.0f, 0.0f, 1.0f, 0.0f,  // Top-left
            -1.0f, 0.0f, -1.0f, 0.5f, 0.5f, 0.5f, 1.0f, 0.0f, 1.0f, 0.0f   // Bottom-left
    };
}

private float[] generateChessboardVertices() {
    float[] vertices = new float[540];
```

```
int index = 0;

float size = 1.0f;
float offset = 1.5f;

for (int z = 0; z < 3; z++) {
    for (int x = 0; x < 3; x++) {
        float posX = x * size - offset;
        float posY = 0.0f;
        float posZ = z * size - offset;

        float r = ((x + z) % 2 == 0) ? 1.0f : 0.0f;
        float g = ((x + z) % 2 == 0) ? 1.0f : 0.0f;
        float b = ((x + z) % 2 == 0) ? 1.0f : 0.0f;
        float a = 1.0f;

        float nx = 0.0f;
        float ny = 1.0f;
        float nz = 0.0f;

        vertices[index++] = posX;
        vertices[index++] = posY;
        vertices[index++] = posZ;
        vertices[index++] = r;
        vertices[index++] = g;
        vertices[index++] = b;
        vertices[index++] = a;
        vertices[index++] = nx;
```

```
vertices[index++] = ny;
vertices[index++] = nz;

vertices[index++] = posX + size;
vertices[index++] = posY;
vertices[index++] = posZ;
vertices[index++] = r;
vertices[index++] = g;
vertices[index++] = b;
vertices[index++] = a;
vertices[index++] = nx;
vertices[index++] = ny;
vertices[index++] = nz;

vertices[index++] = posX + size;
vertices[index++] = posY;
vertices[index++] = posZ + size;
vertices[index++] = r;
vertices[index++] = g;
vertices[index++] = b;
vertices[index++] = a;
vertices[index++] = nx;
vertices[index++] = ny;
vertices[index++] = nz;

vertices[index++] = posX;
vertices[index++] = posY;
vertices[index++] = posZ;
vertices[index++] = r;
```

```
    vertices[index++] = g;
    vertices[index++] = b;
    vertices[index++] = a;
    vertices[index++] = nx;
    vertices[index++] = ny;
    vertices[index++] = nz;

    vertices[index++] = posX + size;
    vertices[index++] = posY;
    vertices[index++] = posZ + size;
    vertices[index++] = r;
    vertices[index++] = g;
    vertices[index++] = b;
    vertices[index++] = a;
    vertices[index++] = nx;
    vertices[index++] = ny;
    vertices[index++] = nz;

    vertices[index++] = posX;
    vertices[index++] = posY;
    vertices[index++] = posZ + size;
    vertices[index++] = r;
    vertices[index++] = g;
    vertices[index++] = b;
    vertices[index++] = a;
    vertices[index++] = nx;
    vertices[index++] = ny;
    vertices[index++] = nz;
}
```

```
        }

        return vertices;
    }

    @Override
    public boolean onCreateOptionsMenu(Menu menu) {
        menu.add(0, MainActivity.MENU_ITEM_SCENE_CUBES, 0, "Cubes");
        menu.add(0, MainActivity.MENU_ITEM_SCENE_PYRAMID, 0, "Pyramid");
        menu.add(0, MainActivity.MENU_ITEM_SCENE_DIFFUSE, 0, "Diffuse");
        menu.add(0, MainActivity.MENU_ITEM_SCENE_SPECULAR, 0, "Specular");
        return true;
    }

    @Override
    public boolean onOptionsItemSelected(MenuItem item) {
        super.setTitle(item.getTitle());

        switch (item.getItemId()) {
            case MainActivity.MENU_ITEM_SCENE_CUBES:
                Framework.getInstance().loadScene(this.cubesScene);
                return true;
            case MainActivity.MENU_ITEM_SCENE_PYRAMID:
                Framework.getInstance().loadScene(this.pyramidScene);
                return true;
            case MainActivity.MENU_ITEM_SCENE_DIFFUSE:
                Framework.getInstance().loadScene(this.diffuseScene);
                return true;
            case MainActivity.MENU_ITEM_SCENE_SPECULAR:
                Framework.getInstance().loadScene(this.specularScene);
                return true;
            default:
                return super.onOptionsItemSelected(item);
        }
    }
}
```

ВИСНОВКИ

У процесі виконання лабораторної роботи №4 створено застосунок Lab4_GLES із чотирма режимами роботи: рендеринг чотирикутника з дифузним і дзеркальним освітленням, піраміди з повною моделлю Фонга та обертанням над шаховим полем, а також решітки з 27 кубів із динамічним керуванням камерою. У кожному режимі реалізовано моделювання освітлення з урахуванням фонової, дифузної та дзеркальної складових, інтерактивність – переміщення джерела світла сенсором, зміна ракурсу сцени, а також налагодження програми на емуляторі й фізичному пристрої Android.

Виконання завдань дало змогу опанувати принципи моделювання освітлення в OpenGL ES, зокрема використання моделі Фонга, обчислення векторів світла й відбиття, а також програмування шейдерів для створення реалістичних ефектів. Робота поглибила розуміння тривимірної графіки та дозволила здобути практичні навички, досягнувши мети – оволодіння техніками програмування освітлення.