documentatie.md

Balls project

Conceptul proiectului

Pentru acest proiect am ales să creăm o animație 2D care implică bile în mișcare, cu ajutorul OpenGL. Am ales această idee pentru că este dinamică și plăcută vizual. Inițial animația începe cu o singură bilă ce se mișcă aleator în chenarul desenat, iar la numărul de coliziuni setat, aceasta se divide în două bile mai mici, acest procedeu repetându-se pentru fiecare bilă până se atinge raza minimă, setată la început. Am urmărit obținerea unei simulări interactive a mișcării și coliziunilor, evidențiind conceptele de fizică, matematică și grafică.

Transformări incluse

În cadrul proiectului am folosit o compunere de translație și scalare pentru a diviza bilele și a realiza mișcarea acestora cu o anumită viteză.

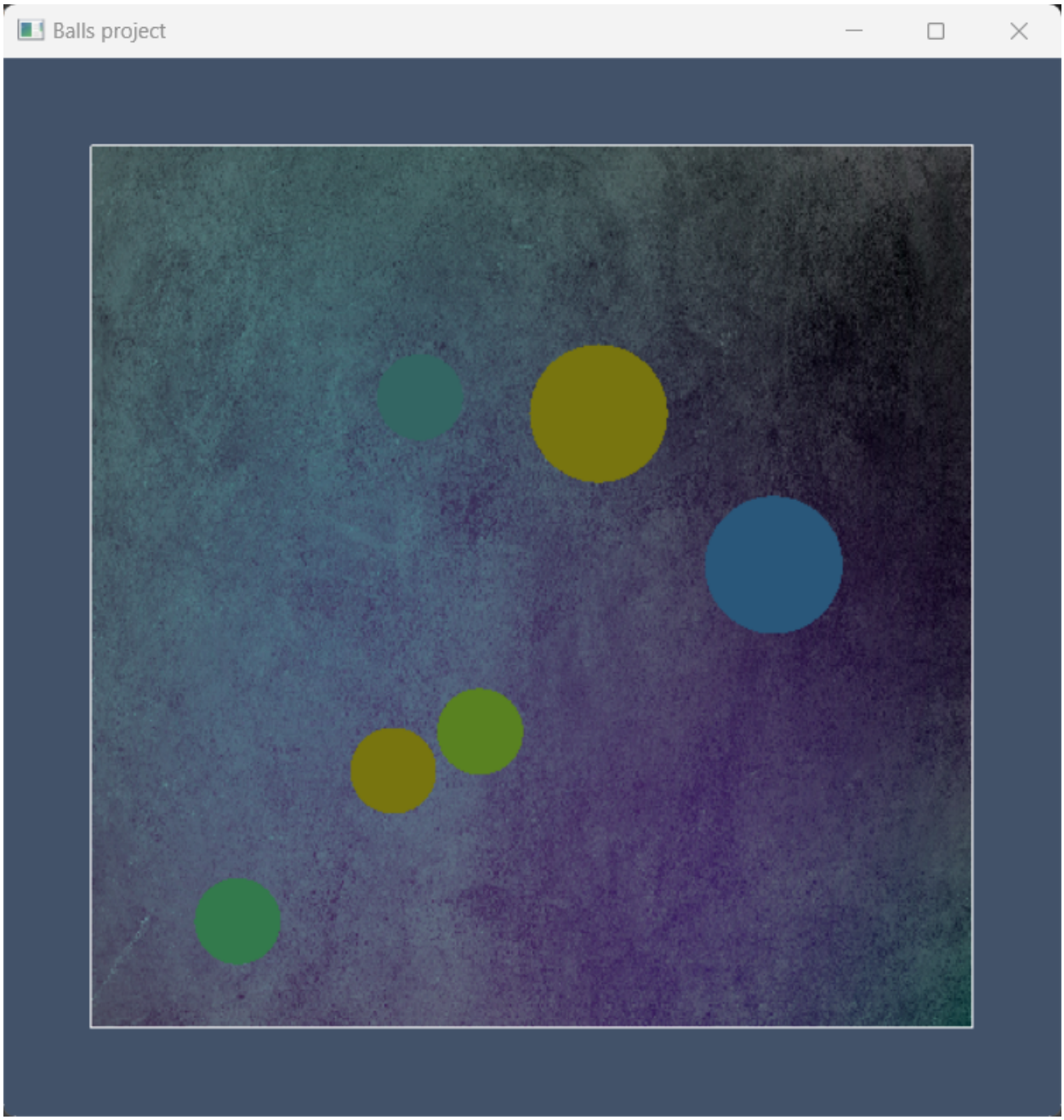
Bilele se mișcă într-un spațiu 2D și se ciocnesc unele cu altele și cu marginile ferestrei, respectând legile conservării impulsului și a energiei cinetice. La coliziuni, vitezele bilelor sunt calculate în funcție de masele lor pentru a asigura o coliziune elastică. Dacă o bilă a suferit un număr specific de coliziuni, se poate diviza în două bile mai mici, fiecare cu o nouă direcție de mișcare.

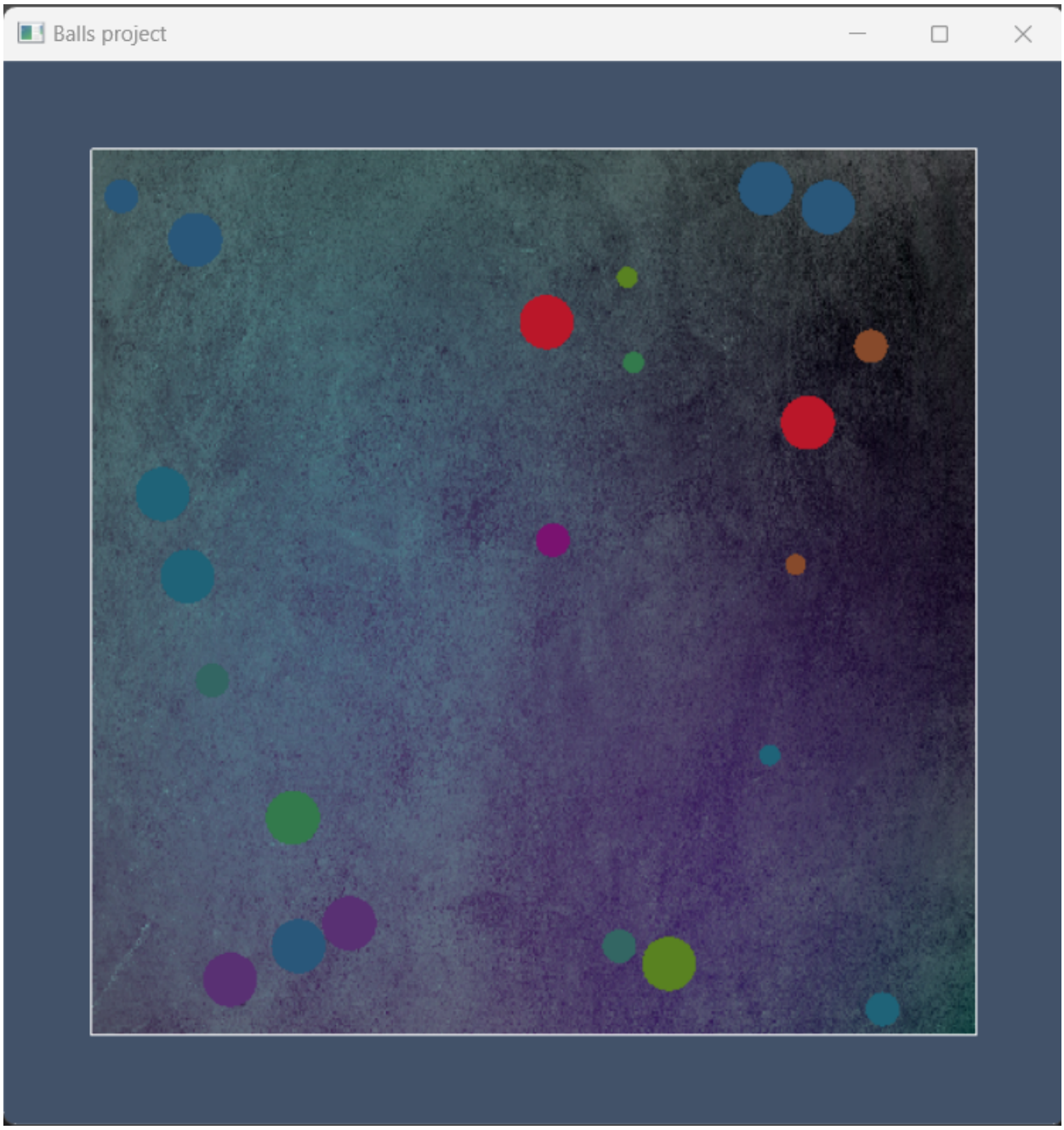
Utilizatorul poate configura inițial viteza și dimensiunea bilelor, precum și numărul maxim de coliziuni înainte de divizare. De asemenea, animația rulează cu o limitare a rate-ului de cadre (60 cadre pe secundă) pentru o experiență uniformă pe diferite sisteme.

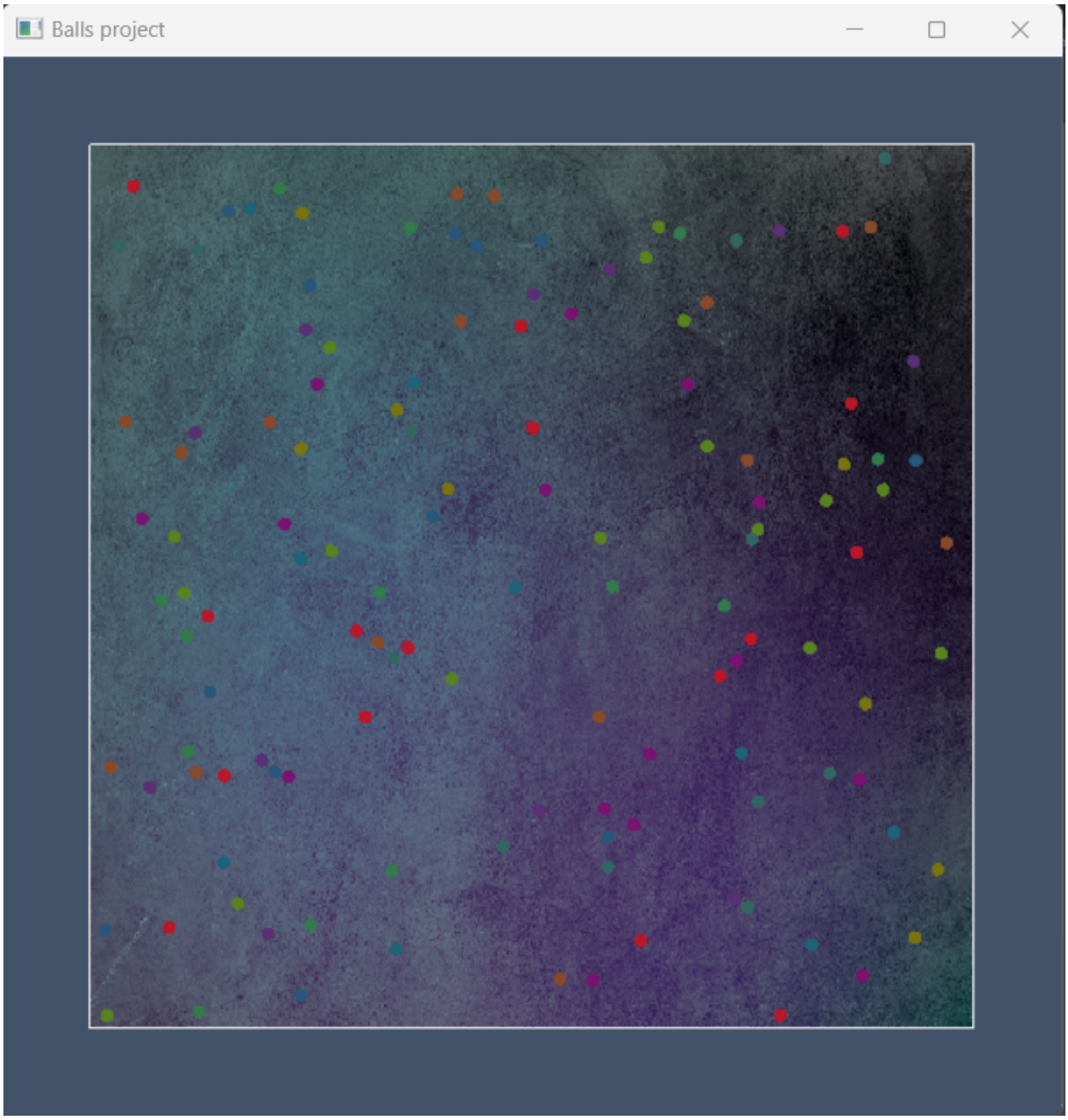
Originalitate

Proiectul este original prin modul în care combină concepte de fizică și matematică pentru a crea o simulare interactivă și captivantă a mișcării bilelor. Printre aspectele originale utilizate în proiect se numără interacțiunea realistă a bilelor, rate-ul de cadre stabilizat, divizarea bilelor și configurabilitatea inițială.

Capturi de ecran relevante




Balls project



Componența echipei

- Airinei Andrei (352) – coliziuni și mișcare a bilelor, limitare a numărului de cadre pe secundă
- Bănilean Alexandru (352) – chenar, desenarea și divizarea unei bile, shadere și texturi

Cod sursă

https://github.com/alexbanilean/BallsProjectOpenGL

Anexa 1 – main.cpp

```
#include <iostream>
#include <vector>
#include <time.h>
#include <windows.h>
#include <stdlib.h>
#include <stdio.h>
#include <GL/glew.h>
#include <GL/freeglut.h>
#include "loadShaders.h"
#include "glm/glm.hpp"
#include "glm/gtc/matrix_transform.hpp"
#include "glm/gtx/transform.hpp"
#include "glm/gtc/type_ptr.hpp"
#include "SOIL.h"

GLuint
VaoId,
VboId,
EboId,
DboId,
ColorBufferId,
ProgramId,
ProgramId2,
myMatrixLocation,
texture,
codColLocation,
colorLocation;

glm::mat4
myMatrix, resizeMatrix;

float xMin = -300.f, xMax = 300.f, yMin = -300.f, yMax = 300.f;
const float PI = 3.1415926;

/* Bounding box */
const glm::vec2 BOX_MIN(-250, -250);
const glm::vec2 BOX_MAX(250, 250);

/*
        Initial configuration
        - play around with these
        - consider that if the maximal area of the objects is close to the area
          of the rectagle your computer will have a bad time
*/
const float INITIAL_SIZE = 100.0f;
const float INITIAL_VELOCITY = 3.0f;
const int MAX_BOUNCES = 8;
const float DECREASE_AMOUNT = 1.6f;
const float MIN_BALL_SIZE = 4.0f;

int codCol;
```

```
std::vector<glm::vec4> possibleColors = {
        glm::vec4(0.2f, 0.48f, 0.3f, 1.0f),
        glm::vec4(0.53f, 0.29f, 0.17f, 1.0f),
        glm::vec4(0.35f, 0.51f, 0.13f, 1.0f),
        glm::vec4(0.35f, 0.19f, 0.45f, 1.0f),
        glm::vec4(0.16f, 0.34f, 0.48f, 1.0f),
        glm::vec4(0.12f, 0.39f, 0.47f, 1.0f),
        glm::vec4(0.48f, 0.07f, 0.44f, 1.0f),
        glm::vec4(0.47f, 0.46f, 0.06f, 1.0f),
        glm::vec4(0.73f, 0.09f, 0.16f, 1.0f),
        glm::vec4(0.20f, 0.40f, 0.39f, 1.0f),
};

class Ball {
public:
        static std::vector<Ball> balls;
        static std::vector<Ball> new_balls;

        glm::vec2 position;
        glm::vec2 velocity;
        glm::vec4 color;
        float size;
        int bounceCount;

        bool operator==(const Ball& other) const {
                return position == other.position &&
                        velocity == other.velocity &&
                        color == other.color &&
                        size == other.size &&
                        bounceCount == other.bounceCount;
        }

private:
        /*
                Elastic collisions of randomized object are slighty impredictiabl
                This computes the reflection of walls as well as pulling the ball
        */
        void WallCollisionCheck() {
                if (position.x - size < BOX_MIN.x) {
                        velocity.x = -velocity.x;
                        position.x = BOX_MIN.x + size;
                        bounceCount++;
                }
                else if (position.x + size > BOX_MAX.x) {
                        velocity.x = -velocity.x;
                        position.x = BOX_MAX.x - size;
                        bounceCount++;
                }

                if (position.y - size < BOX_MIN.y) {
                        velocity.y = -velocity.y;
                        position.y = BOX_MIN.y + size;
                        bounceCount++;
```

```
        }
        else if (position.y + size > BOX_MAX.y) {
                velocity.y = -velocity.y;
                position.y = BOX_MAX.y - size;
                bounceCount++;
        }
}

void Split() {
        if (size > MIN_BALL_SIZE) {
                size /= DECREASE_AMOUNT;
                Ball newBall = *this;

                float randomAngle = static_cast<float>(std::rand()) / RAN
                glm::vec2 dir(std::cos(randomAngle), std::sin(randomAngle

                newBall.velocity = dir * glm::length(velocity);
                this->velocity = -dir * glm::length(velocity);

                color = possibleColors[rand() % possibleColors.size()];
                newBall.color = possibleColors[rand() % possibleColors.si

                float separationDistance = size;
                this->position += dir * separationDistance;
                newBall.position -= dir * separationDistance;

                this->bounceCount = 0;
                newBall.bounceCount = 0;

                balls.push_back(newBall);
        }
}

static void HandleCollisions() {
        for (size_t i = 0; i < balls.size(); ++i) {
                for (size_t j = i + 1; j < balls.size(); ++j) {
                        Ball& ball1 = balls[i];
                        Ball& ball2 = balls[j];

                        glm::vec2 diff = ball2.position - ball1.position;
                        float distance = glm::length(diff);
                        float radiusSum = ball1.size + ball2.size;

                        /* Check for collision */
                        if (distance < radiusSum) {
                                /* Calculate elastic collision response *
                                ElasticCollision(ball1, ball2, diff, dist
                        }
                }
        }
}
```

```
        /*
                WARNING physics part
                This functions calculates perfect elastic collision
                of 2 objects using conservation of kinetic energy and momentum
        */
        static void ElasticCollision(Ball& ball1, Ball& ball2, const glm::vec2& d
                float mass1 = PI * ball1.size * ball1.size;
                float mass2 = PI * ball2.size * ball2.size;
                float totalMass = mass1 + mass2;

                glm::vec2 normal = glm::normalize(diff);
                glm::vec2 tangent(-normal.y, normal.x);

                float dotNormal1 = glm::dot(normal, ball1.velocity);
                float dotNormal2 = glm::dot(normal, ball2.velocity);
                float dotTangent1 = glm::dot(tangent, ball1.velocity);
                float dotTangent2 = glm::dot(tangent, ball2.velocity);

                glm::vec2 tangentVelocity1 = tangent * dotTangent1;
                glm::vec2 tangentVelocity2 = tangent * dotTangent2;

                float newDotNormal1 = (dotNormal1 * (mass1 - mass2) + 2 * mass2 *
                float newDotNormal2 = (dotNormal2 * (mass2 - mass1) + 2 * mass1 *

                glm::vec2 newNormalVelocity1 = normal * newDotNormal1;
                glm::vec2 newNormalVelocity2 = normal * newDotNormal2;

                ball1.velocity = newNormalVelocity1 + tangentVelocity1;
                ball2.velocity = newNormalVelocity2 + tangentVelocity2;

                /* Move balls apart if they're overlapping to prevent sticking */
                float overlap = (ball1.size + ball2.size) - distance;
                if (overlap > 0) {
                        glm::vec2 separation = normal * overlap;
                        ball1.position -= separation * (mass2 / totalMass);
                        ball2.position += separation * (mass1 / totalMass);
                }

                ball1.bounceCount++;
                ball2.bounceCount++;
        }

        auto inline get_position() const
        {
                return glm::translate(glm::mat4(1.0f), glm::vec3(position.x, posi
        }
        auto inline get_scale() const
        {
                return glm::scale(glm::mat4(1.0f), glm::vec3(size, size, 1.0f));
        }
public:

        void Update() {
```

```
                /* Update position */
                position += velocity;

                WallCollisionCheck();

                /* Check for split condition */
                if (bounceCount >= MAX_BOUNCES) {
                        Split();
                }
        }

        auto inline transform() const
        {
                return get_position() * get_scale();
        }

        static inline void SceneUpdate()
        {
                HandleCollisions();
                const int cnt = balls.size();
                /* Ensure we only call update on the balls we have, and don't rec
                for (int i = 0; i < cnt; i++)
                        balls[i].Update();
        }
};

std::vector<Ball> Ball::balls;
std::vector<Ball> Ball::new_balls;

void LoadTexture(const char* photoPath)
{
        glGenTextures(1, &texture);
        glBindTexture(GL_TEXTURE_2D, texture);

        glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_S, GL_CLAMP_TO_EDGE);
        glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_T, GL_CLAMP_TO_EDGE);

        glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
        glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);

        int width, height;
        unsigned char* image = SOIL_load_image(photoPath, &width, &height, 0, SOI

        if (!image) {
                std::cerr << "Error loading image: " << SOIL_last_result() << "\n
                return;
        }

        glTexImage2D(GL_TEXTURE_2D, 0, GL_RGB, width, height, 0, GL_RGB, GL_UNSIG
        glGenerateMipmap(GL_TEXTURE_2D);

        SOIL_free_image_data(image);
        glBindTexture(GL_TEXTURE_2D, 0);
```

```
}


void CreateVBO(void)
{
        GLfloat Vertices[] = {
                BOX_MIN.x, BOX_MIN.y,  0.0f,  1.0f,   1.0f, 1.0f, 1.0f,   0.0f, 0
                BOX_MAX.x, BOX_MIN.y,  0.0f,  1.0f,   1.0f, 1.0f, 1.0f,   1.0f, 0
                BOX_MAX.x, BOX_MAX.y,  0.0f,  1.0f,   1.0f, 1.0f, 1.0f,   1.0f, 1
                BOX_MIN.x, BOX_MAX.y,  0.0f,  1.0f,   1.0f, 1.0f, 1.0f,   0.0f, 1
        };

        /* Indices for vertex order */
        static const GLuint Indices[] =
        {
                0, 1, 2, 3,
                0, 1, 2, 0, 3, 2
        };

        /* Generate circle vertices */
        std::vector<GLfloat> CircleVertices;
        for (int ii = 0; ii < 180; ii++) {
                float theta = 2.0f * PI * float(ii) / float(180);
                float x = cosf(theta);
                float y = sinf(theta);
                CircleVertices.push_back(x);
                CircleVertices.push_back(y);
        }

        /* Bind VAO(Vertex Array Object) */
        glGenVertexArrays(1, &VaoId);

        /* Common buffer for vertices - coordinates, colors and texture coordinat

        glGenBuffers(1, &VboId);
        glBindBuffer(GL_ARRAY_BUFFER, VboId);
        glBufferData(GL_ARRAY_BUFFER, sizeof(Vertices), Vertices, GL_STATIC_DRAW)

        /* Indices buffer */
        glGenBuffers(1, &EboId);
        glBindBuffer(GL_ELEMENT_ARRAY_BUFFER, EboId);
        glBufferData(GL_ELEMENT_ARRAY_BUFFER, sizeof(Indices), Indices, GL_STATIC

        /* Circle vertices buffer */
        glGenBuffers(1, &DboId);
        glBindBuffer(GL_ARRAY_BUFFER, DboId);
        glBufferData(GL_ARRAY_BUFFER, sizeof(GLfloat) * CircleVertices.size(), &C

}

void DestroyVBO(void)
{
        glDisableVertexAttribArray(1);
```

```
	glDisableVertexAttribArray(0);

	glBindBuffer(GL_ARRAY_BUFFER, 0);
	glDeleteBuffers(1, &VboId);
	glDeleteBuffers(1, &EboId);
	glDeleteBuffers(1, &DboId);

	glBindVertexArray(0);
	glDeleteVertexArrays(1, &VaoId);
}

void CreateShaders(void)
{
	ProgramId = LoadShaders("rectangle.vert", "rectangle.frag");
	ProgramId2 = LoadShaders("circles.vert", "circles.frag");
	glUseProgram(ProgramId);
}

void DestroyShaders(void)
{
	glDeleteProgram(ProgramId);
	glDeleteProgram(ProgramId2);
}

void Initialize(void)
{
	/* Screen background color */
	glClearColor(0.26f, 0.32f, 0.41f, 1.0f);

	CreateVBO();
	CreateShaders();

	/* Bind texture */
	LoadTexture("background_texture.png");
	glActiveTexture(GL_TEXTURE0);
	glBindTexture(GL_TEXTURE_2D, texture);

	myMatrixLocation = glGetUniformLocation(ProgramId, "myMatrix");
	codColLocation = glGetUniformLocation(ProgramId, "codCol");
	resizeMatrix = glm::ortho(xMin, xMax, yMin, yMax);

	/* Create initial ball */
	Ball ball;
	ball.position = glm::vec2(0.0f, 0.0f);

	float randomAngle = static_cast<float>(std::rand()) / RAND_MAX * 2 * PI;
	glm::vec2 dir(std::cos(randomAngle), std::sin(randomAngle));

	ball.velocity = dir * INITIAL_VELOCITY;
	ball.color = possibleColors[2];
	ball.size = INITIAL_SIZE;
	ball.bounceCount = 0;
	Ball::balls.push_back(ball);
```

```
}

void RenderFunction(void)
{
        glClear(GL_COLOR_BUFFER_BIT);

        /* Compute transformation matrix and send it to shader*/
        myMatrix = resizeMatrix;
        glUniformMatrix4fv(myMatrixLocation, 1, GL_FALSE, &myMatrix[0][0]);

        /* Bind buffers and load data */
        glBindBuffer(GL_ARRAY_BUFFER, VboId);
        glBindBuffer(GL_ELEMENT_ARRAY_BUFFER, EboId);

        glEnableVertexAttribArray(0);
        glVertexAttribPointer(0, 4, GL_FLOAT, GL_FALSE, 9 * sizeof(GLfloat), (GLv
        glEnableVertexAttribArray(1);
        glVertexAttribPointer(1, 3, GL_FLOAT, GL_FALSE, 9 * sizeof(GLfloat), (GLv
        glEnableVertexAttribArray(2);
        glVertexAttribPointer(2, 2, GL_FLOAT, GL_FALSE, 9 * sizeof(GLfloat), (GLv

        /* Send color to shader */
        glUniform1i(glGetUniformLocation(ProgramId, "backgroundTexture"), 0);

        /* Activate texture in shader */
        codCol = 1;
        glUniform1i(codColLocation, codCol);

        /* Draw the rectangle */
        glDrawElements(GL_POLYGON, 4, GL_UNSIGNED_INT, (void*)(0));

        codCol = 0;
        glUniform1i(codColLocation, codCol);

        glDrawElements(GL_LINE_LOOP, 4, GL_UNSIGNED_INT, (void*)(0));

        /* Bind the circle shader */
        glUseProgram(ProgramId2);
        myMatrixLocation = glGetUniformLocation(ProgramId2, "myMatrix");
        colorLocation = glGetUniformLocation(ProgramId2, "circleColor");

        /* Balls rendering */
        for (const Ball& ball : Ball::balls) {
                /* Compute transformation matrix and send it to shader*/
                myMatrix = resizeMatrix * ball.transform();
                glUniformMatrix4fv(myMatrixLocation, 1, GL_FALSE, &myMatrix[0][0]

                /* Send color to shader */
                glUniform4f(colorLocation, ball.color[0], ball.color[1], ball.col

                /* Bind the circle buffer */
                glBindBuffer(GL_ARRAY_BUFFER, DboId);
                glEnableVertexAttribArray(0);
```

```
                glVertexAttribPointer(0, 2, GL_FLOAT, GL_FALSE, 0, NULL);

                /* Draw the circle */
                glDrawArrays(GL_TRIANGLE_FAN, 0, 180);
        }

        /* Bind the rectangle shader */
        glUseProgram(ProgramId);
        myMatrixLocation = glGetUniformLocation(ProgramId, "myMatrix");
        codColLocation = glGetUniformLocation(ProgramId, "codCol");

        /* Update the scene */
        Ball::SceneUpdate();

        glutSwapBuffers();
        glFlush();
}

void Cleanup(void)
{
        DestroyShaders();
        DestroyVBO();
}

void TimerFunction(int value)
{
        /*
                Fix 60 fps since computation is done on every frame we want it to
                similar on different speed machine and don't consume excesive CPU
        */
        glutPostRedisplay();
        glutTimerFunc(1000 / 120, TimerFunction, 0);
}

int main(int argc, char* argv[])
{
        /* Initialize random seed */
        srand(static_cast<unsigned>(time(nullptr)));

        glutInit(&argc, argv);
        glutInitDisplayMode(GLUT_DOUBLE | GLUT_RGB);
        glutInitWindowSize(600, 600);
        glutInitWindowPosition(400, 100);
        glutCreateWindow("Balls project");

        glewInit();

        /* Register the timer function */
        glutTimerFunc(0, TimerFunction, 0);
        Initialize();
        glutDisplayFunc(RenderFunction);
        glutCloseFunc(Cleanup);
```

```
        glutMainLoop();
}
```

Anexa 2 - rectangle.vert

```
#version 330 core

/* Coordinates */
layout (location = 0) in vec4 in_Position;
/* Colors */
layout (location = 1) in vec4 in_Color;
/* Texture coordinates */
layout (location = 2) in vec2 texCoord;


/* Updated position */
out vec4 gl_Position;
/* Send to rectangle.frag */
out vec4 ex_Color;
out vec2 tex_Coord;

/* Uniform variable */
uniform mat4 myMatrix;

void main(void)
{
    gl_Position = myMatrix * in_Position;
    ex_Color = in_Color;
    tex_Coord = vec2(texCoord.x, 1-texCoord.y);
}
```

Anexa 3 - rectangle.frag

```
#version 330 core

in vec4 ex_Color;
in vec2 tex_Coord;

/* Updated color */
out vec4 out_Color;

/* Uniform variables */
uniform vec4 circleColor;
uniform sampler2D backgroundTexture;
uniform int codCol;

void main(void)
{
```

```
    switch(codCol)
        {
                case 0:
                        out_Color = ex_Color;
                        break;
                case 1:
                        out_Color = texture(backgroundTexture, tex_Coord);
                        break;
                default:
                        break;
        }
}
```

Anexa 4 - circles.vert

```
#version 330 core

/* Coordinates from button */
layout (location = 0) in vec4 in_Position;

/* Updated position */
out vec4 gl_Position;

/* Uniform variable */
uniform mat4 myMatrix;

void main(void)
{
    gl_Position = myMatrix * in_Position;
}
```

Anexa 5 - circles.vert

```
#version 330 core

/* Updated color */
out vec4 out_Color;

/* Uniform variable */
uniform vec4 circleColor;

void main(void)
{
    out_Color = circleColor;
}
```