Politechnika Śląska
Wydział Informatyki, Elektroniki i Informatyki

Computer Programming

«Pool 2D»

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lab group	section 2
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1. Task

Assignment 109

Pool in 2D. Write a program simulating the movement of balls in a 2D billiard game. Results should be presented as an animation (use the Allegro library). Details to discuss.

2. Analysis of the problem

2.1 Data structures:

Most of the data, like initial locations of balls is hard-coded in constant size arrays. Pointers to balls and their textures are stored in dynamic vectors for the purpose of ease of iterating through them using range based for loops.

2.2 Physics of balls:

For calculation of position balls are represented as points moving through 2D space with some velocity and constant deceleration due to friction. For checking of collisions each ball is assumed to have the same diameter of 28 pixels and equal masses (then they can be omitted when calculating velocities after the collision). Each collision is assumed to be perfectly elastic (kinetic energy and momentum are conserved). For the simulation to be run in real time the temporal resolution is variable and dependent on the time that it took to render previous frame. This approach requires small corrections of positions of balls during, resulting from too high time difference, to be resolved locally, by calculating exact time of collision, position of balls at the collision and change in velocities for this exact moment and then positions of balls at the initial time of calculation, effectively going back and forth in time. Another approach basing on finding and aggregating those critical points in time and then calculating state of the system in each one of them, in addition to regular time steps, could result in speed ramp effect (speed of the animation going up and down) when displayed at constant refresh rate. Second approach would provide more accurate simulation, but it would also require post processing compensating high differences in time differences between frames, which makes it unfeasible to use in real time game.

2.3 Pool rules:

There are 16 balls - cue ball (white), eighth ball (black), seven solid colored balls and seven striped ones. Initially all of the balls except cue ball are set up in triangle on the table. There are two players involved. Player 1. begins with "break shot" scattering the balls on the table. First ball pocketed after the break shot decides who plays with solids and who plays with stripes. On the beginning of each turn player sets the direction in which he wants to move the ball by moving the cue, then he decides how hard he wants to strike it using power bar on the right. If player succeeds to pocket his ball he gets another turn unless he also commits a foul. Foul is committed when: player fails to strike his own ball first, no ball hits the cushion, cue ball doesn't hit any other ball or cue ball is pocketed. Committing foul allows the opponent to move the cue ball in the beginning of his next turn.

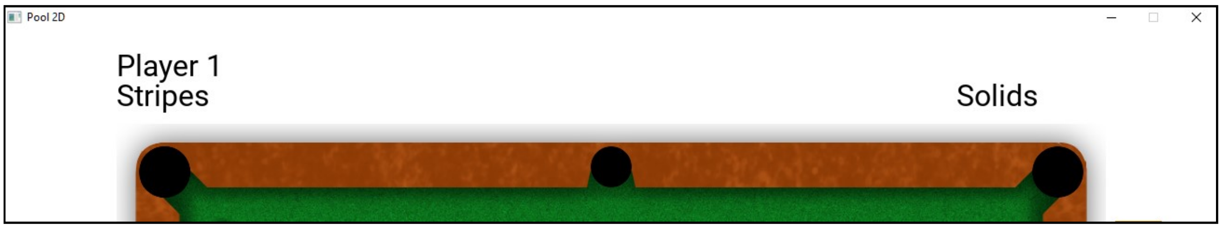
Pocketing black ball after "break shot" ends the game. If player pocketing it has previously pocketed all of his balls and doesn't commit a foul he wins.

3. External specification

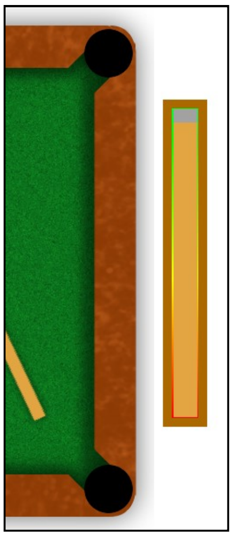
3.1 Running the program:

This is GUI program working in MS Windows operating system. For the program to function correctly *.dll libraries provided in github repository should be located in the same directory as executable file, or in location included in PATH environmental variable and the graphics should be located in gfx subdirectory. The game can be either launched through Windows Explorer or through the command line, when user wants more insight when the program doesn't work properly. In case of some known failure during startup of the program appropriate message is displayed on console output.

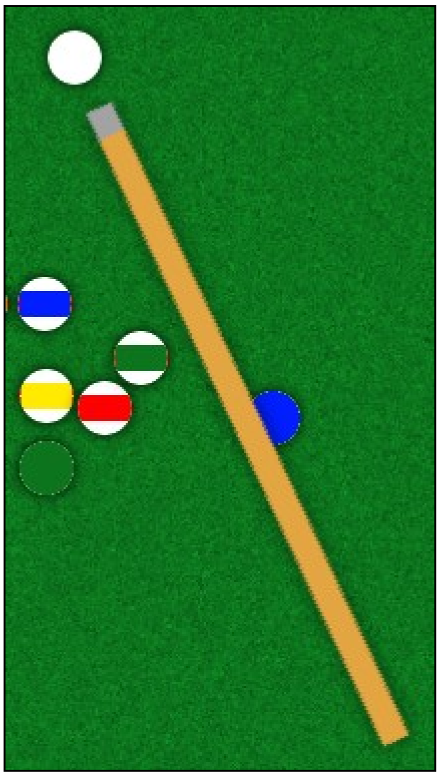
3.2 Game interface:



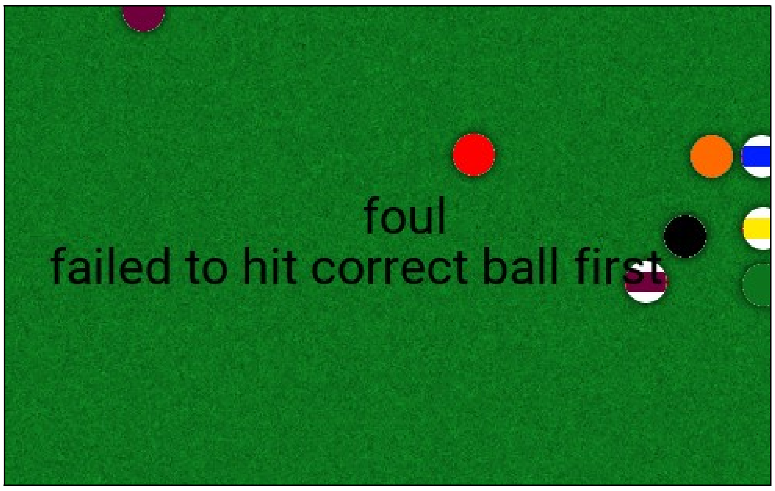
Above the table there is indicator whose turn it is now, along with their ball type if assigned



On the right of the table there is a powerbar - it is used to set how hard cue ball will be striked, it can be adjusted either by dragging it or up/down arrows

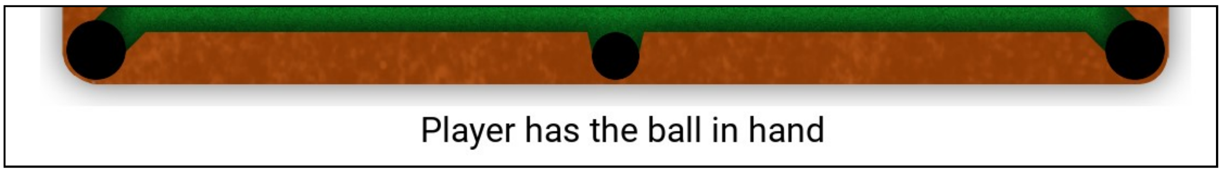


Cue and cue ball - position of cue relative to the ball determines the direction where cue ball will go when hit by cue. The cue can be either dragged around white ball using mouse or moved using left/right arrows. To launch the ball after setting the direction and force Player should press spacebar



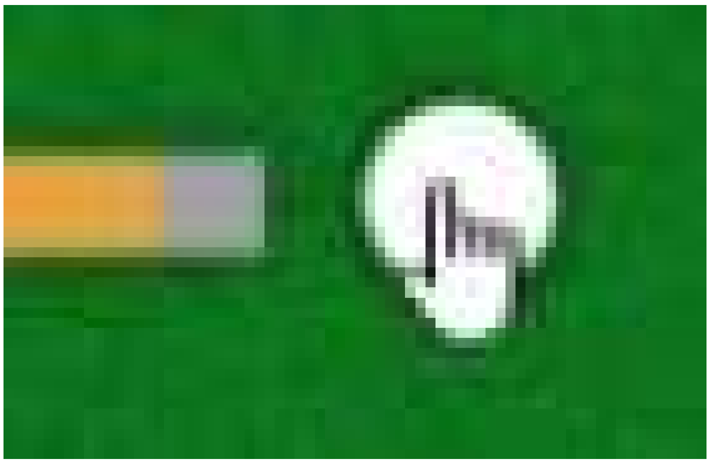
foul
failed to hit correct ball first

When a foul is committed, there is a message displayed on the middle of the screen along with the justification.

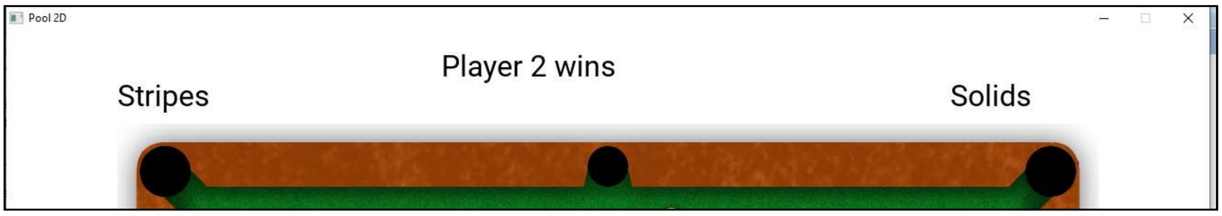


Player has the ball in hand

When one of the players commits a foul the other player has the ball in hand, which means he can move it.



Each object that can be moved using mouse causes mouse pointer hovering over it to change shape



Once the game is over player indicators are replaced by winner indicator. Program stops reacting to any input besides window controls and needs to be restarted for a new game.

4. Internal specification

The program is implemented with OOP paradigm. WinMain function creates new object of class Game and calls it's method run, containing main game loop.

Game

Game- main class of the program

constructor - initializes SDL, loads textures, creates balls, bands and text messages;
run - here is placed main loop of the program. In each iteration SDL events are processed by Game::handle_events function, then game elements are rendered by function Game::render and time elapsed from previous iteration is calculated, it is then used to hide timeouted text fields and to perform physics calculations. After updating positions and speeds of the balls there are performed checks if: ball has been pocketed or all of the balls have stopped, then the actions are taken according to the rules of pool. Next there are performed checks for collisions between balls and balls with bands and correct changes of speeds applied. Collisions with bands and first ball hit by cue ball are remembered, as it is important for determining if the foul has or has not been committed. After this, if black ball has been pocketed program decides who has won the game, after that game goes into "END" state and reacts only to window controlls. Otherwise the program decides whose turn is next based on information if current player has pocketed at least one of his balls and if he committed a foul.
destructor - takes care of destroying textures and proper release of SDL resources for the program to finish gracefully
state variable of enumerative type: WAITING - waiting for players interaction, MOVING_BALL - player moves the ball right now , MOVING_CUE - player moves the ball right now, SETTING_POWER - player

sets the power of the strike, ROLLING - balls are in move, all interactions are checked, END - the game is over, program doesn't react to any interaction beside window controls.
There are also variables used to track if the rules of Poll are being followed, who should play in given moment, with which balls and who wins the game. They are described in the appendix.

Segment

Class Segment represents mathematical segment and is used to describe boundaries of the pool table.
Constructor of class Segment takes as arguments coordinates of initial point and terminal point, they are then converted to length of the segment, initial point and direction vector of the segment.
Segment::check_collision indicates if the ball has collided with given boundary by checking if parts of the vector between initial point of segment and position of given ball parallel to direction and normal vector of segment are less than: length of segment and radius of ball.

TextField

Class TextField is responsible for rendering text on screen.
Constructor takes as arguments: pointer to rendering context, text to be rendered, pointer to font that shall be used, coordinates of top left corner. Using this data the texture containing given text written in given font is generated. Rest of information is stored for future use. Text field is by default hidden and doesn't time out.
TextField::setTimeout is used to set value of timeout in milliseconds, -1 means that text field will never time out
TextField::hide and TextField::show are responsible for changing visibility of the text field
function draw renders displays text on screen and decreases time on screen by dt given in argument

Ball

Class Ball represents basic billiard ball, stores its id(balls in pool are numbered), position and velocity as well as flags describing state of the ball: ball is on table, ball is moving, ball has hit band in this turn.
constructor just initializes values
Ball::update changes position and velocity according to time difference dt given in argument
Ball::draw renders ball in correct place, pointer r is used to obtain rendering context
Ball::collide apply position and velocity changes resulting from collisions with bands and other balls
Ball::check_for_pocket checks if the ball has fallen into any of the pockets and if so, invokes method reacting to this event
Ball::pocket removes ball form the table

CueBall

class CueBall is derived from class Ball
constructor call base class constructor with coordinates and id 0 and initializes flag movable to be false
flag movable is set when player can move the ball
CueBall::move is used to change balls position if it is movable
CueBall::strike forces change of balls velocity

Other classes

classes EightBall, Solid and Stripe are classes derived from Ball mainly for the purpose of identifying them during game using RTTI. EightBall has also modified constructor, because it's id is always 8

5. Testing

The program has been tested by playing the game many times trying to perform legal and illegal moves. Program mostly behaves as it should, but during the testing it came out that it is impossible to win the game following rules. In last stage of game when player has pocketed all of his balls player should be able to hit black ball first, as there are none of his balls left, but the game doesn't allow it. It is caused by the fact, that when player hits ball other than his the game recognizes it as foul and checking if it was eight ball is omitted. Program was also tested with respect to low temporal resolution of simulation. Physics have proven to be unstable when subjected to artificially high time step, but tests on real hardware - both with integrated and dedicated GPU's have shown, that time differences between frames aren't nearly as high and the game runs properly. The game has also been tested with respect to running alongside stress test pushing the usage of the CPU to maximum and no difference in game's behavior was observed.

6. Conclusions

Creating this project has shown that creating fast, reliable and accurate real time physics simulation while keeping track on properties related to Eight Ball Pool is a challenging task requiring knowledge of target platform, it's strengths and downsides and needs to be tested by being subjected to sometimes unrealistic edge-case scenarios.

Appendix
Description of types and functions

Computer Programing: Project

Generated by Doxygen 1.8.17

Chapter 1

README

Place your project here

Chapter 2

Hierarchical Index

2.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

Chapter 3

Class Index

3.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

Chapter 4

File Index

4.1 File List

Here is a list of all documented files with brief descriptions:

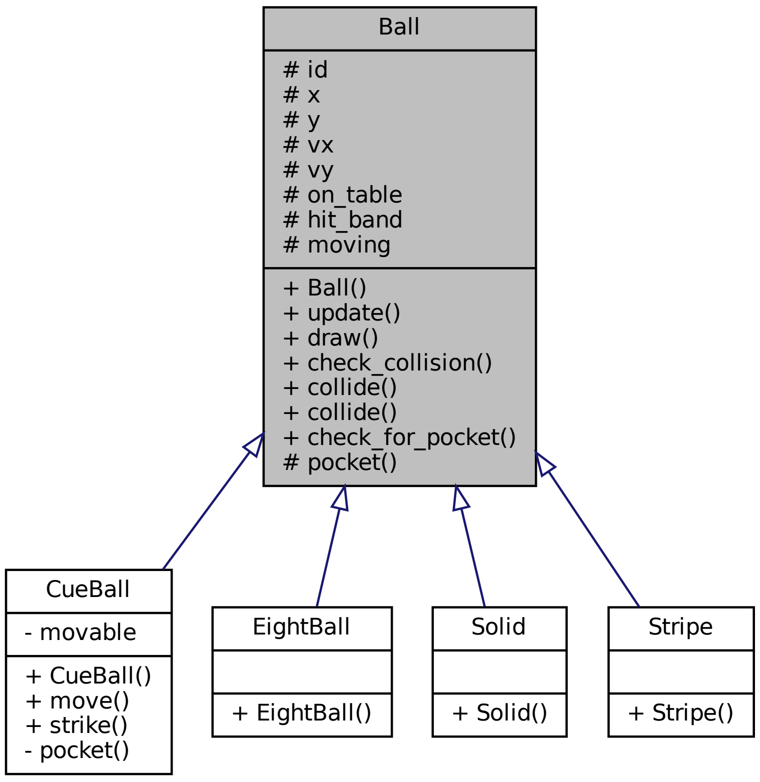
Chapter 5

Class Documentation

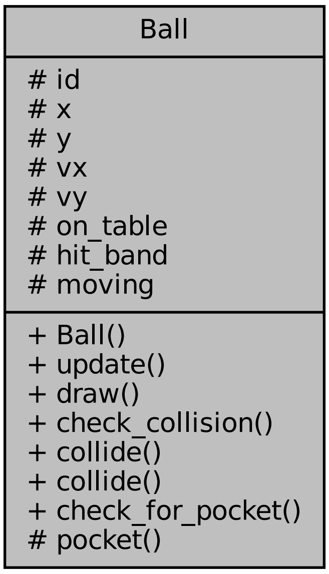
5.1 Ball Class Reference

```
#include <balls.h>
```

Inheritance diagram for Ball:



Collaboration diagram for Ball:



Public Member Functions

- Ball (double x, double y, int id)
- void update (Uint32 dt)
- void draw (Game ∗r)
- bool check_collision (std::shared_ptr< Ball > b)
- void collide (Segment ∗s)
- void collide (std::shared_ptr< Ball > b)
- bool check_for_pocket ()

Protected Member Functions

- virtual void pocket ()

  action taken after pocketing a ball, different for "normal" balls, cue ball and for eight ball

Protected Attributes

- int id

  Billard balls are numbered, cue ball is assumed to have id 0.
- double x

  x coordinate
- double y

  y coordinate
- double vx

x component of velocity

- double vy

  y component of velocity
- bool on_table
- bool hit_band
- bool moving

  flag set to true if ball is moving - used to determine end of turn

Friends

- class **Segment**
- class **Game**

5.1.1 Detailed Description

Class representing basic billard ball

5.1.2 Constructor & Destructor Documentation

5.1.2.1 Ball()

```
Ball::Ball (
             double x,
             double y,
             int id )
```

ball requires specifying position and balls number

Parameters

x	x coordinate
y	y coordinate
id	number of the ball

5.1.3 Member Function Documentation

5.1.3.1 check_collision()

```
bool Ball::check_collision (
             std::shared_ptr< Ball > b )
```

function responsible for checking if collision with ball b occured

Parameters

b	shared pointer to ball to check collisions against

Returns

true if the collision occured

5.1.3.2 check_for_pocket()

```
bool Ball::check_for_pocket ( )
```

function checking if ball has been pocketed

Returns

function returns true if the ball has been pocketed

5.1.3.3 collide() [1/2]

```
void Ball::collide (
             Segment * s )
```

function responsible for handling collision with segment

Parameters

s	pointer to segment to collide with

5.1.3.4 collide() [2/2]

```
void Ball::collide (
             std::shared_ptr< Ball > b )
```

function responsible for handling collision with other ball

Parameters

b	shared pointer to ball to collide with

5.1.3.5 draw()

```
void Ball::draw (
             Game * r )
```

function responsible for displaying the ball

Parameters

r	pointer to Game object holding apropriate rendering context

5.1.3.6 update()

```
void Ball::update (
             Uint32 dt )
```

function responsible for physics and checking for potting and fauls

Parameters

dt	time elapsed from last update in milliseconds

5.1.4 Member Data Documentation

5.1.4.1 hit_band

```
bool Ball::hit_band  [protected]
```

this flag is set to true if ball hit the band in this turn to check if the faul has been commited

5.1.4.2 on_table

```
bool Ball::on_table  [protected]
```

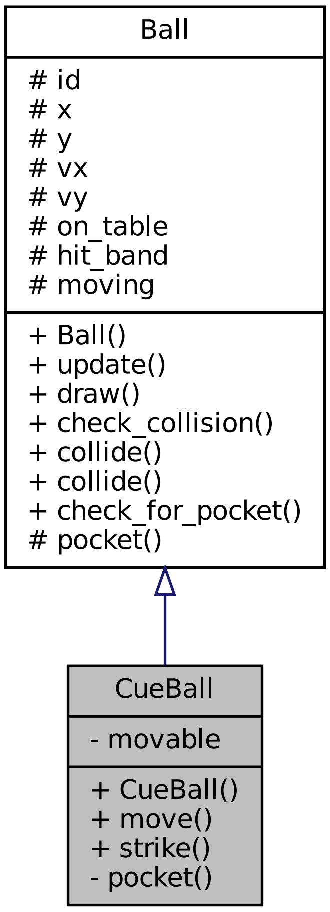
this flag is true if ball is still in the game, if it's false the ball isn't drawn neither checked for collisions

The documentation for this class was generated from the following files:

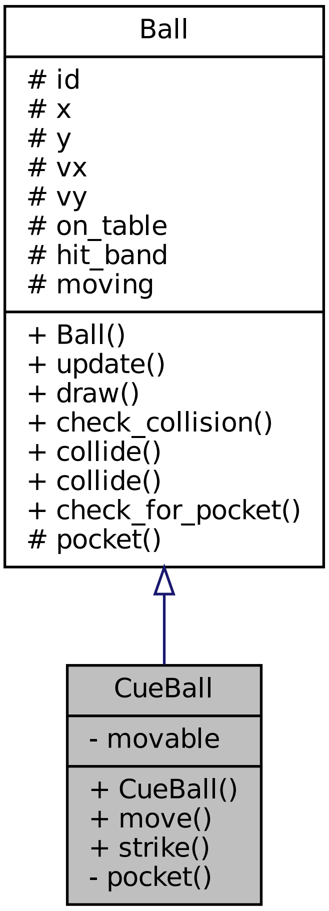
- balls.h
- balls.cpp

5.2 CueBall Class Reference

Inheritance diagram for CueBall:



Collaboration diagram for CueBall:



Public Member Functions

- CueBall (double x, double y)
- void move (double x, double y)
- void strike (double vx, double vy)

Private Member Functions

- void pocket ()

  cue ball after pocketing returns to the table

Private Attributes

- bool movable

  flag set if player has the ball in hand

Friends

- class **Game**

Additional Inherited Members

5.2.1 Constructor & Destructor Documentation

5.2.1.1 CueBall()

```
CueBall::CueBall (
             double x,
             double y )
```

cue ball always has id 0, so it doesn't need to be passed to constructor

Parameters

x	x coordinate
y	y coordinate

5.2.2 Member Function Documentation

5.2.2.1 move()

```
void CueBall::move (
             double x,
             double y )
```

function responsible for moving the ball if player has it in hand

Parameters

x	destination x coordinate
y	destination y corrdinate

5.2.2.2 strike()

```
void CueBall::strike (
                double vx,
                double vy )
```

function initiating movement of white ball

Parameters

vx	horizontal element of velocity
vy	vertical element of velocity

The documentation for this class was generated from the following files:

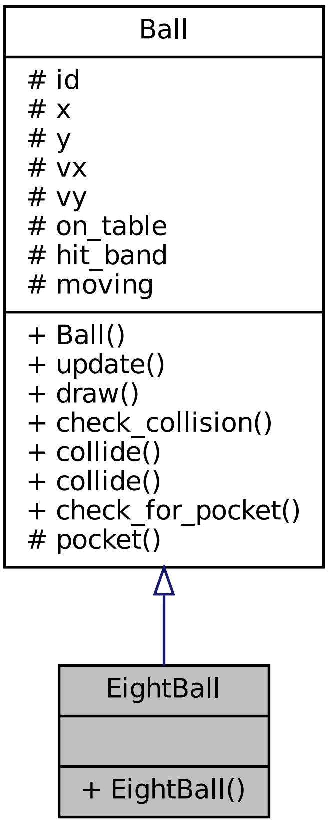
- balls.h
- balls.cpp

5.3 EightBall Class Reference

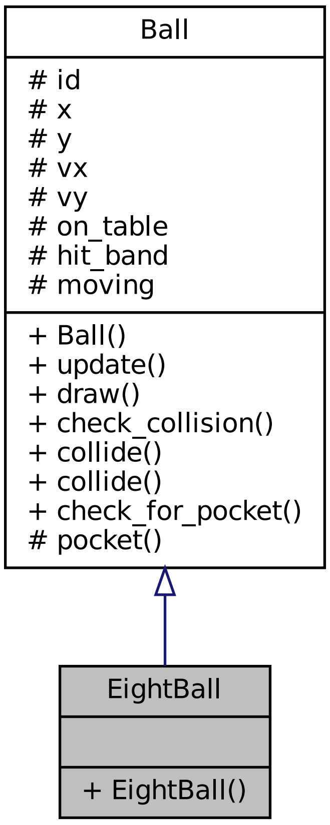
separate class for RTTI and to get constant id

`#include <balls.h>`

Inheritance diagram for EightBall:



Collaboration diagram for EightBall:



Public Member Functions

- EightBall (double x, double y)

Additional Inherited Members

5.3.1 Detailed Description

separate class for RTTI and to get constant id

5.3.2 Constructor & Destructor Documentation

5.3.2.1 EightBall()

```
EightBall::EightBall (
            double x,
            double y )
```

cue ball always has id 8, so it doesn't need to be passed to constructor

Parameters

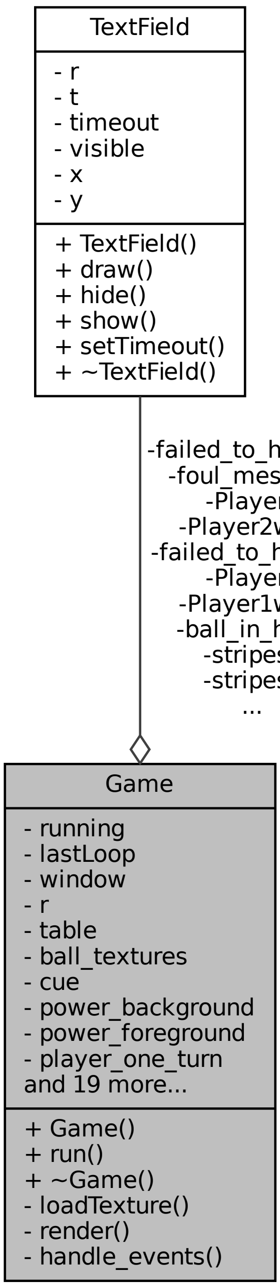
x	x coordinate
y	y coordinate

The documentation for this class was generated from the following files:

- balls.h
- balls.cpp

5.4 Game Class Reference

Collaboration diagram for Game:



Public Member Functions

- Game ()

    constructor taking care of initialising SDL, creating window and loading textures

- void run ()

    main loop of the game
- ∼Game ()

    destructor takes care of proper release of SDL resources

Private Types

- enum {
  WAITING, **MOVING_BALL**, **MOVING_CUE**, **SETTING_POWER**,
  ROLLING, **END** }

    current state of the game

Private Member Functions

- SDL_Texture ∗ loadTexture (const char ∗fname)
- void render ()

    function rendering elements that cannot be timeouted
- void handle_events ()

    function taking care of SDL events - moving mouse, keypresses, closing window e.t.c.

Private Attributes

- bool running

    if this flag is 0, the game stops
- Uint32 lastLoop

    variable for measuring time between frames
- SDL_Window ∗ window

    pointer to the window
- SDL_Renderer ∗ r

    pointer to SDL rendering context
- SDL_Texture ∗ table

    pointer to table texture
- std::vector< SDL_Texture ∗ > ball_textures

    vector of pointers to ball textures
- SDL_Texture ∗ cue

    pointer to cue texture
- SDL_Texture ∗ power_background

    pointer to texture of powerbar background
- SDL_Texture ∗ power_foreground

    pointer to texture of powerbar foreground
- bool player_one_turn = true

    flag showing whose move it is
- std::vector< std::shared_ptr< Ball > > balls

    vector storing pointers to all balls(ones on the table and pocketed ones)
- enum Game:: { ... } state

    current state of the game
- int last_y

    variable tracking mouse movement along vertical axis to set strike power
- int solids_left = 7

number of solid balls left on table

- int stripes_left = 7

  number of striped balls left on table
- std::vector< Segment ∗ > bands

  representation of boundaries of table
- double alpha =0

  angle of cues rotation
- double power = 0

  power of strike
- bool first_hit = true

  flag set if white ball didn't hit any other ball in current turn
- std::shared_ptr< Ball > player_one_balls

  pointer used for RTTI idenfification of balls belonging to player 1
- bool balls_assigned = false

  flag set to true if balls have been assigned, used for faul checking and sanity checks to not try typeid on nullptr
- bool break_shot = true

  flag set if it is first shot of the game
- bool right_ball_pocketed = false

  flag set if player pocketed at least one of his balls in current turn
- bool black_out_of_table = false

  flag set if black ball has been pocketed, pocketing it after break shot means end of the game
- bool foul = false

  flag set if foul has been commited in current turn
- bool ball_pocketed

  flag set if any ball has been pocketed in current turn - exception to foul when no ball hits band
- TextField ∗ **Player1**
- TextField ∗ **Player2**
- TextField ∗ **ball_in_hand**
- TextField ∗ **failed_to_hit_ball**
- TextField ∗ **failed_to_hit_band**
- TextField ∗ **foul_message**
- TextField ∗ **Player1wins**
- TextField ∗ **Player2wins**
- TextField ∗ **pocketed_cue_ball**
- TextField ∗ **solids1**
- TextField ∗ **solids2**
- TextField ∗ **stripes1**
- TextField ∗ stripes2

  pointers to text fields that can be visible on screen

Friends

- class **Ball**

5.4.1 Member Function Documentation

5.4.1.1 loadTexture()

```
SDL_Texture * Game::loadTexture (
              const char * fname )  [private]
```

function loading textures from files

Parameters

fname	name of the graphics file to be loaded as texture

Returns

pointer to SDL texture

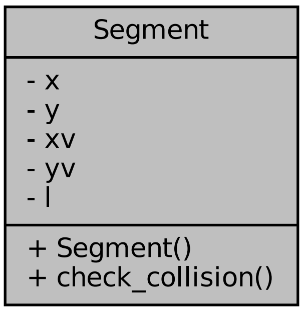
The documentation for this class was generated from the following files:

- classes.h
- classes.cpp

5.5 Segment Class Reference

`#include <classes.h>`

Collaboration diagram for Segment:



Public Member Functions

- Segment (double ax, double ay, double bx, double by)
- bool check_collision (std::shared_ptr< Ball > ball)

Private Attributes

- double x

    x coordinate of initial point
- double y

    y coordinate of initial point
- double xv

    x component of direction vector of the segment
- double yv

    y component of direction vector of the segment
- double l

    length of segment

Friends

- class **Ball**

5.5.1 Detailed Description

Class used to represent boundaries of the table and check for collisions

5.5.2 Constructor & Destructor Documentation

5.5.2.1 Segment()

```
Segment::Segment (
             double ax,
             double ay,
             double bx,
             double by )
```

constructor generating segment from end points

Parameters

ax	x coordinate of initial point
ay	y coordinate of initial point
bx	x coordinate of terminal point
by	y coordinate of terminal point

5.5.3 Member Function Documentation

5.5.3.1 check_collision()

```
bool Segment::check_collision (
             std::shared_ptr< Ball > ball )
```

function for checking collision with ball

Parameters

ball	shared pointer to ball to check collision against

Returns

true if collision has occured

The documentation for this class was generated from the following files:

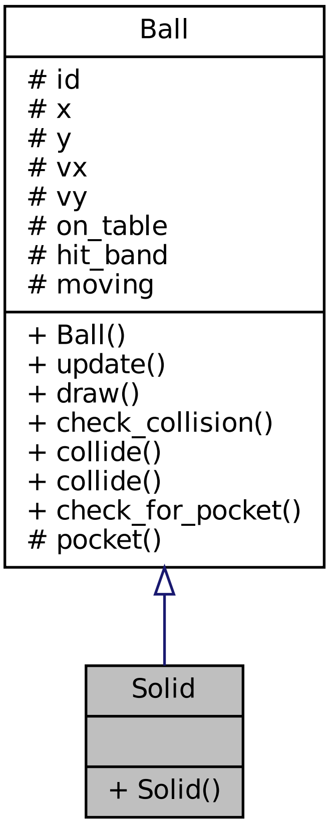
- classes.h
- classes.cpp

5.6 Solid Class Reference

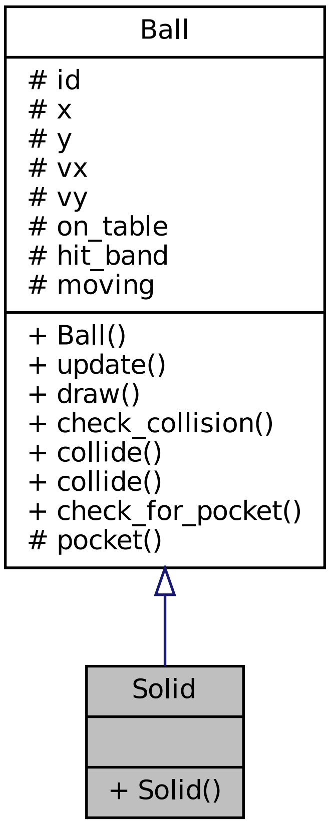
separate class for RTTI

```
#include <balls.h>
```

Inheritance diagram for Solid:



Collaboration diagram for Solid:



Public Member Functions

- Solid (double x, double y, int id)

Additional Inherited Members

5.6.1 Detailed Description

separate class for RTTI

5.6.2 Constructor & Destructor Documentation

5.6.2.1 Solid()

```
Solid::Solid (
            double x,
            double y,
            int id )
```

Parameters

x	x coordinate
y	y coordinate

The documentation for this class was generated from the following files:

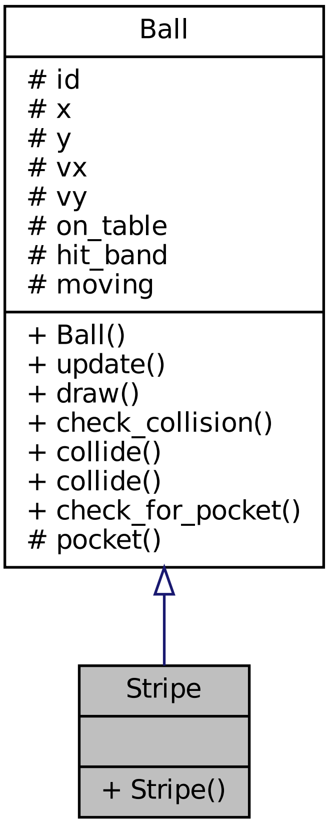
- balls.h
- balls.cpp

5.7 Stripe Class Reference

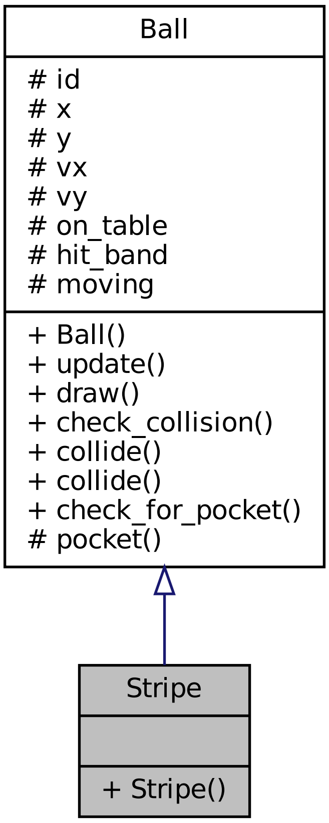
separate class for RTTI

```
#include <balls.h>
```

Inheritance diagram for Stripe:



Collaboration diagram for Stripe:



Public Member Functions

- Stripe (double x, double y, int id)

Additional Inherited Members

5.7.1 Detailed Description

separate class for RTTI

5.7.2 Constructor & Destructor Documentation

5.7.2.1 Stripe()

```
Stripe::Stripe (
            double x,
            double y,
            int id )
```

Parameters

x	x coordinate
y	y coordinate

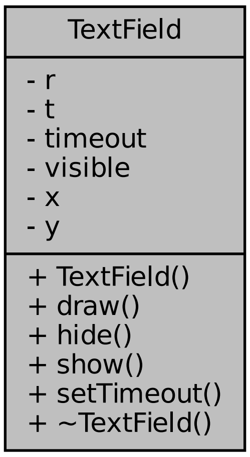
The documentation for this class was generated from the following files:

- balls.h
- balls.cpp

5.8 TextField Class Reference

```
#include <classes.h>
```

Collaboration diagram for TextField:



Public Member Functions

- TextField (SDL_Renderer ∗r, const char ∗text, TTF_Font ∗font, int x, int y)
- void draw (Uint32 dt)
- void hide ()

  function hiding text field
- void show ()

  function showing text field
- void setTimeout (int timeout)
- ∼TextField ()

  destructor needed to destroy texture

Private Attributes

- SDL_Renderer ∗ r

    pointer to SDL rendering context
- SDL_Texture ∗ t

    pointer to texture containing text
- int timeout

    time left to vanish, -1 if text shouldn't be timed out
- bool visible

    flag set if text should be visible
- int x

    x coordinate
- int y

    y coordinate

5.8.1 Detailed Description

Class responsible for rendering text on screen

5.8.2 Constructor & Destructor Documentation

5.8.2.1 TextField()

```
TextField::TextField (
             SDL_Renderer ∗ r,
             const char ∗ text,
             TTF_Font ∗ font,
             int x,
             int y )
```

constructor assigning values to the text field and generating the texture from text

Parameters

r	pointer to SDL rendering context
text	constant text to be rendered by this field
font	pointer to font
x	x coordinate
y	y coordinate

5.8.3 Member Function Documentation

5.8.3.1 draw()

```
void TextField::draw (
            Uint32 dt )
```

function responsible for drawing visible text field and updating time left on screen

Parameters

dt	time elapsed since last call to this function

5.8.3.2 setTimeout()

```
void TextField::setTimeout (
            int timeout )
```

function setting text field's timeout

Parameters

timeout	time for which the text field will be visible on screen, -1 for infinite

The documentation for this class was generated from the following files:

- classes.h
- classes.cpp

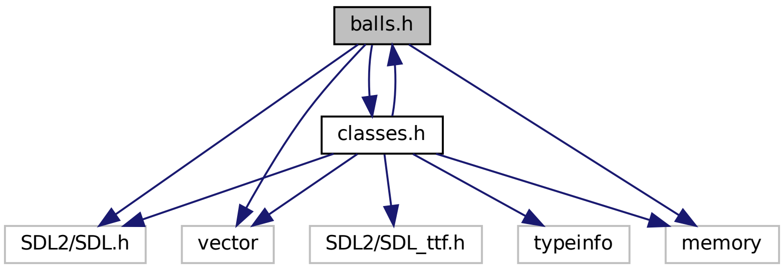
Chapter 6

File Documentation

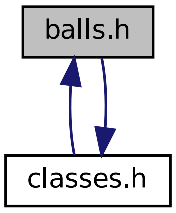
6.1 balls.h File Reference

```
#include <SDL2/SDL.h>
#include <vector>
#include <memory>
#include "classes.h"
```

Include dependency graph for balls.h:



This graph shows which files directly or indirectly include this file:



Classes

- class Ball
- class CueBall
- class EightBall

  separate class for RTTI and to get constant id
- class Solid

  separate class for RTTI
- class Stripe

  separate class for RTTI

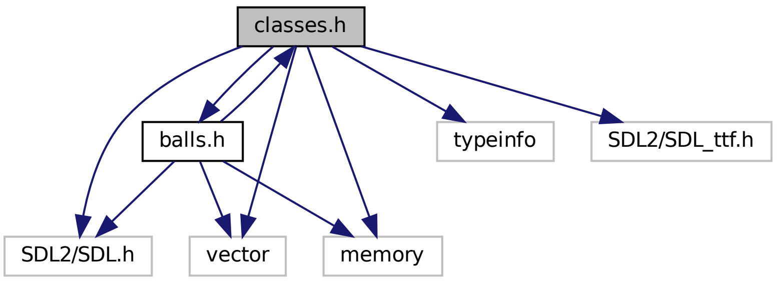
Macros

- #define **XOFF** 120
- #define **YOFF** 101
- #define **WIDTH** 924
- #define **HEIGHT** 461

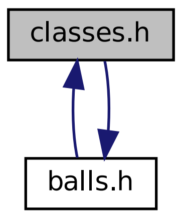
6.2 classes.h File Reference

```
#include "balls.h"
#include <SDL2/SDL.h>
#include <vector>
#include <memory>
#include <typeinfo>
#include <SDL2/SDL_ttf.h>
```

Include dependency graph for classes.h:



This graph shows which files directly or indirectly include this file:



Classes

- class Segment
- class TextField
- class Game

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