

Autonomous Steering Agents

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Chapter 1

Intent

- 1- implementing Craig Reynolds autonomous steering agents
- 2- implementing genetics algorithms
- 3- implementing neural network

1.1 Dependencies

```
$sudo apt-get install libglu1-mesa-dev freeglut3-dev mesa-common-dev
```

```
$sudo apt-get install libboost-all-dev
```

1.2 Resources

<https://natureofcode.com/book/chapter-6-autonomous-agents>

<https://gamedevelopment.tutsplus.com/series/understanding-steering-behaviors-gamedev-12>

<https://videotutorialsrock.com/index.php>

<https://www.opengl.org/resources/libraries/glut/spec3/node1.html>

<https://learnopengl.com/Getting-started/Coordinate-Systems>

Chapter 2

Hierarchical Index

2.1 Class Hierarchy

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

agent	9
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obstacle	36
path	40
point	44
pvector	53
random	63
scenario	63
evade	20
flee	21
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Chapter 3

Class Index

3.1 Class List

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

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flock	22
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graphics	25
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Chapter 4

File Index

4.1 File List

Here is a list of all files with brief descriptions:

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Chapter 5

Class Documentation

5.1 agent Class Reference

```
#include <agent.h>
```

Collaboration diagram for agent:

Public Member Functions

- `agent ()`
default constructor.
- `agent (float x, float y)`
Constructor.
- `~agent ()`
agent destructor
- void `updatePosition` (bool `arrive`)
calculates next position in each update using force applied
- void `setFeatures` (float `s`, float `f`, float `r`, float `m`)
used to initialize the agent

Public Attributes

- string `name`
name of the agent
- `color fillColor`
color of the agent
- `point position`
x and y coordinates of the agent
- `pvector velocity`
velocity of the agent
- `point targetPoint`
target of the agent
- float `maxSpeed`
maximum speed of the agent

- float [maxForce](#)
maximum force of the agent
- [pvector steering](#)
steering force to apply
- [pvector force](#)
total force to apply
- [pvector acceleration](#)
added to velocity in each update
- [pvector desiredVelocity](#)
get using target point and used to get steering force
- float [r](#)
agent slows down as target point gets smaller than radius
- float [mass](#)
used to get acceleration from force
- int [id](#)
used to distinguish specific agent
- bool [arrive](#) = false
defines if agent will have arriving behavior

5.1.1 Detailed Description

Definition at line 20 of file agent.h.

5.1.2 Constructor & Destructor Documentation

5.1.2.1 [agent\(\)](#) [1/2]

```
agent::agent ( )
```

default constructor.

Creates new agent object.

See also

[agent\(float x, float y\)](#)

Definition at line 16 of file agent.cpp.

```
17 {  
18  
19 }
```

5.1.2.2 [agent\(\)](#) [2/2]

```
agent::agent (  
    float x,  
    float y )
```

Constructor.

Creates new agent object.

Parameters

x	position x of the agent
y	position y of the agent

See also

[agent\(\)](#)

Definition at line 21 of file agent.cpp.

```

22 {
23     position      = point(x, y);
24     velocity      = pvector(0.6, 0.0);
25     acceleration  = pvector(0.0, 0.0);
26     steering      = pvector(0.0, 0.0);
27     desiredVelocity = pvector(0.0, 0.0);
28     force         = pvector(0.0, 0.0);
29     targetPoint   = point(0.0, 0.0);
30     fillColor     = color(1.0, 0.0, 0.0);
31 }
```

5.1.2.3 ~agent()

```
agent::~agent ( )
```

agent destructor

invokes when instance is killed

Definition at line 62 of file agent.cpp.

```

63 {
64
65 }
```

5.1.3 Member Function Documentation

5.1.3.1 setFeatures()

```

void agent::setFeatures (
    float s,
    float f,
    float r,
    float m )
```

used to initialize the agent

setting parameters

Parameters

<i>s</i>	maximum velocity
<i>f</i>	maximum force
<i>r</i>	radius for arriving behavior
<i>m</i>	mass

Definition at line 54 of file agent.cpp.

```

55 {
56     this->maxSpeed = s;
57     this->maxForce = f;
58     this->r = r;
59     this->mass = m;
60 }
```

5.1.3.2 updatePosition()

```

void agent::updatePosition (
    bool arrive )
```

calculates next position in each update using force applied

position update is invoked in periodically in a loop

Parameters

<i>arrive</i>	agent has arriving behavior or not
---------------	------------------------------------

See also

[agent\(\)](#)

Definition at line 33 of file agent.cpp.

```

34 {
35     force.limit(maxForce);
36     acceleration = force;
37     velocity += acceleration;
38
39     //arriving behavior implementation
40     if(arrive == true){
41         pvector diff = targetPoint - position;
42         if(diff.magnitude() > r)
43             velocity.limit(maxSpeed);
44         else
45             velocity.limit(maxSpeed * diff.magnitude() / r);
46     }
47     else
48         velocity.limit(maxSpeed);
49
50     position = position + velocity;
51     force = pvector(0,0);
52 }
```

Here is the call graph for this function:

5.1.4 Member Data Documentation

5.1.4.1 acceleration

```
pvector agent::acceleration
```

added to velocity in each update

acceleration to apply

Definition at line 120 of file agent.h.

5.1.4.2 arrive

```
bool agent::arrive = false
```

defines if agent will have arriving behavior

arriving behavior

Definition at line 150 of file agent.h.

5.1.4.3 desiredVelocity

```
pvector agent::desiredVelocity
```

get using target point and used to get steering force

desired velocity to reach the target point

Definition at line 126 of file agent.h.

5.1.4.4 fillColor

```
color agent::fillColor
```

color of the agent

color information passed to graphics

Definition at line 72 of file agent.h.

5.1.4.5 force

`pvector agent::force`

total force to apply

force to apply to agent instance

Definition at line 114 of file agent.h.

5.1.4.6 id

`int agent::id`

used to distinguish specific agent

identification number of the agent

Definition at line 144 of file agent.h.

5.1.4.7 mass

`float agent::mass`

used to get acceleration from force

mass of the agent

Definition at line 138 of file agent.h.

5.1.4.8 maxForce

`float agent::maxForce`

maximum force of the agent

if force of the agent is more than this value, limit function restricts force

Definition at line 102 of file agent.h.

5.1.4.9 maxSpeed

```
float agent::maxSpeed
```

maximum speed of the agent

if velocity of the agent is more than this value, limit function restricts velocity

Definition at line 96 of file agent.h.

5.1.4.10 name

```
string agent::name
```

name of the agent

used to distinguish specific agent

Definition at line 66 of file agent.h.

5.1.4.11 position

```
point agent::position
```

x and y coordinates of the agent

position information

Definition at line 78 of file agent.h.

5.1.4.12 r

```
float agent::r
```

agent slows down as target point gets smaller than radius

radius for arrivin behavior

Definition at line 132 of file agent.h.

5.1.4.13 steering

`pvector` `agent::steering`

steering force to apply

steering force to change direction

Definition at line 108 of file agent.h.

5.1.4.14 targetPoint

`point` `agent::targetPoint`

target of the agent

calculated target point of the agent

Definition at line 90 of file agent.h.

5.1.4.15 velocity

`pvector` `agent::velocity`

velocity of the agent

velocity vector

Definition at line 84 of file agent.h.

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

- `include/agent.h`
- `src/agent.cpp`

5.2 color Class Reference

```
#include <color.h>
```

Collaboration diagram for color:

Public Member Functions

- [color](#) ()
default constructor.
- [color](#) (float r, float g, float b)
Constructor.
- void [createColors](#) ()
fills colors vector with 8 main colors in color bar
- [color](#) [getColor](#) (int i)
Constructor.

Public Attributes

- float [R](#)
red condiment
- float [G](#)
green condiment
- float [B](#)
blue condiment
- vector< [color](#) > [colors](#)
stores main colors

5.2.1 Detailed Description

Definition at line 20 of file color.h.

5.2.2 Constructor & Destructor Documentation

5.2.2.1 [color\(\)](#) [1/2]

```
color::color ( )
```

default constructor.

Create a new color object.

See also

[color\(float r, float g, float b\)](#)

Definition at line 25 of file color.cpp.

```
26 {  
27  
28 }
```

5.2.2.2 [color\(\)](#) [2/2]

```
color::color (  
    float r,  
    float g,  
    float b )
```

Constructor.

Create a new color object.

Parameters

<i>r</i>	red (0-255)
<i>g</i>	green (0-255)
<i>b</i>	blue (0-255)

See also

[path\(\)](#)

Definition at line 13 of file color.cpp.

```

14 {
15     R = r;
16     G = g;
17     B = b;
18 }
```

5.2.3 Member Function Documentation

5.2.3.1 createColors()

```
void color::createColors ( )
```

fills colors vector with 8 main colors in color bar

creates main colors for future use

Definition at line 30 of file color.cpp.

```

31 {
32     colors.push_back(color(0.0, 0.0, 0.0));
33     colors.push_back(color(0.0, 0.0, 1.0));
34     colors.push_back(color(0.0, 1.0, 0.0));
35     colors.push_back(color(0.0, 1.0, 1.0));
36     colors.push_back(color(1.0, 0.0, 0.0));
37     colors.push_back(color(1.0, 0.0, 1.0));
38     colors.push_back(color(1.0, 1.0, 0.0));
39     colors.push_back(color(1.0, 1.0, 1.0));
40 }
```

5.2.3.2 getColor()

```
color color::getColor (
    int i )
```

Constructor.

returns specified color from colors vector

Parameters

<i>i</i>	gets specified color
----------	----------------------

Returns

requested pre-created color instance

Definition at line 20 of file color.cpp.

```
21 {  
22     return colors.at(i);  
23 }
```

Here is the caller graph for this function:

5.2.4 Member Data Documentation

5.2.4.1 B

```
float color::B
```

blue condiment

blue color ratio

Definition at line 69 of file color.h.

5.2.4.2 colors

```
vector<color> color::colors
```

stores main colors

vector of fundamental colors

Definition at line 75 of file color.h.

5.2.4.3 G

```
float color::G
```

green condiment

green color ratio

Definition at line 63 of file color.h.

5.2.4.4 R

```
float color::R
```

red condiment

red color ratio

Definition at line 57 of file color.h.

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

- [include/color.h](#)
- [src/color.cpp](#)

5.3 evade Class Reference

```
#include <evade.h>
```

Inheritance diagram for evade:

Collaboration diagram for evade:

Public Member Functions

- [evade](#) ()

Static Public Member Functions

- static void [loop](#) ()

Additional Inherited Members

5.3.1 Detailed Description

Definition at line 8 of file evade.h.

5.3.2 Constructor & Destructor Documentation

5.3.2.1 evade()

```
evade::evade ( )
```

Definition at line 23 of file evade.cpp.

```
23     {
24     name = "evading";
25     createAgent(STATIC, nullptr, nullptr, nullptr);
26     callback = reinterpret_cast <void(*)()> ( (void *)(&loop) );
27 }
```

5.3.3 Member Function Documentation

5.3.3.1 loop()

```
void evade::loop ( ) [static]
```

Definition at line 8 of file evade.cpp.

```
8     {
9     for(auto it = agents.begin(); it < agents.end(); it++){
10         if((*it).name == "lion"){
11             (*it).targetPoint = view.getMousePosition();
12             (*it).force = behavior.seek(*it);
13             (*it).arrive = true;
14         }
15         else{//gazelle
16             (*it).force = behavior.evade(agents, *it, view);
17         }
18     }
19
20     refresh();
21 }
```

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

- include/[evade.h](#)
- src/[evade.cpp](#)

5.4 flee Class Reference

```
#include <flee.h>
```

Inheritance diagram for flee:

Collaboration diagram for flee:

Public Member Functions

- [flee](#) ()

Static Public Member Functions

- static void [loop](#) ()

Additional Inherited Members

5.4.1 Detailed Description

Definition at line 8 of file flee.h.

5.4.2 Constructor & Destructor Documentation

5.4.2.1 flee()

```
flee::flee ( )
```

Definition at line 16 of file flee.cpp.

```
16     {
17         int agentCount = 196;
18         name = "fleeing troop";
19         createAgent(TROOP, &agentCount, nullptr, nullptr);
20         callback = reinterpret_cast <void(*)()> ( (void *)(&loop) );
21     }
```

5.4.3 Member Function Documentation

5.4.3.1 loop()

```
void flee::loop ( ) [static]
```

Definition at line 8 of file flee.cpp.

```
8     {
9         for(auto it = agents.begin(); it < agents.end(); it++){
10             (*it).force = behavior.flee((*it), view, view.getMousePosition());
11         }
12
13         refresh();
14     }
```

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

- [include/flee.h](#)
- [src/flee.cpp](#)

5.5 flock Class Reference

```
#include <flock.h>
```

Inheritance diagram for flock:

Collaboration diagram for flock:

Public Member Functions

- [flock](#) ()

Static Public Member Functions

- static void [loop](#) ()

Additional Inherited Members

5.5.1 Detailed Description

Definition at line 8 of file flock.h.

5.5.2 Constructor & Destructor Documentation

5.5.2.1 flock()

`flock::flock ()`

Definition at line 28 of file flock.cpp.

```
28     {
29         int agentCount = 50;
30         float maxForce = 0.3;
31         float maxSpeed = 0.8;
32         name = "flocking agents";
33         createAgent(RANDOM, &agentCount, &maxForce, &maxSpeed);
34         callback = reinterpret_cast <void(*)()> ( (void *)(&loop) );
35     }
```

5.5.3 Member Function Documentation

5.5.3.1 loop()

`void flock::loop () [static]`

Definition at line 8 of file flock.cpp.

```
8     {
9         for(auto it = agents.begin(); it < agents.end(); it++){
10             view.forceInScreen((*it));
11
12             pvector sep = behavior.separation(agents, *it);
13             sep.mul(1.5);
14             pvector ali = behavior.align(agents, *it);
15             ali.mul(4);
16             pvector coh = behavior.cohesion(agents, *it);
17             coh.mul(0.1);
18
19             (*it).force = sep + ali + coh;
20             (*it).desiredVelocity = (*it).force + (*it).velocity;
21             (*it).targetPoint = (*it).position + (*it).desiredVelocity;
22             (*it).arrive = true;
23         }
24         refresh();
25     }
26 }
```

Here is the call graph for this function:

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

- [include/flock.h](#)
- [src/flock.cpp](#)

5.6 flowField Class Reference

```
#include <flowField.h>
```

Collaboration diagram for flowField:

Public Member Functions

- [flowField](#) ()
default constructor.
- [flowField](#) (pvector p)
constructor.
- [pvector getField](#) (int x, int y)
get force for individual pixel

5.6.1 Detailed Description

Definition at line 18 of file flowField.h.

5.6.2 Constructor & Destructor Documentation

5.6.2.1 flowField() [1/2]

```
flowField::flowField ( )
```

default constructor.

Create a new [flowField](#) object.

See also

[flowField\(pvector p\)](#)

Definition at line 15 of file flowField.cpp.

```
15 {}
```

5.6.2.2 flowField() [2/2]

```
flowField::flowField (  
    pvector p )
```

constructor.

Create a new [flowField](#) object.

Parameters

p	force vector
-----	--------------

See also[flowField\(\)](#)

Definition at line 10 of file flowField.cpp.

```

11 {
12     createFlowField(p);
13 }
```

5.6.3 Member Function Documentation**5.6.3.1 getField()**

```

pvector flowField::getField (
    int x,
    int y )
```

get force for individual pixel

get force for a specific position

Parameters

x	x coordinate
y	y coordinate

Returns

returns force at specified position

Definition at line 36 of file flowField.cpp.

```

37 {
38     return uniformField[x][y];
39 }
```

Here is the caller graph for this function:

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

- [include/flowField.h](#)
- [src/flowField.cpp](#)

5.7 graphics Class Reference

```
#include <graphics.h>
```

Collaboration diagram for graphics:

Public Member Functions

- void `drawWall` (float border, `color` color)
draws wall
- void `drawAgent` (`agent` &`agent`, `color` &`color`)
drawing agent
- void `drawLine` (`point` p1, `point` p2, `color` cl)
drawing line
- void `drawPath` (`path` &`path`, `color` color)
draws path that consists of points
- void `drawPoint` (`point` p)
drawing point
- void `drawCircle` (`point` p, float radius)
drawing circle
- void `drawText` (string text, `point` p)
drawing text on screen
- void `forceInScreen` (`agent` &`agent`)
changes agent position if it is out of screen
- void `refreshScene` ()
position updates for all agents
- `point` `getMousePosition` ()
gets mouse position
- void `initGraphics` (int *argv, char **argc, void(*callback)())
initialization of graphics

Static Public Member Functions

- static void `timerEvent` (int value)
periodic timer event function
- static void `handleKeypress` (unsigned char key, int x, int y)
key press event of the openGL
- static void `mouseButton` (int button, int state, int x, int y)
mouse press event of the openGL
- static void `handleResize` (int w, int h)
event triggered after resizing
- static void `mouseMove` (int x, int y)
event triggered after moving mouse

Static Public Attributes

- static int `target_x` = `-WIDTH`
mouse position x
- static int `target_y` = `HEIGHT`
mouse position y

5.7.1 Detailed Description

Definition at line 22 of file `graphics.h`.

5.7.2 Member Function Documentation

5.7.2.1 drawAgent()

```
void graphics::drawAgent (
    agent & agent,
    color & color )
```

drawing agent

draws agent and rotates it with its velocity

Parameters

<i>agent</i>	agent to draw
<i>color</i>	color of the agent

Definition at line 180 of file graphics.cpp.

```
181 {
182     glPushMatrix();
183     glTranslatef(agent.position.x, agent.position.y, 0.0f);
184     glRotatef(agent.velocity.getAngle(), 0.0f, 0.0f, 1.0f);
185     glBegin(GL_TRIANGLES);
186     glColor3f( color.R, color.G, color.B);
187     glVertex3f( 1.0f, 0.0f, 0.0f);
188     glVertex3f(-1.0f, 0.5f, 0.0f);
189     glVertex3f(-1.0f, -0.5f, 0.0f);
190     glEnd();
191     glPopMatrix();
192 }
```

Here is the call graph for this function:

5.7.2.2 drawCircle()

```
void graphics::drawCircle (
    point p,
    float radius )
```

drawing circle

draws circle using OpenGL

Parameters

<i>p</i>	center of the circle
<i>radius</i>	radius of the circle

Definition at line 139 of file graphics.cpp.

```
140 {
141     glBegin(GL_LINE_STRIP);
142     glLineWidth(2);
143     for (int i = 0; i <= 300; i++) {
```

```

144     float angle = 2 * PI * i / 300;
145     float x = cos(angle) * radius;
146     float y = sin(angle) * radius;
147     glVertex2d(p.x + x, p.y + y);
148 }
149 glEnd();
150 }

```

5.7.2.3 drawLine()

```

void graphics::drawLine (
    point p1,
    point p2,
    color c1 )

```

drawing line

draws line with specified color

Parameters

<i>p1</i>	start point of the line
<i>p2</i>	end point of the line
<i>color</i>	color of the line

Definition at line 129 of file graphics.cpp.

```

130 {
131     glColor3f( c1.R, c1.G, c1.B);
132     glLineWidth(2);
133     glBegin(GL_LINES);
134     glVertex2f(p1.x, p1.y);
135     glVertex2f(p2.x, p2.y);
136     glEnd();
137 }

```

5.7.2.4 drawPath()

```

void graphics::drawPath (
    path & path,
    color color )

```

draws path that consists of points

draws path using lines

Parameters

<i>path</i>	path to draw
<i>color</i>	color of the path

Definition at line 115 of file graphics.cpp.

```

116 {

```



```

117     point p1, p2;
118     for(auto it = path.points.begin(); it < path.points.end()-1; it++){
119         p1 = point((*it).x, (*it).y - path.width/2) ;
120         p2 = point((*it+1).x, (*it+1).y - path.width/2);
121         drawLine(p1, p2, color.getColor(BLUE));
122
123         p1 = point((*it).x, (*it).y + path.width/2) ;
124         p2 = point((*it+1).x, (*it+1).y + path.width/2);
125         drawLine(p1, p2, color.getColor(BLUE));
126     }
127 }

```

Here is the call graph for this function:

5.7.2.5 drawPoint()

```

void graphics::drawPoint (
    point p )

```

drawing point

draws point using OpenGL

Parameters

<i>p</i>	point to draw
----------	---------------

Definition at line 152 of file graphics.cpp.

```

153 {
154     glColor3f(1,1,1);
155     glPointSize(4.0);
156     glBegin(GL_POINTS);
157     glVertex2f(p.x, p.y);
158     glEnd();
159 }

```

Here is the caller graph for this function:

5.7.2.6 drawText()

```

void graphics::drawText (
    string text,
    point p )

```

drawing text on screen

draws text using OpenGL

Parameters

<i>p</i>	position of the text
<i>text</i>	text to display

Definition at line 22 of file graphics.cpp.

```

23 {
24     glColor3f (0.0, 0.0, 1.0);
25     //glRasterPos2f(-34, 32.5);

```

```

26     glRasterPos2f(p.x, p.y);
27     for ( string::iterator it=text.begin(); it!=text.end(); ++it){
28         glutBitmapCharacter(GLUT_BITMAP_9_BY_15, *it);
29     }
30 }

```

Here is the caller graph for this function:

5.7.2.7 drawWall()

```

void graphics::drawWall (
    float border,
    color color )

```

draws wall

draws square that consists of 4 lines

Parameters

<i>border</i>	position of the wall
<i>color</i>	color of the wall

Definition at line 161 of file graphics.cpp.

```

162 {
163     point p1 {-border, border};
164     point p2 { border, border};
165     drawLine(p1, p2, color.getColor(BLUE));
166
167     p1 = point ( border, border);
168     p2 = point ( border, -border);
169     drawLine(p1, p2, color.getColor(BLUE));
170
171     p1 = point ( border, -border);
172     p2 = point ( -border, -border);
173     drawLine(p1, p2, color.getColor(BLUE));
174
175     p1 = point (-border, border);
176     p2 = point (-border, -border);
177     drawLine(p1, p2, color.getColor(BLUE));
178 }

```

Here is the call graph for this function:

5.7.2.8 forceInScreen()

```

void graphics::forceInScreen (
    agent & agent )

```

changes agent position if it is out of screen

makes the agent stay in screen

Parameters

<i>agent</i>	agent to be in screen
--------------	-----------------------

Definition at line 64 of file graphics.cpp.

```

65 {
66     if (agent.position.x > WIDTH)
67         agent.position.x -= 2 * WIDTH;
68     if (agent.position.x < -WIDTH)
69         agent.position.x += 2 * WIDTH;
70     if (agent.position.y > HEIGHT)
71         agent.position.y -= 2 * HEIGHT;
72     if (agent.position.y < -HEIGHT)
73         agent.position.y += 2 * HEIGHT;
74 }

```

5.7.2.9 getMousePosition()

```
point graphics::getMousePosition ( )
```

gets mouse position

used to get mouse position

Definition at line 59 of file graphics.cpp.

```

60 {
61     return point (graphics::target_x, graphics::target_y);
62 }

```

Here is the call graph for this function:

5.7.2.10 handleKeypress()

```

void graphics::handleKeypress (
    unsigned char key,
    int x,
    int y ) [static]

```

key press event of the openGL

openGL key press event

Parameters

<i>key</i>	key
<i>x</i>	unused but required for openGL
<i>y</i>	unused but required for openGL

Definition at line 108 of file graphics.cpp.

```

109 {
110     if (key == ESC) {
111         exit(0);
112     }
113 }

```

Here is the caller graph for this function:

5.7.2.11 handleResize()

```

void graphics::handleResize (
    int w,
    int h ) [static]

```

event triggered after resizing

openGL screen resize event

Parameters

<i>w</i>	width of the screen
<i>h</i>	height of the screen

Definition at line 84 of file graphics.cpp.

```

85 {
86     glViewport(0, 0, w, h); //Tell OpenGL how to convert from coordinates to pixel values
87     glMatrixMode(GL_PROJECTION); //Switch to setting the camera perspective
88     glLoadIdentity(); //Reset the camera
89     //Set the camera perspective
90     gluPerspective(45.0,           //The camera angle
91                   (double)w / (double)h, //The width-to-height ratio
92                   1.0,           //The near z clipping coordinate
93                   200.0);        //The far z clipping coordinate
94 }
```

Here is the caller graph for this function:

5.7.2.12 initGraphics()

```

void graphics::initGraphics (
    int * argv,
    char ** argc,
    void(*)() callback )
```

initialization of graphics

used to init graphics

Parameters

<i>argv</i>	user parameters
<i>argc</i>	count of user parameters
<i>callback</i>	loop function for openGL periodic callback

Definition at line 42 of file graphics.cpp.

```

43 {
44     glutInit(argv, argc);
45     glutInitDisplayMode(GLUT_DOUBLE | GLUT_RGB | GLUT_DEPTH);
46     glutInitWindowSize(400, 400);
47     glutCreateWindow("Autonomous Steering Agents");
48     glClearColor(0.7f, 0.7f, 0.7f, 1.0f); //set background color
49     glEnable(GL_DEPTH_TEST);
50     glutDisplayFunc(*callback);
51     glutMouseFunc(graphics::mouseButton);
52     glutPassiveMotionFunc(graphics::mouseMove);
53     glutKeyboardFunc(graphics::handleKeypress);
54     glutReshapeFunc(graphics::handleResize);
55     glutTimerFunc(20, graphics::timerEvent, 0);
56     glutMainLoop();
57 }
```

Here is the call graph for this function:

5.7.2.13 mouseButton()

```

void graphics::mouseButton (
```

```

    int button,
    int state,
    int x,
    int y ) [static]

```

mouse press event of the openGL

openGL key mouss press event

Parameters

<i>button</i>	mouse button
<i>x</i>	unused but required for openGL
<i>y</i>	unused but required for openGL

Definition at line 102 of file graphics.cpp.

```

103 {
104     if (button == GLUT_LEFT_BUTTON && state == GLUT_DOWN) {
105     }
106 }

```

Here is the caller graph for this function:

5.7.2.14 mouseMove()

```

void graphics::mouseMove (
    int x,
    int y ) [static]

```

event triggered after moving mouse

openGL mouse move event

Parameters

<i>x</i>	x position of the mouse
<i>y</i>	y position of the mouse

Definition at line 76 of file graphics.cpp.

```

77 {
78     //TODO: mouse position to glut
79     //TODO: magic numbers
80     graphics::target_x = x / 5.88 - 34;
81     graphics::target_y = 34 - y / 5.88;
82 }

```

Here is the caller graph for this function:

5.7.2.15 refreshScene()

```

void graphics::refreshScene ( )

```

position updates for all agents

refresh screen for every existing object

Definition at line 33 of file graphics.cpp.

```
34 {
35     glutSwapBuffers();
36     glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
37     glMatrixMode(GL_MODELVIEW); //Switch to the drawing perspective
38     glLoadIdentity(); //Reset the drawing perspective
39     glTranslatef(0.0f, 0.0f, -85.0f); //Move to the center of the triangle
40 }
```

5.7.2.16 timerEvent()

```
void graphics::timerEvent (
    int value ) [static]
```

periodic timer event function

OpenGL timer event callback

Parameters

<i>value</i>	period as ms
--------------	--------------

Definition at line 96 of file graphics.cpp.

```
97 {
98     glutPostRedisplay(); //Tell GLUT that the display has changed
99     glutTimerFunc(value, timerEvent, 20);
100 }
```

Here is the caller graph for this function:

5.7.3 Member Data Documentation

5.7.3.1 target_x

```
int graphics::target_x = -WIDTH [static]
```

mouse position x

holds mouse y position

Definition at line 153 of file graphics.h.

5.7.3.2 target_y

```
int graphics::target_y = HEIGHT [static]
```

mouse position y

holds mouse x position

Definition at line 159 of file graphics.h.

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

- [include/graphics.h](#)
- [src/graphics.cpp](#)

5.8 mouseFollower Class Reference

```
#include <mouseFollower.h>
```

Inheritance diagram for mouseFollower:

Collaboration diagram for mouseFollower:

Public Member Functions

- [mouseFollower](#) ()

Static Public Member Functions

- static void [loop](#) ()

Additional Inherited Members

5.8.1 Detailed Description

Definition at line 8 of file mouseFollower.h.

5.8.2 Constructor & Destructor Documentation

5.8.2.1 mouseFollower()

```
mouseFollower::mouseFollower ( )
```

Definition at line 17 of file mouseFollower.cpp.

```
17         {
18     int agentCount = 30;
19     float maxForce = 0.3;
20     float maxSpeed = 0.6;
21     name = "mouse following";
22     createAgent(RANDOM, &agentCount, &maxForce, &maxSpeed);
23     callback = reinterpret_cast <void(*)()> ( (void *)(&loop) );
24 }
```

5.8.3 Member Function Documentation

5.8.3.1 loop()

```
void mouseFollower::loop ( ) [static]
```

Definition at line 8 of file mouseFollower.cpp.

```
8      {
9      for(auto it = agents.begin(); it < agents.end(); it++){
10         (*it).targetPoint = view.getMousePosition();
11         (*it).force = behavior.seek(*it);
12         (*it).arrive = true;
13     }
14     refresh();
15 }
```

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

- include/mouseFollower.h
- src/mouseFollower.cpp

5.9 obstacle Class Reference

```
#include <obstacle.h>
```

Collaboration diagram for obstacle:

Public Member Functions

- [obstacle \(\)](#)
default constructor.
- [obstacle \(point p, float r\)](#)
constructor

Public Attributes

- [point p](#)
x and y coordinates
- [float r](#)
the bigger radius the bigger the obstacle

5.9.1 Detailed Description

Definition at line 12 of file obstacle.h.

5.9.2 Constructor & Destructor Documentation

5.9.2.1 obstacle() [1/2]

```
obstacle::obstacle ( )
```

default constructor.

create a new obstacle object.

See also

[obstacle\(point p, float r](#)

Definition at line 15 of file obstacle.cpp.

```
16 {
17
18 }
```

5.9.2.2 obstacle() [2/2]

```
obstacle::obstacle (
    point p,
    float r )
```

constructor

create a new obstacle object.

Parameters

<i>p</i>	center of the circular obstacle
<i>r</i>	radius of the obstacle

See also

[obstacle\(point p, float r\);](#)

Definition at line 20 of file obstacle.cpp.

```
21 {
22     this->p = p;
23     this->r = r;
24 }
```

5.9.3 Member Data Documentation

5.9.3.1 p

```
point obstacle::p
```

x and y coordinates

center point of the obstacle

Definition at line 34 of file obstacle.h.

5.9.3.2 r

```
float obstacle::r
```

the bigger radius the bigger the obstacle

radius of the obstacle

Definition at line 40 of file obstacle.h.

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

- include/[obstacle.h](#)
- src/[obstacle.cpp](#)

5.10 obstacleAvoidance Class Reference

```
#include <obstacleAvoidance.h>
```

Inheritance diagram for obstacleAvoidance:

Collaboration diagram for obstacleAvoidance:

Public Member Functions

- [obstacleAvoidance](#) ()

Static Public Member Functions

- static void [loop](#) ()
- static void [createObstacle](#) (vector< [obstacle](#) > &[obstacles](#))

Static Public Attributes

- static vector< [obstacle](#) > [obstacles](#)

Additional Inherited Members

5.10.1 Detailed Description

Definition at line 9 of file obstacleAvoidance.h.

5.10.2 Constructor & Destructor Documentation

5.10.2.1 obstacleAvoidance()

```
obstacleAvoidance::obstacleAvoidance ( )
```

Definition at line 34 of file obstacleAvoidance.cpp.

```
34         {
35     name = "avoid obstacles";
36     createAgent(STATIC, nullptr, nullptr, nullptr);
37     createObstacle(obstacles);
38     callback = reinterpret_cast <void(*)()> ( (void *)(&loop) );
39 }
```

5.10.3 Member Function Documentation

5.10.3.1 createObstacle()

```
void obstacleAvoidance::createObstacle (
    vector< obstacle > & obstacles ) [static]
```

Definition at line 28 of file obstacleAvoidance.cpp.

```
28         {
29     obstacles.push_back(obstacle(point(0,0), 8));
30     obstacles.push_back(obstacle(point(-20,0), 3));
31     obstacles.push_back(obstacle(point(20,-10), 4));
32 }
```

Here is the call graph for this function:

5.10.3.2 loop()

```
void obstacleAvoidance::loop ( ) [static]
```

Definition at line 10 of file obstacleAvoidance.cpp.

```
10     {
11     for(auto it = agents.begin(); it < agents.end(); it++){
12         for(auto it = obstacles.begin(); it < obstacles.end(); it++){
13             point p = (*it).p;
14             view.drawCircle(p, (*it).r);
15         }
16
17         (*it).targetPoint = view.getMousePosition();
18         pvector seek = behavior.seek(*it);
19         seek.mul(0.5);
20
21         pvector avoid = behavior.avoid(obstacles, *it);
22         (*it).force = avoid + seek;
23         (*it).arrive = true;
24     }
25     refresh();
26 }
```

Here is the call graph for this function:

5.10.4 Member Data Documentation

5.10.4.1 obstacles

```
vector< obstacle > obstacleAvoidance::obstacles [static]
```

Definition at line 13 of file obstacleAvoidance.h.

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

- include/[obstacleAvoidance.h](#)
- src/[obstacleAvoidance.cpp](#)

5.11 path Class Reference

```
#include <path.h>
```

Collaboration diagram for path:

Public Member Functions

- [path](#) ()
Default constructor.
- [path](#) (float [width](#))
Constructor.
- void [addPoint](#) ([point](#) p)
adds a new point to the path

Public Attributes

- vector< [point](#) > [points](#)
points added to the path
- int [width](#)
defines width of the path

5.11.1 Detailed Description

Definition at line 15 of file path.h.

5.11.2 Constructor & Destructor Documentation

5.11.2.1 path() [1/2]

```
path::path ( )
```

Default constructor.

Create a new path object.

See also

[path\(float width\)](#)

Definition at line 16 of file path.cpp.

```
17 {  
18  
19 }
```

5.11.2.2 path() [2/2]

```
path::path (  
    float width )
```

Constructor.

Create a new path object.

Parameters

<i>width</i>	The width of the path.
--------------	------------------------

See also

[path\(\)](#)

Definition at line 21 of file path.cpp.

```
22 {  
23     this->width = width;  
24 }
```

5.11.3 Member Function Documentation

5.11.3.1 addPoint()

```
void path::addPoint (  
    point p )
```

adds a new point to the path

Used when customizing path

Parameters

<i>point</i>	new point to add to the path
--------------	------------------------------

Definition at line 11 of file path.cpp.

```
12 {
13     points.push_back(p);
14 }
```

Here is the caller graph for this function:

5.11.4 Member Data Documentation

5.11.4.1 [points](#)

```
vector<point> path::points
```

points added to the path

path is created from these points

Definition at line 43 of file path.h.

5.11.4.2 [width](#)

```
int path::width
```

defines width of the path

path width

Definition at line 49 of file path.h.

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

- [include/path.h](#)
- [src/path.cpp](#)

5.12 pathFollower Class Reference

```
#include <pathFollower.h>
```

Inheritance diagram for pathFollower:

Collaboration diagram for pathFollower:

Public Member Functions

- [pathFollower](#) ()

Static Public Member Functions

- static void [loop](#) ()
- static void [createPath](#) ([path](#) &p)

Static Public Attributes

- static [path](#) [myPath](#)

Additional Inherited Members

5.12.1 Detailed Description

Definition at line 8 of file pathFollower.h.

5.12.2 Constructor & Destructor Documentation

5.12.2.1 pathFollower()

```
pathFollower::pathFollower ( )
```

Definition at line 28 of file pathFollower.cpp.

```
28 {
29     int agentCount = 40;
30     float maxForce = 0.2;
31     float maxSpeed = 0.4;
32     myPath = path(8);
33     createPath(myPath);
34     name = "path following";
35     createAgent(RANDOM, &agentCount, &maxForce, &maxSpeed);
36     callback = reinterpret_cast<void(*)()> ( (void *)(&loop) );
37 }
```

5.12.3 Member Function Documentation

5.12.3.1 createPath()

```
void pathFollower::createPath (
    path & p ) [static]
```

Definition at line 21 of file pathFollower.cpp.

```
21 {
22     p.addPoint(point(-40, 5));
23     p.addPoint(point(-14, 15));
24     p.addPoint(point( 10, 7));
25     p.addPoint(point( 40, 12));
26 }
```

Here is the call graph for this function:

5.12.3.2 loop()

```
void pathFollower::loop ( ) [static]
```

Definition at line 10 of file pathFollower.cpp.

```
10 {
11     for(auto it = agents.begin(); it < agents.end(); it++){
12         view.drawPath(myPath, myColor);
13         pvector seek = behavior.stayInPath(*it, myPath, view);
14         pvector sep = behavior.separation(agents, *it);
15         sep.mul(5);
16         (*it).force = sep + seek;
17     }
18     refresh();
19 }
```

Here is the call graph for this function:

5.12.4 Member Data Documentation

5.12.4.1 myPath

```
path pathFollower::myPath [static]
```

Definition at line 12 of file pathFollower.h.

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

- include/[pathFollower.h](#)
- src/[pathFollower.cpp](#)

5.13 point Class Reference

```
#include <point.h>
```

Collaboration diagram for point:

Public Member Functions

- [point](#) ()
default constructor
- [point](#) (float x, float y)
constructor
- void [div](#) (float d)
divide point
- void [mul](#) (float d)
multiply point
- void [print](#) (const string &s)
debug function
- void [getNormalPoint](#) ([point](#) predicted, [point](#) start, [point](#) end)
gets a points normal point on a vector
- [point operator+](#) ([pvector](#) const &obj)
used between vector and point
- [point operator+](#) ([point](#) const &obj)
used between point and point
- [pvector operator-](#) ([point](#) const &obj)
used between point and point
- bool [operator==](#) ([point](#) const &obj)
used between point and point

Public Attributes

- float [x](#)
x position of the point
- float [y](#)
y position of the point

5.13.1 Detailed Description

Definition at line 15 of file point.h.

5.13.2 Constructor & Destructor Documentation

5.13.2.1 [point\(\)](#) [1/2]

```
point::point ( )
```

default constructor

create a new point instance

See also

[point\(float x, float y\)](#)

Definition at line 21 of file point.cpp.

```
21 {}
```

Here is the caller graph for this function:

5.13.2.2 point() [2/2]

```
point::point (
    float x,
    float y )
```

constructor

create a new point instance

Parameters

<i>x</i>	position x of the point
<i>y</i>	position y of the point

See also

[point\(\)](#)

Definition at line 15 of file point.cpp.

```
16 {
17     this->x = x;
18     this->y = y;
19 }
```

5.13.3 Member Function Documentation

5.13.3.1 div()

```
void point::div (
    float d )
```

divide point

helper function to divide point position

Parameters

<i>d</i>	scalar to divide position of the point
----------	----------------------------------------

Definition at line 38 of file point.cpp.

```
39 {
40     x = x / d;
41     y = y / d;
42 }
```

Here is the caller graph for this function:

5.13.3.2 getNormalPoint()

```
void point::getNormalPoint (
    point predicted,
    point start,
    point end )
```

gets a points normal point on a vector

provides normal point on a vector of a point

Parameters

<i>predicted</i>	point that caller require normal on the vector
<i>start</i>	start point of the vector
<i>end</i>	end point of the vector

Definition at line 67 of file point.cpp.

```
68 {
69     pvector a = predicted - start;
70     pvector b = end - start;
71     b.normalize();
72     float a_dot_b = a.dotProduct(b);
73     b.mul(a_dot_b);
74     point normalPoint = start + b;
75     this->x = normalPoint.x;
76     this->y = normalPoint.y;
77 }
```

Here is the call graph for this function: Here is the caller graph for this function:

5.13.3.3 mul()

```
void point::mul (
    float d )
```

multiply point

helper function to multiply point position

Parameters

<i>d</i>	scalar to multiply position of the point
----------	------------------------------------------

Definition at line 44 of file point.cpp.

```
45 {
46     x = x * d;
47     y = y * d;
48 }
```

Here is the caller graph for this function:

5.13.3.4 operator+() [1/2]

```
point point::operator+ (
    point const & obj )
```

used between point and point

overloaded + operator

Parameters

<i>obj</i>	point to add
------------	--------------

Returns

subtracted result

Definition at line 51 of file point.cpp.

```
52 {  
53     point res;  
54     res.x = x + obj.x;  
55     res.y = y + obj.y;  
56     return res;  
57 }
```

5.13.3.5 operator+() [2/2]

```
point point::operator+ (  
    pvector const & obj )
```

used between vector and point

overloaded + operator

Parameters

<i>obj</i>	vector to add
------------	---------------

Returns

subtracted result

Definition at line 23 of file point.cpp.

```
24 {  
25     point res;  
26     res.x = x + obj.x;  
27     res.y = y + obj.y;  
28     return res;  
29 }
```

5.13.3.6 operator-()

```
pvector point::operator- (  
    point const & obj )
```

used between point and point

overloaded - operator

Parameters

<i>obj</i>	point to subtract
------------	-------------------

Returns

subtracted result

Definition at line 59 of file point.cpp.

```
60 {  
61     pvector res;  
62     res.x = x - obj.x;  
63     res.y = y - obj.y;  
64     return res;  
65 }
```

5.13.3.7 operator==()

```
bool point::operator== (  
    point const & obj )
```

used between point and point

overloaded == operator

Parameters

<i>obj</i>	point to compare
------------	------------------

Returns

true or false

Definition at line 31 of file point.cpp.

```
32 {  
33     if(x == obj.x && y == obj.y)  
34         return true;  
35     return false;  
36 }
```

5.13.3.8 print()

```
void point::print (  
    const string & s )
```

debug function

prints position of the point

Parameters

s	explanation string of the log
---	-------------------------------

Definition at line 79 of file point.cpp.

```
80 {  
81     cout << " " << s << " " << x << " " << y << endl;  
82 }
```

5.13.4 Member Data Documentation

5.13.4.1 x

```
float point::x
```

x position of the point

x coordinate

Definition at line 99 of file point.h.

5.13.4.2 y

```
float point::y
```

y position of the point

y coordinate

Definition at line 105 of file point.h.

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

- [include/point.h](#)
- [src/point.cpp](#)

5.14 prison Class Reference

```
#include <prison.h>
```

Inheritance diagram for prison:

Collaboration diagram for prison:

Public Member Functions

- [prison\(\)](#)

Static Public Member Functions

- static void [loop\(\)](#)

Additional Inherited Members

5.14.1 Detailed Description

Definition at line 8 of file prison.h.

5.14.2 Constructor & Destructor Documentation

5.14.2.1 prison()

```
prison::prison ( )
```

Definition at line 20 of file prison.cpp.

```
20     {
21         int agentCount = 30;
22         float maxForce = 0.5;
23         float maxSpeed = 0.6;
24
25         name = "stay in prison";
26         createAgent(RANDOM, &agentCount, &maxForce, &maxSpeed);
27         callback = reinterpret_cast <void(*)()> ( (void *)(&loop) );
28     }
```

5.14.3 Member Function Documentation

5.14.3.1 loop()

```
void prison::loop ( ) [static]
```

Definition at line 11 of file prison.cpp.

```
11     {
12         for(auto it = agents.begin(); it < agents.end(); it++){
13             view.drawWall(WALL, myColor);
14             (*it).force = behavior.stayInArea(*it, WALL - DISTANCE);
15             (*it).force += behavior.separation(agents, *it);
16         }
17         refresh();
18     }
```

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

- include/[prison.h](#)
- src/[prison.cpp](#)

5.15 pursuit Class Reference

```
#include <pursuit.h>
```

Inheritance diagram for pursuit:

Collaboration diagram for pursuit:

Public Member Functions

- [pursuit\(\)](#)

Static Public Member Functions

- static void [loop\(\)](#)

Additional Inherited Members

5.15.1 Detailed Description

Definition at line 8 of file pursuit.h.

5.15.2 Constructor & Destructor Documentation

5.15.2.1 pursuit()

```
pursuit::pursuit ( )
```

Definition at line 23 of file pursuit.cpp.

```
23     {
24         name = "pursuit";
25         createAgent(STATIC, nullptr, nullptr, nullptr);
26         callback = reinterpret_cast <void(*)()> ( (void *)(&loop) );
27     }
```

5.15.3 Member Function Documentation

5.15.3.1 loop()

```
void pursuit::loop ( ) [static]
```

Definition at line 8 of file pursuit.cpp.

```
8         {
9     for(auto it = agents.begin(); it < agents.end(); it++){
10         if((*it).name == "gazelle"){
11             (*it).targetPoint = view.getMousePosition();
12             (*it).force = behavior.seek(*it);
13         }
14         else{//lion
15             (*it).force = behavior.pursuit(agents, *it, view);
16         }
17         (*it).arrive = true;
18     }
19
20     refresh();
21 }
```

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

- include/pursuit.h
- src/pursuit.cpp

5.16 pvector Class Reference

```
#include <pvector.h>
```

Collaboration diagram for pvector:

Public Member Functions

- [pvector](#) ()
default constructor
- [pvector](#) (float x, float y)
constructor
- float [magnitude](#) ()
calculates magnitude of the vector
- [pvector](#) & [normalize](#) ()
normalize vector
- void [div](#) (float i)
divides vector by given scalar value
- void [mul](#) (float i)
multiplies vector by given scalar value
- void [add](#) ([pvector](#) p)
addition of vectors
- void [limit](#) (float limit)
limits vector with the given parameter
- float [getAngle](#) ()
get angle using its x and y magnitudes
- float [dotProduct](#) ([pvector](#) v)
dot product of two vectors
- float [angleBetween](#) ([pvector](#) v)
angle is calculated using dot product

- void `print` (const string &s)
debug function
- `pvector operator+=` (`pvector` const &obj)
used between vectors
- `pvector operator+` (`pvector` const &obj)
used between vectors
- `pvector operator-` (`pvector` const &obj)
used between vectors
- `pvector operator-` (`point` const &obj)
used between vector and point
- `pvector operator+` (`point` const &obj)
used between vector and point
- bool `operator==` (`pvector` const &obj)
used between vectors

Public Attributes

- float `x`
used between vector and point
- float `y`
used between vector and point

5.16.1 Detailed Description

Definition at line 17 of file `pvector.h`.

5.16.2 Constructor & Destructor Documentation

5.16.2.1 `pvector()` [1/2]

```
pvector::pvector ( )
```

default constructor

create a new `pvector` instance

See also

[`pvector\(float x, float y\)`](#)

Definition at line 35 of file `pvector.cpp`.

```
36 {
37
38 }
```

5.16.2.2 `pvector()` [2/2]

```
pvector::pvector (
    float x,
    float y )
```

constructor

create a new `pvector` instance

Parameters

<i>x</i>	x magnitude of the vector
<i>y</i>	y magnitude of the vector

See also

[pvector\(\)](#)

Definition at line 40 of file pvector.cpp.

```
41 {  
42     this->x = x;  
43     this->y = y;  
44 }
```

5.16.3 Member Function Documentation

5.16.3.1 add()

```
void pvector::add (  
    pvector p )
```

addition of vectors

vector addition

Parameters

<i>p</i>	vector to add
----------	---------------

Definition at line 58 of file pvector.cpp.

```
59 {  
60     x = x + p.x;  
61     y = y + p.y;  
62 }
```

5.16.3.2 angleBetween()

```
float pvector::angleBetween (  
    pvector v )
```

angle is calculated using dot product

angle calculation between two vectors

Parameters

<i>v</i>	vector to calculate angle
----------	---------------------------

Returns

angle value between two vectors

Definition at line 23 of file pvector.cpp.

```

24 {
25     float angle = this->dotProduct(v) / (this->magnitude() * v.magnitude());
26     angle = acos(angle) * 180 / PI;
27     return angle;
28 }
```

Here is the call graph for this function: Here is the caller graph for this function:

5.16.3.3 div()

```

void pvector::div (
    float i )
```

divides vector by given scalar value

vector division

Parameters

<i>i</i>	scalar value to divide
----------	------------------------

Definition at line 46 of file pvector.cpp.

```

47 {
48     x = x / i;
49     y = y / i;
50 }
```

Here is the caller graph for this function:

5.16.3.4 dotProduct()

```

float pvector::dotProduct (
    pvector v )
```

dot product of two vectors

dot product calculation

Parameters

<i>v</i>	vector to calculate dot product
----------	---------------------------------

Returns

returns scalar dot product value

Definition at line 30 of file pvector.cpp.

```
31 {
32     return ((x * v.x) + (y * v.y));
33 }
```

Here is the caller graph for this function:

5.16.3.5 getAngle()

```
float pvector::getAngle ( )
```

get angle using its x and y magnitudes

calculates vector angle

Returns

angle of the vector

Definition at line 16 of file pvector.cpp.

```
17 {
18     float angle;
19     angle = atan2 (this->y, this->x) * 180 / PI;
20     return angle;
21 }
```

Here is the caller graph for this function:

5.16.3.6 limit()

```
void pvector::limit (
    float limit )
```

limits vector with the given parameter

vector limitation

Parameters

<i>limit</i>	upper limit to restrict vector
--------------	--------------------------------

Definition at line 83 of file pvector.cpp.

```
84 {
85     this->normalize();
86     this->mul(limit);
87 }
```

Here is the call graph for this function: Here is the caller graph for this function:

5.16.3.7 magnitude()

```
float pvector::magnitude ( )
```

calculates magnitude of the vector

uses pisagor theorem for magnitude calculation

Returns

magnititude of the vector

Definition at line 64 of file pvector.cpp.

```
65 {
66     return sqrt((this->x * this->x) + (this->y * this->y));
67 }
```

Here is the caller graph for this function:

5.16.3.8 mul()

```
void pvector::mul (
    float i )
```

multiplies vector by given scalar value

vector multiplication

Parameters

<i>i</i>	scalar value to multiply
----------	--------------------------

Definition at line 52 of file pvector.cpp.

```
53 {
54     x = x * i;
55     y = y * i;
56 }
```

Here is the caller graph for this function:

5.16.3.9 normalize()

```
pvector & pvector::normalize ( )
```

normalize vector

divides vector by magnitude

Returns

normalized vector

Definition at line 69 of file pvector.cpp.

```
70 {
71     float magnitude = this->magnitude();
72     if(magnitude != 0){
73         this->x = this->x / magnitude;
74         this->y = this->y / magnitude;
75     }
76     else{
77         this->x = 0;
78         this->y = 0;
79     }
80     return *this;
81 }
```

Here is the caller graph for this function:

5.16.3.10 operator+() [1/2]

```
pvector pvector::operator+ (
    point const & obj )
```

used between vector and point

overloaded + operator

Parameters

<i>obj</i>	point to add
------------	--------------

Returns

sum

Definition at line 111 of file pvector.cpp.

```
112 {
113     pvector res;
114     res.x = x + obj.x;
115     res.y = y + obj.y;
116     return res;
117 }
```

5.16.3.11 operator+() [2/2]

```
pvector pvector::operator+ (
    pvector const & obj )
```

used between vectors

overloaded + operator

Parameters

<i>obj</i>	vector to add
------------	---------------

Returns

sum of vectors

Definition at line 89 of file pvector.cpp.

```
90 {
91     pvector res;
92     res.x = x + obj.x;
93     res.y = y + obj.y;
94     return res;
95 }
```

5.16.3.12 operator+=()

```
pvector pvector::operator+= (
    pvector const & obj )
```

used between vectors

overloaded += operator

Parameters

<i>obj</i>	vector to add
------------	---------------

Returns

sum of vectors

Definition at line 97 of file pvector.cpp.

```
98 {
99     x = x + obj.x;
100     y = y + obj.y;
101     return *this;
102 }
```

5.16.3.13 operator-() [1/2]

```
pvector pvector::operator- (
    point const & obj )
```

used between vector and point

overloaded - operator

Parameters

<i>obj</i>	point to subtract
------------	-------------------

Returns

difference

Definition at line 119 of file pvector.cpp.

```
120 {
121     pvector res;
122     res.x = x - obj.x;
123     res.y = y - obj.y;
124     return res;
125 }
```


5.16.3.14 operator-() [2/2]

```
pvector pvector::operator- (
    pvector const & obj )
```

used between vectors

overloaded - operator

Parameters

<i>obj</i>	vector to subtract
------------	--------------------

Returns

difference of vectors

Definition at line 132 of file pvector.cpp.

```
133 {
134     pvector res;
135     res.x = x - obj.x;
136     res.y = y - obj.y;
137     return res;
138 }
```

5.16.3.15 operator==()

```
bool pvector::operator==(
    pvector const & obj )
```

used between vectors

overloaded == operator

Parameters

<i>obj</i>	vector to check if equal
------------	--------------------------

Returns

true or false

Definition at line 104 of file pvector.cpp.

```
105 {
106     if (x == obj.x && y == obj.y)
107         return true;
108     return false;
109 }
```

5.16.3.16 print()

```
void pvector::print (
    const string & s )
```

debug function

prints position of the vector

Parameters

s	explanation string of the log
---	-------------------------------

Definition at line 127 of file pvector.cpp.

```
128 {
129     cout << s << " " << x << " " << y << endl;
130 }
```

5.16.4 Member Data Documentation

5.16.4.1 x

```
float pvector::x
```

used between vector and point

x magnitude of the vector

Definition at line 159 of file pvector.h.

5.16.4.2 y

```
float pvector::y
```

used between vector and point

y magnitude of the vector

Definition at line 165 of file pvector.h.

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

- [include/pvector.h](#)
- [src/pvector.cpp](#)

5.17 random Class Reference

```
#include <random.h>
```

Collaboration diagram for random:

Static Public Member Functions

- static void [createRandomArray](#) (int *arr, int size)

5.17.1 Detailed Description

Definition at line 3 of file random.h.

5.17.2 Member Function Documentation

5.17.2.1 createRandomArray()

```
void random::createRandomArray (  
    int * arr,  
    int size ) [static]
```

Definition at line 7 of file random.cpp.

```
7  
8     srand(time(NULL));  
9     for(int i=0; i<size; i++)  
10         arr[i] = i+1;  
11  
12     for (int i=0; i < size; i++){  
13         int r = rand() % size;  
14         swap(arr[i], arr[r]);  
15     }  
16 }
```

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

- include/[random.h](#)
- src/[random.cpp](#)

5.18 scenario Class Reference

```
#include <scenario.h>
```

Inheritance diagram for scenario:

Collaboration diagram for scenario:

Public Member Functions

- [scenario](#) ()
- void [createAgent](#) (int type, int *count, float *force, float *speed)
- void [initGL](#) (int *argv, char **argc)

Static Public Member Functions

- static void [refresh](#) ()

Public Attributes

- void(* [callback](#))()

Static Public Attributes

- static vector< [agent](#) > [agents](#)
- static [graphics](#) [view](#)
- static [steeringBehavior](#) [behavior](#)
- static [color](#) [myColor](#)
- static string [name](#)

5.18.1 Detailed Description

Definition at line 12 of file `scenario.h`.

5.18.2 Constructor & Destructor Documentation

5.18.2.1 `scenario()`

```
scenario::scenario ( )
```

Definition at line 20 of file `scenario.cpp`.

```
21 {  
22     srand(time(NULL));  
23     myColor.createColors();  
24     view = graphics();  
25 }
```

5.18.3 Member Function Documentation

5.18.3.1 createAgent()

```
void scenario::createAgent (
    int type,
    int * count,
    float * force,
    float * speed )
```

Definition at line 97 of file scenario.cpp.

```
98 {
99     if (type == TROOP){
100         createTroop(*count);
101     }
102     else if (type == RANDOM){
103         createRandomAgents(*count, *force, *speed);
104     }
105     else if (type == STATIC){
106         createStaticAgents();
107     }
108     else{
109         //error message
110     }
111 }
```

5.18.3.2 initGL()

```
void scenario::initGL (
    int * argv,
    char ** argc )
```

Definition at line 15 of file scenario.cpp.

```
15 {
16     view.initGraphics(argc, argv, callback);
17 }
```

Here is the caller graph for this function:

5.18.3.3 refresh()

```
void scenario::refresh ( ) [static]
```

Definition at line 27 of file scenario.cpp.

```
27 {
28     for(auto it = agents.begin(); it < agents.end(); it++){
29         (*it).updatePosition((*it).arrive);
30         view.drawAgent(*it, (*it).fillColor);
31     }
32
33     view.drawText(name, point(-34, 32.25)); //TODO: magic numbers, define left corner
34     view.refreshScene();
35 }
```

Here is the call graph for this function:

5.18.4 Member Data Documentation

5.18.4.1 agents

```
vector< agent > scenario::agents [static]
```

Definition at line 18 of file scenario.h.

5.18.4.2 behavior

```
steeringBehavior scenario::behavior [static]
```

Definition at line 20 of file scenario.h.

5.18.4.3 callback

```
void(* scenario::callback) ()
```

Definition at line 23 of file scenario.h.

5.18.4.4 myColor

```
color scenario::myColor [static]
```

Definition at line 21 of file scenario.h.

5.18.4.5 name

```
string scenario::name [static]
```

Definition at line 22 of file scenario.h.

5.18.4.6 view

```
graphics scenario::view [static]
```

Definition at line 19 of file scenario.h.

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

- include/[scenario.h](#)
- src/[scenario.cpp](#)

5.19 steeringBehavior Class Reference

```
#include <steeringBehavior.h>
```

Collaboration diagram for steeringBehavior:

Public Member Functions

- [pvector stayInArea](#) ([agent &agent](#), int turnPoint)
- [pvector inFlowField](#) ([agent &agent](#), [flowField &flow](#))
- [pvector stayInPath](#) ([agent &agent](#), [path &path](#), [graphics view](#))
- [pvector seek](#) ([agent &agent](#))
- [pvector separation](#) (vector< [agent](#) > agents, [agent &agent](#))
- [pvector cohesion](#) (vector< [agent](#) > boids, [agent &agent](#))
- [pvector align](#) (vector< [agent](#) > boids, [agent &agent](#))
- [pvector wander](#) ([agent &agent](#))
- [pvector pursuit](#) (vector< [agent](#) > boids, [agent &pursuer](#), [graphics view](#))
- [pvector evade](#) (vector< [agent](#) > boids, [agent &evader](#), [graphics view](#))
- [pvector flee](#) ([agent &agent](#), [graphics &view](#), [point p](#))
- [pvector avoid](#) (vector< [obstacle](#) > obstacles, [agent &agent](#))
- void [setAngle](#) ([pvector &p](#), float angle)

5.19.1 Detailed Description

Definition at line 28 of file steeringBehavior.h.

5.19.2 Member Function Documentation

5.19.2.1 align()

```
pvector steeringBehavior::align (
    vector< agent > boids,
    agent & agent )
```

Definition at line 105 of file steeringBehavior.cpp.

```
105 {
106     float neighborDist = 30; //TODO: magic number
107     pvector sum {0,0};
108     int count = 0;
109     for(auto it = boids.begin(); it < boids.end(); it++){
110         float d = (agent.position - (*it).position).magnitude();
111         if( (d > 0) && (d < neighborDist) ){
112             sum += (*it).velocity;
113             count++;
114         }
115     }
116     if(count > 0){
117         sum.div(count);
118         sum.normalize().mul(agent.maxSpeed);
119         agent.steering = sum - agent.velocity;
120         return agent.steering;
121     }
122     return pvector(0,0);
123 }
```

Here is the call graph for this function:

5.19.2.2 avoid()

```
pvector steeringBehavior::avoid (
    vector< obstacle > obstacles,
    agent & agent )
```

Definition at line 166 of file steeringBehavior.cpp.

```
166 {
167     float dynamic_length = agent.velocity.magnitude() / agent.maxSpeed;
168     pvector vel = agent.velocity;
169     vel.normalize().mul(dynamic_length);
170     pvector ahead = vel + agent.position;
171     vel.mul(6);
172     pvector ahead2 = vel + agent.position;
173     //view.drawPoint(point(ahead.x, ahead.y));
174     //view.drawPoint(point(ahead2.x, ahead2.y));
175
176     for(auto it = obstacles.begin(); it < obstacles.end(); it++){
177         float dist = (ahead - (*it).p).magnitude();
178         float dist2 = (ahead2 - (*it).p).magnitude();
179         if(dist < (*it).r + 2 || dist2 < (*it).r + 2){
180             pvector avoidance = ahead - (*it).p;
181             avoidance.normalize().mul(20);
182             /*a = point(avoidance.x, avoidance.y);
183             view.drawLine(agent.position, agent.position + a, color(0,1,0));*/
184             return avoidance;
185         }
186     }
187     return pvector(0,0);
188 }
```

Here is the call graph for this function:

5.19.2.3 cohesion()

```
pvector steeringBehavior::cohesion (
    vector< agent > boids,
    agent & agent )
```

Definition at line 125 of file steeringBehavior.cpp.

```
125 {
126     float neighborDist = 20; //TODO: magic number
127     point sum {0,0};
128     int count = 0;
129     for(auto it = boids.begin(); it < boids.end(); it++){
130         float d = (agent.position - (*it).position).magnitude();
131         if( (d > 0) && (d < neighborDist) ){
132             sum = sum + (*it).position;
133             count++;
134         }
135     }
136     if(count > 0){
137         sum.div(count);
138         agent.targetPoint = sum;
139         return seek(agent);
140     }
141     return pvector(0,0);
142 }
```

Here is the call graph for this function:

5.19.2.4 evade()

```
pvector steeringBehavior::evade (
    vector< agent > boids,
    agent & evader,
    graphics view )
```


Definition at line 36 of file steeringBehavior.cpp.

```

36                                     {
37     agent target;
38     for(auto it = boids.begin(); it < boids.end(); it++){
39         if((*it).name == "lion"){
40             target = *it;
41         }
42     }
43
44     point p = point(evader.position.x + 2, evader.position.y - 2);
45     view.drawText(evader.name, p);
46     p = point(target.position.x + 2, target.position.y - 2);
47     view.drawText(target.name, p);
48
49     pvector targetVel = target.velocity;
50     targetVel.mul(5); //TODO: magic number
51
52     point futurePos = target.position + targetVel;
53     view.drawPoint(futurePos);
54
55     pvector dist = evader.position - futurePos;
56     dist.normalize().mul(1 / dist.magnitude());
57
58     evader.targetPoint = evader.position + dist;
59     return flee(evader, view, futurePos);
60 }

```

Here is the call graph for this function:

5.19.2.5 flee()

```

pvector steeringBehavior::flee (
    agent & agent,
    graphics & view,
    point p )

```

Definition at line 20 of file steeringBehavior.cpp.

```

20                                     {
21     pvector dist = agent.targetPoint - p;
22     view.drawPoint(agent.targetPoint);
23
24     if(dist.magnitude() < 15){ //TODO: magic number
25         agent.arrive = false;
26         agent.desiredVelocity = agent.position - p;
27     }
28     else{
29         agent.arrive = true;
30         agent.desiredVelocity = agent.targetPoint - agent.position;
31     }
32     agent.steering = agent.desiredVelocity - agent.velocity;
33     return agent.steering;
34 }

```

Here is the call graph for this function:

5.19.2.6 inFlowField()

```

pvector steeringBehavior::inFlowField (
    agent & agent,
    flowField & flow )

```

Definition at line 218 of file steeringBehavior.cpp.

```

218                                     {
219     //pos_x, pos_y must be non negative integer
220     int pos_x = abs((int)agent.position.x) % WIDTH;
221     int pos_y = abs((int)agent.position.y) % HEIGHT;
222     //TODO: modification required for non uniform fields
223     return flow.getField(pos_x, pos_y);
224 }

```

Here is the call graph for this function:

5.19.2.7 pursuit()

```
pvector steeringBehavior::pursuit (
    vector< agent > boids,
    agent & pursuer,
    graphics view )
```

Definition at line 62 of file steeringBehavior.cpp.

```
62 {
63     agent target;
64     for(auto it = boids.begin(); it < boids.end(); it++){
65         if((*it).name == "gazelle"){
66             target = *it;
67         }
68     }
69
70     point p = point(target.position.x + 2, target.position.y - 2);
71     view.drawText(target.name, p);
72     p = point(pursuer.position.x + 2, pursuer.position.y - 2);
73     view.drawText(pursuer.name, p);
74
75     float dist = (target.position - pursuer.position).magnitude();
76     float t = dist / target.maxSpeed;
77
78     pvector targetVel = target.velocity;
79     targetVel.mul(t);
80     point futurePos = target.position + targetVel;
81     pursuer.targetPoint = futurePos;
82     return seek(pursuer);
83 }
```

Here is the call graph for this function:

5.19.2.8 seek()

```
pvector steeringBehavior::seek (
    agent & agent )
```

Definition at line 190 of file steeringBehavior.cpp.

```
190 {
191     agent.desiredVelocity = agent.targetPoint - agent.position;
192     agent.steering = agent.desiredVelocity - agent.velocity;
193     return agent.steering;
194 }
```

5.19.2.9 separation()

```
pvector steeringBehavior::separation (
    vector< agent > agents,
    agent & agent )
```

Definition at line 144 of file steeringBehavior.cpp.

```
144 {
145     float desiredSeparation = 5; //TODO: magic number
146     pvector sum = pvector(0,0);
147     int count = 0;
148     for(auto it = agents.begin(); it < agents.end(); it++){
149         float d = (agent.position - (*it).position).magnitude();
150         if( (d > 0) && (d < desiredSeparation) ){
151             pvector diff = agent.position - (*it).position;
152             diff.normalize().div(d);
153             sum = sum + diff;
154             count++;
155         }
156     }
157     if(count > 0){
158         sum.div(count);
159         sum.normalize().mul(agent.maxSpeed);
160         agent.steering = sum - agent.velocity;
161         return agent.steering;
162     }
163     return pvector(0,0);
164 }
```

Here is the call graph for this function:

5.19.2.10 setAngle()

```
void steeringBehavior::setAngle (
    pvector & p,
    float angle )
```

Definition at line 15 of file steeringBehavior.cpp.

```
15 {
16     p.x = cos ( angle * PI / 180.0 );
17     p.y = sin ( angle * PI / 180.0 );
18 }
```

5.19.2.11 stayInArea()

```
pvector steeringBehavior::stayInArea (
    agent & agent,
    int turnPoint )
```

Definition at line 226 of file steeringBehavior.cpp.

```
226 {
227     if(agent.position.x >= turnPoint){
228         agent.desiredVelocity = pvector( -agent.maxSpeed, agent.velocity.y );
229         agent.steering = agent.desiredVelocity - agent.velocity;
230         return agent.steering;
231     }
232     else if(agent.position.x <= -turnPoint){
233         agent.desiredVelocity = pvector( agent.maxSpeed, agent.velocity.y );
234         agent.steering = agent.desiredVelocity - agent.velocity;
235         return agent.steering;
236     }
237     else if(agent.position.y >= turnPoint){
238         agent.desiredVelocity = pvector( agent.velocity.x, -agent.maxSpeed );
239         agent.steering = agent.desiredVelocity - agent.velocity;
240         return agent.steering;
241     }
242     else if(agent.position.y <= -turnPoint){
243         agent.desiredVelocity = pvector( agent.velocity.x, agent.maxSpeed );
244         agent.steering = agent.desiredVelocity - agent.velocity;
245         return agent.steering;
246     }
247     return pvector(0,0);
248 }
```

5.19.2.12 stayInPath()

```
pvector steeringBehavior::stayInPath (
    agent & agent,
    path & path,
    graphics view )
```

Definition at line 196 of file steeringBehavior.cpp.

```
196 {
197     float worldRecord = 1000000; //TODO: magic number
198     point normalPoint, predictedPos, start, end;
199     pvector distance;
200     for(auto it = path.points.begin(); it < path.points.end()-1; it++){
201         start = point ((*it).x, (*it).y);
202         end = point ((*it+1).x, (*it+1).y);
203         predictedPos = agent.position + agent.velocity;
204         normalPoint.getNormalPoint(predictedPos, start, end);
205         if (normalPoint.x < start.x || normalPoint.x > end.x){
206             normalPoint = end;
207         }
208         distance = predictedPos - normalPoint;
```

```

209         if (distance.magnitude() < worldRecord){
210             worldRecord = distance.magnitude();
211             agent.targetPoint = end;
212         }
213         view.drawPoint(agent.targetPoint);
214     }
215     return seek(agent);
216 }

```

Here is the call graph for this function:

5.19.2.13 wander()

```

pvector steeringBehavior::wander (
    agent & agent )

```

Definition at line 85 of file steeringBehavior.cpp.

```

85     {
86         pvector circleCenter = agent.velocity;
87         circleCenter.normalize().mul(CIRCLE_DISTANCE + CIRCLE_RADIUS);
88
89         int wanderAngle = (rand() % 360);
90         pvector displacement {0, 1};
91         setAngle(displacement, wanderAngle);
92         displacement.mul(CIRCLE_RADIUS);
93
94         agent.desiredVelocity = displacement + circleCenter;
95         agent.steering = agent.desiredVelocity - agent.velocity;
96
97         //move it to the center when it is out of screen
98         if(agent.position.x > WIDTH || agent.position.x < -WIDTH ||
99            agent.position.y > HEIGHT || agent.position.y < -HEIGHT)
100             agent.position = point(0,0);
101
102         return agent.steering;
103     }

```

Here is the call graph for this function:

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

- include/steeringBehavior.h
- src/steeringBehavior.cpp

5.20 wander Class Reference

```
#include <wander.h>
```

Inheritance diagram for wander:

Collaboration diagram for wander:

Public Member Functions

- [wander \(\)](#)

Static Public Member Functions

- static void [loop \(\)](#)

Additional Inherited Members

5.20.1 Detailed Description

Definition at line 8 of file wander.h.

5.20.2 Constructor & Destructor Documentation

5.20.2.1 wander()

wander::wander ()

Definition at line 16 of file wander.cpp.

```

16     {
17         int agentCount = 30;
18         float maxForce = 0.3;
19         float maxSpeed = 0.6;
20
21         name = "wandering objects";
22         createAgent(RANDOM, &agentCount, &maxForce, &maxSpeed);
23         callback = reinterpret_cast<void(*)()> ( (void *)(&loop) );
24     }
```

5.20.3 Member Function Documentation

5.20.3.1 loop()

void wander::loop () [static]

Definition at line 8 of file wander.cpp.

```

8     {
9         for(auto it = agents.begin(); it < agents.end(); it++){
10             (*it).force = behavior.wander(*it);
11         }
12
13         refresh();
14     }
```

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

- include/wander.h
- src/wander.cpp

5.21 windy Class Reference

```
#include <windy.h>
```

Inheritance diagram for windy:

Collaboration diagram for windy:

Public Member Functions

- [windy\(\)](#)

Static Public Member Functions

- static void [loop\(\)](#)

Static Public Attributes

- static [flowField](#) [flow](#)

Additional Inherited Members

5.21.1 Detailed Description

Definition at line 9 of file windy.h.

5.21.2 Constructor & Destructor Documentation

5.21.2.1 windy()

windy::windy ()

Definition at line 21 of file windy.cpp.

```

21     {
22         int agentCount = 30;
23         float maxForce = 0.3;
24         float maxSpeed = 0.6;
25
26         name = "flow field";
27         createAgent(RANDOM, &agentCount, &maxForce, &maxSpeed);
28         callback = reinterpret_cast<void(*)()> ( (void *)(&loop) );
29     }
```

5.21.3 Member Function Documentation

5.21.3.1 loop()

void windy::loop () [static]

Definition at line 10 of file windy.cpp.

```

10     {
11         for(auto it = agents.begin(); it < agents.end(); it++){
12             flow = flowField(pvector(GRAVITY));
13             (*it).force = behavior.inFlowField(*it, flow);
14
15             flow = flowField(pvector(WIND_WEST));
16             (*it).force += behavior.inFlowField(*it, flow);
17         }
18         refresh();
19     }
```

5.21.4 Member Data Documentation

5.21.4.1 flow

```
flowField windy::flow [static]
```

Definition at line 13 of file windy.h.

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

- include/windy.h
- src/windy.cpp

Chapter 6

File Documentation

6.1 include/agent.h File Reference

agent class defines all agent specifications

```
#include "point.h"
#include "color.h"
#include "flowField.h"
#include <vector>
#include <string>
Include dependency graph for agent.h:
```

6.2 include/color.h File Reference

color class used for agent, path, wall etc. color

```
#include <vector>
Include dependency graph for color.h: This graph shows which files directly or indirectly include this file:
```

Classes

- class `color`

Enumerations

- enum `num` {
 `BLACK` =0, `BLUE`, `GREEN`, `CYAN`,
 `RED`, `MAGENDA`, `YELLOW`, `WHITE` }
 used to get color from colors vector

6.2.1 Detailed Description

color class used for agent, path, wall etc. color

Author

Mehmet Rıza Öz - mehmetrizaoz@gmail.com

Date

13.05.2021

6.2.2 Enumeration Type Documentation

6.2.2.1 num

enum [num](#)

used to get color from colors vector

color names for fundamental colors

Enumerator

BLACK	
BLUE	
GREEN	
CYAN	
RED	
MAGENDA	
YELLOW	
WHITE	

Definition at line 18 of file color.h.

```
18 { BLACK=0, BLUE, GREEN, CYAN, RED, MAGENDA, YELLOW, WHITE };
```

6.3 include/evade.h File Reference

```
#include "scenario.h"
```

```
#include <vector>
```

Include dependency graph for evade.h: This graph shows which files directly or indirectly include this file:

Classes

- class [evade](#)

6.4 include/flee.h File Reference

```
#include "scenario.h"
#include <vector>
```

Include dependency graph for flee.h: This graph shows which files directly or indirectly include this file:

Classes

- class [flee](#)

6.5 include/flock.h File Reference

```
#include "scenario.h"
#include <vector>
```

Include dependency graph for flock.h: This graph shows which files directly or indirectly include this file:

Classes

- class [flock](#)

6.6 include/flowField.h File Reference

[flowField](#) class, screen can be filled with a force for each pixel

```
#include "pvector.h"
```

Include dependency graph for flowField.h: This graph shows which files directly or indirectly include this file:

Classes

- class [flowField](#)

Macros

- `#define` [FIELD_WIDTH](#) 34
- `#define` [FIELD_HEIGHT](#) 34
- `#define` [WIND_WEST](#) 0.1, 0.0
- `#define` [GRAVITY](#) 0.0, -0.1

6.6.1 Detailed Description

[flowField](#) class, screen can be filled with a force for each pixel

Author

Mehmet Rıza Öz - mehmetrizaoz@gmail.com

Date

13.05.2021

6.6.2 Macro Definition Documentation

6.6.2.1 FIELD_HEIGHT

```
#define FIELD_HEIGHT 34
```

Definition at line 13 of file flowField.h.

6.6.2.2 FIELD_WIDTH

```
#define FIELD_WIDTH 34
```

Definition at line 12 of file flowField.h.

6.6.2.3 GRAVITY

```
#define GRAVITY 0.0, -0.1
```

Definition at line 16 of file flowField.h.

6.6.2.4 WIND_WEST

```
#define WIND_WEST 0.1, 0.0
```

Definition at line 15 of file flowField.h.

6.7 include/graphics.h File Reference

graphics class, drives OpenGL

```
#include "agent.h"  
#include "path.h"
```

Include dependency graph for graphics.h: This graph shows which files directly or indirectly include this file:

Classes

- class [graphics](#)

Macros

- `#define WIDTH 34`
- `#define HEIGHT 34`
- `#define ESC 27`
- `#define PI 3.14159265`

6.7.1 Detailed Description

graphics class, drives openGL

Author

Mehmet Rıza Öz - mehmetrizaoz@gmail.com

Date

15.05.2021

6.7.2 Macro Definition Documentation

6.7.2.1 ESC

```
#define ESC 27
```

Definition at line 16 of file graphics.h.

6.7.2.2 HEIGHT

```
#define HEIGHT 34
```

Definition at line 14 of file graphics.h.

6.7.2.3 PI

```
#define PI 3.14159265
```

Definition at line 17 of file graphics.h.

6.7.2.4 WIDTH

```
#define WIDTH 34
```

Definition at line 13 of file graphics.h.

6.8 include/mouseFollower.h File Reference

```
#include "scenario.h"  
#include <vector>
```

Include dependency graph for mouseFollower.h: This graph shows which files directly or indirectly include this file:

Classes

- class [mouseFollower](#)

6.9 include/obstacle.h File Reference

circular obstacles for agent avoidance behaviors

```
#include "point.h"
```

Include dependency graph for obstacle.h: This graph shows which files directly or indirectly include this file:

Classes

- class [obstacle](#)

6.9.1 Detailed Description

circular obstacles for agent avoidance behaviors

Author

Mehmet Rıza Öz - mehmetrizaoz@gmail.com

Date

12.05.2021

6.10 include/obstacleAvoidance.h File Reference

```
#include "scenario.h"  
#include "obstacle.h"  
#include <vector>
```

Include dependency graph for obstacleAvoidance.h: This graph shows which files directly or indirectly include this file:

Classes

- class [obstacleAvoidance](#)

6.11 include/path.h File Reference

path class used for path following steering behaviors.

```
#include "point.h"  
#include <vector>
```

Include dependency graph for path.h: This graph shows which files directly or indirectly include this file:

Classes

- class [path](#)

6.11.1 Detailed Description

path class used for path following steering behaviors.

Author

Mehmet Rıza Öz - mehmetrizaoz@gmail.com

Date

12.05.2021

6.12 include/pathFollower.h File Reference

```
#include "scenario.h"  
#include <vector>
```

Include dependency graph for pathFollower.h: This graph shows which files directly or indirectly include this file:

Classes

- class [pathFollower](#)

6.13 include/point.h File Reference

point class used for point operations

```
#include "pvector.h"  
#include <string>
```

Include dependency graph for point.h: This graph shows which files directly or indirectly include this file:

Classes

- class [point](#)

6.13.1 Detailed Description

point class used for point operations

Author

Mehmet Rıza Öz - mehmetrizaoz@gmail.com

Date

15.05.2021

6.14 include/prison.h File Reference

```
#include "scenario.h"
```

```
#include <vector>
```

Include dependency graph for prison.h: This graph shows which files directly or indirectly include this file:

Classes

- class [prison](#)

6.15 include/pursuit.h File Reference

```
#include "scenario.h"
```

```
#include <vector>
```

Include dependency graph for pursuit.h: This graph shows which files directly or indirectly include this file:

Classes

- class [pursuit](#)

6.16 include/pvector.h File Reference

pvector class used for 2D vector operations

```
#include <string>
```

Include dependency graph for pvector.h: This graph shows which files directly or indirectly include this file:

Classes

- class [pvector](#)

Macros

- #define [PI](#) 3.14159265

6.16.1 Detailed Description

pvector class used for 2D vector operations

Author

Mehmet Rıza Öz - mehmetrizaoz@gmail.com

Date

15.05.2021

6.16.2 Macro Definition Documentation

6.16.2.1 PI

```
#define PI 3.14159265
```

Definition at line 11 of file pvector.h.

6.17 include/random.h File Reference

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

Classes

- class [random](#)

6.18 include/scenario.h File Reference

```
#include "agent.h"  
#include "graphics.h"  
#include "steeringBehavior.h"  
#include <vector>
```

Include dependency graph for scenario.h: This graph shows which files directly or indirectly include this file:

Classes

- class [scenario](#)

Enumerations

- enum [types](#) { [RANDOM](#) =0, [STATIC](#), [TROOP](#) }

6.18.1 Enumeration Type Documentation

6.18.1.1 types

enum [types](#)

Enumerator

RANDOM	
STATIC	
TROOP	

Definition at line 10 of file scenario.h.

```
10 { RANDOM=0, STATIC, TROOP };
```

6.19 include/steeringBehavior.h File Reference

```
#include "flowField.h"
#include <vector>
#include "graphics.h"
#include "obstacle.h"
```

Include dependency graph for steeringBehavior.h: This graph shows which files directly or indirectly include this file:

Classes

- class [steeringBehavior](#)

Macros

- #define [CIRCLE_DISTANCE](#) 0.1
- #define [CIRCLE_RADIUS](#) 0.4
- #define [FOLLOW_MOUSE](#) 1
- #define [STAY_IN_FIELD](#) 2
- #define [IN_FLOW_FIELD](#) 3
- #define [AVOID_OBSTACLE](#) 4

- `#define STAY_IN_PATH 5`
- `#define FLOCK 6`
- `#define WANDER 7`
- `#define FLEE 8`
- `#define PURSUIT 9`
- `#define EVADE 10`

6.19.1 Macro Definition Documentation

6.19.1.1 AVOID_OBSTACLE

```
#define AVOID_OBSTACLE 4
```

Definition at line 14 of file steeringBehavior.h.

6.19.1.2 CIRCLE_DISTANCE

```
#define CIRCLE_DISTANCE 0.1
```

Definition at line 8 of file steeringBehavior.h.

6.19.1.3 CIRCLE_RADIUS

```
#define CIRCLE_RADIUS 0.4
```

Definition at line 9 of file steeringBehavior.h.

6.19.1.4 EVADE

```
#define EVADE 10
```

Definition at line 20 of file steeringBehavior.h.

6.19.1.5 FLEE

```
#define FLEE 8
```

Definition at line 18 of file steeringBehavior.h.

6.19.1.6 FLOCK

```
#define FLOCK 6
```

Definition at line 16 of file steeringBehavior.h.

6.19.1.7 FOLLOW_MOUSE

```
#define FOLLOW_MOUSE 1
```

Definition at line 11 of file steeringBehavior.h.

6.19.1.8 IN_FLOW_FIELD

```
#define IN_FLOW_FIELD 3
```

Definition at line 13 of file steeringBehavior.h.

6.19.1.9 PURSUIT

```
#define PURSUIT 9
```

Definition at line 19 of file steeringBehavior.h.

6.19.1.10 STAY_IN_FIELD

```
#define STAY_IN_FIELD 2
```

Definition at line 12 of file steeringBehavior.h.

6.19.1.11 STAY_IN_PATH

```
#define STAY_IN_PATH 5
```

Definition at line 15 of file steeringBehavior.h.

6.19.1.12 WANDER

```
#define WANDER 7
```

Definition at line 17 of file steeringBehavior.h.

6.20 include/wander.h File Reference

```
#include "scenario.h"  
#include <vector>
```

Include dependency graph for wander.h: This graph shows which files directly or indirectly include this file:

Classes

- class [wander](#)

6.21 include/windy.h File Reference

```
#include "scenario.h"  
#include "flowField.h"  
#include <vector>
```

Include dependency graph for windy.h: This graph shows which files directly or indirectly include this file:

Classes

- class [windy](#)

6.22 main.cpp File Reference

```
#include <iostream>  
#include "mouseFollower.h"  
#include "prison.h"  
#include "windy.h"  
#include "wander.h"  
#include "pursuit.h"  
#include "flee.h"  
#include "scenario.h"  
#include "evade.h"  
#include "flock.h"  
#include "pathFollower.h"  
#include "obstacleAvoidance.h"
```

Include dependency graph for main.cpp:

Functions

- void [menu](#) ()
- int [main](#) (int argc, char **argv)

Variables

- int `mode`

6.22.1 Function Documentation

6.22.1.1 `main()`

```
int main (
    int argc,
    char ** argv )
```

Definition at line 32 of file main.cpp.

```
32     {
33         menu();
34
35         scenario* sc;
36
37         if(mode == FOLLOW_MOUSE){
38             *sc = mouseFollower();
39         }
40         else if(mode == STAY_IN_FIELD){
41             *sc = prison();
42         }
43         else if(mode == IN_FLOW_FIELD){
44             *sc = windy();
45         }
46         else if(mode == WANDER){
47             *sc = wander();
48         }
49         else if(mode == PURSUIT){
50             *sc = pursuit();
51         }
52         else if(mode == FLEE){
53             *sc = flee();
54         }
55         else if(mode == EVADE){
56             *sc = evade();
57         }
58         else if(mode == FLOCK){
59             *sc = flock();
60         }
61         else if(mode == STAY_IN_PATH){
62             *sc = pathFollower();
63         }
64         else if(mode == AVOID_OBSTACLE){
65             *sc = obstacleAvoidance();
66         }
67
68         sc->initGL(&argc, argv);
69
70         return 0;
71     }
```

Here is the call graph for this function:

6.22.1.2 `menu()`

```
void menu ( )
```

Definition at line 18 of file main.cpp.

```
18     {
19         cout << "Follow Mouse      : 1" << endl;
20         cout << "Stay in Field      : 2" << endl;
21         cout << "In Flow Field     : 3" << endl;
22         cout << "OBSTACLE AVOIDANCE : 4" << endl;
```

```
23     cout << "Stay in Path      : 5" << endl;
24     cout << "FLOCK           : 6" << endl;
25     cout << "WANDER          : 7" << endl;
26     cout << "FLEE            : 8" << endl;
27     cout << "PURSUIT         : 9" << endl;
28     cout << "EVADE           : 10" << endl;
29     cin >> mode;
30 }
```

Here is the caller graph for this function:

6.22.2 Variable Documentation

6.22.2.1 mode

```
int mode
```

Definition at line 16 of file main.cpp.

6.23 README.md File Reference

6.24 src/agent.cpp File Reference

implementation of the agent class

```
#include "agent.h"
#include "pvector.h"
#include "graphics.h"
#include "random.h"
#include <iostream>
Include dependency graph for agent.cpp:
```

6.24.1 Detailed Description

implementation of the agent class

Author

Mehmet Rıza Öz - mehmetrizaoz@gmail.com

Date

14.05.2021

6.25 src/color.cpp File Reference

color class implementation

```
#include "color.h"
#include <vector>
Include dependency graph for color.cpp:
```

6.25.1 Detailed Description

color class implementation

Author

Mehmet Rıza Öz - mehmetrizaoz@gmail.com

Date

13.05.2021

6.26 src/evade.cpp File Reference

```
#include "scenario.h"
#include "evade.h"
#include <iostream>
#include <GL/glut.h>
Include dependency graph for evade.cpp:
```

6.27 src/flee.cpp File Reference

```
#include "scenario.h"
#include "flee.h"
#include <iostream>
#include <GL/glut.h>
Include dependency graph for flee.cpp:
```

6.28 src/flock.cpp File Reference

```
#include "scenario.h"
#include "flock.h"
#include <iostream>
#include <GL/glut.h>
Include dependency graph for flock.cpp:
```


6.29 src/flowField.cpp File Reference

[flowField](#) class implementation

```
#include "flowField.h"
```

Include dependency graph for flowField.cpp:

6.29.1 Detailed Description

[flowField](#) class implementation

Author

Mehmet Rıza Öz - mehmetrizaoz@gmail.com

Date

13.05.2021

6.30 src/graphics.cpp File Reference

graphics class implementation

```
#include "graphics.h"
#include <GL/glut.h>
#include <iostream>
#include "math.h"
```

Include dependency graph for graphics.cpp:

6.30.1 Detailed Description

graphics class implementation

Author

Mehmet Rıza Öz - mehmetrizaoz@gmail.com

Date

15.05.2021

6.31 src/mouseFollower.cpp File Reference

```
#include "scenario.h"
#include "mouseFollower.h"
#include <iostream>
#include <GL/glut.h>
```

Include dependency graph for mouseFollower.cpp:

6.32 src/obstacle.cpp File Reference

obstacle class implementation

```
#include "obstacle.h"
#include "graphics.h"
#include "point.h"
#include <vector>
Include dependency graph for obstacle.cpp:
```

6.32.1 Detailed Description

obstacle class implementation

Author

Mehmet Rıza Öz - mehmetrizaoz@gmail.com

Date

12.05.2021

6.33 src/obstacleAvoidance.cpp File Reference

```
#include "scenario.h"
#include "obstacleAvoidance.h"
#include <iostream>
#include <GL/glut.h>
Include dependency graph for obstacleAvoidance.cpp:
```

6.34 src/path.cpp File Reference

path class implementation

```
#include "path.h"
#include "graphics.h"
Include dependency graph for path.cpp:
```

6.34.1 Detailed Description

path class implementation

Author

Mehmet Rıza Öz - mehmetrizaoz@gmail.com

Date

12.05.2021

6.35 src/pathFollower.cpp File Reference

```
#include "scenario.h"
#include "pathFollower.h"
#include <iostream>
#include <GL/glut.h>
Include dependency graph for pathFollower.cpp:
```

6.36 src/point.cpp File Reference

point class implementation file

```
#include "point.h"
#include "pvector.h"
#include <string>
#include <iostream>
Include dependency graph for point.cpp:
```

6.36.1 Detailed Description

point class implementation file

Author

Mehmet Rıza Öz - mehmetrizaoz@gmail.com

Date

15.05.2021

6.37 src/prison.cpp File Reference

```
#include "scenario.h"
#include "prison.h"
#include <iostream>
#include <GL/glut.h>
Include dependency graph for prison.cpp:
```

Macros

- #define [WALL](#) 30
- #define [DISTANCE](#) 2

6.37.1 Macro Definition Documentation

6.37.1.1 DISTANCE

```
#define DISTANCE 2
```

Definition at line 7 of file prison.cpp.

6.37.1.2 WALL

```
#define WALL 30
```

Definition at line 6 of file prison.cpp.

6.38 src/pursuit.cpp File Reference

```
#include "scenario.h"
#include "pursuit.h"
#include <iostream>
#include <GL/glut.h>
```

Include dependency graph for pursuit.cpp:

6.39 src/pvector.cpp File Reference

pvector class implementation

```
#include "pvector.h"
#include "math.h"
#include "point.h"
#include <iostream>
#include <string>
```

Include dependency graph for pvector.cpp:

6.39.1 Detailed Description

pvector class implementation

Author

Mehmet Rıza Öz - mehmetrizaoz@gmail.com

Date

15.05.2021

6.40 src/random.cpp File Reference

```
#include "random.h"
#include <stdlib.h>
#include <iostream>
Include dependency graph for random.cpp:
```

6.41 src/scenario.cpp File Reference

```
#include "scenario.h"
#include "random.h"
#include <iostream>
Include dependency graph for scenario.cpp:
```

Macros

- `#define MAX_NUMBER_OF_AGENTS 50`

6.41.1 Macro Definition Documentation

6.41.1.1 MAX_NUMBER_OF_AGENTS

```
#define MAX_NUMBER_OF_AGENTS 50
```

Definition at line 5 of file scenario.cpp.

6.42 src/steeringBehavior.cpp File Reference

```
#include "steeringBehavior.h"
#include "pvector.h"
#include "agent.h"
#include "path.h"
#include "point.h"
#include <vector>
#include "graphics.h"
#include "math.h"
#include "obstacle.h"
#include <iostream>
#include <GL/glut.h>
Include dependency graph for steeringBehavior.cpp:
```

6.43 src/wander.cpp File Reference

```
#include "scenario.h"
#include "wander.h"
#include <iostream>
#include <GL/glut.h>
Include dependency graph for wander.cpp:
```

6.44 src/windy.cpp File Reference

```
#include "scenario.h"
#include "windy.h"
#include <iostream>
#include <GL/glut.h>
Include dependency graph for windy.cpp:
```

6.45 test/test_suites.cpp File Reference

```
#include <boost/test/included/unit_test.hpp>
#include "../include/pvector.h"
#include "../include/point.h"
#include <iostream>
Include dependency graph for test_suites.cpp:
```

Macros

- `#define BOOST_TEST_MODULE test_suites`

Functions

- [BOOST_AUTO_TEST_CASE](#) (s1t1)
- [BOOST_AUTO_TEST_CASE](#) (s1t2)
- [BOOST_AUTO_TEST_CASE](#) (s1t3)
- [BOOST_AUTO_TEST_CASE](#) (s1t4)
- [BOOST_AUTO_TEST_CASE](#) (s1t5)
- [BOOST_AUTO_TEST_CASE](#) (s1t6)
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- [BOOST_AUTO_TEST_CASE](#) (s2t2)
- [BOOST_AUTO_TEST_CASE](#) (s2t3)

6.45.1 Macro Definition Documentation

6.45.1.1 BOOST_TEST_MODULE

```
#define BOOST_TEST_MODULE test_suites
```

Definition at line 1 of file test_suites.cpp.

6.45.2 Function Documentation

6.45.2.1 BOOST_AUTO_TEST_CASE() [1/12]

```
BOOST_AUTO_TEST_CASE (
    slt1 )
```

Definition at line 12 of file test_suites.cpp.

```
13 {
14     pvector p1 = pvector(0, 4);
15     pvector p2 = pvector(3, 0);
16     pvector p3 = p1 + p2;
17     BOOST_CHECK(p3.magnitude() == 5);
18 }
```

Here is the call graph for this function:

6.45.2.2 BOOST_AUTO_TEST_CASE() [2/12]

```
BOOST_AUTO_TEST_CASE (
    slt2 )
```

Definition at line 20 of file test_suites.cpp.

```
21 {
22     pvector p1 = pvector(1, 1);
23     p1.mul(3);
24     pvector p2 = pvector(3, 3);
25     BOOST_CHECK(p1 == p2);
26 }
```

Here is the call graph for this function:

6.45.2.3 BOOST_AUTO_TEST_CASE() [3/12]

```
BOOST_AUTO_TEST_CASE (
    slt3 )
```

Definition at line 28 of file test_suites.cpp.

```
29 {
30     pvector p1 = pvector(5, 5);
31     p1.div(5);
32     pvector p2 = pvector(1, 1);
33     BOOST_CHECK(p1 == p2);
34 }
```

Here is the call graph for this function:

6.45.2.4 BOOST_AUTO_TEST_CASE() [4/12]

```
BOOST_AUTO_TEST_CASE (
    slt4 )
```

Definition at line 36 of file test_suites.cpp.

```
37 {
38     pvector p1 = pvector(1, 4);
39     pvector p2 = pvector(3, 2);
40     float dotProduct = p1.dotProduct(p2);
41     BOOST_CHECK(dotProduct == 11);
42 }
```

Here is the call graph for this function:

6.45.2.5 BOOST_AUTO_TEST_CASE() [5/12]

```
BOOST_AUTO_TEST_CASE (
    slt5 )
```

Definition at line 44 of file test_suites.cpp.

```
45 {
46     pvector p1 = pvector(10, 10);
47     pvector p2 = pvector(0, 10);
48     float angle = p1.angleBetween(p2);
49     BOOST_CHECK(angle == 45);
50 }
```

Here is the call graph for this function:

6.45.2.6 BOOST_AUTO_TEST_CASE() [6/12]

```
BOOST_AUTO_TEST_CASE (
    slt6 )
```

Definition at line 52 of file test_suites.cpp.

```
53 {
54     pvector p1 = pvector(3, 4);
55     float angle = p1.getAngle();
56     BOOST_CHECK(angle < 53.2 && angle > 52.8);
57 }
```

Here is the call graph for this function:

6.45.2.7 BOOST_AUTO_TEST_CASE() [7/12]

```
BOOST_AUTO_TEST_CASE (
    slt7 )
```

Definition at line 59 of file test_suites.cpp.

```
60 {
61     pvector p1 = pvector(2, 2);
62     p1.normalize();
63     float range = 0.01;
64     BOOST_CHECK_CLOSE_FRACTION(0.707, p1.x, range);
65     BOOST_CHECK_CLOSE_FRACTION(0.707, p1.y, range);
66 }
```

Here is the call graph for this function:

6.45.2.8 BOOST_AUTO_TEST_CASE() [8/12]

```
BOOST_AUTO_TEST_CASE (
    slt8 )
```

Definition at line 68 of file test_suites.cpp.

```
69 {
70     pvector p1 = pvector(2, 2);
71     p1.limit(3);
72     float range = 0.01;
73     BOOST_CHECK_CLOSE_FRACTION(2.12, p1.x, range);
74     BOOST_CHECK_CLOSE_FRACTION(2.12, p1.y, range);
75 }
```

Here is the call graph for this function:

6.45.2.9 BOOST_AUTO_TEST_CASE() [9/12]

```
BOOST_AUTO_TEST_CASE (
    slt9 )
```

Definition at line 77 of file test_suites.cpp.

```
78 {
79     pvector p1 = pvector(1, 1);
80     p1 += pvector(1, 1);
81     BOOST_CHECK(p1 == pvector(2, 2));
82     p1 = pvector(1, 1) + pvector(3, 3);
83     BOOST_CHECK(p1 == pvector(4, 4));
84     p1 = pvector(4, 1) - pvector(3, 3);
85     BOOST_CHECK(p1 == pvector(1, -2));
86     p1 = pvector(4, 1) - point(3, 3);
87     BOOST_CHECK(p1 == pvector(1, -2));
88     p1 = pvector(4, 1) + point(3, 3);
89     BOOST_CHECK(p1 == pvector(7, 4));
90 }
```

Here is the call graph for this function:

6.45.2.10 BOOST_AUTO_TEST_CASE() [10/12]

```
BOOST_AUTO_TEST_CASE (
    s2t1 )
```

Definition at line 96 of file test_suites.cpp.

```
97 {
98     point p1 = point(1, 1);
99     p1.mul(3);
100     point p2 = point(3, 3);
101     BOOST_CHECK(p1 == p2);
102 }
```

Here is the call graph for this function:

6.45.2.11 BOOST_AUTO_TEST_CASE() [11/12]

```
BOOST_AUTO_TEST_CASE (
    s2t2 )
```

Definition at line 104 of file test_suites.cpp.

```
105 {
106     point p1 = point(4, 4);
107     p1.div(4);
108     point p2 = point(1, 1);
109     BOOST_CHECK(p1 == p2);
110 }
```

Here is the call graph for this function:

6.45.2.12 BOOST_AUTO_TEST_CASE() [12/12]

```
BOOST_AUTO_TEST_CASE (
    s2t3 )
```

Definition at line 112 of file test_suites.cpp.

```
113 {
114     point p1 = point(1,1) + point(3,3);
115     BOOST_CHECK(p1 == point(4,4));
116     p1 = point(1,1) + pvector(3,3);
117     BOOST_CHECK(p1 == point(4,4));
118     pvector p2 = point(1,1) - point(3,3);
119     BOOST_CHECK(p2 == pvector(-2,-2));
120 }
```

Here is the call graph for this function:

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