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PS0: Hello World

The Assignment

Hello World was our first Computing IV assignment. The main goal of this assignment was to setup our Linux build environment and to test out the SFML audio/graphics library. This included getting Linux running – either through a Virtualbox image or natively, and running some SFML example code to test out SFML. We then had to extend the demo code to make it do something interesting. I was already familiar with Linux at this point, so it really didn't take very long to setup my environment – a few sudo apt-get install commands and I had SFML ready to test out.

Key Concepts

As this was just first assignment, I did not really use any algorithms to create the program. Mostly just basic programming stuff like variables, objects, a couple of while / for loops for keeping the window open and for moving the sprites around. The main idea of this assignment after all was just to test out SFML's different classes, which included Images, Sprites, Text, Texture, and Keyboard. The Texture / Image / Sprite classes also interact with each other – you must load an image into a Texture, and a sprite must set a Texture to be used.

For this assignment, I created a program that uses SFML's sprite class to display a moving image on an SFML window. I added some basic controls to move it around – arrow keys for up/down/left/right, the plus key (+) to increase the size of the sprite and the minus key (-) decreases the size of the image. I also messed around with a few other parts of SFML – I got text to display on the screen, and made a second image move around in a set pattern.

What I Learned

I learned a few things about SFML in this assignment. A few things I learned were: how to use SFML at a basic level, how to display images in an SFML window and even how to control a sprites using SFML's Keyboard library. I did not learn much about Linux, or how to setup a build environment for Linux. This is because I have used Linux previously in a Computing II lab (Prof. Adams), and I have also used Linux in a research lab (Prof. Martin's ECG lab). Personally I also dual-boot Windows and Linux as well, and wrote all of my Computing III C++ programs in Linux – so things like setting up SFML were simple since all I needed to do was boot Linux up and run sudo apt-get install.

Screenshots



Source code for PS0 Hello World

NOTE: For this first assignment, there was no requirement for any header files (.hpps) or implementation files (other .cpps). As such, just the Makefile and main.cpp are listed.

Makefile

```
1 CC = g++
2
3 all:
4     $(CC) -c main.cpp -Wall -Werror -ansi -pedantic
5     $(CC) main.o -o sfml-app -lsfml-graphics -lsfml-window -lsfml-system
6
7 clean:
8     rm main.o
9     rm sfml-app
```

Main.cpp

```
1 #include <iostream>
2 #include <SFML/Graphics.hpp>
3 #include <string>
4
5 using namespace std;
6 using namespace sf;
7
8 int main()
9 {
10     // Set the size of the window.
11     // In this case I make it 605 by 605. The title is "Program 0".
12     RenderWindow window(VideoMode(605, 605), "Program 0: Doge Sprite Moves");
13
14     // Change the framerate to make it easier to see the image moving.
15     window.setFramerateLimit(1);
16
17     // Loads a doge from file - in this case a doge
18     Texture image_texture;
19
20     // Check to see if the file loaded correctly.
21     // I make just the doge part of the image load - it's actually 300 by 372
22     // but I cut off 50 pixels from the height.
23     if (!image_texture.loadFromFile("sprite.png", IntRect(0, 50, 300, 300)))
24     {
25         // Return failure if the image doesn't load
26         cout << "Failed to load image!\n";
27         return EXIT_FAILURE;
28     }
29
30     // Make the image look nice.
31     image_texture.setSmooth(true);
32
33     // Now set the doge using the texture
34     Sprite doge;
35     doge.setTexture(image_texture);
36
37     // Set the origin for rotation to the center of the doge.
38     doge.setOrigin(150, 125);
39
40     // Move to the top left corner.
41     doge.move(150, 100);    // Top left corner
42
43     // Create an image to move in a rectangle pattern
44     Texture image2_texture;
45
46     // Load the image
47     if (!image2_texture.loadFromFile("doga.png"))
48     {
49         // Return failure if the image doesn't load
50         cout << "Failed to load image!\n";
51         return EXIT_FAILURE;
52     }
53
54     image2_texture.setSmooth(true);
```

```
55
56 // Second doge settings
57 Sprite doge2;
58 doge2.setTexture(image2_texture); // Set the texture
59 doge2.scale(.25f, .25f); // Shrink the image
60 doge2.setOrigin(732, 620); // Set the center of the image
61 doge2.move(300, 300); // Move the image to the top left corner
62
63 int dir = 1;
64
65 // Create a graphical text to display
66 Font font;
67 if (!font.loadFromFile("arial.ttf"))
68 {
69     cout << "Failed to load font!\n";
70     return EXIT_FAILURE;
71 }
72
73 // Create a text.
74 Text text("Woof", font, 70);
75
76 // Move the text to the bottom center (roughly)
77 text.move(230,500);
78
79 // Window loop
80 while (window.isOpen())
81 {
82     // Process events
83     Event event;
84
85     while(window.pollEvent(event))
86     {
87         // Close window : exit
88         if (event.type == Event::Closed)
89         {
90             window.close();
91         }
92
93         // Move the image if an arrow key is pressed.
94         else if(Event::KeyPressed)
95         {
96             // Arrow keys will move the doge in the
97             // expected direction.
98             if (Keyboard::isKeyPressed(Keyboard::Left))
99             {
100                 doge2.move(-15, 0);
101             }
102             else if (Keyboard::isKeyPressed(Keyboard::Right))
103             {
104                 doge2.move(15, 0);
105             }
106             else if (Keyboard::isKeyPressed(Keyboard::Up))
107             {
108                 doge2.move(0, -15);
109             }
110             else if (Keyboard::isKeyPressed(Keyboard::Down))
111             {
```

```

112         doge2.move(0, 15);
113     }
114
115     // Enter will rotate the doge
116     else if (Keyboard::isKeyPressed(Keyboard::Space))
117     {
118         doge2.rotate(45);
119     }
120
121     // Pressing + will increase the size of the doge.
122     else if (Keyboard::isKeyPressed(Keyboard::Add))
123     {
124         doge2.scale(1.05f, 1.05f);
125     }
126
127     // Pressing - will decrease the size of the doge.
128     else if (Keyboard::isKeyPressed(Keyboard::Subtract))
129     {
130         doge2.scale(.95f, .95f);
131     }
132
133     // Pressing escape will quit the program.
134     else if (Keyboard::isKeyPressed(Keyboard::Escape))
135     {
136         return 0;
137     }
138 }
139
140
141     // Clear the screen - so that the doge's previous image gets erased.
142 window.clear();
143
144     // Ifs that will keep the Doge sprite moving in a rectangle pattern.
145     // Basically they increase int dir by 1 until it reaches 5, then it
146     // resets the int dir to 1.
147 switch(dir)
148 {
149     case 1:
150         doge.move(300, 0);           // Top right corner
151         dir++;
152         break;
153
154     case 2:
155         doge.move(0, 325);          // Bottom right corner
156         dir++;
157         break;
158
159     case 3:
160         doge.move(-300, 0);         // Bottom left corner
161         dir++;
162         break;
163
164     case 4:
165         doge.move(0, -325);         // Top left corner again.
166         dir++;
167         break;
168

```

```
169     default:
170         dir = 1;
171         break;
172     }
173
174     // Redraw the doge
175     window.draw(doge);
176
177     // This is the second doge - the one that moves in a rectangle.
178     window.draw(doge2);
179
180     // Draw the string
181     window.draw(text);
182
183     // Update the window
184     window.display();
185 }
186
187     return 0;
188 }
```

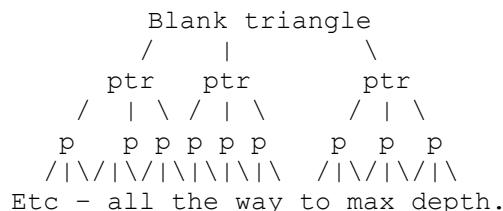
PS1: Recursive Graphic

The Assignment

For this second assignment, we were tasked with implementing the Sierpinski triangle assignment from Princeton. The main idea behind the assignment was to use recursion to create a complex looking triangle that in reality takes only a little bit of code to generate. The main program was to take an integer, N, which would be used to control the depth of the recursion. Our program would then draw one triangle at depth 1, four triangles at depth 2 and so – in effect drawing triangles within each other recursively. A second part of the assignment was to create our own recursively image – different than the Sierpinski triangle design, but still using recursion to generate a cool looking image. I was able to create both the Sierpinski triangle design and my own circle within a circle (which changes colors) design.

Key Concepts

Key to this program was the idea of recursion. I had to figure out a way to implement the triangle drawing within each other recursively, and do so without using a ton of resources. I found the best way to do this was using pointers to other triangles – the first main triangle has three Sierpinski pointers, and those also have pointers to three more triangles and so on until the max depth is reached. I recreated a little diagram in my README file that illustrates this quite well:



By using pointers, I was able to recursively draw the triangles out in the Sierpinski::Draw method – I just did something like:

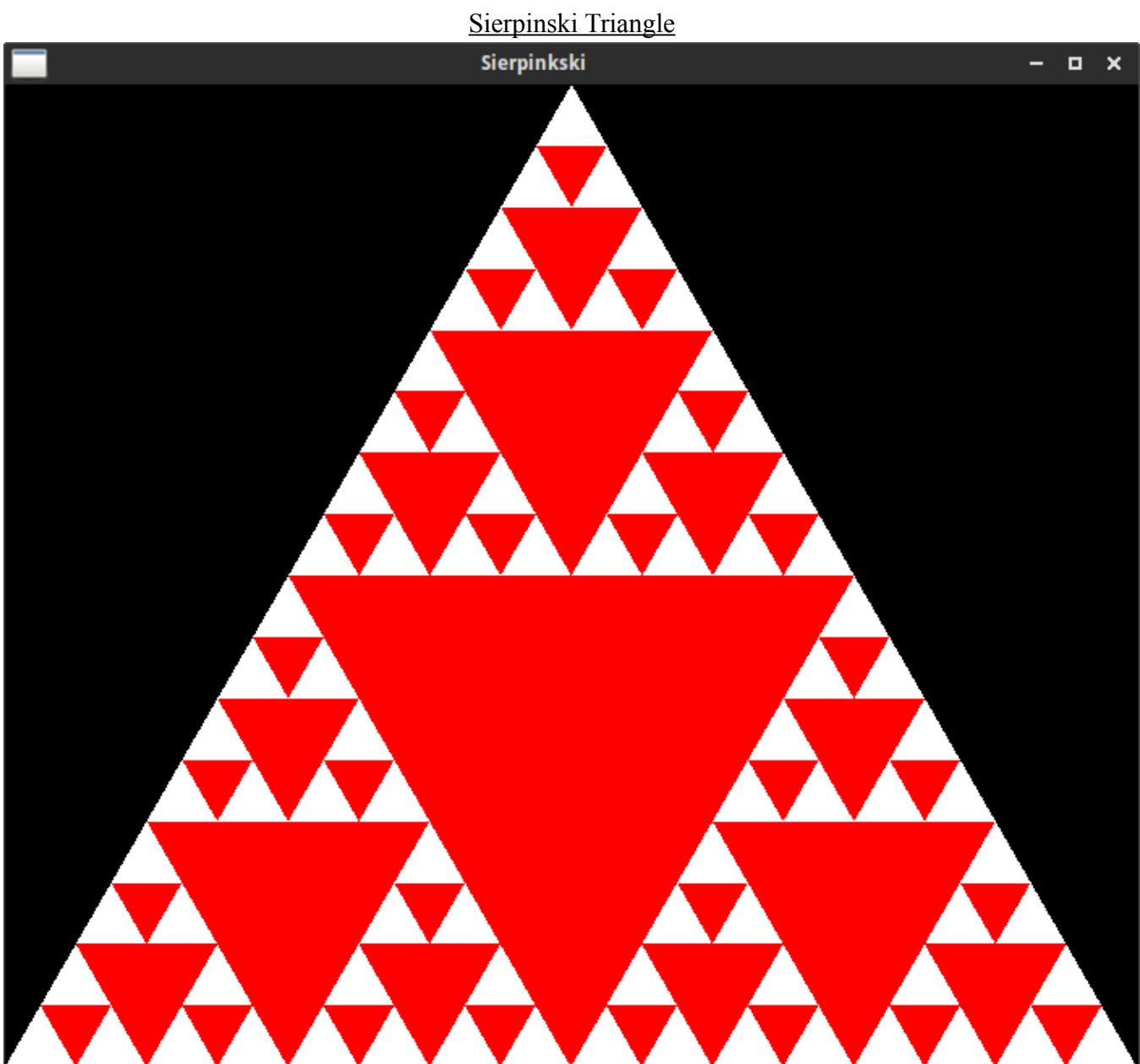
```
150     _triangle1->draw(target, states);
151     _triangle2->draw(target, states);
152     _triangle3->draw(target, states);
```

This ends up calling draw on each triangle, which in turn called draw on all of their triangles, until the recursion depth is reached.

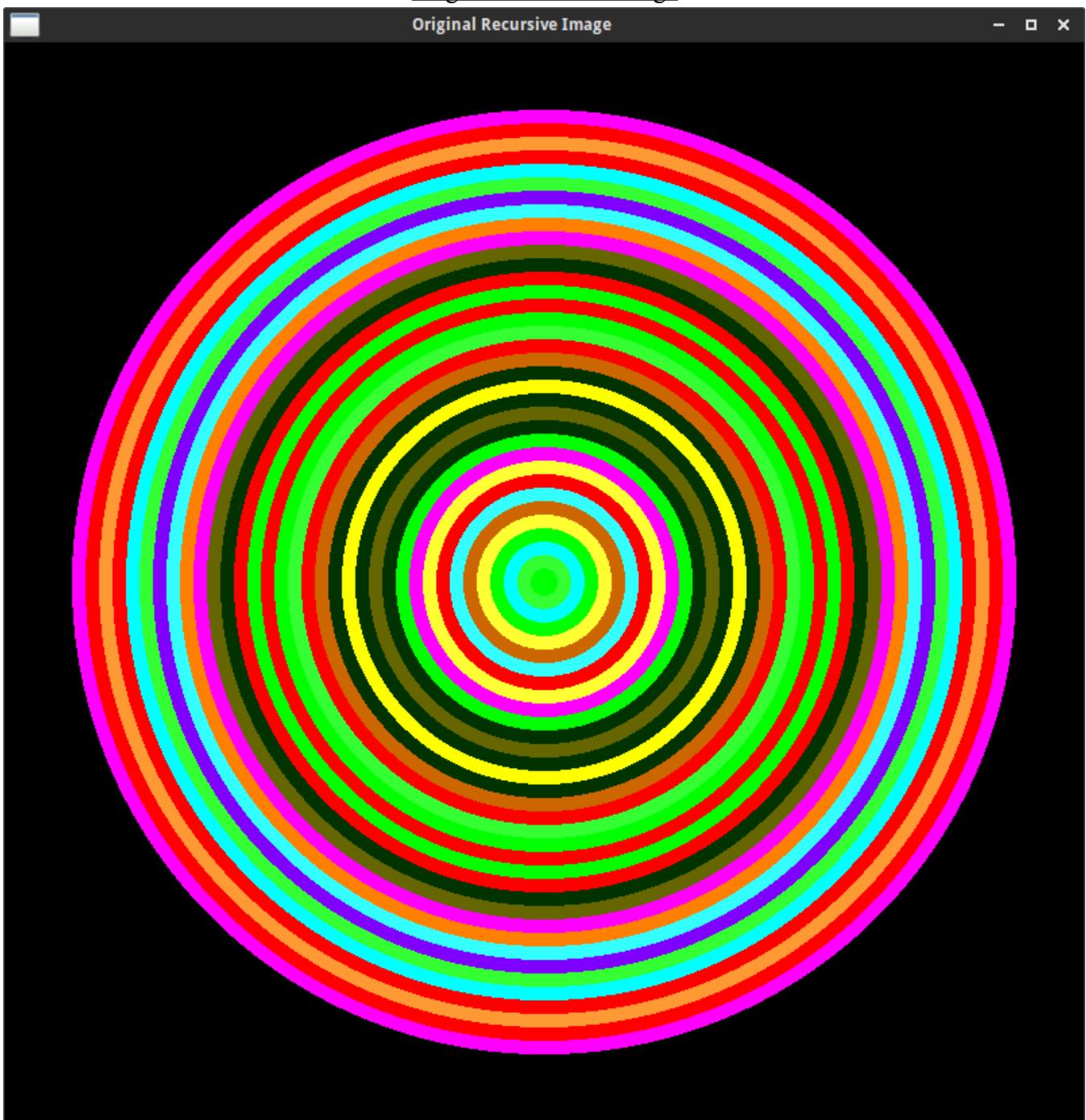
What I Learned

I ended up learning a little bit about recursion – I had used it before in previous classes, but never quite like this, where I was able to use pointers to other objects in order to recursively go back and draw them out. Implementing my own design after learning how to draw an object recursively was also much easier, as I already knew how I could set up the code, I just had to think about what kind of image I wanted to draw and how to make it look interesting. In the end, it was a fun assignment that taught me about recursion in a different way than I was used to.

Screenshots



Original Recursive Image



*Note: I also uploaded the original design to imgur a while back.
You can check out the animation at the following links:*

5FPS version: <https://imgur.com/e3kgJPT>

60FPS version (lots of colors): <https://imgur.com/qeALOGf>

Source Code for PS1 Recursive Graphic

Makefile

```
1  # Makefile for the sierpinski project / original recursive image
2  # Flags to save on typing all this out
3  CC = g++
4  CFLAGS = -Wall -Werror -ansi -pedantic
5  LFLAGS = -lsfml-graphics -lsfml-window -lsfml-system
6
7  # Make both projects
8  all: sierpinski original
9
10 # Original image related code
11 original: o_main.o original.o
12         $(CC) o_main.o original.o -o original $(LFLAGS)
13
14 o_main.o: o_main.cpp original.hpp
15         $(CC) -c o_main.cpp $(CFLAGS)
16
17 original.o: original.cpp original.hpp
18         $(CC) -c original.cpp $(CFLAGS)
19
20
21 # Sierpinski triangle related code
22 sierpinski: main.o sierpinski.o
23         $(CC) main.o sierpinski.o -o sierpinski $(LFLAGS)
24
25 main.o: main.cpp sierpinski.hpp
26         $(CC) -c main.cpp $(CFLAGS)
27
28 sierpinski.o: sierpinski.cpp sierpinski.hpp
29         $(CC) -c sierpinski.cpp $(CFLAGS)
30
31 # Cleanup
32 clean:
33         rm *.o
34         rm sierpinski
35         rm original
```

Main.cpp

```
1  /*
2   * Copyright 2015 Jason Downing
3   *
4   */
5 #include "sierpinski.hpp"
6
7 int main(int argc, char* argv[]) {
8     // Make sure we are given exactly 3 arguments
9     if ( argc < 3 || argc > 4 ) {
10         // Let the user know the correct way of calling the program.
11         std::cout << "./sierpinski [recursion-depth] [side-length] \n";
12         return -1;
13     }
14
15     int depth = atoi(argv[1]);
16     int side = atoi(argv[2]);
17
18     cout << "depth: " << depth << endl;
19     cout << "side: " << side << endl;
20
21     // Added this since I do not think it would be logical
22     // to have negative (-2, -3, etc) recursion
23     if (depth < 0) {
24         std::cout << "depth should be greater than 0 - ";
25         std::cout << "illogical to have negative recursion.\n";
26         return -2;
27     }
28
29     // Sierpinski object, calls default constructor
30     Sierpinski obj(depth, side);
31
32     int window_height = static_cast<int>(.5)*sqrt(3.0)*static_cast<float>(side);
33
34     sf::RenderWindow window(sf::VideoMode(side, window_height), "Sierpinski");
35
36     // Change the framerate to make it easier to see the image moving.
37     window.setFramerateLimit(1);
38
39     // Window loop
40     while (window.isOpen()) {
41         // Process events
42         sf::Event event;
43
44         while (window.pollEvent(event)) {
45             // Close window : exit
46             if (event.type == sf::Event::Closed) {
47                 window.close();
48             } else if (sf::Keyboard::isKeyPressed(sf::Keyboard::Escape)) {
49                 window.close();
50             }
51         }
52
53         window.clear();
54         window.draw(obj);    // Call the draw object in the sierpinski class
```

```
55         window.display();
56     }
57
58     return 0;
59 }
60
```

Sierpinski.hpp

```
1  #ifndef SIERPINSKI_HPP
2  #define SIERPINSKI_HPP
3
4  #include <cmath>
5  #include <iostream>
6  #include <SFML/Graphics.hpp>
7  #include <vector>
8
9  using namespace std;
10
11 class Sierpinski : public sf::Drawable
12 {
13 public:
14     // Constructor that takes just depth and side
15     Sierpinski(int depth, int side);
16
17     // Constructor that takes three points and depth
18     Sierpinski(sf::Vector2f top, sf::Vector2f left,
19                 sf::Vector2f right, int depth);
20
21     // Destructor
22     ~Sierpinski();
23
24 private:
25     // Draw method
26     void virtual draw(sf::RenderTarget& target, sf::RenderStates states) const;
27
28     // Member variables
29     int _depth;
30     sf::Vector2f _top, _left, _right;
31     sf::Vector2f _p1, _p2, _p3;
32
33     // Pointers to additional triangles.
34     Sierpinski *_triangle1, *_triangle2, *_triangle3;
35 };
36
37 #endif
38
```

Sierpinski.cpp

```
1 #include <cmath>
2 #include <iostream>
3 #include <SFML/Graphics.hpp>
4 #include <vector>
5 #include "sierpinski.hpp"
6
7 using namespace std;
8
9 /*
10
11      _top
12      .
13      / \
14      /   \
15      /     \
16      p1 ----- p3
17      / \   / \
18      /   \ /   \
19      /     \   \
20      .-----.
21 _left    p2    _right
22
23 The above is an ASCII representation of what this code does.
24 We have _top, _left, _right member variables we use to
25 to draw the triangle in the middle using p1/p2/p3
26
27 */
28
29 // Constructor           Initialize private variables)
30 Sierpinski::Sierpinski(int depth, int side) : _depth (depth)
31 {
32     // Initialize other member variables - top, left, right
33     _top = sf::Vector2f(side / 2, 0);
34
35     // Calculate the height using triangle geometry
36     float height = .5 * sqrt(3.0) * (float) side;
37
38     // Calculate left and right using the height.
39     _left = sf::Vector2f(0, height);
40     _right = sf::Vector2f(side-1, height);
41
42     /* Call the constructor that accepts 3 points.
43      * First find p1, p2, p3.
44      * To do so, use the midpt formula:
45      *
46      * ( (x1 + x2) / 2 , (y1 + y2) / 2 )
47      *
48      */
49     _p1 = sf::Vector2f(((_top.x + _left.x) / 2), ((_top.y + _left.y) / 2));
50     _p2 = sf::Vector2f(((_left.x + _right.x) / 2), ((_left.y + _right.y) / 2));
51     _p3 = sf::Vector2f(((_top.x + _right.x) / 2), ((_top.y + _right.y) / 2));
52
53     if (_depth - 1 > 0)
54 {
```

```

55     // Now that we have the points, create 3 triangles
56     _triangle1 = new Sierpinski(_p1, _left, _p2, depth - 1);
57     _triangle2 = new Sierpinski(_top, _p1, _p3, depth - 1);
58     _triangle3 = new Sierpinski(_p3, _p2, _right, depth - 1);
59 }
60 else {
61     _triangle1 = NULL;
62     _triangle2 = NULL;
63     _triangle3 = NULL;
64 }
65 }
66
67
68 Sierpinski::Sierpinski(sf::Vector2f top, sf::Vector2f left,
69                         sf::Vector2f right, int depth) : _depth (depth)
70 {
71     // End of the recursion.
72     if(depth <= 0)
73     {
74         // Set the 3 triangle pointers to null
75         _triangle1 = NULL;
76         _triangle2 = NULL;
77         _triangle3 = NULL;
78
79         return;
80     }
81
82     // Set member variables - points of the triangle
83     _top = top;
84     _left = left;
85     _right = right;
86
87     // Set the filled triangle points - use midpoint formula
88     _p1 = sf::Vector2f( ((top.x + left.x) / 2), ((top.y + left.y) / 2) );
89     _p2 = sf::Vector2f( ((left.x + right.x) / 2), ((left.y + right.y) / 2) );
90     _p3 = sf::Vector2f( ((top.x + right.x) / 2), ((top.y + right.y) / 2) );
91
92     // Now that we have the points, create 3 triangles
93     _triangle1 = new Sierpinski(_p1, left, _p2, depth - 1);
94     _triangle2 = new Sierpinski(top, _p1, _p3, depth - 1);
95     _triangle3 = new Sierpinski(_p3, _p2, right, depth - 1);
96 }
97
98
99 // Destructor
100 Sierpinski::~Sierpinski()
101 {
102     // Need to destroy all the objects that were created
103     if(_triangle1 != NULL)
104     {
105         // Recursively call the destructor
106         delete _triangle1;
107         delete _triangle2;
108         delete _triangle3;
109     }
110
111     // After we clear the allocated objects, we don't have to worry about

```

```
112 // stuff allocated on the stack since that will be handled automagically.
113 }
114
115
116 void Sierpinski::draw(sf::RenderTarget& target,
117                         sf::RenderStates states) const {
118     // Check the beginning dimensions of the overall triangle
119     cout << "_depth is: " << _depth << endl;
120     cout << "_top is: (" << _top.x << ", " << _top.y << ") \n";
121     cout << "_left is (" << _left.x << ", " << _left.y << ") \n";
122     cout << "_right is (" << _right.x << ", " << _right.y << ") \n";
123
124     // The outside triangle.
125     sf::ConvexShape triangle;
126     triangle.setPointCount(3);
127     triangle.setPoint(0, _left);
128     triangle.setPoint(1, _right);
129     triangle.setPoint(2, _top);
130
131     // The filled upside down triangle.
132     sf::ConvexShape triangle2;
133     triangle2.setPointCount(3);
134     triangle2.setPoint(0, _p1);
135     triangle2.setPoint(1, _p2);
136     triangle2.setPoint(2, _p3);
137     triangle2.setFillColor(sf::Color::Red);
138
139     // Draw the two triangles above.
140     target.draw(triangle);
141
142     // Make _depth just print out a blank triangle
143     if(_depth > 0)
144     {
145         target.draw(triangle2);
146     }
147
148     if(_triangle1 != NULL)
149     {
150         _triangle1->draw(target, states);
151         _triangle2->draw(target, states);
152         _triangle3->draw(target, states);
153     }
154 }
```

o_main.cpp

```
1  /*
2   * Copyright 2015 Jason Downing
3   *
4   */
5 #include "original.hpp"
6
7 int main(int argc, char* argv[]) {
8     // Make sure we are given exactly 2 arguments
9     if (argc < 2 || argc > 3) {
10         // Let the user know the correct way of calling the program.
11         std::cout << "./original [recursion-depth]" << "\n";
12         return -1;
13     }
14
15     int depth = atoi(argv[1]);
16
17     Original obj(depth);
18
19     sf::RenderWindow window(sf::VideoMode(800, 800),
20                           "Original Recursive Image");
21
22     // Change the framerate to make it easier to see the image moving.
23     window.setFramerateLimit(60);
24
25     // Window loop
26     while (window.isOpen()) {
27         // Process events
28         sf::Event event;
29
30         while (window.pollEvent(event)) {
31             // Close window : exit
32             if (event.type == sf::Event::Closed) {
33                 window.close();
34             } else if (sf::Keyboard::isKeyPressed(sf::Keyboard::Escape)) {
35                 window.close();
36             }
37         }
38
39         window.clear();
40         window.draw(obj);      // Call the draw object in the Original class
41         window.display();
42     }
43
44     return 0;
45 }
46
```

original.hpp

```
1      /*
2       * Copyright 2015 Jason Downing
3       *
4      */
5      #ifndef ORIGINAL_HPP
6      #define ORIGINAL_HPP
7
8      #include <stdlib.h>
9      #include <SFML/Graphics.hpp>
10     #include <time.h>
11     #include <cmath>
12     #include <iostream>
13     #include <vector>
14
15     class Original : public sf::Drawable {
16     public:
17         // Constructor that takes just depth and side
18         explicit Original(int depth);
19
20         // Constructor that takes three points and depth
21         Original(float radius, int depth);
22
23         // Destructor
24         ~Original();
25
26     private:
27         // Draw method
28         void virtual draw(sf::RenderTarget& target,
29                           sf::RenderStates states) const;
30
31         // Member variables
32         int _depth;
33         float _radius;
34
35         // Pointers to additional triangles.
36         Original *_circle;
37     };
38
39 #endif
```

original.cpp

```
1  /*
2   * Copyright 2015 Jason Downing
3   *
4   */
5 #include "original.hpp"
6
7 /*
8  * Initial coordinates of the circle will be:
9  * 1) set the origin to be radius, radius - this makes it so that
10     the circle's center for transforming / moving / etc
11     is its middle point.
12 * 2) set the position to be the center of the screen
13 */
14
15
16 // Constructor with just the depth as a parameter
17 Original::Original(int depth) {
18     // Seed the rand function for random colors - uses current time to do so
19     srand(time(NULL));
20
21     // Set the initial depth
22     _depth = depth;
23
24     // Set the initial radius.
25     _radius = 350;
26
27     // Create a new circle;
28     _circle = new Original(_radius - 10, _depth - 1);
29 }
30
31
32 // Constructor with coordinates - recursive
33 Original::Original(float radius, int depth) {
34     // When depth is less than 0, the recursion is done.
35     if (depth < 0) {
36         _circle = NULL;
37
38         return;
39     }
40
41     // Set member variables
42     _depth = depth;
43     _radius = radius;
44
45     // Create a new circle;
46     _circle = new Original(_radius - 10, _depth - 1);
47     return;
48 }
49
50
51 // Destructor
52 Original::~Original() {
53     if (_circle != NULL) {
54         delete _circle;
```

```
55     }
56 }
57
58
59 // Draw method
60 void Original::draw(sf::RenderTarget& target,
61                     sf::RenderStates states) const {
62     std::cout << "_depth is: " << _depth << std::endl;
63     std::cout << "_Radius is: " << _radius << std::endl;
64
65     // First circle
66     sf::CircleShape shape(_radius);
67     shape.setOrigin(_radius, _radius);
68     shape.setPosition(400, 400);
69     shape.setPointCount(10000);
70
71     unsigned int seed = time(NULL);
72
73     // Make a random number between 1 and 19
74     // That means there will be 19 different colors flashing!
75     int random_number = rand_r(&seed) % 19 + 1;
76
77     // Make three random numbers
78
79     // Color object
80     sf::Color color(0, 0, 0, 255);
81
82     switch (random_number) {
83         case 1:
84             // Red Color
85             shape.setFillColor(sf::Color::Red);
86             break;
87
88         case 2:
89             // Orange Color
90             color.r = 255;
91             color.g = 128;
92             color.b = 0;
93             shape.setFillColor(color);
94             break;
95
96         case 3:
97             // Yellow Color
98             shape.setFillColor(sf::Color::Yellow);
99             break;
100
101        case 4:
102            // Green
103            shape.setFillColor(sf::Color::Green);
104            break;
105
106        case 5:
107            // Magenta
108            shape.setFillColor(sf::Color::Magenta);
109            break;
110
111        case 6:
```

```
112     // Cyan
113     shape.setFillColor(sf::Color::Cyan);
114     break;
115
116     case 7:
117         // Purple
118         color.r = 127;
119         color.g = 0;
120         color.b = 255;
121         shape.setFillColor(color);
122         break;
123
124     case 8:
125         // Pink
126         color.r = 255;
127         color.g = 0;
128         color.b = 255;
129         shape.setFillColor(color);
130         break;
131
132
133     case 9:
134         // Dark Orange
135         color.r = 204;
136         color.g = 102;
137         color.b = 0;
138         shape.setFillColor(color);
139         break;
140
141
142     case 10:
143         // Dark Blue
144         color.r = 0;
145         color.g = 0;
146         color.b = 102;
147         shape.setFillColor(color);
148         break;
149
150
151     case 11:
152         // Dark Purple
153         color.r = 255;
154         color.g = 0;
155         color.b = 0;
156         shape.setFillColor(color);
157         break;
158
159     case 12:
160         // Dark Green
161         color.r = 0;
162         color.g = 51;
163         color.b = 0;
164         shape.setFillColor(color);
165         break;
166
167     case 13:
168         // Gold
```

```
169     color.r = 102;
170     color.g = 102;
171     color.b = 0;
172     shape.setFillColor(color);
173     break;
174
175     case 14:
176         // Lime Green
177         color.r = 51;
178         color.g = 255;
179         color.b = 51;
180         shape.setFillColor(color);
181         break;
182
183     case 15:
184         // Lime Green
185         color.r = 51;
186         color.g = 255;
187         color.b = 51;
188         shape.setFillColor(color);
189         break;
190
191     case 16:
192         // Light Orange
193         color.r = 255;
194         color.g = 153;
195         color.b = 51;
196         shape.setFillColor(color);
197         break;
198
199     case 17:
200         // Light Yellow
201         color.r = 255;
202         color.g = 255;
203         color.b = 51;
204         shape.setFillColor(color);
205         break;
206
207     case 18:
208         // Light Blue
209         color.r = 51;
210         color.g = 255;
211         color.b = 255;
212         shape.setFillColor(color);
213         break;
214
215     case 19:
216         // Light Red
217         color.r = 255;
218         color.g = 0;
219         color.b = 0;
220         shape.setFillColor(color);
221         break;
222
223     default:
224         break;
225 }
```

```

226
227 /*
228 * Colors to use
229 * I generated these using:
230 * http://www.rapidtables.com/web/color/RGB_Color.htm
231 * I then used the Color() constructor which takes a
232 * Red, Green, Blue int for setting
233 * custom colors.
234 *
235 * "Standard colors"
236 * Red      -> sf::Color::Color(255, 0, 0)
237 * Orange   -> sf::Color::Color(255, 128, 0)
238 * Yellow   -> sf::Color::Color(255, 255, 51)
239 * Green    -> sf::Color::Color(0, 153, 0)
240 * Blue     -> sf::Color::Color(0, 0, 255)
241 * Purple   -> sf::Color::Color(127, 0, 255)
242 * Pink     -> sf::Color::Color(255, 0, 255)
243 *
244 * "Dark colors"
245 * Dark Orange: sf::Color::Color(204, 102, 0)
246 * Dark Blue:   sf::Color::Color(0, 0, 102)
247 * Dark Purple: sf::Color::Color(255, 0, 0)
248 * Dark Green:  sf::Color::Color(0, 51, 0)
249 * Gold:        sf::Color::Color(102, 102, 0)
250 *
251 * "Light colors"
252 * Lime Green:  sf::Color::Color(51, 255, 51)
253 * Light Orange: sf::Color::Color(255, 153, 51)
254 * Light Yellow: sf::Color::Color(255, 255, 51)
255 * Light Blue:   sf::Color::Color(51, 255, 255)
256 * Light Blue:   sf::Color::Color(51, 153, 255)
257 * Light Purple: sf::Color::Color(153, 51, 255)
258 * Light Red:    sf::Color::Color(255, 0, 0)
259 *
260 */
261
262 // Draw this circle
263 target.draw(shape);
264
265 // Recusive calls
266 if (_circle != NULL) {
267     _circle->draw(target, states);
268 }
269 }
270

```

PS2a: Linear Feedback Shift Register and Unit Testing

The Assignment

This assignment required us to implement Princeton's Linear Feedback Shift Register. This type of register shift all bits left one position, and then XOR's the left most bit and the seed bit to fill the empty space on the far right side after the shift left. Our main goals were to implement the shift register in a class called "LFSR" and to implement several unit tests using the Boost test framework.

Key Concepts

We used the Boost test framework to test our LFSR class, which in my code I represent the shift register as a C++ string. I also used an integer to hold the tap position, and this allowed me to use C++'s string / ostringstream objects to implement the step and generate methods. Shifting left was accomplished by feeding the string representing the register into an ostringstream object and then appending the result of XORing the left most bit with the tap position. The Boost test framework was used to test our LFSR class, by using Boost's auto rest case method's to test the step / generate methods against edge cases, typical cases and even some of Princeton's test cases.

What I Learned

This assignment taught me a lot about testing in C++. I had never really thought much about testing my code using unit tests – in the past, I've done a combination of compiling, making sure the program runs, and then manually testing different aspects to see if it looks "OK". Using the Boost test framework made things simple – I could write tests and then change my code and with a few commands know that I did not just break code that was previously working. In the future I plan to continue using unit testing for projects I work on that get complex / hard to manually test often.

Screenshots

The screenshot shows a terminal window titled "ps2a : bash - Konsole". The window has a menu bar with "File", "Edit", "View", "Bookmarks", "Settings", and "Help". The main area of the terminal displays the following command-line session:

```
jason@jason-desktop: ps2a$ make clean
rm *.o
rm *.out
rm ps2a
jason@jason-desktop: ps2a$ make
g++ -c main.cpp -Wall -Werror -ansi -pedantic
g++ -c LFSR.cpp -Wall -Werror -ansi -pedantic
g++ main.o LFSR.o -o main.out
g++ -c test.cpp LFSR.hpp -Wall -Werror -ansi -pedantic
g++ test.o LFSR.o -o ps2a -lboost_unit_test_framework
jason@jason-desktop: ps2a$ ./main.out
Test case 1.
11010000101 1
10100001011 1
01000010110 0
10000101100 0
00001011001 1
00010110010 0
00101100100 0
01011001001 1
10110010010 0
01100100100 0

Example
of
running
my
main.out
(extra
main)
and ps2a
(runs the
Boost
unit
tests)

Test case 2.
00001011001 25
01100100100 4
10010011110 30
011110111011 27
01101110010 18
110010111010 26
011010111100 28
01110011000 24
01100010111 23
01011111101 29
0111 3
1
jason@jason-desktop: ps2a$ ./ps2a
Running 3 test cases...
*** No errors detected
jason@jason-desktop: ps2a$
```

The terminal window has a title bar "ps2a : bash - Konsole" and a status bar at the bottom with "ps2a : bash".

Source Code for PS2a Linear Feedback Shift Register

Makefile

```
1      # Makefile for PS2a
2      # Flags to save on typing all this out
3      CC= g++
4      CFLAGS= -Wall -Werror -ansi -pedantic
5      Boost= -lboost_unit_test_framework
6
7      # Make both projects
8      all: main.out ps2a
9
10     # Boost unit tests
11     ps2a: test.o LFSR.o
12         $(CC) test.o LFSR.o -o ps2a $(Boost)
13
14     test.o: test.cpp LFSR.hpp
15         $(CC) -c test.cpp LFSR.hpp $(CFLAGS)
16
17     # Main tester
18     main.out: main.o LFSR.o
19         $(CC) main.o LFSR.o -o main.out
20
21     main.o: main.cpp LFSR.hpp
22         $(CC) -c main.cpp $(CFLAGS)
23
24     LFSR.o: LFSR.cpp LFSR.hpp
25         $(CC) -c LFSR.cpp $(CFLAGS)
26
27     # Cleanup
28     clean:
29         rm *.o
30         rm *.out
31         rm ps2a
```

main.cpp

```
1 #include <iostream>
2 #include <string>
3 #include <sstream>
4 #include "LFSR.hpp"
5
6 // Testing the LFSR class
7
8 int main()
9 {
10    LFSR test("01101000010", 8);
11
12    std::cout << "Test case 1. \n";
13
14    // Test case 1 from the princeton site.
15
16    for(int i = 0; i < 10; i++)
17    {
18        int bit = test.step();
19        std::cout << test << " " << bit << std::endl;
20    }
21
22    LFSR test2("01101000010", 8);
23    std::cout << "\n\nTest case 2.\n";
24
25    // Test case 2 from the princeton site.
26    for(int i = 0; i < 10; i++)
27    {
28        int r = test2.generate(5);
29        std::cout << test2 << " " << r << std::endl;
30    }
31
32    LFSR test3("0101", 2);
33    int num = test3.generate(2);
34
35    std::cout << test3 << " " << num << std::endl;
36
37    LFSR test4("0011010010", 3);
38
39    int num2 = test4.generate(4);
40
41    std::cout << num2;
42
43    return 0;
44 }
```

LFSR.hpp

```
1  #ifndef LFSR_HPP
2  #define LFSR_HPP
3
4  #include <iostream>
5
6  class LFSR {
7  public:
8      LFSR(std::string seed, int t);      // Constructor
9      int step();                      // simulates one step
10     int generate(int k);            // simulates k steps
11
12    // Overloaded << operator
13    friend std::ostream& operator<< (std::ostream &out, LFSR &cLFSR);
14
15 private:
16     std::string bits;                // holds the LFSR
17     int tap;
18 };
19
20#endif
```

LFSR.cpp

```
1 #include <iostream>
2 #include <string>
3 #include <sstream>
4 #include "LFSR.hpp"
5
6 // Implementation file for the LFSR class
7
8 // Constructor
9 LFSR::LFSR(std::string seed, int t)
10 {
11     // Sets initial seed / tap position
12     bits = seed;
13     tap = t;
14 }
15
16
17 // simulates one step
18 int LFSR::step()
19 {
20     /*
21      * We need to XOR the left most position with the tap position.
22      * The left most position is just bits[0] - the very left most bit.
23      *
24      * The tap position can be found using the following formula:
25      * tap position = size() - tap - 1
26      *
27      * It works by converting the tap position value into array indexes
28      *
29     */
30
31     // Find the index of the tap position.
32     int tap_pos = bits.length() - tap - 1;
33
34     // XOR the tap position with the left most bit
35     int res = bits[0] ^ bits[tap_pos];
36
37     // We need to go through and shift all bits left now.
38     std::string::size_type i;
39     std::ostringstream ostrng;    // Using string streams to append the
40                                // the XOR result
41
42     // Now shift everything left.
43     for(i = 0; (unsigned)i < bits.length() - 1; i++)
44     {
45         ostrng << bits[i + 1];
46     }
47
48     // Append the XOR result
49     ostrng << res;
50
51     // Save the updated string - ostrng.str() converts a string stream
52     // back into a string
53     bits = ostrng.str();
54 }
```

```
55     // Return the XOR result bit
56     return res;
57 }
58
59
60 // simulates k steps
61 int LFSR::generate(int k)
62 {
63     // Intialize variable to zero.
64     int x = 0;
65
66     for(int i = 0; i < k; i++)
67     {
68         x = (x * 2) + step();
69     }
70
71     return x;
72 }
73
74
75 // returns a string rep. of the LFSR
76 std::ostream& operator<< (std::ostream &out, LFSR &cLFSR)
77 {
78     out << cLFSR.bits;
79     return out;
80 }
```

test.cpp

```
1 #include <iostream>
2 #include <string>
3 #include <sstream>
4 #include "LFSR.hpp"
5
6 #define BOOST_TEST_DYN_LINK
7 #define BOOST_TEST_MODULE Main
8 #include <boost/test/unit_test.hpp>
9
10 // The initial test that was in this file.
11 BOOST_AUTO_TEST_CASE(fiveBitsTapAtTwo)
12 {
13     LFSR l("00111", 2);
14     BOOST_REQUIRE(l.step() == 1);
15     BOOST_REQUIRE(l.step() == 1);
16     BOOST_REQUIRE(l.step() == 0);
17     BOOST_REQUIRE(l.step() == 0);
18     BOOST_REQUIRE(l.step() == 0);
19     BOOST_REQUIRE(l.step() == 1);
20     BOOST_REQUIRE(l.step() == 1);
21     BOOST_REQUIRE(l.step() == 0);
22
23     LFSR l2("00111", 2);
24     BOOST_REQUIRE(l2.generate(8) == 198);
25 }
26
27
28 // My first test. I just tested what Princeton's
29 // website gave as examples.
30 // In this case, they use 11 bit seeds with a tap of 8.
31 BOOST_AUTO_TEST_CASE(PrincetonExamples)
32 {
33     // The simulate step test
34     LFSR test("01101000010", 8);
35
36     BOOST_REQUIRE(test.step() == 1);
37     BOOST_REQUIRE(test.step() == 1);
38     BOOST_REQUIRE(test.step() == 0);
39     BOOST_REQUIRE(test.step() == 0);
40     BOOST_REQUIRE(test.step() == 1);
41     BOOST_REQUIRE(test.step() == 0);
42     BOOST_REQUIRE(test.step() == 0);
43     BOOST_REQUIRE(test.step() == 1);
44     BOOST_REQUIRE(test.step() == 0);
45     BOOST_REQUIRE(test.step() == 0);
46
47     // The generate test from Princeton
48     LFSR test2("01101000010", 8);
49     BOOST_REQUIRE(test2.generate(5) == 25);
50     BOOST_REQUIRE(test2.generate(5) == 4);
51     BOOST_REQUIRE(test2.generate(5) == 30);
52     BOOST_REQUIRE(test2.generate(5) == 27);
53     BOOST_REQUIRE(test2.generate(5) == 18);
54     BOOST_REQUIRE(test2.generate(5) == 26);
```

```
55     BOOST_REQUIRE(test2.generate(5) == 28);
56     BOOST_REQUIRE(test2.generate(5) == 24);
57     BOOST_REQUIRE(test2.generate(5) == 23);
58     BOOST_REQUIRE(test2.generate(5) == 29);
59 }
60
61
62 // A couple of tests making sure the constructor functions
63 // as intended. This also tests the << operator as well.
64 BOOST_AUTO_TEST_CASE(Constructor_Tests)
65 {
66     LFSR test("001100", 5);
67     std::stringstream buffer;
68     buffer << test;
69
70     // Make sure the constructor saves the seed correctly.
71     BOOST_REQUIRE(buffer.str().compare("001100") == 0);
72
73     // Try a much larger seed - 30 bits for example.
74     LFSR test2("000000011111111001010101011", 10);
75     buffer.str(""); // Clear the stringstream object
76     buffer.clear();
77     buffer << test2;
78
79     // Make sure the constructor saves the seed correctly.
80     BOOST_REQUIRE(buffer.str().compare("0000000111111110010101011") == 0);
81
82     // Now try a very small seed - 1 bit for example.
83     LFSR test3("1", 1);
84     buffer.str(""); // Clear the stringstream object
85     buffer.clear();
86     buffer << test3;
87
88     // Make sure the constructor saves the seed correctly.
89     BOOST_REQUIRE(buffer.str().compare("1") == 0);
90 }
91
92
93
```

PS2b: Image Encoding

The Assignment

This assignment builds on the previous assignment (PS2a). Using the LFSR class we built in PS2a, we were tasked with creating a program that reads in a photo from the command line and then outputs the same image, but encoded (encrypted). The LFSR class was used to encode the image by left shifting all the bits in the image – thus encoding it using XOR. We also had to display the image to an SFML window and save the encrypted image to a file.

Key Concepts

The main thing that this assignment used was the LFSR class from the previous homework, PS2a. The LFSR class that we built uses a shift register to store bits and has two methods, step and generate, that we used to left shift all the bits. We also used several SFML objects, such as textures, images and sprites to read in the file, encode the file and output the final encoded image to both the screen and disk. The image class was the main way we encoded the image – we were able to get both the red, green and blue pixel using `.getPixel()`, as seen on line #58 in the `main.cpp` file.

What I Learned

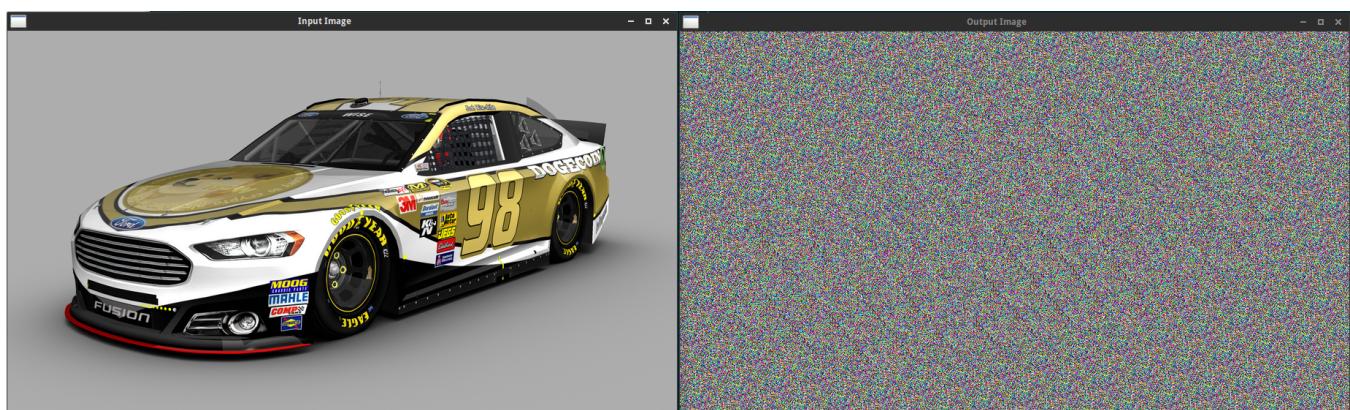
This project was quite fun to work with, as it used previous material that we had already built. In a way, it was neat to build something for one homework assignment and then get to reuse it to build another assignment. There was not much new material that I learned from this assignment though – since it uses the LFSR class, most of that material carries over. Perhaps most useful was the encoding portion of the assignment though. Playing around with pixels and XORing them to get an encoded image, and then displaying the final encrypted image was pretty cool. However, that portion of the assignment also uses XOR, so I didn't really learn anything new per say. I mostly found other uses for the LFSR class, and that was an interesting learning experience – getting to reuse old code for a different purpose.

Screenshots

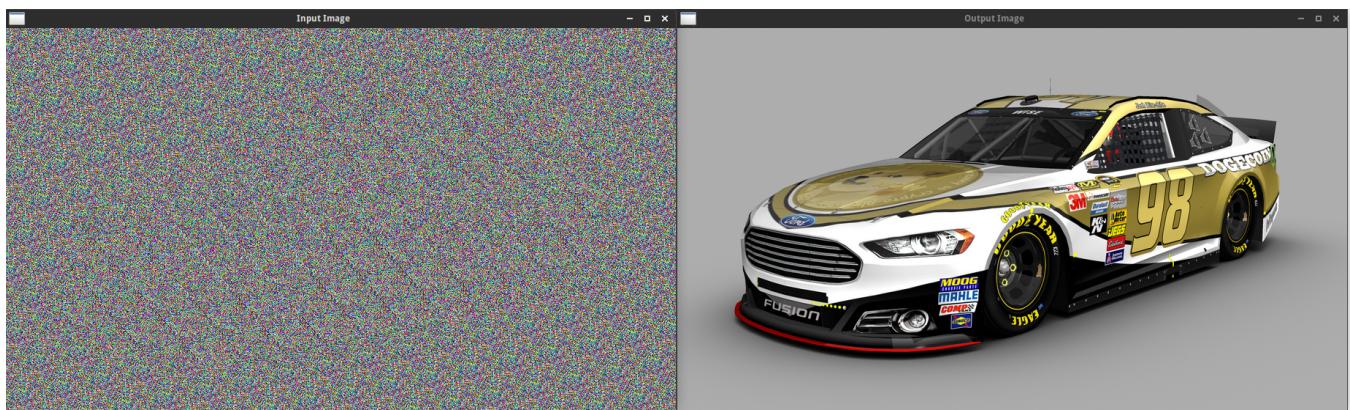
Original image – the #98 DOGECAR



Encoding an image:



Decoding an encrypted image:



Source Code for PS2b Image Encoding

Makefile

```
1 # Makefile for PS2b
2 # Flags to save on typing all this out
3 CC= g++
4 CFLAGS= -Wall -Werror -ansi -pedantic
5 SFMLFLAGS= -lsfml-graphics -lsfml-window -lsfml-system
6
7 # Make ps2b
8 all: PhotoMagic
9
10 # ps2b executable
11 PhotoMagic: PhotoMagic.o LFSR.o
12     $(CC) PhotoMagic.o LFSR.o -o PhotoMagic $(SFMLFLAGS)
13
14 # object files
15 PhotoMagic.o: PhotoMagic.cpp LFSR.hpp
16     $(CC) -c PhotoMagic.cpp LFSR.hpp $(CFLAGS)
17
18 LFSR.o: LFSR.cpp LFSR.hpp
19     $(CC) -c LFSR.cpp $(CFLAGS)
20
21 # Cleanup
22 clean:
23     rm *.o
24     rm PhotoMagic
25
```

Photomagic.cpp (main)

```
1 #include <iostream>
2 #include <string>
3 #include <sstream>
4 #include <SFML/System.hpp>
5 #include <SFML/Window.hpp>
6 #include <SFML/Graphics.hpp>
7 #include "LFSR.hpp"
8
9
10 int main(int argc, char* argv[])
11 {
12     // Must enter
13     if(argc != 5)
14     {
15         std::cout << "Usage: $ ./PhotoMagic [input file]";
16         std::cout << "[output file] [seed] [tap] \n";
17         return -1;
18     }
19
20     // Save the command line arguments to variables
21     std::string input_filename(argv[1]);
22     std::string output_filename(argv[2]);
23     std::string seed(argv[3]);
24     int tap = atoi(argv[4]);
25
26     // LFSR stuff
27     LFSR randomizer(seed, tap);
28
29     // Setup the two images
30     sf::Image input_image;
31     if (!input_image.loadFromFile(input_filename))
32     {
33         return -1;
34     }
35
36     sf::Image output_image;
37     if (!output_image.loadFromFile(input_filename))
38     {
39         return -1;
40     }
41
42     // p is a pixel
43     sf::Color p;
44
45     // Setup the two windows
46     sf::Vector2u size = input_image.getSize();
47     sf::RenderWindow input_window(sf::VideoMode(size.x, size.y),
48                                  "Input Image");
49     sf::RenderWindow output_window(sf::VideoMode(size.x, size.y),
50                                  "Output Image");
51
52     // Randomize the bits in the image
53     for(int x= 0; x < (signed)size.x; x++)
54     {
```

```

55     for(int y = 0; y < (signed)size.y; y++)
56     {
57         // Get the current pixel from the input image
58         p = input_image.getPixel(x, y);
59
60         // XOR the pixels
61         p.r = p.r ^ randomizer.generate(tap);
62         p.g = p.g ^ randomizer.generate(tap);
63         p.b = p.b ^ randomizer.generate(tap);
64
65         // Modify just the output image
66         output_image.setPixel(x, y, p);
67     }
68 }
69
70 // Load the images into textures
71 sf::Texture input_texture, output_texture;
72 input_texture.loadFromFile(input_image);
73 output_texture.loadFromFile(output_image);
74
75 // Then load the textures into sprites
76 sf::Sprite input_sprite, output_sprite;
77 input_sprite.setTexture(input_texture);
78 output_sprite.setTexture(output_texture);
79
80 // Window loop
81 while (input_window.isOpen() && output_window.isOpen())
82 {
83     sf::Event event;
84
85     while (input_window.pollEvent(event))
86     {
87         if (event.type == sf::Event::Closed)
88         {
89             input_window.close();
90         }
91     }
92
93     while (output_window.pollEvent(event))
94     {
95         if (event.type == sf::Event::Closed)
96         {
97             output_window.close();
98         }
99     }
100
101    input_window.clear();
102    input_window.draw(input_sprite);      // Input image
103    input_window.display();
104
105    output_window.clear();
106    output_window.draw(output_sprite);    // Output image
107    output_window.display();
108 }
109
110 // Save the modified image to the output file
111 if (!output_image.saveToFile(output_filename))

```

```
112  {
113      return -1;
114  }
115
116  return 0;
117 }
```

LFSR.hpp

```
1  #ifndef LFSR_HPP
2  #define LFSR_HPP
3
4  #include <iostream>
5
6  class LFSR {
7  public:
8      LFSR(std::string seed, int t); // Constructor
9      int step(); // simulates one step
10     int generate(int k); // simulates k steps
11
12    // Overloaded << operator
13    friend std::ostream& operator<< (std::ostream &out, LFSR &cLFSR);
14
15 private:
16     std::string bits; // holds the LFSR
17     int tap;
18 };
19
20#endif
```

LFSR.cpp

```
1 #include <iostream>
2 #include <string>
3 #include <sstream>
4 #include "LFSR.hpp"
5
6 // Implementation file for the LFSR class
7
8 // Constructor
9 LFSR::LFSR(std::string seed, int t)
10 {
11     // Sets initial seed / tap position
12     bits = seed;
13     tap = t;
14 }
15
16
17 // simulates one step
18 int LFSR::step()
19 {
20     /*
21      * We need to XOR the left most position with the tap position.
22      * The left most position is just bits[0] - the very left most bit.
23      *
24      * The tap position can be found using the following formula:
25      * tap position = size() - tap - 1
26      *
27      * It works by converting the tap position value into array indexes
28      *
29     */
30
31     // Find the index of the tap position.
32     int tap_pos = bits.length() - tap - 1;
33
34     // XOR the tap position with the left most bit
35     int res = bits[0] ^ bits[tap_pos];
36
37     // We need to go through and shift all bits left now.
38     std::string::size_type i;
39     std::ostringstream ostring;    // Using string streams to append the
40                                // the XOR result
41
42     // Now shift everything left.
43     for(i = 0; (unsigned)i < bits.length() - 1; i++)
44     {
45         ostring << bits[i + 1];
46     }
47
48     // Append the XOR result
49     ostring << res;
50
51     // Save the updated string - ostring.str() converts a string stream
52     // back into a string
53     bits = ostring.str();
54
55     // Return the XOR result bit
```

```
56     return res;
57 }
58
59
60 // simulates k steps
61 int LFSR::generate(int k)
62 {
63     // Initialize variable to zero.
64     int x = 0;
65
66     for(int i = 0; i < k; i++)
67     {
68         x = (x * 2) + step();
69     }
70
71     return x;
72 }
73
74
75 // returns a string rep. of the LFSR
76 std::ostream& operator<< (std::ostream &out, LFSR &cLFSR)
77 {
78     out << cLFSR.bits;
79     return out;
80 }
```

PS3a: N-Body Simulation: static universe

The Assignment

For this assignment, we worked through Princeton's N-Body Simulation problem. It sets out to model the universe on a 2D plane, using Newton's laws of gravity to make the simulation realistic. We read in two command line arguments – total simulation time and the time step – and then displayed a static universe to the screen. The finished, moving universe was implemented in PS3b. This portion of the assignment mainly focused on reading in a file from standard I/O, and using that file's data to populate sprites (displaying the various planets) at the correct location in an SFML window.

Key Concepts

For this assignment, we used a few key C++ / Linux ideas. The first was using the < command line operator to read in a file to standard I/O. Inside the main program, I just used cin to read the file's contents – someone could, if they wanted to, type all of the planet's data in manually. To read in data easily, we also overloaded the >> operator – this way, we were able to just type:

[REDACTED]

While not required by the assignment, I also overloaded the << operator to provide an easy way to test the program – just one line will output all the data inside the bodys object to standard I/O, like so:

[REDACTED]

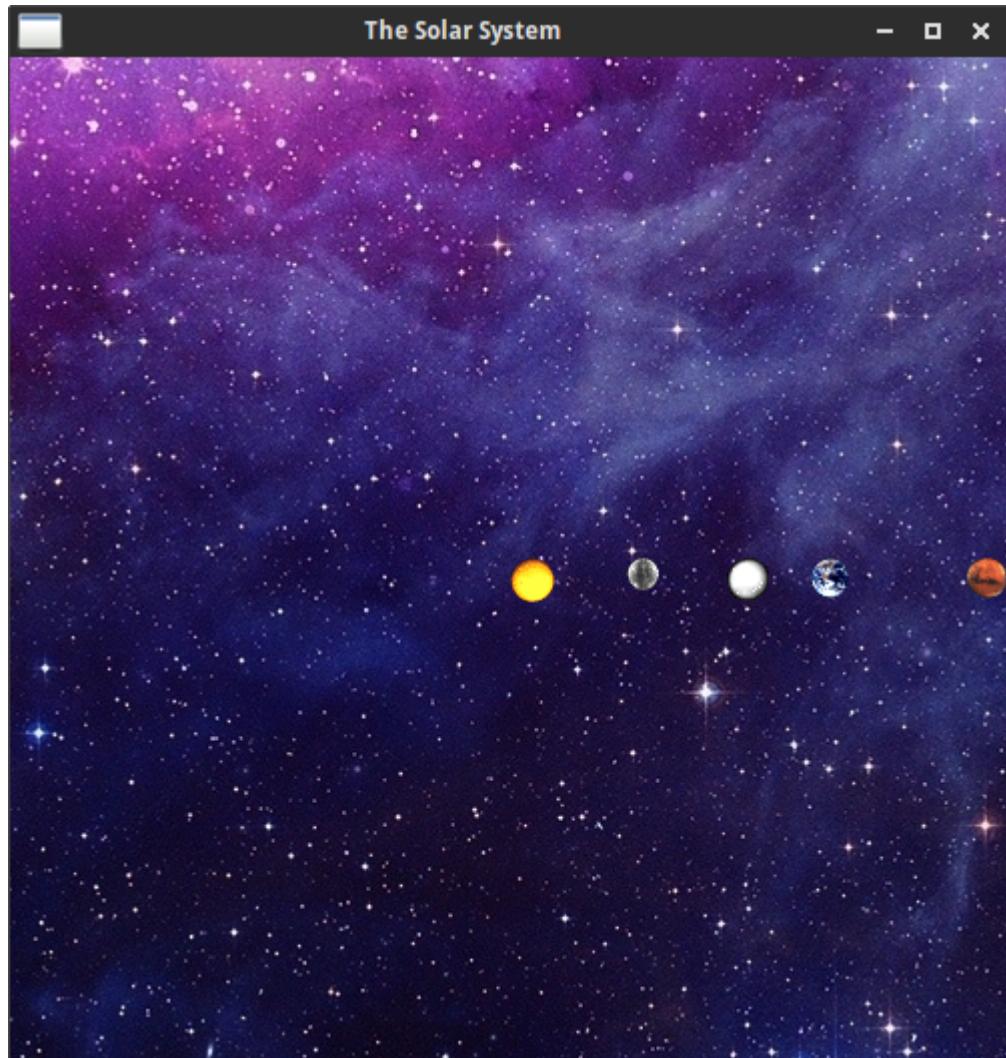
One other thing I had to do was create a method to convert X / Y positions of the planets to SFML coordinates. I was able to do this by realizing that the SFML window system sets (0, 0) as the top left corner. To convert the coordinates to the SFML system, I added half the height or side of the given window to the coordinate. There is a huge comment block on lines 52 – 82 of the bodys.cpp file explaining this math in more detail.

What I Learned

One other thing we had to do involved implementing the draw method in our bodys class – this was something I hadn't really done in a while, so it was interesting to play around with the draw method to get it to work. I did not really learn much from overloading the >> operator – I had done that a few times before, so I was familiar with how to do that. In fact I even overloaded the << operator for debugging purposes, so I was quite familiar with using those operators. Likewise, we've dealt with SFML's textures, images and sprite objects before, so displaying the planets wasn't a problem. Perhaps the biggest thing I learned was how to convert the coordinates from planetary units to SFML's units – this took some time to get right, as the planets wouldn't show up sometimes, and other times would show up in the wrong place. When I finally got it working though, it was pretty cool to have the planets all lined up nicely.

Screenshots

The Universe



Source Code for PS3a

Makefile

```
1 # Makefile for ps3a
2 # Flags to save on typing all this out
3 CC= g++
4 CFLAGS= -Wall -Werror -ansi -pedantic
5 SFMLFLAGS= -lsfml-graphics -lsfml-window -lsfml-system
6
7 # Make ps2b
8 all:    NBody
9
10 # body executable
11 NBody: main.o body.o
12     $(CC) main.o body.o -o NBody $(SFMLFLAGS)
13
14 # object files
15 main.o: main.cpp body.hpp
16     $(CC) -c main.cpp body.hpp $(CFLAGS)
17
18 body.o: body.cpp body.hpp
19     $(CC) -c body.cpp body.hpp $(CFLAGS)
20
21 # Cleanup
22 clean:
23     rm *.o
24     rm NBody
25
```

main.cpp

```
1 #include "body.hpp"
2
3 int main(int argc, char* argv[]) {
4
5     // Get the first two numbers in the text file.
6     // The first should be an int telling us how many planets there are.
7     // The second should be a float telling us the radius of the universe.
8     std::string num_planets, radius;
9
10    // Use cin to redirect the input
11    std::cin >> num_planets;
12    std::cin >> radius;
13
14    // Now we know how many planets + the radius.
15    // Convert these from std::strings to int / float
16    int number_planets = atoi(num_planets.c_str());
17    float universe_radius = atof(radius.c_str());
18
19    std::cout << "Num of planets: " << number_planets << std::endl;
20    std::cout << "Radius: " << universe_radius << std::endl << std::endl;
21
22    // Create a vector of body objects
23    std::vector<body> body_vector;
24
25    // Loop through, create 5 (or however many we're asked for)
26    // body objects using the input file.
27    for(int i = 0; i < number_planets; i++)
28    {
29        // Create a new object
30        body* tmp = new body();
31
32        // Read input into the object
33        std::cin >> *tmp;
34
35        // Set the radius and the planet positions.
36        tmp->set_radius(universe_radius);
37        tmp->set_position();
38
39        // Save the object to the vector
40        body_vector.push_back(*tmp);
41
42        // Test the object (debugging)
43        std::cout << *tmp;
44    }
45
46    // SFML Window
47    sf::RenderWindow window(sf::VideoMode(window_side, window_height),
48                           "The Solar System");
49
50    // Change the frame rate to make it easier to see the image moving.
51    window.setFramerateLimit(1);
52
53    // Background image
54    sf::Image background_image;
```

```

55
56 // Background image
57 if (!background_image.loadFromFile("stars.jpg"))
58 {
59     return -1;      // Quit if the file doesn't exist.
60 }
61
62 // Load the image into a texture
63 sf::Texture background_texture;
64 background_texture.loadFromImage(background_image);
65
66 // Load the texture into a sprite
67 sf::Sprite background_sprite;
68 background_sprite.setTexture(background_texture);
69
70 // Set the position to make the background look cool
71 background_sprite.setPosition(sf::Vector2f(-700, -700));
72
73 // Window loop
74 while (window.isOpen())
75 {
76     // Process events
77     sf::Event event;
78
79     while(window.pollEvent(event))
80     {
81         // Close window : exit
82         if (event.type == sf::Event::Closed)
83         {
84             window.close();
85         }
86
87         // Pressing escape will quit the program.
88         else if (sf::Keyboard::isKeyPressed(sf::Keyboard::Escape))
89         {
90             window.close();
91         }
92     }
93
94     window.clear();
95
96     // Draws the starry background (
97     // black backgrounds are so lame for a solar system)
98     window.draw(background_sprite);
99
100    // Display the vector of objects
101    std::vector<body>::iterator it;
102
103    for(it = body_vector.begin(); it != body_vector.end(); it++)
104    {
105        window.draw(*it);
106    }
107
108    window.display();
109 }
110 return 0;
111 }
```

body.hpp

```
1 #include <iostream>
2 #include <string>
3 #include <fstream>
4 #include <vector>
5 #include <SFML/System.hpp>
6 #include <SFML/Window.hpp>
7 #include <SFML/Graphics.hpp>
8
9 // Constants for the window size.
10 const int window_height = 500;
11 const int window_side = 500;
12
13 class body: public sf::Drawable
14 {
15 public:
16
17     // Constructors
18     body();
19     body(double pos_x, double pos_y, double vel_x, double vel_y,
20          double obj_mass, double radius, std::string file_name);
21
22     void set_radius(float radius);
23     void set_position(); // Sets the planets positions
24
25     // Overridden operator >> for inputing from a file
26     friend std::istream& operator>> (std::istream &input, body &cBody);
27
28     // Overridden operator << for debugging
29     friend std::ostream& operator<< (std::ostream &output, body &cBody);
30
31 private:
32
33     // Draw method
34     void virtual draw(sf::RenderTarget& target, sf::RenderStates states) const;
35
36     // Member variables
37     double _pos_x, _pos_y;
38     double _vel_x, _vel_y;
39     double _mass;
40     double _radius;
41     std::string _filename;
42
43     // Image related objects
44     sf::Image _image;
45     sf::Sprite _sprite;
46     sf::Texture _texture;
47 };
```

body.cpp

```
1 #include "body.hpp"
2
3 // Default Constructor
4 body::body()
5 {
6     // Does nothing since I call the setter methods and the >> operator.
7     return;
8 }
9
10
11 // Constructor with parameters
12 body::body(double pos_x, double pos_y, double vel_x, double vel_y,
13             double obj_mass, double radius, std::string file_name)
14 {
15     // Set member variables
16     _pos_x = pos_x;
17     _pos_y = pos_y;
18     _vel_x = vel_x;
19     _vel_y = vel_y;
20     _mass = obj_mass;
21     _filename = file_name;
22
23     // Load the image into an image object
24     if (!_image.loadFromFile(file_name))
25     {
26         return;    // Quit if the file doesn't exist.
27     }
28
29     // Load the image into a texture
30     _texture.loadFromImage(_image);
31
32     // Load the texture into a sprite
33     _sprite.setTexture(_texture);
34
35     // Set the position from the Vector2f for position
36     _sprite.setPosition(sf::Vector2f(_pos_x, _pos_y));
37 }
38
39
40 // Sets the universe radius
41 void body::set_radius(float radius)
42 {
43     _radius = radius;
44     return;
45 }
46
47
48 // Sets the planets position
49 void body::set_position()
50 {
51     /*
52      * The math here probably needs some explanation:
53      *
54      * First thing I do is divide the pos by the radius. This gets me a nice
```

```

55     * ratio I can use. For the earth this value comes out to .5984.
56     *
57     * Next, I use this ratio and multiply it by EITHER half the width
58     * or height of the window (depends on whether its a x or y coordinate.
59     * x corresponds to wide, y corresponds with height)
60     * which gets me a position that is actually in the SFML coordinate system.
61     *
62     * Finally, now that I have the position in SFML coordinates, I adjust
63     * for the fact that the SFML window's center is half the height and side.
64     * Example would be a window of 500 by 500 has its center at 250, 250.
65     * The coordinates that we are given in the planets.txt file actually
66     * have their center at 0,0. So even though I have the SFML coordinates,
67     * I must add 250 to both the x and y coordinates to
68     * make the planets show up in the center of the screen.
69     *
70     * Example math for the earth:
71     * [pos to radius ratio] * [side OR height / 2]
72     * .5984 * 250 = 149.6
73     *
74     * The 149.6 in this case works perfectly with the SFML coordinate system.
75     * We just add 250 to get the center for SFML coordinate, which would
76     * come out to 399.6
77     *
78     * A quick note - y coordinates all have a '0' by default, so the below math
79     * actually just sets all the y coordinates to 250 - which is the center of
80     * the SFML height (0 to 500, 250 is the middle).
81     *
82     */
83     _pos_x = ( (_pos_x / _radius) * (window_side / 2) ) + (window_side / 2);
84     _pos_y = ( (_pos_y / _radius) * (window_height / 2) ) + (window_height / 2);
85
86     // Set the position from the Vector2f for position
87     _sprite.setPosition(sf::Vector2f(_pos_x, _pos_y));
88 }
89
90
91 // Drawable method
92 void body::draw(sf::RenderTarget& target, sf::RenderStates states) const
93 {
94     // Testing outputting an image.
95     target.draw(_sprite);
96 }
97
98
99 // Overridden operator >> for inputting from a file
100 std::istream& operator>> (std::istream &input, body &cBody)
101 {
102     // Read input into the object
103     input >> cBody._pos_x >> cBody._pos_y;
104     input >> cBody._vel_y >> cBody._vel_y;
105     input >> cBody._mass >> cBody._filename;
106
107     // Now set up the images
108     // Just like the constructor
109
110     // Load the image into an image object
111     if (!cBody._image.loadFromFile(cBody._filename))

```

```
112  {
113      return input;      // Quit if the file doesn't exist.
114  }
115
116 // Load the image into a texture
117 cBody._texture.loadFromImage(cBody._image);
118
119 // Load the texture into a sprite
120 cBody._sprite.setTexture(cBody._texture);
121
122 // Set the initial position
123 cBody._sprite.setPosition(sf::Vector2f(cBody._pos_x, cBody._pos_y));
124
125 return input;
126 }
127
128
129 // Overridden operator << for debugging
130 // Very useful for finding out why stuff doesn't work.
131 std::ostream& operator<< (std::ostream &output, body &cBody)
132 {
133     // For debugging, output all the data stored in the object.
134     output << "Filename: " << cBody._filename << std::endl;
135     output << "Pos (x): " << cBody._pos_x << std::endl;
136     output << "Pos (y): " << cBody._pos_y << std::endl;
137     output << "Vel (x): " << cBody._vel_x << std::endl;
138     output << "Vel (y): " << cBody._vel_y << std::endl;
139     output << "Mass: " << cBody._mass << std::endl << std::endl;
140
141     return output;
142 }
143
```

PS3b: N-Body Simulation:

Using Newton's laws of physics, animate the universe

The Assignment

This assignment builds on the previous one, PS3a. In the previous assignment, we created a static universe – in PS3b, we made the universe move and respond to Newton's law of universal gravitation and Newton's second law of motion.

Key Concepts

The main concepts for this assignment deal with Physics. They include:

- Newton's law of universal gravitation
- The principle of superposition
- Newton's second law of motion

We implemented these concepts in PS3b by using a few formulas, such as:

```
F = (G * M1 * M2) / R^2
R = square root (R2)
R2 = (Δx)^2 + (Δy)^2
Δx = x2 - x1
Δy = y2 - y1
```

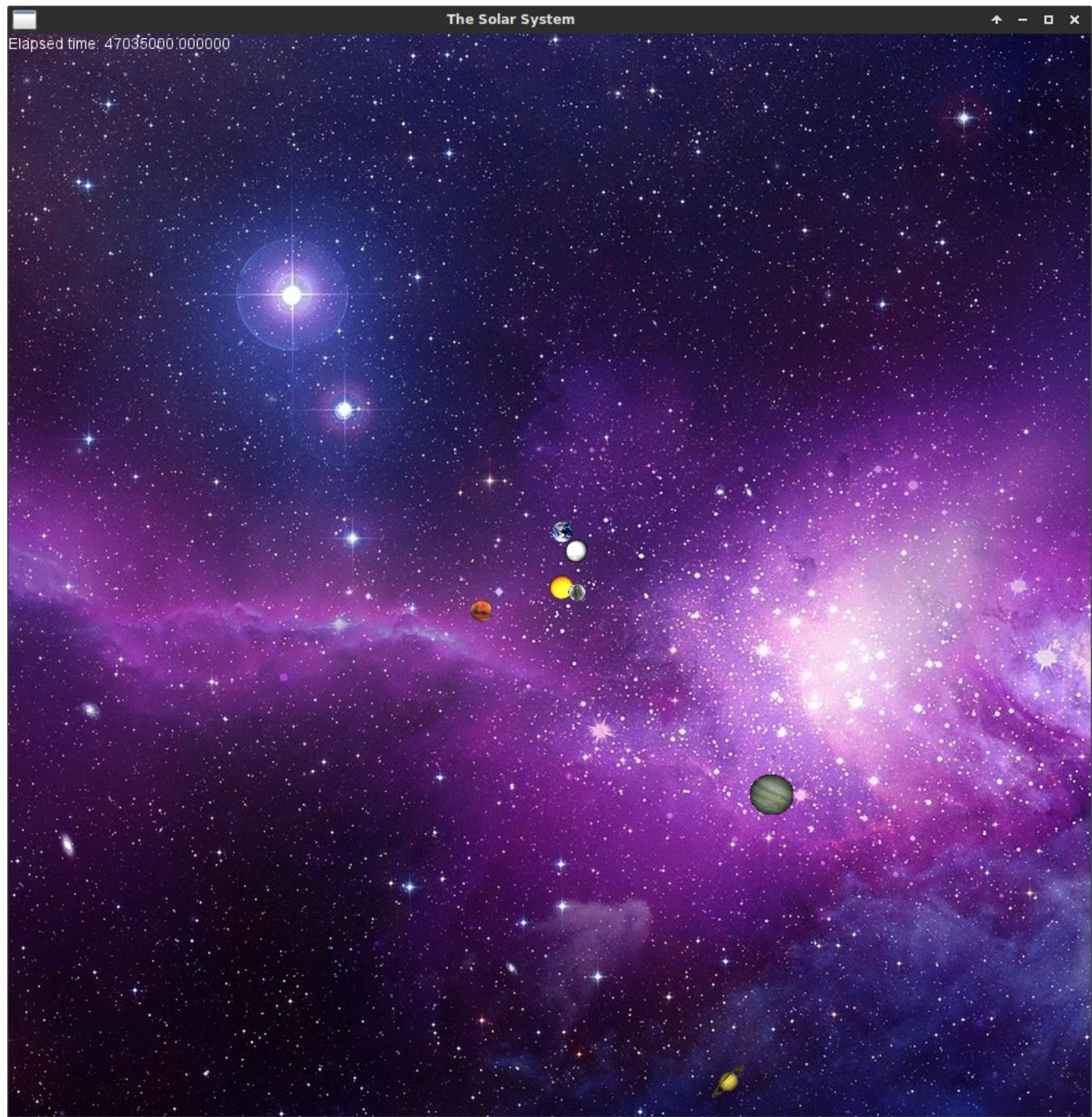
These formulas can be found on lines 67 to 72 in the find_force() method of body.cpp.

Using these formulas, we were able to simulate the movement of the planets throughout the universe. This was a tricky part of the assignment, as getting the formulas right is the key to making the universe work correctly.

What I Learned

I mainly learned a little physics in this assignment and with that how to implement different equations in a program. It was pretty tricky to get the equations correct, as I found out while programming this assignment, if you get just one equation wrong or slightly off, you can send all the planets into chaos. Once you've implemented them correctly, you'll get a nice simulation of the universe. Besides implementing the physics portion, I also learned how to play music using SFML's audio library. I did this as an extra credit portion of the assignment, but it was still pretty neat to get the theme song to *2001: A Space Odyssey* playing while the planets rotate around the Sun.

Screenshots



Screenshot of PS3b running.

I also decided to quickly record two videos of PS3b running. (*NOTE: these include audio!*)

The first is my custom universe (just the inner four planets): <https://youtu.be/OyRrBp7g9Zw>

The second is a video of solarsystem.txt running: <https://youtu.be/VcYZwKWZVhA>

Source Code for PS3b

Makefile

```
1  # Makefile for ps3b
2  # Flags to save on typing all this out
3  CC= g++
4  CFLAGS= -Wall -Werror -std=c++0x -pedantic
5  SFMLFLAGS= -lsfml-graphics -lsfml-window -lsfml-system -lsfml-audio
6
7  # Make ps2b
8  all: NBody
9
10 # body executable
11 NBody:      main.o body.o
12         $(CC) main.o body.o -o NBody $(SFMLFLAGS)
13
14 # object files
15 main.o:      main.cpp body.hpp
16         $(CC) -c main.cpp body.hpp $(CFLAGS)
17
18 body.o:      body.cpp body.hpp
19         $(CC) -c body.cpp body.hpp $(CFLAGS)
20
21 # Cleanup
22 clean:
23         rm *.o
24         rm *.gch
25         rm NBody
26
```

main.cpp

```
1 #include "body.hpp"
2
3 int main(int argc, char* argv[])
4 {
5     if(argc != 3)    // We just want 3 arguments
6     {
7         // ./NBody 157788000.0 25000.0 < planets.txt
8         std::cout << "Usage: ./NBody [simulation time]";
9         std::cout << "[time step] < planets.txt\n";
10        return -1;
11    }
12
13    // Get the simulation time / time step from the command line arguments
14    std::string sim_time(argv[1]);
15    std::string step_time(argv[2]);
16    std::string::size_type sz;      // alias of size_t (this is for using stod)
17
18    // Debugging
19    std::cout << "Simulation time: " << sim_time << "\n";
20    std::cout << "Time Step: " << step_time << "\n\n";
21
22    // Convert these strings to doubles
23    double simulation_time = 0;
24    double simu_time = std::stod(sim_time, &sz);
25    double time_step = std::stod(step_time, &sz);
26
27    // Get the first two numbers in the text file.
28    std::string num_planets, radius;
29
30    // Use cin to redirect the input
31    std::cin >> num_planets;
32    std::cin >> radius;
33
34    // Now we know how many planets + the radius.
35    // Convert these from std::strings to int / float
36    int number_planets = std::stoi(num_planets, &sz);
37    double universe_radius = std::stod(radius, &sz);
38
39    // Debugging
40    std::cout << "Num of planets: " << number_planets << std::endl;
41    std::cout << "Radius: " << universe_radius << std::endl << std::endl;
42
43    // Create a vector of body objects
44    std::vector<body> body_vector;
45
46    // Loop through, create 5 (or however many we're asked for)
47    // body objects using the input file.
48    for(int i = 0; i < number_planets; i++)
49    {
50        // Create a new object
51        body* tmp = new body();
52
53        // Read input into the object
54        std::cin >> *tmp;
```

```
55 // Set the radius and the planet positions.
56 tmp->set_radius(universe_radius);
57 tmp->set_position();
58
59 // Save the object to the vector
60 body_vector.push_back(*tmp);
61
62 // Test the object (debugging)
63 std::cout << *tmp;
64
65 }
66
67 // SFML Window
68 sf::RenderWindow window(sf::VideoMode(window_side, window_height),
69 "The Solar System");
70
71 // Change the framerate to make it easier to see the image moving.
72 window.setFramerateLimit(60);
73
74 // Background image
75 sf::Image background_image;
76
77 // Background image
78 if (!background_image.loadFromFile("stars.jpg"))
79 {
80     return -1; // Quit if the file doesn't exist.
81 }
82
83 // Declare and load a font
84 sf::Font time_font;
85 time_font.loadFromFile("arial.ttf");
86
87 // Text for displaying the current simulation time.
88 sf::Text time_text;
89
90 // Select the font
91 time_text.setFont(time_font); // font is a sf::Font
92
93 // Set the character size
94 time_text.setCharacterSize(14); // in pixels, not points!
95
96 // Set the color
97 time_text.setColor(sf::Color::White);
98
99 // Load the music file
100 sf::Music music;
101 if (!music.openFromFile("2001.ogg"))
102 {
103     return -1; // error
104 }
105
106 // PLAY THE EPIC TUNE
107 music.play();
108
109 // Load the image into a texture
110 sf::Texture background_texture;
111 background_texture.loadFromImage(background_image);
```

```

112
113 // Load the texture into a sprite
114 sf::Sprite background_sprite;
115 background_sprite.setTexture(background_texture);
116
117 // Set the position to make the background look cool
118 // background_sprite.setPosition(sf::Vector2f(-700, -700));
119
120 std::vector<body>::iterator it;
121 std::vector<body>::iterator x, y;
122
123 while (window.isOpen())
124 {
125     sf::Event event;
126
127     while(window.pollEvent(event))
128     {
129         if (event.type == sf::Event::Closed)
130         {
131             window.close();
132         }
133     }
134
135     window.clear();
136
137     // Draws the starry background
138     // (black backgrounds are so lame for a solar system)
139     window.draw(background_sprite);
140
141     // I cast to an int to keep the time sane looking
142     time_text.setString("Elapsed time:" + std::to_string(simulation_time));
143
144     // Display the time in the left hand corner of the window
145     window.draw(time_text);
146
147     // Calculate the net force on each body object
148     x = body_vector.begin();
149     double force_x, force_y;
150
151     // First loop goes through the whole body vector
152     // so we make sure each body object gets its net force updated.
153     for(int a = 0; a < number_planets; a++)
154     {
155         y = body_vector.begin();
156         force_x = 0;
157         force_y = 0;
158
159         // Second loop goes through the body vector again, so that
160         // the current body object gets effected by every other body object.
161         for(int b = 0; b < number_planets; b++)
162         {
163             if(a != b) // Make sure not include the force on the body itself.
164             {
165                 // Basically - (earth, earth) shouldn't be a case.
166                 force_x += find_forcex(*x, *y);
167                 force_y += find_forcey(*x, *y);
168             }
169             y++;
170         }
171     }

```

```
169     }
170     // Update the forces inside the current object
171     x->set_forces(force_x, force_y);
172     x++;
173 }
174
175 // Display the vector of objects
176 for(it = body_vector.begin(); it != body_vector.end(); it++)
177 {
178     window.draw(*it);
179     std::cout << *it << std::endl;
180
181     // While we're displaying the objects, might as
182     // well move it forward one step!
183     it->step(time_step);
184     it->set_position();    // Update image position.
185 }
186
187 window.display();
188
189 // Increase simulation time variable by the simulation step
190 simulation_time += time_step;
191
192 // Stop when we've reached the simulation time
193 if(simulation_time == simu_time)
194 {
195     break;
196 }
197 }
198
199 // For debugging to compare against Princeton's data
200 // (This basically prints out the final positions / velocities / etc)
201 std::cout << "\n\n\n";
202 for(it = body_vector.begin(); it != body_vector.end(); it++)
203 {
204     std::cout << *it << std::endl;
205 }
206
207 return 0;
```

body.hpp

```
1 #include <math.h>
2 #include <iostream>
3 #include <string>
4 #include <fstream>
5 #include <vector>
6 #include <SFML/Audio.hpp>
7 #include <SFML/Graphics.hpp>
8 #include <SFML/System.hpp>
9 #include <SFML/Window.hpp>
10
11 // Constants for the window size.
12 const int window_height = 1000;
13 const int window_side = 1000;
14
15 // Physics Constants
16 const double gravity = 6.67e-11;
17
18 class body: public sf::Drawable
19 {
20 public:
21
22     // Constructors
23     body();
24     body(double pos_x, double pos_y, double vel_x, double vel_y,
25          double obj_mass, double radius, std::string file_name);
26
27     // Set radius / image position
28     void set_radius(float radius);
29     void set_position();           // Sets the planets positions
30
31     // Force related methods
32     friend double find_forcex(body &Body1, body &Body2);
33     friend double find_forcey(body &Body1, body &Body2);
34     void set_forces(double forcex, double forcey);
35
36     // Time step
37     void step(double time_t);
38
39     // Overridden operator >> for inputing from a file
40     friend std::istream& operator>> (std::istream &input, body &cBody);
41
42     // Overridden operator << for debugging
43     friend std::ostream& operator<< (std::ostream &output, body &cBody);
44
45 private:
46
47     // Draw method
48     void virtual draw(sf::RenderTarget& target, sf::RenderStates states) const;
49
50     // Member variables
51     double _acc_x, _acc_y;
52     double _for_x, _for_y;
53     double _pos_x, _pos_y;
54     double _vel_x, _vel_y;
```

```
55     double _mass, _radius;
56     std::string _filename;
57
58     // Image related objects
59     sf::Image _image;
60     sf::Sprite _sprite;
61     sf::Texture _texture;
62 }
```

body.cpp

```
1 #include "body.hpp"
2
3 // Default Constructor
4 body::body()
5 {
6     // Does nothing since I call the setter methods and the >> operator.
7     return;
8 }
9
10
11 // Constructor with parameters
12 body::body(double pos_x, double pos_y, double vel_x, double vel_y,
13             double obj_mass, double radius, std::string file_name)
14 {
15     // Set member variables
16     _pos_x = pos_x;
17     _pos_y = pos_y;
18     _vel_x = vel_x;
19     _vel_y = vel_y;
20     _mass = obj_mass;
21     _filename = file_name;
22
23     // Load the image into an image object
24     if (!_image.loadFromFile(file_name))
25     {
26         return;    // Quit if the file doesn't exist.
27     }
28
29     // Load the image into a texture
30     _texture.loadFromImage(_image);
31
32     // Load the texture into a sprite
33     _sprite.setTexture(_texture);
34
35     // Set the position from the Vector2f for position
36     _sprite.setPosition(sf::Vector2f(_pos_x, _pos_y));
37 }
38
39
40 // Sets the universe radius
41 void body::set_radius(float radius)
42 {
43     _radius = radius;
44     return;
45 }
46
47
48 // Sets the forces for a given object
49 void body::set_forces(double forcex, double forcey)
50 {
51     _for_x = forcex;
52     _for_y = forcey;
53 }
54
```

```

55
56 // Finds the force (x) between two body objects
57 double find_forcex(body &Body1, body &Body2)
58 {
59     /*
60     * Formulas:
61     * F = (G * M1 * M2) / R^2
62     * R =
63     * R^2 = R squared
64     * Δx = x2 - x1
65     * Δy = y2 - y1
66     */
67     double dx = Body2._pos_x - Body1._pos_x;
68     double dy = Body2._pos_y - Body1._pos_y;
69     double R2 = pow(dx, 2) + pow(dy, 2);
70     double R = sqrt(R2);
71     double force = (gravity * Body1._mass * Body2._mass) / R2;
72     double for_x = force * (dx / R);
73
74     std::cout << "Body1 Filename: " << Body1._filename << "\n";
75     std::cout << "dx: " << dx << "\n";
76     std::cout << "dy: " << dy << "\n";
77     std::cout << "Force: " << force << "\n";
78     std::cout << "Force(x) " << for_x << "\n";
79     std::cout << "Gravity: " << gravity << "\n";
80     std::cout << "Body1 Mass: " << Body1._mass << "\n";
81     std::cout << "Body2 Mass: " << Body2._mass << "\n\n";
82
83     return for_x;
84 }
85
86
87 // Finds the force (y) between two body objects
88 double find_forcey(body &Body1, body &Body2)
89 {
90     /*
91     * Formula is: F = (G * M1 * M2) / R^2
92     */
93     double dx = Body2._pos_x - Body1._pos_x;
94     double dy = Body2._pos_y - Body1._pos_y;
95     double R2 = pow(dx, 2) + pow(dy, 2);
96     double R = sqrt(R2);
97     double force = (gravity * Body1._mass * Body2._mass) / R2;
98     double for_y = force * (dy / R);
99
100    std::cout << "Body1 Filename: " << Body1._filename << "\n";
101    std::cout << "dx: " << dx << "\n";
102    std::cout << "dy: " << dy << "\n";
103    std::cout << "Force: " << force << "\n";
104    std::cout << "Force(y) " << for_y << "\n";
105    std::cout << "Gravity: " << gravity << "\n";
106    std::cout << "Body1 Mass: " << Body1._mass << "\n";
107    std::cout << "Body2 Mass: " << Body2._mass << "\n\n";
108
109    return for_y;
110 }
111

```

```

112
113     void body::step(double time_t)
114 {
115     /*
116      * Convert forces into acceleration
117      *
118      * F = m * a
119      * Ax = Fx / m
120      * Ay = Fy / m
121      *
122      */
123     _acc_x = _for_x / _mass;
124     _acc_y = _for_y / _mass;
125
126     /*
127      * Calculate change in velocity
128      *
129      * dvelx = (ax * time_step)
130      * _velx = _velx + (ax * time_step)
131      *
132      * (vx + Δt ax, vy + Δt ay)
133      *
134      */
135     _vel_x = _vel_x + (_acc_x * time_t);
136     _vel_y = _vel_y + (_acc_y * time_t);
137
138     /*
139      * Body moves based on its velocity
140      *
141      * _xpos = _xpos + (_xvel * time_step)
142      *
143      * (px + Δt vx, py + Δt vy)
144      *
145      */
146     _pos_x = _pos_x + (_vel_x * time_t);
147     _pos_y = _pos_y + (_vel_y * time_t);
148
149 }
150
151
152 // Sets the planets position
153 void body::set_position()
154 {
155     /*
156      * The math here probably needs some explaining:
157      *
158      * First thing I do is divide the pos by the radius. This gets me a nice
159      * ratio I can use. For the earth this value comes out to .5984.
160      *
161      * Next, I use this ratio and multiply it by EITHER half the width or
162      * height of the window (depends on whether its a x or y coordinate).
163      * x corresponds to wide, y corresponds with height)
164      * which gets me a position that is actually in the SFML coordinate system.
165      *
166      * Finally, now that I have the position in SFML coordinates, I adjust
167      * for the fact that the SFML window's center is half the height and side.
168      * Example would be a window of 500 by 500 has its center at 250, 250.

```

```

169     * The coordinates that we are given in the planets.txt file actually
170     * have their center at 0,0. So even though I have the SFML coordinates,
171     * I must add 250 to both the x and y coordinates to
172     * make the planets show up in the center of the screen.
173     *
174     * Example math for the earth:
175     * [pos to radius ratio] * [side OR height / 2]
176     * .5984 * 250 = 149.6
177     *
178     * The 149.6 in this case works perfectly with the SFML coordinate system.
179     * We just add 250 to get the center for SFML coordinate, which would come
180     * out to 399.6
181     *
182     * A quick note: y coordinates all have a '0' by default, so the below math
183     * actually just sets all the y coordinates to 250 - which is the center of
184     * the SFML height (0 to 500, 250 is the middle).
185     *
186     */
187
188 // Note - using temp variables to avoid modifying the member variables and
189 // having to switch back/forth between astronomical and pixel measurements.
190 double pos_x = (_pos_x / _radius) * (window_side/2) + (window_side/2);
191 double pos_y = (_pos_y/_radius) * (window_height/2) + (window_height/2);
192
193 // Set the position from the Vector2f for position
194 // Flip the x and y positions for going counter-clockwise
195 _sprite.setPosition(sf::Vector2f(pos_y, pos_x));
196 }
197
198
199 // Drawable method
200 void body::draw(sf::RenderTarget& target, sf::RenderStates states) const
201 {
202     // Testing outputting an image.
203     target.draw(_sprite);
204 }
205
206
207 // Overridden operator >> for inputting from a file
208 std::istream& operator>> (std::istream &input, body &cBody)
209 {
210     // Read input into the object
211     input >> cBody._pos_x >> cBody._pos_y;
212     input >> cBody._vel_x >> cBody._vel_y;
213     input >> cBody._mass >> cBody._filename;
214
215     // Now set up the images
216     // Just like the constructor
217
218     // Load the image into an image object
219     if (!cBody._image.loadFromFile(cBody._filename))
220     {
221         return input;    // Quit if the file doesn't exist.
222     }
223
224     // Load the image into a texture
225     cBody._texture.loadFromImage(cBody._image);

```

```

226
227     // Load the texture into a sprite
228     cBody._sprite.setTexture(cBody._texture);
229
230     // Set the initial position
231     cBody._sprite.setPosition(sf::Vector2f(cBody._pos_x, cBody._pos_y));
232
233     // Set force / acceleration to 0.
234     cBody._for_x = 0;
235     cBody._for_y = 0;
236     cBody._acc_x = 0;
237     cBody._acc_y = 0;
238
239     return input;
240 }
241
242
243 // Overriddden operator << for debugging
244 // Very useful for finding out why stuff doesn't work.
245 std::ostream& operator<< (std::ostream &output, body &cBody)
246 {
247     // For debugging, output all the data stored in the object.
248     output << "Filename: " << cBody._filename << std::endl;
249     output << "Acceleration (x): " << cBody._acc_x << std::endl;
250     output << "Acceleration (y): " << cBody._acc_y << std::endl;
251     output << "Force (x): " << cBody._for_x << std::endl;
252     output << "Force (y): " << cBody._for_y << std::endl;
253     output << "Pos (x): " << cBody._pos_x << std::endl;
254     output << "Pos (y): " << cBody._pos_y << std::endl;
255     output << "Vel (x): " << cBody._vel_x << std::endl;
256     output << "Vel (y): " << cBody._vel_y << std::endl;
257     output << "Mass: " << cBody._mass << std::endl;
258     output << "Radius: " << cBody._radius << std::endl << std::endl;
259
260     return output;
261 }
```

PS4: Edit Distance

The Assignment

For PS4, we implemented a program to find the optimal alignment of two strings. Princeton calls it the alignment of two DNA strings. A key idea for this program was also to use dynamic programming to make calculating the edit distance efficient.

Key Concepts

The main concept that was introduced for this program is known as the Needleman-Wunsch method, which is a way of using dynamic programming to calculate subproblems, and then use those subproblems to find the main solution. In the case of this program, we used an NxM matrix to do so. This works by first calculating the easy edit distances – and then using those solutions to find the next round of edit distances, until you've arrived at the solution in the [0][0] cell of the matrix.

We also were able to recover the path that our algorithm took by retracing our steps through the matrix. We did this by using a few rules:

1. The optimal alignment matches $x[i]$ up with $y[j]$. In this case, we must have $\text{opt}[i][j] = \text{opt}[i+1][j+1]$ if $x[i]$ equals $y[j]$, or $\text{opt}[i][j] = \text{opt}[i+1][j+1] + 1$ otherwise.
2. The optimal alignment matches $x[i]$ up with a gap. In this case, we must have $\text{opt}[i][j] = \text{opt}[i+1][j] + 2$.
3. The optimal alignment matches $y[j]$ up with a gap. In this case, we must have $\text{opt}[i][j] = \text{opt}[i][j+1] + 2$.

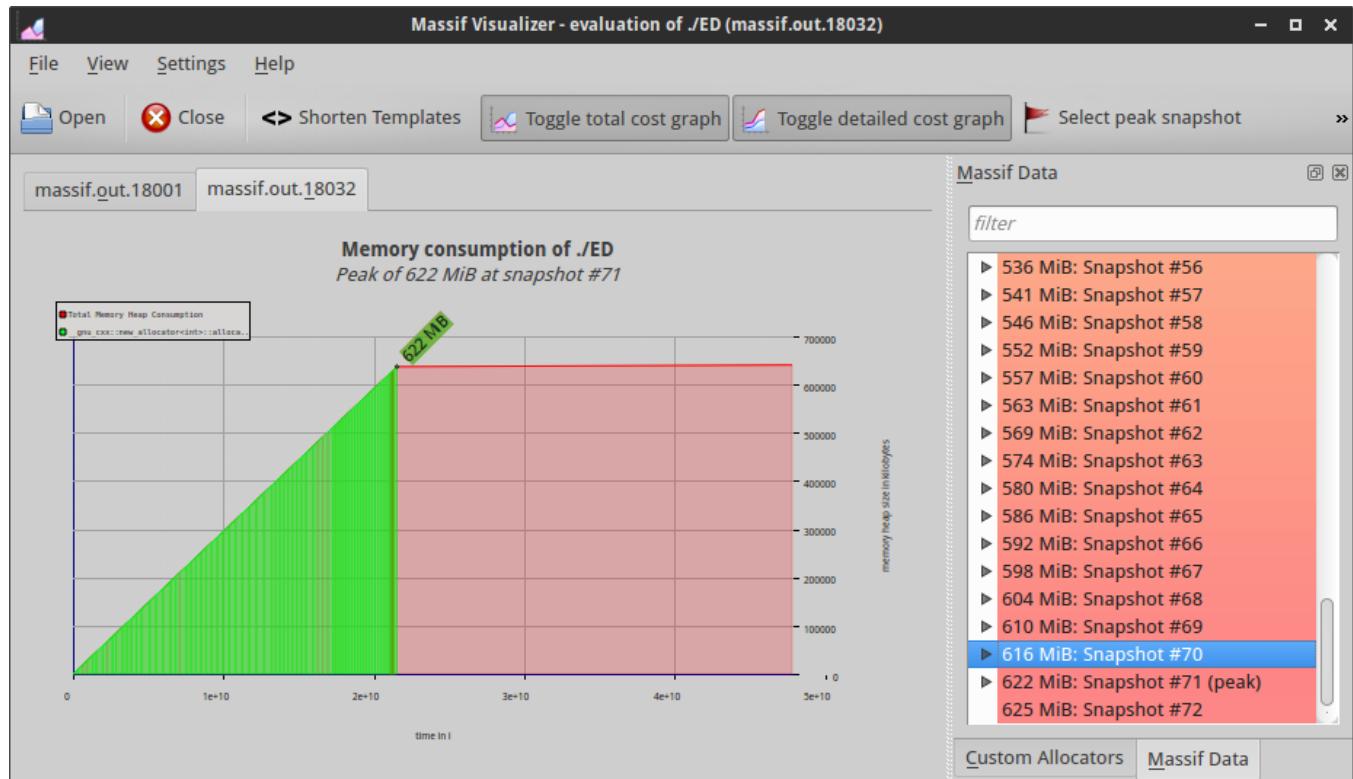
[Source: Princeton's webpage for this assignment.](#)

Using these three rules, we will be able to go from the top left most cell of the matrix ([0][0]), where we originally found the final edit distance, and then trace our steps back to the bottom right most cell ([N][M]).

What I Learned

I learned a few things from this assignment. First, that vectors are pretty inefficient compared to c arrays – seeing the results of other classmates' implementations on iSENSE showed me that. I also got to play around with valgrind, which I've used in the past. I found a nice way of visualizing valgrind's results as well using massif visualizer. See the screenshot from it in the screenshots section. Also, using the Needleman-Wunsch method to calculate subproblems was pretty interesting – that was not something I had really considered before, so it has given me an insight into other methods of programming.

Screenshots



Screenshot of Massif Visualizer, showing how much RAM PS4 used on my machine.

```
ps4 : bash - Konsole
File Edit View Bookmarks Settings Help
jason@jason-desktop: ps4$ make
g++ -c main.cpp ED.hpp -g -Wall -Werror -std=c++0x -pedantic
g++ -c ED.cpp ED.hpp -g -Wall -Werror -std=c++0x -pedantic
g++ main.o ED.o -o ED -lsfml-system
jason@jason-desktop: ps4$ ./ED < sequence/example10.txt
Edit distance = 7
A T 1
A A 0
C - 2
A A 0
G G 0
T G 1
T T 0
A - 2
C C 0
C A 1

Printing out the Matrix for debug purposes:
 7   6   6   7   9   8   9   11  13  14  16
 8   6   5   5   7   8   8   9   11  12  14
10   8   6   4   5   6   7   7   9   10  12
12  10   8   6   4   4   5   6   7   8   10
13  11   9   7   5   4   3   4   5   6   8
15  13  11   9   7   5   3   2   3   4   6
16  14  12  11   9   7   5   3   1   2   4
18  16  14  12  10   8   6   4   3   1   2
20  18  16  14  12  10   8   6   4   2   0

Edit distance = 7
Execution time is 0.000159 seconds
jason@jason-desktop: ps4$
```

Screenshot of PS4 running the example10 input file.

Source Code for PS4

Makefile

```
1  # Makefile for PS4
2  # Flags to save on typing all this out
3  CC= g++
4  CFLAGS= -g -Wall -Werror -std=c++0x -pedantic
5  SFLAGS= -lsfml-system
6
7  # Make ps4
8  all:      ED
9
10 # body executable
11 ED: main.o ED.o
12     $(CC) main.o ED.o -o ED $(SFLAGS)
13
14 # object files
15 main.o: main.cpp ED.hpp
16     $(CC) -c main.cpp ED.hpp $(CFLAGS)
17
18 ED.o:   ED.cpp ED.hpp
19     $(CC) -c ED.cpp ED.hpp $(CFLAGS)
20
21 # Cleanup
22 clean:
23     rm *.o
24     rm *.gch
25     rm ED
```

main.cpp

```
1 #include "ED.hpp"
2
3 int main(int argc, const char* argv[])
4 {
5     // Time calculations
6     sf::Clock clock;
7     sf::Time t;
8
9     // Read in two strings from stdin
10    std::string string1, string2;
11    std::cin >> string1 >> string2;
12
13    // Check stdin
14    //    std::cout << "String 1: " << string1 << "\n";
15    //    std::cout << "String 2: " << string2 << "\n";
16
17    // Declare a ED object
18    ED ed_test(string1, string2);
19
20    // Find the Edit Distance
21    int distance = ed_test.OptDistance();
22
23    // Get the string alignment
24    std::string alignment = ed_test.Alignment();
25
26    // Print out the edit distance
27    std::cout << "Edit distance = " << distance << "\n";
28    std::cout << alignment; // this should have newlines inside of it!
29
30    // Debug the Matrix
31    ed_test.PrintMatrix();
32
33    // I'm printing this out again to make it easier
34    // when running tests for the README.
35    std::cout << "\nEdit distance = " << distance;
36    t = clock.getElapsedTime();
37    std::cout << "\nExecution time is " << t.asSeconds() << " seconds \n";
38
39    return 0;
40 }
```

ED.hpp

```
1  #ifndef ED_HPP
2  #define ED_HPP
3
4  #include <iostream>
5  #include <iomanip>
6  #include <sstream>
7  #include <string>
8  #include <stdexcept>      // std::out_of_range
9  #include <vector>
10 #include <SFML/System.hpp>
11
12 class ED
13 {
14     public:
15         ED();
16         ED(std::string string_one, std::string string_two);
17         ~ED();
18         int penalty(char a, char b);
19         int min(int a, int b, int c);
20         int OptDistance();
21         std::string Alignment();
22
23         // Debug method - just prints out what the Matrix should look like.
24         void PrintMatrix();
25
26     private:
27         std::string _string_one, _string_two;
28
29         // Large vector, which holds inside of it vectors of type integer.
30         std::vector< std::vector<int> > _matrix;
31     };
32
33 #endif
```

ED.cpp

```
1 #include "ED.hpp"
2
3 // Default constructor
4 ED::ED()
5 {
6
7 }
8
9
10 // Constructor with parameters
11 ED::ED(std::string string_one, std::string string_two)
12 {
13     _string_one = string_one;
14     _string_two = string_two;
15 }
16
17
18 // Destructor
19 ED::~ED()
20 {
21
22 }
23
24
25 // Returns the penalty of the two characters.
26 int ED::penalty(char a, char b)
27 {
28     if(a == b)      // Equal characters
29     {
30         return 0;
31     }
32
33     else if(a != b)
34     { // not equal and no spaces
35         return 1;
36     }
37
38     // If something fails, return a -1.
39     // We can check this for errors.
40     return -1;
41 }
42
43
44 // Finds the minimum integer
45 int ED::min(int a, int b, int c)
46 {
47     if(a < b && a < c)
48     {
49         return a;
50     }
51
52     else if(b < a && b < c)
53     {
54         return b;
```

```

55     }
56
57     else if(c < a && c < b)
58     {
59         return c;
60     }
61
62     // They are all equal if we get here.
63     // So just return a cause w/e
64     return a;
65 }
66
67
68     // Finds the optimal distance between the two strings
69     int ED::OptDistance()
70     {
71         // This is where we should do some sort of loop and populate
72         // the matrix. We should use the penalty and min methods as well.
73
74         int i, j;
75         int N = _string_one.length();
76         int M = _string_two.length();
77
78         // Create the Matrix
79         /*
80             * Quick note - it seems the vector of a vector of ints actually runs
81             * like this:
82             * -----> this is one vector
83             * -----> another vector
84             * -----> etc
85             *
86             * So each column is a vector of ints.
87             * And the entire vector is a vector of a vector of ints.
88             * With each vector inside the large vector pointing to vectors,
89             * which are technically the columns.
90             *
91             * This is important for some of the math down below, which follows
92             * Princeton's site but can get confusing due to how the vectors seem
93             * to be making themselves.
94             *
95         */
96         for(i = 0; i <= M; i++)
97         {
98             std::vector<int> tmp;
99             _matrix.push_back(tmp);
100
101             // Now push '0's back into the given vector
102             for(j = 0; j <= N; j++)
103             {
104                 _matrix.at(i).push_back(0);
105             }
106         }
107
108         // Start by filling out the bottom row
109         for(i = 0; i <= M; i++)
110         {
111             // Very bottom row

```

```

112         _matrix[i][N] = 2 * (M - i);
113     }
114
115     // Now fill out the side row.
116     for(j = 0; j <= N; j++)
117     {
118         // Very right most column
119         _matrix[M][j] = 2 * (N - j);
120     }
121
122     // Now that we have the initial sides, we can go ahead and
123     // calculate the rest of the sub problems.
124     for(i = M - 1; i >= 0; i--)
125     {
126         for(j = N - 1; j >= 0; j--)
127         {
128             // Using Princeton's formula, we can just calculate every single row!
129             /*
130             * Note - min of 3 numbers, which we must get
131             *         from using the penalty method.
132             */
133             int opt1 = _matrix[i+1][j+1] +
134                 penalty(_string_one[j], _string_two[i]);
135             int opt2 = _matrix[i+1][j] + 2;
136             int opt3 = _matrix[i][j+1] + 2;
137
138             _matrix[i][j] = min(opt1, opt2, opt3);
139         }
140     }
141
142     return _matrix[0][0];
143 }
144
145 // This is a test method which will print out the matrix, so we can compare
146 // against Princeton's site to see if we're doing it right.
147 void ED::PrintMatrix()
148 {
149     std::cout << "\n\nPrinting out the Matrix for debug purposes: \n\n";
150
151     // Iterator the large vector
152     std::vector< std::vector<int> >::iterator a;
153
154     // Iterator to each vector of integers.
155     std::vector<int>::iterator b;
156
157     for(a = _matrix.begin(); a != _matrix.end(); a++)
158     {
159         for(b = (*a).begin(); b != (*a).end(); b++)
160         {
161             // Using std::right and setw(3) to align numbers to the right.
162             // See the stackoverflow post in the README for an example
163             std::cout << std::right << std::setw(3) << *b << " ";
164         }
165         std::cout << "\n";
166     }
167 }
```

```

168
169 // Returns the alignment
170 // Here we should trace the matrix and find the string
171 // that displays the actual alignment.
172 std::string ED::Alignment()
173 {
174 // Let's declare a stringstream object to hold the string we want to return.
175 std::ostringstream return_string;
176
177 // Get M & N for going through the Matrix
178 // NOTE: I use standard MxN Matrix notation - that is,
179 // M is the number of rows, N is the number of columns.
180 int M = _string_two.length();
181 int N = _string_one.length();
182
183 int i = 0, j = 0;
184 int pen, opt1, opt2, opt3;
185 std::string ret_str;
186
187 // More debug stuff to check where the code is heading.
188 // std::cout << "We want: " << _matrix[M-1][N-1] << "\n";
189
190 // A while loop will work here since we want to move either diagonally,
191 // down or right.
192 while(i < M || j < N) // Need to run until we hit the far bottom right!
193 {
194     // Checking vector bounds with try/catch
195     try{
196         pen = penalty(_string_one[j], _string_two[i]);
197         opt1 = _matrix.at(i+1).at(j+1) + pen;
198     }
199     catch(const std::out_of_range& error)
200     {
201         // out of range
202         opt1 = -1;
203     }
204     try{
205         opt2 = _matrix.at(i+1).at(j) + 2;
206     }catch(const std::out_of_range& error)
207     {
208         // out of range
209         opt2 = -1;
210     }
211     try{
212         opt3 = _matrix.at(i).at(j+1) + 2;
213     }catch(const std::out_of_range& error)
214     {
215         // out of range
216         opt3 = -1;
217     }
218
219     // Move diagonally
220     if(_matrix[i][j] == opt1)
221     {
222         return_string << _string_one[j] << " ";
223         return_string << _string_two[i] << " " << pen << "\n";

```

```
225     i++;
226     j++;
227 }
228
229 // Move down
230 else if(_matrix[i][j] == opt2)
231 {
232     return_string << "-" << _string_two[i] << " 2\n";
233     i++;
234 }
235
236 // Move right
237 else if(_matrix[i][j] == opt3)
238 {
239     return_string << _string_one[j] << " -" << " 2\n";
240     j++;
241 }
242
243 // Get the string from the ostringstream object & return it.
244 ret_str = return_string.str();
245
246 return ret_str;
247 }
```

PS5a: Ring Buffer

The Assignment

For this assignment, we implemented a RingBuffer, complete with unit tests and exceptions. Implementing the RingBuffer was the main goal of the assignment, and it works by wrapping around like a circle array in order to store values – in our case, 16 bit integers. Boost unit tests were also used to check the RingBuffer for errors, and the RingBuffer was designed to throw certain exceptions for specific errors. Some exceptions include `std::invalid_argument` if you attempt to create a RingBuffer with a capacity of 0 or less, and `std::runtime_error` if you attempt to enqueue a full RingBuffer or dequeue or peek at an empty RingBuffer.

Key Concepts

The main concepts for this assignment focused on implementing the RingBuffer using exceptions, which is something we had not really discussed in class before this assignment. Try / Catch blocks were used to test for invalid actions. Another key idea was using Google's cpplint python script to check our code for consistency. This was introduced in the optional PSX assignment, but it was the first time we began to use cpplint in class. Boost was also used to check the RingBuffer, and ensure that the buffer threw the correct exceptions when it was supposed to, and no exceptions were thrown for valid actions.

What I Learned

Exceptions and cpplint were what I really took away from this assignment. Having only used exceptions a few times in Computing III, I was somewhat rusty at them. It did not take too long to figure them out though, and having used them in this class, I was able to apply exceptions to another class – Android Development, which uses Java and Java, like C++, uses exceptions a fair amount. Cpplint was also an interesting tool to use. Mainly in the class absolutely hate it, but I found it to be useful at times. It forced me to change some bad coding habits, such as using really long lines (80+ characters in length). At the same time though, it forced me to program Google's way, which is annoying if you've already got a programming style that you like (which I did somewhat have). For example, I used to like putting brackets on a separate line, but after using cpplint I've become used to putting them on the same line as the if / loop statement. This was hard to get used to, but now that I am used to it I've pretty much stuck with that style for other programming assignments that I do outside of class.

Screenshots

Screenshot of PS5a running, as well as a main test program.

Source Code for PS5a

Makefile

```
1  # Makefile for PS5a
2  # Flags to save on typing all this out
3  CC= g++
4  CFLAGS= -g -Wall -Werror -std=c++0x -pedantic
5  Boost= -lboost_unit_test_framework
6
7  # Make ps5a & a dummy tester
8  all:    ps5a main.out
9
10 # PS5 executable
11 ps5a:    test.o RingBuffer.o
12     $(CC) test.o RingBuffer.o -o ps5a $(Boost)
13
14 # main.out is just a basic test executable
15 main.out: main.o RingBuffer.o
16     $(CC) main.o RingBuffer.o -o main.out
17
18 # Object files
19 RingBuffer.o: RingBuffer.cpp RingBuffer.hpp
20     $(CC) -c RingBuffer.cpp RingBuffer.hpp $(CFLAGS)
21
22 test.o: test.cpp RingBuffer.hpp
23     $(CC) -c test.cpp RingBuffer.hpp $(CFLAGS)
24
25 main.o: main.cpp RingBuffer.hpp
26     $(CC) -c main.cpp RingBuffer.hpp $(CFLAGS)
27
28 # Cleanup object files
29 clean:
30     rm *.o
31     rm *.gch
32     rm ps5a
33     rm *.out
```

main.cpp

```
1  /*
2   * Copyright 2015 Jason Downing
3   * All rights reserved.
4   * MIT Licensed - see http://opensource.org/licenses/MIT for details.
5   *
6   */
7 #include "RingBuffer.hpp"
8
9 int main() {
10    std::cout << "Test main.\n";
11
12    RingBuffer test(100);
13    test.enqueue(1);
14    test.enqueue(2);
15    test.enqueue(3);
16    std::cout << "Peek: " << test.peek() << "\n";
17
18    std::cout << "Deq 1: " << test.dequeue() << "\n";
19    std::cout << "Deq 2: " << test.dequeue() << "\n";
20
21
22    test.output();
23
24    // Test looping back around
25    RingBuffer test2(3);
26
27    test2.enqueue(1);
28    test2.enqueue(2);
29    test2.enqueue(3);
30
31    test2.dequeue();
32    test2.dequeue();
33    test2.dequeue();
34
35    test2.enqueue(1);
36    test2.enqueue(2);
37    test2.enqueue(3);
38    test2.dequeue();
39    test2.enqueue(4);
40
41    test2.output();
42
43    return 0;
44 }
45
```

RingBuffer.hpp

```
1  /*
2   * Copyright 2015 Jason Downing
3   * All rights reserved.
4   * MIT Licensed - see http://opensource.org/licenses/MIT for details.
5   *
6   */
7  #include <stdint.h>
8  #include <iostream>
9  #include <string>
10 #include <sstream>
11 #include <exception>
12 #include <stdexcept>
13 #include <vector>
14
15 class RingBuffer {
16 public:
17     // API functions
18
19     // Empty ring buffer, with given max capacity.
20     explicit RingBuffer(int capacity);
21     int size();                                // return # of items in the buffer.
22     bool isEmpty();                            // is size == 0?
23     bool isFull();                             // is size == capacity?
24     void enqueue(int16_t x);                  // add item x to the end.
25     int16_t dequeue();                         // delete and return item from the front
26     int16_t peek();                            // return (don't delete) item from the front.
27
28     // Other functions
29     void output();
30
31 private:
32     std::vector<int16_t> _buffer;
33     int _first;
34     int _last;
35     int _capacity;
36     int _size;
37 };
38
```

RingBuffer.cpp

```
1  /*
2   * Copyright 2015 Jason Downing
3   * All rights reserved.
4   * MIT Licensed - see http://opensource.org/licenses/MIT for details.
5   */
6  */
7 #include "RingBuffer.hpp"
8
9 // Create an empty ring buffer, with given max capacity.
10 RingBuffer::RingBuffer(int capacity) {
11     if (capacity < 1) {
12         throw
13             std::invalid_argument("RB constructor: capacity must be greater than zero");
14     }
15
16     _last = 0;
17     _first = 0;
18     _size = 0;
19     _capacity = capacity;
20     _buffer.resize(capacity);
21
22     return;
23 }
24
25
26 // Return # of items in the buffer.
27 int RingBuffer::size() {
28     return _size;
29 }
30
31
32 // Is size == 0?
33 bool RingBuffer::isEmpty() {
34     // Determine if the RingBuffer is empty.
35     if (_size == 0) {
36         return true;
37     } else {
38         return false;
39     }
40 }
41
42
43 // Is size == capacity?
44 bool RingBuffer::isFull() {
45     // Determine if size equals capacity.
46     if (_size == _capacity) {
47         return true;
48     } else {
49         return false;
50     }
51 }
52
53
54 // Add item x to the end.
```

```

55 void RingBuffer::enqueue(int16_t x) {
56     // See if the buffer is full
57     if (isFull()) {
58         throw
59             std::runtime_error("enqueue: can't enqueue to a full ring");
60     }
61
62     // Check to see if we need to loop last back around to 0.
63     if (_last >= _capacity) {
64         _last = 0;
65     }
66
67     // If we don't throw any exceptions, then continue on!
68     _buffer.at(_last) = x;
69
70     // Increase counter variables.
71     _last++;
72     _size++;
73 }
74
75
76 // Delete and return item from the front
77 int16_t RingBuffer::dequeue() {
78     if (isEmpty()) {
79         throw
80             std::runtime_error("dequeue: can't dequeue to an empty ring");
81     }
82
83     // Remove from the front.
84     int16_t first = _buffer.at(_first);
85     _buffer.at(_first) = 0;
86
87     // Decrease counter variables.
88     _first++;
89     _size--;
90
91     // Check to see if we need to loop first back around to 0.
92     if (_first >= _capacity) {
93         _first = 0;
94     }
95
96     return first;
97 }
98
99
100// Return (don't delete) item from the front.
101int16_t RingBuffer::peek() {
102    // This is an easy function - return the first buffer position.
103    if (isEmpty()) {
104        throw
105            std::runtime_error("peek: can't peek an empty ring");
106    }
107
108    return _buffer.at(_first);
109}
110
111

```

```
112// Dumps the variables to stdout
113void RingBuffer::output() {
114    std::cout << "    First: " << _first << "\n";
115    std::cout << "    Last: " << _last << "\n";
116    std::cout << "Capacity: " << _capacity << "\n";
117    std::cout << "Size: " << _size << "\n";
118    std::cout << "Vector size: " << _buffer.size() << "\n";
119    std::cout << "Vector capacity: " << _buffer.capacity() << "\n";
120    std::cout << "Buffer (no blanks): \n";
121
122    int x = 0;
123    int y = _first;
124
125    while (x < _size) {
126        // Make the loop go back to 0 to continue printing.
127        if (y >= _capacity) {
128            y = 0;
129        }
130
131        std::cout << _buffer[y] << " ";
132        y++;
133        x++;
134    }
135
136    std::cout << "\nDump the entire buffer (including blanks): \n";
137
138    for (int x = 0; x < _capacity; x++) {
139        std::cout << _buffer[x] << " ";
140    }
141
142    std::cout << "\n\n";
143}
144
```

test.cpp

```
1  /*
2   * Copyright 2015 Jason Downing
3   * All rights reserved.
4   * MIT Licensed - see http://opensource.org/licenses/MIT for details.
5   *
6   */
7 #define BOOST_TEST_DYN_LINK
8 #define BOOST_TEST_MODULE Main
9 #include <boost/test/unit_test.hpp>
10
11 #include "RingBuffer.hpp"
12
13 // Tests various aspects of the constructor.
14 BOOST_AUTO_TEST_CASE(Constructor) {
15     // Normal constructor - shouldn't fail.
16     BOOST_REQUIRE_NO_THROW(RingBuffer(100));
17
18     // These should fail.
19     BOOST_REQUIRE_THROW(RingBuffer(0), std::exception);
20     BOOST_REQUIRE_THROW(RingBuffer(0), std::invalid_argument);
21     BOOST_REQUIRE_THROW(RingBuffer(-1), std::invalid_argument);
22 }
23
24
25 // Checks the size() method
26 BOOST_AUTO_TEST_CASE(Size) {
27     RingBuffer test(1);
28
29     // This should be size 0.
30     BOOST_REQUIRE(test.size() == 0);
31
32     test.enqueue(5);
33
34     // This should be size 1.
35     BOOST_REQUIRE(test.size() == 1);
36
37     test.dequeue();
38     BOOST_REQUIRE(test.size() == 0);
39 }
40
41
42 // Checks the isEmpty() method
43 BOOST_AUTO_TEST_CASE(isEmpty) {
44     // This should be true
45     RingBuffer test(5);
46     BOOST_REQUIRE(test.isEmpty() == true);
47
48     // This should be false
49     RingBuffer test2(5);
50     test2.enqueue(5);
51     BOOST_REQUIRE(test2.isEmpty() == false);
52 }
```

```
55 // Checks the isFull() method
56 BOOST_AUTO_TEST_CASE(isFull) {
57     RingBuffer test(5);
58     BOOST_REQUIRE(test.isFull() == false);
59
60     RingBuffer test2(1);
61     test2.enqueue(5);
62     BOOST_REQUIRE(test2.isFull() == true);
63 }
64
65
66 // Test enqueue
67 BOOST_AUTO_TEST_CASE(Enqueue) {
68     // These test basic enqueueing
69     RingBuffer test(5);
70
71     BOOST_REQUIRE_NO_THROW(test.enqueue(1));
72     BOOST_REQUIRE_NO_THROW(test.enqueue(2));
73     BOOST_REQUIRE_NO_THROW(test.enqueue(3));
74     BOOST_REQUIRE_NO_THROW(test.enqueue(4));
75     BOOST_REQUIRE_NO_THROW(test.enqueue(5));
76     BOOST_REQUIRE_THROW(test.enqueue(6), std::runtime_error);
77 }
78
79
80 // Test dequeue
81 BOOST_AUTO_TEST_CASE(Dequeue) {
82     RingBuffer test(5);
83
84     test.enqueue(0);
85     test.enqueue(1);
86     test.enqueue(2);
87
88     BOOST_REQUIRE(test.dequeue() == 0);
89     BOOST_REQUIRE(test.dequeue() == 1);
90     BOOST_REQUIRE(test.dequeue() == 2);
91     BOOST_REQUIRE_THROW(test.dequeue(), std::runtime_error);
92 }
```

PS5b: Karplus-Strong String Simulation and Guitar Hero

The Assignment

In the second part of PS5, we used the RingBuffer from PS5a to create a model of a Guitar, by implementing the Karplus-Strong algorithm to simulate the plucking of a guitar string. We were tasked with implementing a few methods to simulate the playing of a guitar – such as pluck, tic, sample, etc. Finally, we also made the main program, GuitarHero, respond to keyboard presses, which each key generated a different note.

Key Concepts

The main algorithm was used in this assignment was the Karplus-Strong algorithm, which was used to simulate the plucking of a guitar. The Karplus-Strong algorithm works by modeling frequencies, and it takes the first two values, averages them and then multiplies the result by the energy decay factor, which in our case was .996. This, along with the RingBuffer, allowed us to model sound (to some degree) and made it seem like a guitar string was being plucked.

What I Learned

Learning about the Karplus-Strong algorithm was quite interesting, and it gave me insight on how to model sound in a program. It was fairly tricky to get the Karplus-Strong update correct as well, and I also got a lot of segfaults when I first wrote the program using pointers. After I switched to a member initialization list I found the segfaults went away and the program was able to work somewhat. I also ran into issues with getting the sound to play, but I'm not entirely sure how I fixed that – I guess playing around with the keyboard settings for SFML helped. Which speaking of that, SFML's Keyboard library is pretty useful for controlling a piano / guitar / etc – I also thought about its uses in simple 2D games, which along with the planet stuff from PS3 could make a pretty cool space invaders like game. Perhaps one day I'll try playing around with those again for fun.

Screenshots

The screenshot shows a terminal window titled "ps5b : GuitarHero - Konsole". The window has a menu bar with "File", "Edit", "View", "Bookmarks", "Settings", and "Help". The main area of the terminal displays the following command-line session:

```
jason@jason-desktop: ps5b$ clear
jason@jason-desktop: ps5b$ make clean
rm *.o
rm *.gch
rm GuitarHero
rm GTest
jason@jason-desktop: ps5b$ make
g++ -c GuitarHero.cpp GuitarString.hpp -g -Wall -Werror -std=c++0x -pedantic
g++ -c GuitarString.cpp GuitarString.hpp -g -Wall -Werror -std=c++0x -pedantic
g++ -c RingBuffer.cpp RingBuffer.hpp -g -Wall -Werror -std=c++0x -pedantic
g++ GuitarHero.o GuitarString.o RingBuffer.o -o GuitarHero -lsfml-graphics -lsfml-window
-lsfml-system -lsfml-audio
g++ -c GTest.cpp -lboost_unit_test_framework
g++ GTest.o GuitarString.o RingBuffer.o -o GTest -lboost_unit_test_framework
jason@jason-desktop: ps5b$ ./GTest
Running 1 test case...
Sample is: 0
Sample is: 2000
Sample is: 4000
Sample is: -10000
Sample is: 996
Sample is: 2988
Sample is: -2988
Sample is: -4483
Sample is: 1984
Sample is: 0

*** No errors detected
jason@jason-desktop: ps5b$ ./GuitarHero
Keyboard key is: 2
Attempting to play sound...
Keyboard key is: 4
Attempting to play sound...
Keyboard key is: 5
Attempting to play sound...
Keyboard key is: 7
Attempting to play sound...
Keyboard key is: 8
Attempting to play sound...
Keyboard key is: 9
Attempting to play sound...
Keyboard key is: 9
Attempting to play sound...
Keyboard key is: 2
Attempting to play sound...
Keyboard key is: 2
```

Screenshot of PS5b running – including GTest, and some keyboard debugging couts.

Source Code for PS5b

Makefile

```
1  # Makefile for PS5b
2  # Flags to save on typing all this out
3  CC= g++
4  CFLAGS= -g -Wall -Werror -std=c++0x -pedantic
5  SFLAGS= -lsfml-graphics -lsfml-window -lsfml-system -lsfml-audio
6  Boost= -lboost_unit_test_framework
7
8  # Make ps5a & a dummy tester
9  all:    GuitarHero GTest
10
11 # PS5B executable
12 GuitarHero: GuitarHero.o GuitarString.o RingBuffer.o
13     $(CC) GuitarHero.o GuitarString.o RingBuffer.o -o GuitarHero $(SFLAGS)
14
15 # GTest executable
16 GTest: GTest.o GuitarString.o RingBuffer.o
17     $(CC) GTest.o GuitarString.o RingBuffer.o -o GTest $(Boost)
18
19 # Object files
20 GuitarHero.o:    GuitarHero.cpp GuitarString.hpp
21     $(CC) -c GuitarHero.cpp GuitarString.hpp $(CFLAGS)
22
23 GuitarString.o: GuitarString.cpp GuitarString.hpp
24     $(CC) -c GuitarString.cpp GuitarString.hpp $(CFLAGS)
25
26 RingBuffer.o: RingBuffer.cpp RingBuffer.hpp
27     $(CC) -c RingBuffer.cpp RingBuffer.hpp $(CFLAGS)
28
29 GTest.o:    GTest.cpp
30     $(CC) -c GTest.cpp $(Boost)
31
32 # Cleanup object files
33 clean:
34     rm *.o
35     rm *.gch
36     rm GuitarHero
37     rm GTest
```

GuitarHero.cpp (main)

```
1  /*
2   * Copyright 2015 Jason Downing
3   * All rights reserved.
4   * MIT Licensed - see http://opensource.org/licenses/MIT for details.
5   */
6  */
7 #include <SFML/Graphics.hpp>
8 #include <SFML/System.hpp>
9 #include <SFML/Audio.hpp>
10 #include <SFML/Window.hpp>
11
12 #include <math.h>
13 #include <limits.h>
14
15 #include <iostream>
16 #include <string>
17 #include <exception>
18 #include <stdexcept>
19 #include <vector>
20
21 #include "RingBuffer.hpp"
22 #include "GuitarString.hpp"
23
24 #define CONCERT_A 440.0
25 #define SAMPLES_PER_SEC 44100
26 const int keyboard_size = 37;
27
28 std::vector<sf::Int16> makeSamplesFromString(GuitarString gs) {
29     std::vector<sf::Int16> samples;
30
31     gs.pluck();
32     int duration = 8; // seconds
33     int i;
34     for (i= 0; i < SAMPLES_PER_SEC * duration; i++) {
35         gs.tic();
36         samples.push_back(gs.sample());
37     }
38
39     return samples;
40 }
41
42 int main() {
43     sf::RenderWindow window(sf::VideoMode(800, 800), "SFML Guitar Hero");
44     sf::Event event;
45
46     // sample vector / freq - all reused.
47     double freq;
48     std::vector<sf::Int16> sample;
49
50     // Samples vector of a vector
51     std::vector<std::vector<sf::Int16>> samples(keyboard_size);
52     std::vector<sf::SoundBuffer> buffers(keyboard_size);
53     std::vector<sf::Sound> sounds(keyboard_size);
54 }
```

```

55 // From Princeton.
56 std::string keyboard = "q2we4r5ty7u8i9op-[=zxdcfvgbnjmkg,.;/` ";
57
58 // For loop to go through the entire keyboard.
59 for (int i = 0; i < (signed)keyboard.size(); i++) {
60     // Set the frequency and make a GuitarString.
61     freq = CONCERT_A * pow(2, (i - 24)/12.0));
62     GuitarString tmp = GuitarString(freq);
63
64     // Make a vector of sf::Int16, will act as a sample.
65     sample = makeSamplesFromString(tmp);
66     samples[i] = sample;
67
68     // Load the above same into the buffer vector.
69     if (!buffers[i].loadFromSamples(&samples[i][0],
70         samples[i].size(), 2, SAMPLES_PER_SEC)) {
71         throw
72     std::runtime_error("sf::SoundBuffer: failed to load from samples.");
73     }
74
75     // Now load the buffer into a sf::sound.
76     sounds[i].setBuffer(buffers[i]);
77 }
78
79 while (window.isOpen()) {
80     while (window.pollEvent(event)) {
81         if (event.type == sf::Event::TextEntered) {
82             // This detects unicode characters
83             if (event.text.unicode < 128) {
84                 // Convert the key from unicode to ASCII
85                 char key = static_cast<char>(event.text.unicode);
86
87                 // Now go through the keyboard string and if we find a match,
88                 // then access that sound and play it.
89                 for (int i = 0; i < (signed)keyboard.size(); i++) {
90                     if (keyboard[i] == key) {
91                         std::cout << "Keyboard key is: " << keyboard[i] << "\n";
92                         std::cout << "Attempting to play sound...\n";
93                         sounds[i].play();
94                         break;
95                     }
96                 }
97             }
98         }
99     }
100
101     window.clear();
102     window.display();
103 }
104 return 0;
105}
106

```

GuitarString.hpp

```
1  /*
2   * Copyright 2015 Jason Downing
3   * All rights reserved.
4   * MIT Licensed - see http://opensource.org/licenses/MIT for details.
5   *
6   */
7 #ifndef GUITARSTRING_HPP
8 #define GUITARSTRING_HPP
9
10 #include <SFML/Audio.hpp>
11 #include <SFML/Graphics.hpp>
12 #include <SFML/System.hpp>
13 #include <SFML/Window.hpp>
14 #include <cmath>
15 #include <iostream>
16 #include <string>
17 #include <vector>
18 #include "RingBuffer.hpp"
19
20 const int SAMPLING_RATE = 44100;
21 const double ENERGY_DECAY_FACTOR = 0.996;
22
23 class GuitarString {
24 public:
25     // create a guitar string of the given freq using a rate of 44,100
26     explicit GuitarString(double frequency);
27
28     // create a guitar string with size and initial values of the vector init
29     explicit GuitarString(std::vector<sf::Int16> init);
30
31     // pluck the guitar string by replacing the buffer with random values
32     void pluck();
33     void tic();           // advance the simulation one time step
34     sf::Int16 sample();    // return the current sample
35     int time();          // return number of times tic was called so far
36 private:
37     RingBuffer _buff;
38     int _N;
39     int _tic;
40 };
41#endif
```

GuitarString.cpp

```
1  /*
2   * Copyright 2015 Jason Downing
3   * All rights reserved.
4   * MIT Licensed - see http://opensource.org/licenses/MIT for details.
5   *
6   */
7 #include "GuitarString.hpp"
8 #include <vector>
9
10
11 // Create a guitar string of the given freq using a rate of 44,100
12 GuitarString::GuitarString(double frequency):
13                                     _buff(ceil(SAMPLING_RATE / frequency)) {
14     // Ringbuffer will be this large.
15     _N = ceil(SAMPLING_RATE / frequency);
16
17     // Enqueue N (44,100 / freq) 0's.
18     for (int i = 0; i < _N; i++) {
19         _buff.enqueue((int16_t)0);
20     }
21
22     // Set _tic to 0 for the tic / time methods.
23     _tic = 0;
24 }
25
26
27 // Create a guitar string with size and initial values of the vector init
28 GuitarString::GuitarString(std::vector<sf::Int16> init):
29                                     _buff(init.size()) {
30     // RingBuffer will be as large as the array.
31     _N = init.size();
32
33     // Iterator to keep track of the vector.
34     std::vector<sf::Int16>::iterator it;
35
36     // Enqueue all the items in the vector.
37     for (it = init.begin(); it < init.end(); it++) {
38         _buff.enqueue((int16_t)*it);
39     }
40
41     // Set _tic to 0 for the tic / time methods.
42     _tic = 0;
43 }
44
45
46 // pluck the guitar string by replacing the buffer with random values
47 void GuitarString::pluck() {
48     // Remove N items
49     for (int i = 0; i < _N; i++) {
50         _buff.dequeue();
51     }
52
53     // Add N random items between -32768 to 32767
54     for (int i = 0; i < _N; i++) {
```

```

55     _buff.enqueue((sf::Int16)(rand() & 0xffff)); //NOLINT
56 }
57
58     return;
59 }
60
61
62 // advance the simulation one time step
63 void GuitarString::tic() {
64     // First get the first value, and dequeue it at the same time.
65     int16_t first = _buff.dequeue();
66
67     // Get the second value (DON'T dequeue it)
68     int16_t second = _buff.peek();
69
70     // Now we can apply the Karplus-Strong update:
71     // Take the first two values, average them and multiply by the
72     // ENERGY_DECAY_FACTOR
73     int16_t avg = (first + second) / 2;
74     int16_t karplus = avg * ENERGY_DECAY_FACTOR;
75
76     // Debugging code.
77     std::cout << "Karplus is: " << karplus << "\n";
78
79     // Now enqueue the Karplus-Strong update.
80     _buff.enqueue((sf::Int16)karplus);
81
82     _tic++;
83
84     return;
85 }
86
87
88 // return the current sample
89 sf::Int16 GuitarString::sample() {
90     // Get the value of the item at the front of the RingBuffer
91     sf::Int16 sample = (sf::Int16)_buff.peek();
92
93     return sample;
94 }
95
96
97 // return number of times tic was called so far
98 int GuitarString::time() {
99     return _tic;
100 }
```

RingBuffer.hpp

```
1  /*
2   * Copyright 2015 Jason Downing
3   * All rights reserved.
4   * MIT Licensed - see http://opensource.org/licenses/MIT for details.
5   *
6   */
7  #include <stdint.h>
8  #include <iostream>
9  #include <string>
10 #include <sstream>
11 #include <exception>
12 #include <stdexcept>
13 #include <vector>
14
15 class RingBuffer {
16 public:
17     // API functions
18
19     // Empty ring buffer, with given max capacity.
20     explicit RingBuffer(int capacity);
21     int size();                                // return # of items in the buffer.
22     bool isEmpty();                            // is size == 0?
23     bool isFull();                             // is size == capacity?
24     void enqueue(int16_t x);                  // add item x to the end.
25     int16_t dequeue();                         // delete and return item from the front
26     int16_t peek();                            // return (don't delete) item from the front.
27
28     // Other functions
29     void output();
30
31 private:
32     std::vector<int16_t> _buffer;
33     int _first;
34     int _last;
35     int _capacity;
36     int _size;
37 };
38
```

RingBuffer.cpp

```
1  /*
2   * Copyright 2015 Jason Downing
3   * All rights reserved.
4   * MIT Licensed - see http://opensource.org/licenses/MIT for details.
5   */
6  */
7 #include "RingBuffer.hpp"
8
9 // Create an empty ring buffer, with given max capacity.
10 RingBuffer::RingBuffer(int capacity) {
11     if (capacity < 1) {
12         throw
13             std::invalid_argument("RB constructor: capacity must be greater than zero");
14     }
15
16     _last = 0;
17     _first = 0;
18     _size = 0;
19     _capacity = capacity;
20     _buffer.resize(capacity);
21
22     return;
23 }
24
25
26 // Return # of items in the buffer.
27 int RingBuffer::size() {
28     return _size;
29 }
30
31
32 // Is size == 0?
33 bool RingBuffer::isEmpty() {
34     // Determine if the RingBuffer is empty.
35     if (_size == 0) {
36         return true;
37     } else {
38         return false;
39     }
40 }
41
42
43 // Is size == capacity?
44 bool RingBuffer::isFull() {
45     // Determine if size equals capacity.
46     if (_size == _capacity) {
47         return true;
48     } else {
49         return false;
50     }
51 }
52
53
54 // Add item x to the end.
```

```

55 void RingBuffer::enqueue(int16_t x) {
56     // See if the buffer is full
57     if (isFull()) {
58         throw
59             std::runtime_error("enqueue: can't enqueue to a full ring");
60     }
61
62     // Check to see if we need to loop last back around to 0.
63     if (_last >= _capacity) {
64         _last = 0;
65     }
66
67     // If we don't throw any exceptions, then continue on!
68     _buffer.at(_last) = x;
69
70     // Increase counter variables.
71     _last++;
72     _size++;
73 }
74
75
76 // Delete and return item from the front
77 int16_t RingBuffer::dequeue() {
78     if (isEmpty()) {
79         throw
80             std::runtime_error("dequeue: can't dequeue to an empty ring");
81     }
82
83     // Remove from the front.
84     int16_t first = _buffer.at(_first);
85     _buffer.at(_first) = 0;
86
87     // Decrease counter variables.
88     _first++;
89     _size--;
90
91     // Check to see if we need to loop first back around to 0.
92     if (_first >= _capacity) {
93         _first = 0;
94     }
95
96     return first;
97 }
98
99
100// Return (don't delete) item from the front.
101int16_t RingBuffer::peek() {
102     // This is an easy function - return the first buffer position.
103     if (isEmpty()) {
104         throw
105             std::runtime_error("peek: can't peek an empty ring");
106     }
107
108     return _buffer.at(_first);
109}
110
111

```

```
112// Dumps the variables to stdout
113void RingBuffer::output() {
114    std::cout << "    First: " << _first << "\n";
115    std::cout << "    Last: " << _last << "\n";
116    std::cout << "Capacity: " << _capacity << "\n";
117    std::cout << "Size: " << _size << "\n";
118    std::cout << "Vector size: " << _buffer.size() << "\n";
119    std::cout << "Vector capacity: " << _buffer.capacity() << "\n";
120    std::cout << "Buffer (no blanks): \n";
121
122    int x = 0;
123    int y = _first;
124
125    while (x < _size) {
126        // Make the loop go back to 0 to continue printing.
127        if (y >= _capacity) {
128            y = 0;
129        }
130
131        std::cout << _buffer[y] << " ";
132        y++;
133        x++;
134    }
135
136    std::cout << "\nDump the entire buffer (including blanks): \n";
137
138    for (int x = 0; x < _capacity; x++) {
139        std::cout << _buffer[x] << " ";
140    }
141
142    std::cout << "\n\n";
143}
144
```

PS6: Markov Model of Natural Language

The Assignment

For PS6, we created a class that implements Markov chains to model English text. Markov chains are statistical model of text, which count the occurrences and sequences of characters in an English word / sentence. The MarkovModel class uses several methods, such as freq() which returns the frequency of a character in a k-gram (fixed number of text), and randk() which returns a random character that follows a given k-gram. Using this MarkovModel class allows us to generate pseudo-random text through the use of statistics – and specifically using the gen() method, which returns a string of random characters following a given k-gram.

Key Concepts

The key idea behind this assignment is to understand and implement Markov chains, which are statistical models of English text. To build this Markov Model class, I used a C++ map, which I set up as a std::string, int map – that is, the k-gram is the key to the map, and the int is the value, or number of occurrences of the given k-gram. We had several methods that were used to model the Markov chains:

1. Freq() – two versions of this method, one for finding the frequency of k-grams and another for finding the frequency of a character following the given k-gram.
2. Randk() – generates a random character that follows the given k-gram
3. Gen() – generates a string of length T characters which simulates a trajectory through the given Markov chain.

These four methods were critical to getting the TextGenerator program working correctly. The program was designed to take an input text, and output pseudo-random text using the MarkovModel class. I was able to get my TextGenerator program to work rather well. Some example outputs of my TextGenerator program can be found in the screenshots section.

What I Learned

I learned a fair amount about Markov chains, and how to model them. I also found out that many text prediction programs use this idea, which was pretty interesting to hear about. For example, most auto correct functions on smart phones use a Markov chain to predict what you are trying to say. They do this by determining the frequencies of characters, just like we did, and then they use these frequencies to make an educated guess on what word you are trying to type / say / etc. It was pretty neat to figure out how these programs actually work, and to implement a design that is used in the real world was pretty cool. Inputting text into the finished program is also quite fun, as you get completely unexpected outputs, but these outputs actually make sense when you think about how the text is generated – it's random, but at the same time it is based on how the original text was structured.

Screenshots

```
jason@jason-desktop: ps6$ make clean
rm *.o
rm *.gch
rm TextGenerator
rm mmtest
jason@jason-desktop: ps6$ make
g++ -c TextGenerator.cpp MarkovModel.hpp -g -Wall -Werror -std=c++0x -pedantic
g++ -c MarkovModel.cpp  MarkovModel.hpp -g -Wall -Werror -std=c++0x -pedantic
g++ TextGenerator.o MarkovModel.o -o TextGenerator
g++ -c mmtest.cpp -lboost_unit_test_framework
g++ mmtest.o MarkovModel.o -o mmtest -lboost_unit_test_framework
jason@jason-desktop: ps6$ ./mmtest
Running 3 test cases...

*** No errors detected
jason@jason-desktop: ps6$
```

Screenshot of the Markov Model class being compiled / tested against the provided mmtest.cpp file.

The screenshot shows a terminal window titled "ps6 : bash - Konsole". The window has a menu bar with "File", "Edit", "View", "Bookmarks", "Settings", and "Help". The main area displays the following text:

```
jason@jason-desktop: ps6$ ./TextGenerator 6 500 < OpeningExercises2014.txt
ORIGINAL INPUT TEXT BELOW THIS LINE.

Good afternoon and welcome to Opening Exercises.
What a special pleasure it is to greet Princeton's Great Class of 2018!
I also offer a warm welcome to our new graduate students, faculty and staff members, and all of you who are returning to campus after the summer.
Today we carry on a tradition that dates back at least to 1802, when Nassau Hall was the site of an opening exercise for Princeton students.
The event switched to other sites before moving in 1929 to the University Chapel, where we g

FINAL OUTPUT TEXT BELOW THIS LINE.

Good after the site of an entirely new begin your favorite times of the Princeton community.
I hope that cares enough about the teachers who made the sense of imminent discovered in projects of independ on whom they will require some mystery that you will make it easy to feel both fortunate and evil wizards with that Professor Wolf seems to suggest that causes us, when that presidents with meaning might be, to wonder whether welcome to live , to read so meaningful, not just the teach you, some l
jason@jason-desktop: ps6$
```

Screenshot of running the following command:

```
$ ./TextGenerator 6 500 < OpeningExercises2014.txt
```

Source Code for PS6

Makefile

```
1  # Makefile for PS6
2  # Flags to save on typing all this out
3  CC = g++
4  CFLAGS = -g -Wall -Werror -std=c++0x -pedantic
5  SFLAGS = -lsfml-graphics -lsfml-window -lsfml-system -lsfml-audio
6  Boost = -lboost_unit_test_framework
7
8  # Make ps5a & a dummy tester
9  all:    TextGenerator mmtest
10
11 # PS6 executable
12 TextGenerator: TextGenerator.o MarkovModel.o
13     $(CC) TextGenerator.o MarkovModel.o -o TextGenerator
14
15 mmtest: mmtest.o MarkovModel.o
16     $(CC) mmtest.o MarkovModel.o -o mmtest $(Boost)
17
18 # Object files
19 TextGenerator.o:TextGenerator.cpp MarkovModel.hpp
20     $(CC) -c TextGenerator.cpp MarkovModel.hpp $(CFLAGS)
21
22 MarkovModel.o:MarkovModel.cpp MarkovModel.hpp
23     $(CC) -c MarkovModel.cpp MarkovModel.hpp $(CFLAGS)
24
25 mmtest.o:mmtest.cpp
26     $(CC) -c mmtest.cpp $(Boost)
27
28 # Cleanup object files
29 clean:
30     rm *.o
31     rm *.gch
32     rm TextGenerator
33     rm mmtest
```

TextGenerator.cpp

```
1  /*
2   * Copyright 2015 Jason Downing
3   * All rights reserved.
4   * MIT Licensed - see http://opensource.org/licenses/MIT for details.
5   *
6   */
7 #include <string>
8 #include "MarkovModel.hpp"
9
10 int main(int argc, const char* argv[]) {
11     // Make sure the user knows how to use our amazing TextGenerator program.
12     if (argc != 3) {
13         std::cout << "Usage: ./TextGenerator (int K) (int T)\n";
14         return 0;
15     }
16
17     // For some weird reason, need to use a string to please -fpermissive
18     // Can't just cast to int with getting:
19     // error: cast from 'const char*' to 'int' loses precision [-fpermissive]
20     std::string str_k(argv[1]);
21     std::string str_t(argv[2]);
22
23     // Get the command line arguments as ints.
24     int k = std::stoi(str_k);
25     int t = std::stoi(str_t);
26
27     // Check the arguments for sanity
28     // std::cout << "k is: " << k << "\n";
29     // std::cout << "t is: " << t << "\n";
30
31     // Now take input from standard IO.
32     // Note: using Roy's solution from the discussion group.
33     std::string input = "";
34     std::string current_txt = "";    // Set these to NULL just to be sure.
35
36     // This will read the entire file that you pipe into stdio.
37     while (std::cin >> current_txt) {
38         input += " " + current_txt;
39         current_txt = "";
40     }
41
42     // I figured we should output the user's input for sanity checking.
43     std::cout << "ORIGINAL INPUT TEXT BELOW THIS LINE.\n\n";
44
45     // Only show the first T characters that the user cares about though.
46     for (int a = 0; a < t; a++) {
47         std::cout << input[a];
48
49         // This is for formatting, I just wanted to be able to read the text.
50         if (input[a] == '.' || input[a] == '!') {
51             std::cout << "\n";
52         }
53     }
54 }
```

```
55 // Whenever stand IO hits a newline, we've finished taking input and
56 // can actually do fun text generating stuff!
57
58 // First make a final output string to use.
59 std::string output_string = "";
60
61 // We also need to use a MarkovModel object! Give it the int k as the
62 // order. Also, the input text will be our string that we pass to the
63 // constructor.
64 MarkovModel amazing(input, k);
65
66 output_string += "" + amazing.gen(input.substr(0, k), t);
67
68 // We're done! Just output the text to standard IO for the user to see. ^_^
69 std::cout << "\n\nFINAL OUTPUT TEXT BELOW THIS LINE.\n\n";
70
71 // Rather then just dump to cout, I figured I'd format this nicely too.
72 // I just added a bunch of newlines.
73 for (int a = 0; a < t; a++) {
74     std::cout << output_string[a];
75
76     // This is for formatting, I just wanted to be able to read the text.
77     if (output_string[a] == '.' || output_string[a] == '!') {
78         std::cout << "\n";
79     }
80 }
81
82 std::cout << "\n";
83
84 // Dump the object to test it.
85 // std::cout << "\n\n" << amazing << "\n";
86
87 return 0;
88 }
```

MarkovModel.hpp

```
1  /* Copyright 2015 Jason Downing
2   * All rights reserved.
3   * MIT Licensed - see http://opensource.org/licenses/MIT for details.
4   */
5  #ifndef MARKOVMODEL_HPP
6  #define MARKOVMODEL_HPP
7  #include <algorithm>
8  #include <iostream>
9  #include <map>
10 #include <string>
11 #include <stdexcept>
12
13
14 class MarkovModel {
15 public:
16     /* Creates a Markov model of order k from the given text.
17      * Assume that the text has a length of at least k. */
18     MarkovModel(std::string text, int k);
19
20     // Order k of Markov model
21     int order();
22
23     /* Number of occurrences of kgram in text.
24      * -> throw an exception if kgram is not of length k */
25     int freq(std::string kgram);
26
27     /* Number of times that character c follows kgram
28      * If order = 0, return number of times char c appears
29      * -> throw an exception if kgram is not of length k */
30     int freq(std::string kgram, char c);
31
32     /* Random character following given kgram
33      * -> Throw an exception if kgram is not of length k.
34      * -> Throw an exception if no such kgram. */
35     char randk(std::string kgram);
36
37     /* Generate a string of length T characters by simulating a
38      * trajectory through the corresponding Markov chain.
39      * The first k characters of the newly generated string should be
40      * the argument kgram. ** Assume that T is at least k. **
41      * -> Throw an exception if kgram is not of length k. */
42     std::string gen(std::string kgram, int T);
43
44     /* overload the stream insertion operator and display the internal
45      * state of the Markov Model. Print out the order, the alphabet,
46      * and the frequencies of the k-grams and k+1-grams. */
47     friend std::ostream& operator<< (std::ostream &out, MarkovModel &mm);
48
49 private:
50     int _order;
51     std::map<std::string, int> _kgrams;
52     std::string _alphabet;
53 };
54 #endif
```

MarkovModel.cpp

```
1  /* Copyright 2015 Jason Downing
2   * All rights reserved.
3   * MIT Licensed - see http://opensource.org/licenses/MIT for details.
4   */
5  #include "MarkovModel.hpp"
6  #include <algorithm>
7  #include <map>
8  #include <string>
9  #include <stdexcept>
10 #include <vector>
11 #include <utility>
12
13 /* Creates a Markov model of order k from the given text.
14  * Assume that the text has a length of at least k. */  

15 MarkovModel::MarkovModel(std::string text, int k) {
16     // Set the order.
17     _order = k;
18
19     // Seed the random number generator for later.
20     srand((int)time(NULL)); //NOLINT
21
22     // Need to treat the text as circular!
23     // So wrap around the first k characters.
24     // Add the wrap around portion.
25     std::string text_circular = text;    // Make a copy.
26
27     for (int a = 0; a < _order; a++) {
28         text_circular.push_back(text[a]);
29     }
30
31     int text_len = text.length(); // Find the text's length, easier later on.
32
33     // Now we need to set the alphabet.
34     char tmp;
35     bool inAlpha = false;
36
37     // Go through the entire text and pick out all the individual letters,
38     for (int i = 0; i < text_len; i++) {
39         tmp = text.at(i);
40         inAlpha = false;
41
42         // See if this letter has been added to the alphabet.
43         for (unsigned int y = 0; y < _alphabet.length(); y++) {
44             // tmp is already in the alphabet!
45             // Also ignore upper case,
46             if (_alphabet.at(y) == tmp) {
47                 inAlpha = true; // Match it as being in the alphabet.
48             }
49         }
50
51         // If tmp isn't in the alphabet, isAlpha should be FALSE.
52         // So push it back to the alphabet.
53         if (!inAlpha) {
54             _alphabet.push_back(tmp);
55         }
56
57     }
58
59     // Now we have to make sure the alphabet is sorted.
60     std::sort(_alphabet.begin(), _alphabet.end());
61 }
```

```

56     }
57
58     // Now that we've got the alphabet, why not sort it alphabetically?
59     std::sort(_alphabet.begin(), _alphabet.end());
60
61     std::string tmp_str;
62     int x, y;
63
64     // Do up to text.length() substring comparisons.
65     // This first part just "finds" kgrams and puts a "0" next to them.
66     for (x = _order; x <= _order + 1; x++) {
67         // Go through the entire text.
68         for (y = 0; y < text_len; y++) {
69             // This collects all given kgrams, and adds a "0" that we can use
70             // later on to increment. We basically find ALL the kgrams, then
71             // find their occurrences after.
72
73             // current kgram we want.
74             tmp_str.clear();
75             tmp_str = text_circular.substr(y, x);
76
77             // Insert the 0.
78             _kgrams.insert(std::pair<std::string, int>(tmp_str, 0));
79         }
80     }
81
82     // Need an iterator for going through the kgrams map.
83     std::map<std::string, int>::iterator it;
84     int count_tmp = 0;
85
86     // Now let's count the kgrams!
87     // Uses same loop as above.
88     for (x = _order; x <= _order + 1; x++) {
89         // Go through the entire text.
90         for (y = 0; y < text_len; y++) {
91             // Let's get the current kgram we're comparing against.
92
93             tmp_str.clear();
94             tmp_str = text_circular.substr(y, x);
95
96             // Now let's get the kgram's current count.
97             it = _kgrams.find(tmp_str);
98             count_tmp = it->second;
99
100            // Increment the count by 1.
101            count_tmp++;
102
103            // Reinsert the count into the map.
104            _kgrams[tmp_str] = count_tmp;
105        }
106    }
107 }
108
109
110 // Order k of Markov model
111 int MarkovModel::order() {
112     return _order;

```

```

113 }
114
115
116 /* Number of occurrences of kgram in text.
117 * -> Throw an exception if kgram is not of length k */
118 int MarkovModel::freq(std::string kgram) {
119     // Throw an exception if kgram is not of length k
120     if (kgram.length() != (unsigned)_order) {
121         throw
122             std::runtime_error("Error - kgram not of length k.");
123     }
124
125     // Use std::map::find to see if we can find the kgram.
126     std::map<std::string, int>::iterator it;
127     it = _kgrams.find(kgram);
128
129     // If it equals map::end, we didn't find it, so return 0.
130     if (it == _kgrams.end()) {
131         return 0;
132     }
133
134     // Other wise return the given kgram since we found it.
135     return it->second;
136 }
137
138
139 /* Number of times that character c follows kgram
140 * If order = 0, return number of times char c appears
141 * -> Throw an exception if kgram is not of length k */
142 int MarkovModel::freq(std::string kgram, char c) {
143     // Throw an exception if kgram is not of length k
144     if (kgram.length() != (unsigned)_order) {
145         throw
146             std::runtime_error("Error - kgram not of length k.");
147     }
148
149     // use std::map::find to see if we can find the kgram + c.
150     std::map<std::string, int>::iterator it;
151     kgram.push_back(c);
152     it = _kgrams.find(kgram);
153
154     // If it equals map::end, we didn't find it, so return 0.
155     if (it == _kgrams.end()) {
156         return 0;
157     }
158
159     // Other wise return the given kgram since we found it.
160     return it->second;
161 }
162
163
164 /* Returns a random character following the given kgram
165 * -> Throw an exception if kgram is not of length k.
166 * -> Throw an exception if no such kgram. */
167 char MarkovModel::randk(std::string kgram) {
168     // Throw an exception if kgram is not of length k.
169     if (kgram.length() != (unsigned)_order) {

```

```

170     throw std::runtime_error("Error - kgram not of length k (randk)");
171 }
172
173 // Need an iterator for going through the kgrams map.
174 std::map<std::string, int>::iterator it;
175
176 // Search through and see if we find the given kgram.
177 it = _kgrams.find(kgram);
178
179 // We didn't find it. Throw an exception.
180 if (it == _kgrams.end()) {
181     throw std::runtime_error("Error: Could not find the given kgram! (randk)");
182 }
183
184 // Get the freq of the given kgram. (we will rand by this number!)
185 int kgram_freq = freq(kgram);
186
187 // Picking a random int from the possible characters.
188 // This should be an int from 1 to the total number of possible letters.
189 int random_value = rand() % kgram_freq; //NOLINT
190
191 double test_freq = 0;
192 double random_num = static_cast<double>(random_value) / kgram_freq;
193 double last_values = 0;
194
195 // Go through all the letters.
196 for (unsigned int a = 0; a < _alphabet.length(); a++) {
197     // This line basically calculates the probability as a double.
198     test_freq = static_cast<double>(freq(kgram, _alphabet[a])) / kgram_freq;
199
200     // NOTE: I'm comparing our random number, which we got from rand()ing
201     // the kgram_freq against the test freq, and making that test_freq is
202     // NOT 0. My logic is if a letter has "0" appearances in the kgram,
203     // then its probability of showing up is exactly 0 / kgram_freq, which
204     // is 0. I add the sum of all the last values as well as that is how
205     // you do this sort of math.
206     // Credit to the amazing stackoverflow post which gave me this idea,
207     // but I actually turned it into a more "dynamic" implementation by adding
208     // the sum of all the last frequencies.
209     if (random_num < test_freq + last_values && test_freq != 0) {
210         // Return this letter since it matches.
211         return _alphabet[a];
212     }
213
214     // I think the above comment details this nicely. Its basically a sum
215     // counter for all of the last few frequencies. I add them up here to
216     // avoid missing the second frequency by mistake. I think it would also
217     // possibly cause the below "return '-'" statement too, since if you sum
218     // something before you expect to its going to cause an error.
219     last_values += test_freq;
220 }
221
222 // This is here for error checking. We should never reach this point unless
223 // something in the above code is wrong.
224 return '-';
225 }
226

```

```

227
228 /* Generate a string of length T characters by simulating a trajectory
229 * through the corresponding Markov chain.
230 * The first k characters of the newly generated string should be
231 * the argument kgram. ** Assume that T is at least k. */
232 * -> Throw an exception if kgram is not of length k. */
233 std::string MarkovModel::gen(std::string kgram, int T) {
234     // Throw an exception if kgram is not of length k.
235     if (kgram.length() != (unsigned)_order) {
236         throw std::runtime_error("Error - kgram not of length k. (gen)");
237     }
238
239     // We need to take the given kgram, and add "T" characters to it, based
240     // on the given kgram's frequencies and whatever we add to its frequencies.
241     // This confused me at first and I think I now understand how to deal with
242     // this function.
243
244     // We first call randk on the original kgram, then we append add it to
245     // a new string with both the original kgram and the new character.
246     // We note that "T" is the final length of the string, so if we have a
247     // order 2 kgram, and T equals 4, we gotta add just two characters.
248     // So we keep running until we've hit string length of T.
249
250     // The final string we will return. We'll build it up over time.
251     std::string final_string = "";
252
253     // Temp char for using to collect the return value from randk()
254     char return_char;
255
256     // Add the kgram to it.
257     final_string += "" + kgram;
258
259     // Now the magic loop - loop until final_string's length equals T.
260     // Which, T - the length of the kgram can get us there!
261     for (unsigned int a = 0; a < (T - (unsigned)_order); a++) {
262         // Call randk on the substring we're looking at.
263         // Note we want just _order long kgram to compare against.
264         return_char = randk(final_string.substr(a, _order));
265
266         // Add the return_char to final_string
267         final_string.push_back(return_char);
268
269         // Keep looping til it stops.
270     }
271
272     // When we get here, we're done. YAY.
273     return final_string;
274 }
275
276
277 /* Overload the stream insertion operator and display the internal
278 * state of the Markov Model. Print out the order, the alphabet,
279 * and the frequencies of the k-grams and k+1-grams. */
280 std::ostream& operator<< (std::ostream &out, MarkovModel &mm) {
281     out << "\n_Order: " << mm._order << "\n";
282     out << "Alphabet: " << mm._alphabet << "\n";
283

```

```
284     out << "Kgrams map: \n\n";
285
286     std::map<std::string, int>::iterator it;
287
288     for (it = mm._kgrams.begin(); it != mm._kgrams.end(); it++) {
289         out << it->first << "\t" << it->second << "\n";
290     }
291
292     return out;
293 }
```

PS7a: Kronos Time Clock Log Parsing Boot Parsing

The Assignment

This assignment asked us to use regular expressions to parse a log file from a Kronos InTouch time clock. To parse the file, we used Boost's regular expression library (regex), along with Boost's date/time libraries. This allowed us to create an output file that verifies whether a time clock successfully booted or failed to boot. I was able to accomplish this, and pass all of Bottlenose's tests successfully.

Key Concepts

The main idea for this assignment was regular expressions, and specifically how to use Boost's regex library to find matches in a string. A secondary idea was to get used to using date and time libraries to mess with dates and do some calculations on them. Boost's regex library was pretty easy to use – simply using boost::regex_match or boost::regex_search was enough to find a match against the regular expressions I created. The following expressions were what I used to match start boots, and successful completions:

```
std::string start_string = "([0-9]{4})-([0-9]{2})-([0-9]{2}) ";
start_string += "([0-9]{2}):([0-9]{2}):([0-9]{2}): \\\(log.c.166\\) ";
start_string += "server started";
```

This is my regex to detect the boot statement. It finds a matching line with a time stamp, following by the words "(log.c.166) server started". Matching the regex against this whole statement made it easy to pull the date and time from the current line.

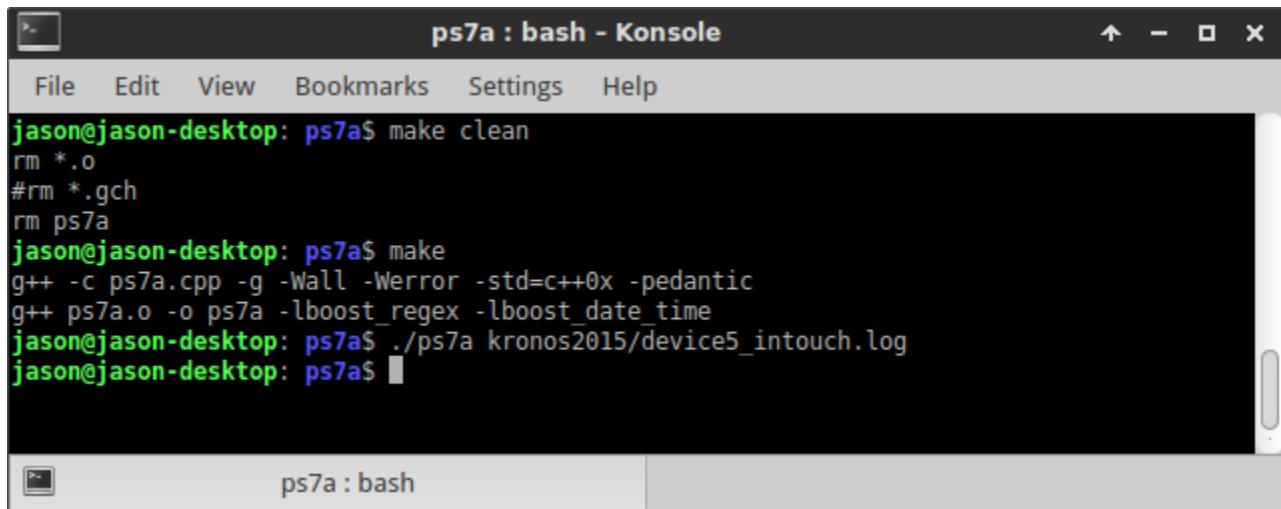
```
std::string end_string = "([0-9]{4})-([0-9]{2})-([0-9]{2}) ";
end_string += "([0-9]{2}):([0-9]{2}):([0-9]{2}).([0-9]{3}):INFO:oejs.";
end_string += "AbstractConnector:Started SelectChannelConnector@0.0.0.0:9080";
```

I used this regex to find a successful boot. A successful boot is marked by a time stamp, followed by the string: "INFO:oejs.AbstractConnector:Started SelectChannelConnector@0.0.0.0:9080". As with the boot statement, I pulled the date / time from the smatch variable that I passed to the regex search / match methods.

What I Learned

I learned a ton about using regular expressions in this program – enough, that I feel like I could probably do some other parsing of files in the future if a job or future class requires it. I also can see a lot of practical uses for a program such as this – an intern (probably me in the future) could easily create parsing program to verify successful / failure code, or to double check that certain devices are working properly. It was also pretty handy to learn about date and time. Having used Boost's date and time libraries, I feel pretty good about using other libraries in the future that involve date and time. It has given me a solid introduction to working with dates – perhaps in the future I may need to do something that involves calculation dates and time.

Screenshots



The screenshot shows a terminal window titled "ps7a : bash - Konsole". The window has a menu bar with "File", "Edit", "View", "Bookmarks", "Settings", and "Help". The main area of the terminal displays the following command-line session:

```
jason@jason-desktop: ps7a$ make clean
rm *.o
#rm *.gch
rm ps7a
jason@jason-desktop: ps7a$ make
g++ -c ps7a.cpp -g -Wall -Werror -std=c++0x -pedantic
g++ ps7a.o -o ps7a -lboost_regex -lboost_date_time
jason@jason-desktop: ps7a$ ./ps7a kronos2015/device5_intouch.log
jason@jason-desktop: ps7a$
```

The terminal window is titled "ps7a : bash" at the bottom.

Screenshot of running PS7a on device5_intouch.log

```
==== Device boot ====
31063(kronos2015/device5_intouch.log): 2014-01-26 09:55:07 Boot Start
31176(kronos2015/device5_intouch.log): 2014-01-26 09:58:04 Boot Completed
  » Boot Time: 177000ms.

==== Device boot ====
31274(kronos2015/device5_intouch.log): 2014-01-26 12:15:18 Boot Start
**** Incomplete boot ****.

==== Device boot ====
31293(kronos2015/device5_intouch.log): 2014-01-26 14:02:39 Boot Start
31401(kronos2015/device5_intouch.log): 2014-01-26 14:05:24 Boot Completed
  » Boot Time: 165000ms.

==== Device boot ====
32623(kronos2015/device5_intouch.log): 2014-01-27 12:27:55 Boot Start
**** Incomplete boot ****.

==== Device boot ====
32641(kronos2015/device5_intouch.log): 2014-01-27 12:30:23 Boot Start
**** Incomplete boot ****.

==== Device boot ====
32656(kronos2015/device5_intouch.log): 2014-01-27 12:32:51 Boot Start
**** Incomplete boot ****.

==== Device boot ====
32674(kronos2015/device5_intouch.log): 2014-01-27 12:35:19 Boot Start
**** Incomplete boot ****.

==== Device boot ====
32693(kronos2015/device5_intouch.log): 2014-01-27 14:02:38 Boot Start
32801(kronos2015/device5_intouch.log): 2014-01-27 14:05:21 Boot Completed
  » Boot Time: 163000ms.
```

*Partial view of what the output file for device5_intouch.log looks like.
This file was named device5_intouch.log.rpt by ps7a.*

Source Code for PS7a

Makefile

```
1  # Makefile for PS7a
2  # Flags to save on typing all this out
3  CC = g++
4  CFLAGS = -g -Wall -Werror -std=c++0x -pedantic
5  SFLAGS = -lsfml-graphics -lsfml-window -lsfml-system -lsfml-audio
6  Boost = -lboost_regex -lboost_date_time
7
8  # Make ps5a & a dummy tester
9  all:    ps7a
10
11 # PS7A executable
12 ps7a:    ps7a.o
13     $(CC) ps7a.o -o ps7a $(Boost)
14
15 # Object files
16 ps7a.o: ps7a.cpp
17     $(CC) -c ps7a.cpp $(CFLAGS)
18
19 # Cleanup object files
20 clean:
21     rm *.o
22     rm ps7a
23
```

main.cpp

```
1  /*
2   * Copyright 2015 Jason Downing
3   * All rights reserved.
4   * MIT Licensed - see http://opensource.org/licenses/MIT for details.
5   *
6   */
7  #include <boost/regex.hpp>
8  #include <iostream>
9  #include <fstream>
10 #include <string>
11 #include "boost/date_time/gregorian/gregorian.hpp"
12 #include "boost/date_time posix_time.hpp"
13
14 // Annoying to type these out.
15 using boost::gregorian::date;
16 using boost::gregorian::from_simple_string;
17 using boost::gregorian::date_period;
18 using boost::gregorian::date_duration;
19
20 using boost::posix_time::ptime;
21 using boost::posix_time::time_duration;
22
23 int main(int argc, const char* argv[]) {
24     // Make sure the user knows how to use our amazing log parser.
25     if (argc != 2) {
26         std::cout << "./ps7a device1_intouch.log\n";
27         return 0;
28     }
29
30     // Counters
31     int lines_scan = 1;      // START AT LINE 1 - not 0. opps.
32     int boot_success = 0;
33     int boot_total = 0;
34
35     // Some strings we need. File names, other stuff.
36     std::string file_name(argv[1]);
37     std::string output_name = file_name + ".rpt";
38     std::string report = "";
39     std::string boots = "";
40
41     // Begin time / End time strings.
42     std::string begin_date = "";
43     std::string end_date = "";
44
45     // A BUNCH OF STUFF I DON'T CARE.
46     std::string full_date;
47     int hours = 0;
48     int minutes = 0;
49     int seconds = 0;
50
51     ptime begin;
52     ptime end;
53
54     date date1;
```

```

55     date date2;
56
57     time_duration time_diff;
58
59     // Need to match against something like this:
60     // Start of boot: 2014-02-01 14:02:32: (log.c.166) server started
61     // Success if we find:
62     // "2014-01-26 09:58:04.362:INFO:oejs.AbstractConnector:Started
63     // SelectChannelConnector@0.0.0.0:9080"
64     std::string start_string = "([0-9]{4})-([0-9]{2})-([0-9]{2}) ";
65     start_string += "([0-9]{2}):([0-9]{2}):([0-9]{2}):\ \\\(log.c.166\\\) ";
66     start_string += "server started";
67     std::string end_string = "([0-9]{4})-([0-9]{2})-([0-9]{2}) ";
68     end_string += "([0-9]{2}):([0-9]{2}):([0-9]{2}).([0-9]{3}):INFO:oejs.";
69     end_string += "AbstractConnector:Started SelectChannelConnector@0.0.0.0:9080";
70
71     // Make two regexes
72     boost::regex start_regex(start_string, boost::regex::perl);
73     boost::regex end_regex(end_string);
74
75     // Use this for getting parts of the matched string.
76     boost::smatch sm;
77
78     // report += "Device boot report.\n\n";
79     // report += "InTouch log file: " + file_name + "\n";
80
81     // Read the file here and do stuff.
82     // Save stuff to a string with formatting to output later on.
83     std::string line;
84     std::ifstream file(file_name.c_str());
85
86     // Need to keep track of when we've found a start.
87     bool found_start = false;
88
89     if (file.is_open()) {
90         while (getline(file, line)) {
91             // We've got the current string here and can do stuff with it.
92
93             // Wipe the begin_time / end_time strings
94             begin_date.clear();
95             end_date.clear();
96
97             // Let's try and see if we found a start boot.
98             if (boost::regex_search(line, sm, start_regex)) {
99                 // Get the start time, save it for later.
100                 // Note: sm[0] is the ENTIRE match. We just want the date.
101                 begin_date = sm[1] + "-" + sm[2] + "-" + sm[3];
102                 begin_date += " " + sm[4] + ":" + sm[5] + ":" + sm[6];
103
104                 full_date = sm[1] + "-" + sm[2] + "-" + sm[3];
105                 date1 = date(from_simple_string(full_date));
106
107                 hours = std::stoi(sm[4]);
108                 minutes = std::stoi(sm[5]);
109                 seconds = std::stoi(sm[6]);
110
111                 begin = ptime(date1, time_duration(hours, minutes, seconds));

```

```

112
113     // We can use this begin_time for calculations later on.
114
115     // If we already found a start, then this is an incomplete boot.
116     if (found_start == true) {
117         boots += "**** Incomplete boot **** \n\n";
118     }
119
120     // Now we want to add this to the output string as boot start.
121     boots += "==== Device boot ====\n";
122     boots += std::to_string(lines_scan) + "(" + file_name + "): ";
123     boots += begin_date + " Boot Start\n";
124
125     boot_total++;
126
127     // Match this as a "found_start"
128     found_start = true;
129 }
130
131 // Or did we find a successful boot?
132 if (boost::regex_match(line, sm, end_regex)) {
133     // Get the end time, save it for later.
134     end_date = sm[1] + "-" + sm[2] + "-" + sm[3];
135     end_date += " " + sm[4] + ":" + sm[5] + ":" + sm[6];
136
137     full_date = sm[1] + "-" + sm[2] + "-" + sm[3];
138     date2 = date(from_simple_string(full_date));
139
140     hours = std::stoi(sm[4]);
141     minutes = std::stoi(sm[5]);
142     seconds = std::stoi(sm[6]);
143
144     end = ptime(date2, time_duration(hours, minutes, seconds));
145
146     // Add the end boot line and total time it took to get here.
147     boots += std::to_string(lines_scan) + "(" + file_name + "): ";
148     boots += end_date + " Boot Completed\n";
149
150     // Do some magic here and calculate the time it took to boot in ms
151     // Use the begin_time and the end_time variables.
152
153     // Time calculation stuff.
154     time_diff = end - begin;
155
156     // Now add the time difference.
157     boots += "\tBoot Time: ";
158     boots += std::to_string(time_diff.total_milliseconds()) + "ms \n\n";
159
160     boot_success++;
161
162     // Match found_start as false for the next loop.
163     found_start = false;
164 }
165
166     lines_scan++;
167 }
168 file.close();

```

```
169 }
170
171 // Add lines scanned to the report.
172 // report += "Lines scanned: " + std::to_string(lines_scan) + "\n\n";
173
174 // We can figure out success boots and fail boots now.
175 // report += "Device boot count: initiated = " + std::to_string(boot_total);
176 // report += ", completed: " + std::to_string(boot_success) + "\n\n\n";
177
178 // Need to remove an extra newline from the end of the boot report.
179 // This way the file will completely match the test cases on Bottlenose.
180 boots.erase(boots.end() - 1);
181
182 // We should now add the boot reports to the end of this report.
183 report += boots;
184
185 // Now let's print out our report string. It has already been formatted
186 // correctly so it should be fairly simple to just dump it to stdio.
187 // std::cout << report;
188
189 // And we can even save this to a file with the extension ".rpt"
190 // which would be something like "device5_intouch.log.rpt"
191 // or filename + ".rpt"
192 std::ofstream out(output_name.c_str());
193 out << report;
194 out.close();
195
196 return 0;
197 }
```