COMPUTING 2040 PORTFOLIO

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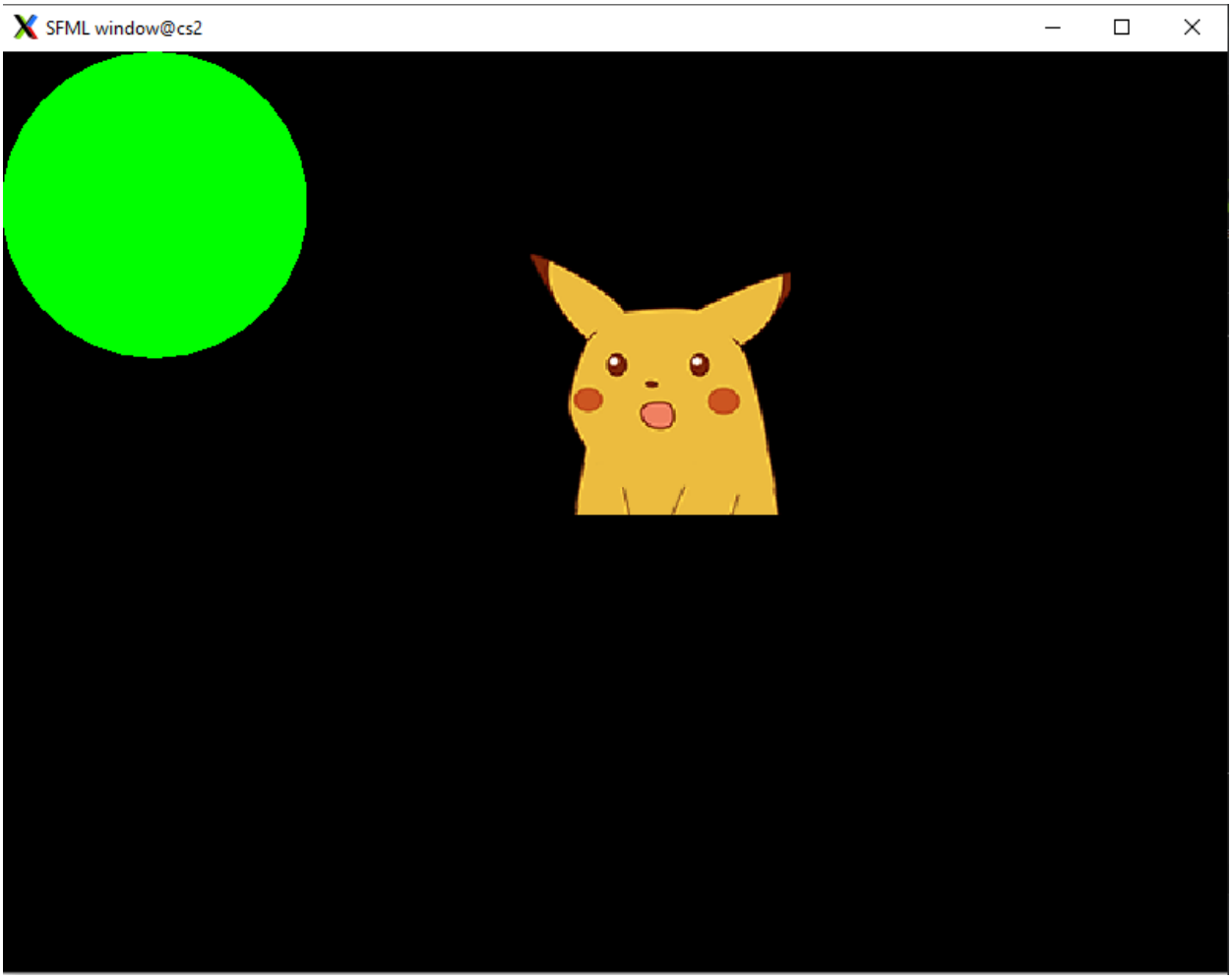
PS0: Hello World with SFML

Discussion:

This project was an introduction to SFML. I was able to modify the SFML tutorial demo and include an additional sprite and have it respond to key presses on the keyboard. To do this, I utilized the SFML framework and a while loop that constantly checked for new events so that the program could modify the sprite. Through this project, I was able to become familiar with the SFML libraries and increase familiarity with event listeners.

Screenshot:



Code:

Main.cpp:

```
01| #include <SFML/Audio.hpp>
02| #include <SFML/Graphics.hpp>
03| int main()
04| {
05|     // Create the main window
06|     sf::RenderWindow window(sf::VideoMode(800, 600), "SFML window");
07|     //make green circle
08|     sf::CircleShape shape(100.f);
09|     shape.setFillColor(sf::Color::Green);
10|     // Load a sprite to display
11|     sf::Texture texture;
12|     if (!texture.loadFromFile("sprite.png"))
13|         return EXIT_FAILURE;
14|     sf::Sprite sprite(texture);
15|
16|     // showSprite variable to maintain toggle outside of game loop.
17|     bool showSprite = true;
18|
19|     // Start the game loop
20|     while (window.isOpen())
21|     {
22|         // Process events
23|         sf::Event event;
24|         while (window.pollEvent(event))
25|         {
26|             //move sprite when arrow keys are pressed
27|             if(event.type == sf::Event::KeyPressed){
28|               switch(event.key.code){
29|                 case sf::Keyboard::Up:
30|                   if(showSprite)
31|                     sprite.move(0,-3);
32|                   break;
33|                 case sf::Keyboard::Down:
34|                   if(showSprite)
35|                     sprite.move(0,3);
36|                   break;
37|                 case sf::Keyboard::Right:
38|                   if(showSprite)
39|                     sprite.move(5,0);
40|                   break;
41|                 case sf::Keyboard::Left:
42|                   if(showSprite)
43|                     sprite.move(-5,0);
44|                   break;
45|                 case sf::Keyboard::Space:
46|                   showSprite = showSprite == true ? false : true;
47|                   break;
48|                 default:
49|                   break;
50|               }
51|             }
52|             //
53|             if(event.type == sf::Event::MouseWheelScrolled){
54|               if(showSprite){
```

```
55|                 if(event.mouseWheelScroll.delta > 0)
56|                   sprite.scale(1.1, 1.1);
57|                 else{
58|                   sprite.scale(0.9,0.9);
59|                 }
60|               }
61|             }
62|             // Close window: exit
63|             if (event.type == sf::Event::Closed)
64|                 window.close();
65|         }
66|         // Clear screen
67|         window.clear();
68|         //draw circle
69|         window.draw(shape);
70|         // Draw the sprite
71|         if(showSprite)
72|           window.draw(sprite);
73|         // Update the window
74|         window.display();
75|     }
76|     return EXIT_SUCCESS;
77| }
78|
```

PS1: Linear Feedback Shift Register

PS1a: Linear Feedback Shift Register (Part A)

Discussion:

In this portion of the project, I familiarized myself with a linear feedback shift register(LFSR). This allowed me to make pseudo-random numbers based off a seed and several hardcoded tap positions. To implement this LFSR, I simply used a string to keep track of the register and the binary XOR operation to find the next number based on the tap positions. I also used cppboost to test the program, so I became more familiar with unit testing.

Console Output (Running Boost Test):

Running 3 test cases...

*** No errors detected

Code:

Makefile:

```
01| CC = g++
02| CFLAGS = -std=c++11 -c -g -Og -Wall -Werror -pedantic
03| OBJ = test.o
04| DEPS = FibLFSR.h
05| LIBS = FibLFSR.cpp
06| EXE = boosttest
07|
08| all: $(OBJ)
09|     $(CC) $(OBJ) -o $(EXE) $(LIBS)
10|
11| %.o: %.cpp $(DEPS)
12|     $(CC) $(CFLAGS) -o $@ $<
13|
14| clean:
15|     rm $(OBJ) $(EXE)
16|
```

test.cpp

```
01| #include <iostream>
02| #include <string>
03| #include "FibLFSR.h"
04| #define BOOST_TEST_DYN_LINK
05| #define BOOST_TEST_MODULE Main
06| #include <boost/test/included/unit_test.hpp>
07|
08| //initial test in file.
```

```
09| BOOST_AUTO_TEST_CASE(sixteenBitsThreeTaps) {
10|
11|    FibLFSR l("1011011000110110");
12|    BOOST_REQUIRE(l.step() == 0);
13|    BOOST_REQUIRE(l.step() == 0);
14|    BOOST_REQUIRE(l.step() == 0);
15|    BOOST_REQUIRE(l.step() == 1);
16|    BOOST_REQUIRE(l.step() == 1);
17|    BOOST_REQUIRE(l.step() == 0);
18|    BOOST_REQUIRE(l.step() == 0);
19|    BOOST_REQUIRE(l.step() == 1);
20|
21|    FibLFSR l2("1011011000110110");
22|    BOOST_REQUIRE(l2.generate(9) == 51);
23| }
24|
25| BOOST_AUTO_TEST_CASE(constructors){
26|    FibLFSR normalConstructorTest("1011011000110110"); //makes a
constructor with 16 bits, which should work
27|
28|    boost::test_tools::output_test_stream output; //redirects the
constructors overloaded << to the boost test stream.
29|    output << normalConstructorTest;
30|    BOOST_REQUIRE(output.is_equal("1011011000110110")); //checks to see if
output matches what it is supposed to be, which is the parameter for the
constructor
31|
32|    BOOST_CHECK_THROW(FibLFSR normalConstructorTest("10110110001"),
std::length_error); //makes a constructor with 11 bits, which should throw an
exception due to length
33|
34|    BOOST_CHECK_THROW(FibLFSR normalConstructorTest("10110110001000000"),
std::length_error); //makes a constructor with 17 bits, which should throw an
exception due to length
35|
36|    BOOST_CHECK_THROW(FibLFSR normalConstructorTest("101101100011011A"),
std::invalid_argument); //makes a constructor with 11 bits, which should
throw an exception due to invalid argument (bits aren't 0's and 1's)
37| }
38|
39| //more extensive generate tests
40| BOOST_AUTO_TEST_CASE(moreGenerate) {
41|
42|    FibLFSR generatorTest("1010101111000111");
43|
44|    //just checks generate function at different k values.
45|    BOOST_REQUIRE(generatorTest.generate(5) == 4);
46|    BOOST_REQUIRE(generatorTest.generate(7) == 32);
47|    BOOST_REQUIRE(generatorTest.generate(11) == 893);
48|    BOOST_REQUIRE(generatorTest.generate(13) == 3929);
49|    BOOST_REQUIRE(generatorTest.generate(4) == 8);
50|    BOOST_REQUIRE(generatorTest.generate(15) == 7711);
51|    BOOST_REQUIRE(generatorTest.generate(16) == 21874);
52|    BOOST_CHECK_THROW(generatorTest.generate(20), std::invalid_argument);
// should throw an invalid argument exception because k is larger than the 16
bit register.
```

```
53|    BOOST_CHECK_THROW(generatorTest.generate(-5), std::invalid_argument);
// should throw an invalid argument exception because k is negative
54| }
55|
```

fibLFSR.h

```
01| #include <iostream>
02| #include <string>
03| #include "FibLFSR.h"
04| #define BOOST_TEST_DYN_LINK
05| #define BOOST_TEST_MODULE Main
06| #include <boost/test/included/unit_test.hpp>
07|
08| //initial test in file.
09| BOOST_AUTO_TEST_CASE(sixteenBitsThreeTaps) {
10|
11|    FibLFSR l("1011011000110110");
12|    BOOST_REQUIRE(l.step() == 0);
13|    BOOST_REQUIRE(l.step() == 0);
14|    BOOST_REQUIRE(l.step() == 0);
15|    BOOST_REQUIRE(l.step() == 1);
16|    BOOST_REQUIRE(l.step() == 1);
17|    BOOST_REQUIRE(l.step() == 0);
18|    BOOST_REQUIRE(l.step() == 0);
19|    BOOST_REQUIRE(l.step() == 1);
20|
21|    FibLFSR l2("1011011000110110");
22|    BOOST_REQUIRE(l2.generate(9) == 51);
23| }
24|
25| BOOST_AUTO_TEST_CASE(constructors){
26|    FibLFSR normalConstructorTest("1011011000110110"); //makes a
constructor with 16 bits, which should work
27|
28|    boost::test_tools::output_test_stream output; //redirects the
constructors overloaded << to the boost test stream.
29|    output << normalConstructorTest;
30|    BOOST_REQUIRE(output.is_equal("1011011000110110")); //checks to see if
output matches what it is supposed to be, which is the parameter for the
constructor
31|
32|    BOOST_CHECK_THROW(FibLFSR normalConstructorTest("10110110001"),
std::length_error); //makes a constructor with 11 bits, which should throw an
exception due to length
33|
34|    BOOST_CHECK_THROW(FibLFSR normalConstructorTest("1011011000100000"),
std::length_error); //makes a constructor with 17 bits, which should throw an
exception due to length
35|
36|    BOOST_CHECK_THROW(FibLFSR normalConstructorTest("101101100011011A"),
std::invalid_argument); //makes a constructor with 11 bits, which should
throw an exception due to invalid argument (bits aren't 0's and 1's)
37| }
38|
39| //more extensive generate tests
40| BOOST_AUTO_TEST_CASE(moreGenerate) {
```

```
41|
42|    FibLFSR generatorTest("1010101111000111");
43|
44|    //just checks generate function at different k values.
45|    BOOST_REQUIRE(generatorTest.generate(5) == 4);
46|    BOOST_REQUIRE(generatorTest.generate(7) == 32);
47|    BOOST_REQUIRE(generatorTest.generate(11) == 893);
48|    BOOST_REQUIRE(generatorTest.generate(13) == 3929);
49|    BOOST_REQUIRE(generatorTest.generate(4) == 8);
50|    BOOST_REQUIRE(generatorTest.generate(15) == 7711);
51|    BOOST_REQUIRE(generatorTest.generate(16) == 21874);
52|    BOOST_CHECK_THROW(generatorTest.generate(20), std::invalid_argument);
// should throw an invalid argument exception because k is larger than the 16
bit register.
53|    BOOST_CHECK_THROW(generatorTest.generate(-5), std::invalid_argument);
// should throw an invalid argument exception because k is negative
54| }
55|
```

fibLFSR.cpp:

```
01| #include <iostream>
02| #include <string>
03| #include <stdexcept>
04| #include "FibLFSR.h"
05|
06| FibLFSR::FibLFSR(std::string seed){
07|     if(seed.length() == 16){ //makes sure that the length of the seed is
16/
08|         for(char& c : seed){
09|             if(c != '0' && c != '1'){ //checks the characters to make
sure they are 0's and 1's
10|                 throw std::invalid_argument("this is not a string of
0's and 1's"); //exception thrown if characters are not 0's and 1's
11|             }
12|         }
13|         //sets the seed to bitString variable.
14|         bitString = seed;
15|     }
16|     else{
17|         throw std::length_error("length is not 16 bits.");
18|     }
19| }
20|
21| int FibLFSR::step(){
22|     //xor equation of ((left most XOR 13th bit) XOR 12th bit)XOR 10th
bit). since the first two are both characters, i'm not "-'0'" them to get
their value as an int because it wouldn't change the XOR value. However,
XORing 0000000001 with '0' would give a wildly different value, so I "-'0'"
to change their value to their numerical value at the bit level.
23|     int add = ((bitString.at(0)^(bitString.at(2))^(bitString.at(3)-
'0'))^(bitString.at(5)-'0'));
24|     bitString = bitString.substr(1) + std::to_string(add); //add the
result while ditching the most significant bit.
25|  //   std::cout << bitString << " " << add << std::endl;
26|     return add;
```

```
27| }
28|
29| int FibLFSR::generate(int k){
30|     if(k>16 || k<0){ // checks to make sure we aren't checking more bits
than the register is. also negative numbers make no sense, so those are
checked for as well.
31|         throw std::invalid_argument( "k is larger than register or
negative"); //exception thrown if k is larger than the register or negative.
32|     }
33|     int count = 0;
34|     for(int i = 0; i<k; i++){
35|         count = count*2 + step();
36|     }
37| //    std::cout << bitString << " " << count << std::endl;
38|     return count;
39| }
40|
41| //prints out the current bitString saved in LFSR
42| std::ostream& operator<< (std::ostream &out, FibLFSR &a)
43| {
44|   out << a.bitString;
45|   return out;
46| }
47|
```

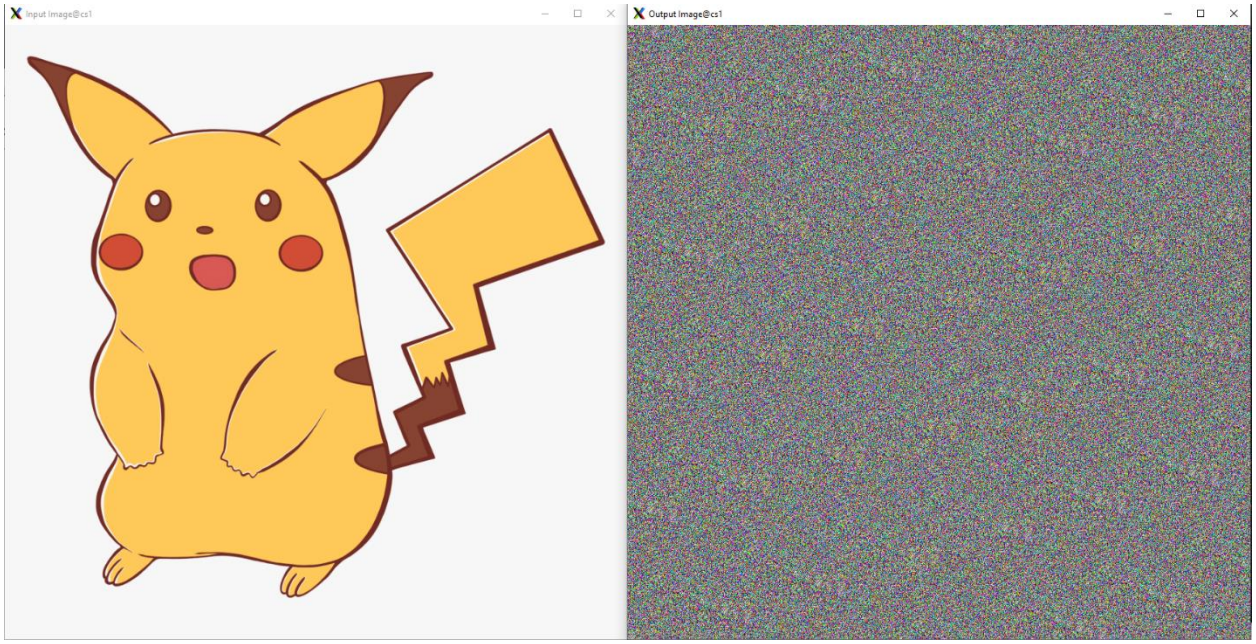
PS1b Linear Feedback Shift Register (Part B)

Discussion:

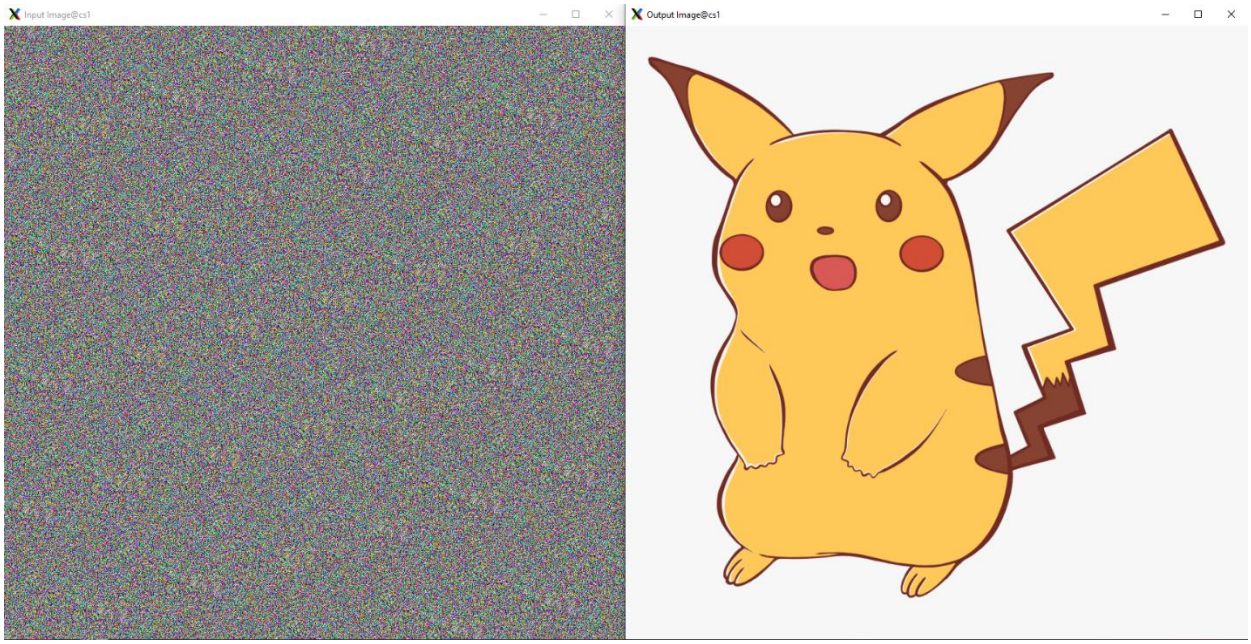
I extended the LFSR to be able to encode image files so that they become static if they are not decoded with the right algorithm. I integrated SFML, which I had utilized in PS0, to open the resulting encoded/decoded image in its own window. The resulting image is also saved as a png file. This project helped me become more familiar with the encoding process and how we scramble our data from others.

Screenshots:

Encoding:



Decoding:



Code:

Note: Since PS1b builds off PS1a, reused files will not be included in the code section if they were not modified.

Makefile:

```
01| CC = g++
02| CFLAGS = -std=c++11 -c -g -Og -Wall -Werror -pedantic
03| OBJ = PhotoMagic.o
04| DEPS = FibLFSR.h
05| LIBS = FibLFSR.cpp -lsfml-graphics -lsfml-window -lsfml-system
06| EXE = PhotoMagic
07|
08| all: $(OBJ)
09|     $(CC) $(OBJ) -o $(EXE) $(LIBS)
10|
11| %.o: %.cpp $(DEPS)
12|     $(CC) $(CFLAGS) -o $@ $<
13|
14| clean:
15|     rm $(OBJ) $(EXE)
16|
```

Photomagic.cpp:

```
001| #include <SFML/System.hpp>
002| #include <SFML/Window.hpp>
003| #include <SFML/Graphics.hpp>
004| #include "FibLFSR.h"
005|
006| sf::Image transform(sf::Image& image, FibLFSR* randomizer);
```

```
007|
008| sf::Image transform(sf::Image& image, FibLFSR* randomizer){
009|   sf::Color p;
010|   sf::Vector2u size = image.getSize();
011|   // Randomize the bits in the image
012|   for(int x= 0; x < (signed)size.x; x++){
013|     for(int y = 0; y < (signed)size.y; y++){
014|     // Get the current pixel from the input image
015|     p = image.getPixel(x, y);
016|
017|     // XOR the pixels
018|     p.r = p.r ^ randomizer->generate(8);
019|     p.g = p.g ^ randomizer->generate(8);
020|     p.b = p.b ^ randomizer->generate(8);
021|
022|     // Modify just the output image
023|     image.setPixel(x, y, p);
024|     }
025|   }
026|   return image;
027| }
028|
029|
030| int main(int argc, char* argv[]){
031|     //check that 4 command line inputs were entered
032|     if(argc != 4){
033|       throw std::length_error ("There are not 4 command line arguments.
Please use ./executable inputImage outputImage seed");
034|     }
035|
036|     // Create the input image
037|     sf::Image inputImage;
038|     if (!inputImage.loadFromFile(argv[1])){
039|       throw std::invalid_argument("This is not a valid image file");
040|     }
041|
042|     // Create the output image
043|     sf::Image outputImage;
044|     if (!outputImage.loadFromFile(argv[1])){
045|       throw std::invalid_argument("This is not a valid image file");
046|     }
047|
048|     //Create the  FibLFSR randomizer
049|     FibLFSR randomizer(argv[3]);
050|
051|     // Create Vector24 variable to get dimensions for windows
052|     sf::Vector2u size = inputImage.getSize();
053|
054|     // Modify the output file and save it
055|     if (!(transform(outputImage, &randomizer).saveToFile(argv[2]))){
056|       return -1;
057|     }
058|
059|     //make window for original image
060|     sf::RenderWindow original(sf::VideoMode(size.x, size.y), "Input
Image");
061|
```

```
062|     //make window for transformed image
063|     sf::RenderWindow transformed(sf::VideoMode(size.x, size.y), "Output
Image");
064|
065|
066|     //Create texture for input for original
067|     sf::Texture inputTexture;
068|     inputTexture.loadFromImage(inputImage);
069|
070|     //Create sprite from texture for original
071|     sf::Sprite inputSprite;
072|     inputSprite.setTexture(inputTexture);
073|
074|     //Create texture for input for transformed
075|     sf::Texture outputTexture;
076|     outputTexture.loadFromImage(outputImage);
077|
078|     //Create sprite from texture for transformed
079|     sf::Sprite outputSprite;
080|     outputSprite.setTexture(outputTexture);
081|
082|     // Start the game loop
083|     while (original.isOpen() && transformed.isOpen())
084|   {
085|     sf::Event event;
086|
087|     while (original.pollEvent(event))
088|     {
089|       if (event.type == sf::Event::Closed)
090|       {
091|         original.close();
092|       }
093|     }
094|
095|     while (transformed.pollEvent(event))
096|     {
097|       if (event.type == sf::Event::Closed)
098|       {
099|         transformed.close();
100|       }
101|     }
102|
103|     original.clear();
104|     original.draw(inputSprite);    // Input image
105|     original.display();
106|
107|     transformed.clear();
108|     transformed.draw(outputSprite);    // Output image
109|     transformed.display();
110|   }
111|
112|
113|     return EXIT_SUCCESS;
114| }
115|
```

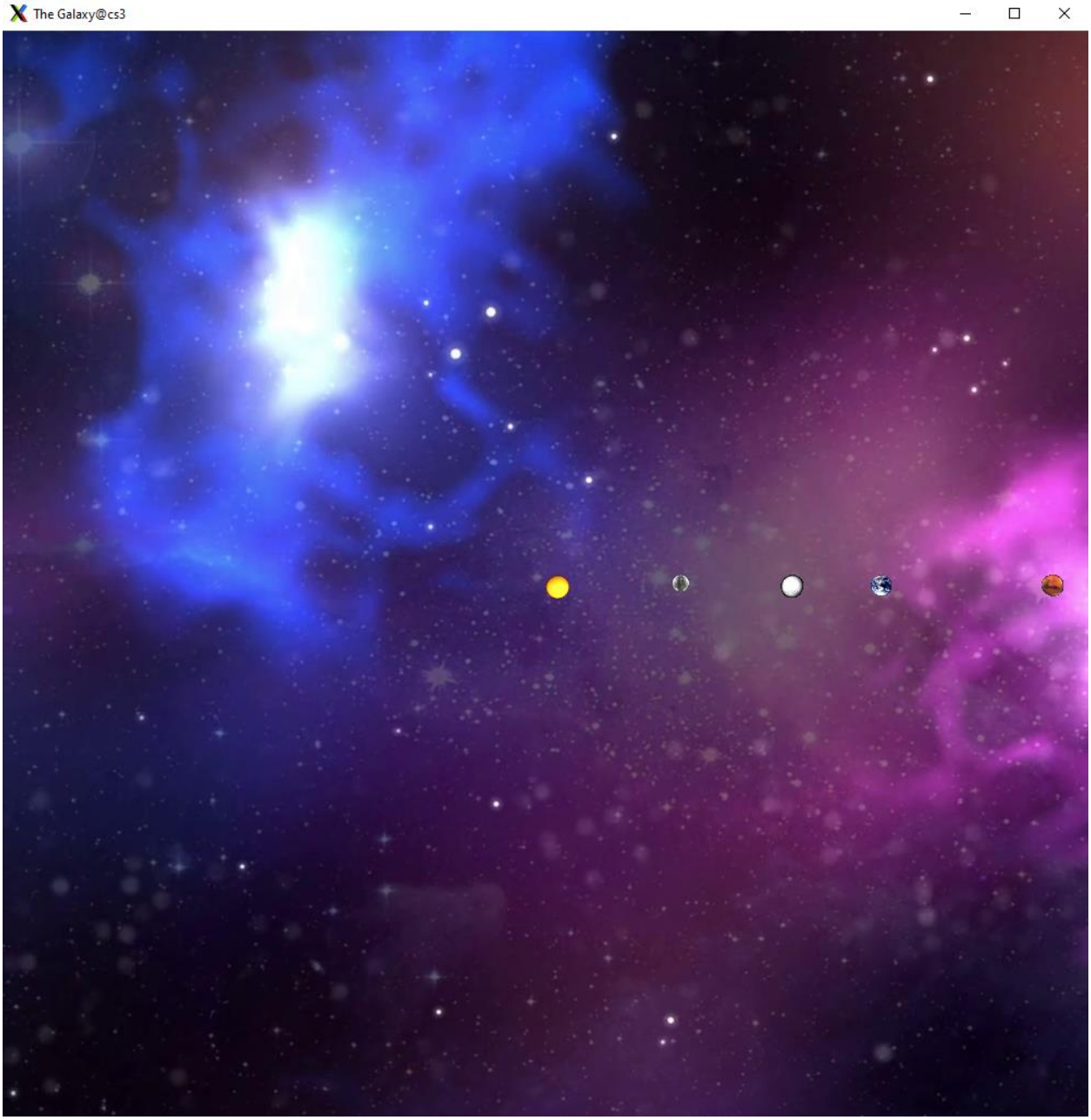
PS2: Nbody Simulation

PS2a: Nbody Simulation (Part A)

Discussion:

In this project, I used SFML to create a window to show the planets given to me for the assignment. It reads the information from a planets.txt file. During this project, I learned how to redirect a file as input using terminal. Previously, I had not known of this and had been hand typing any inputs that I needed. A key algorithm I used was to calculate at what distance I should be showing the planets. I first used the dimensions of the window that I made in SFML as a benchmark (halved it because the planets distance is from the center of the universe). Then, based on the radius of the universe and the distance of a given body form the center, I made a ratio to use so that I knew where to place the planet. That ratio was then converted to pixels so that I could place it on the window via SFML. I also used a vector to hold all the bodies in the universe class so that all the celestial bodies were all in one place and very intuitive to access as well as iterate over.

Screenshot:



Code:

Makefile:

```
CC = g++
CFLAGS = -std=c++14 -c -g -Og -Wall -Werror -pedantic
OBJ = Universe.o CelestialBody.o main.o
LIBS = -lsfml-graphics -lsfml-system -lsfml-window
EXE = NBody

all: NBody

NBody: $(OBJ)
    $(CC) $(OBJ) -o $(EXE) $(LIBS)

CelestialBody.o: CelestialBody.cpp CelestialBody.hpp
    $(CC) $(CFLAGS) -o $@ $<

Universe.o: Universe.cpp Universe.hpp
    $(CC) $(CFLAGS) -o $@ $<

main.o: main.cpp Universe.hpp
    $(CC) $(CFLAGS) -o $@ $<

clean:
    rm *.o
    rm $(EXE)

```

main.cpp

```
#include "Universe.hpp"
#include <SFML/Graphics.hpp>

int main(){
  int numPlanets;
  float radius;
  std::cin >> numPlanets >> radius;


  universe galaxy = universe(numPlanets, radius);

  sf::RenderWindow window(sf::VideoMode(defaultWindowSize.x,
defaultWindowSize.y), "The Galaxy");

  //create image for background
  sf::Image background;

  //if load fails, throw error
  if(!background.loadFromFile("space.png")){
     throw std::invalid_argument("no file for celestialImage");
  }

  //creating texture for background
  sf::Texture backgroundTexture;
  backgroundTexture.loadFromImage(background);

  //creating sprite for background
```

```
27|   sf::Sprite backgroundSprite;
28|   backgroundSprite.setTexture(backgroundTexture);
29|
30|   while (window.isOpen()){
31|         // Process events
32|         sf::Event event;
33|         while (window.pollEvent(event)){
34|             // Close window: exit
35|             if (event.type == sf::Event::Closed){
36|                 window.close();
37|             }
38|         }
39|         window.clear();
40|
41|         //draw background
42|         window.draw(backgroundSprite);
43|
44|
45|         //function in universe class to draw all celestialBodies in
universe object uses target.draw() in the function.
46|         galaxy.draw(window);
47|
48|         window.display();
49|     }
50|
51|
52|   return 0;
53| }
54|
```

Universe.hpp

```
01| #ifndef  UNIVERSE_H
02| #define  UNIVERSE_H
03| #include "CelestialBody.hpp"
04| #include <vector>
05| #include <memory>
06|
07| class universe{
08|   public:
09|     //default constructor
10|     universe();
11|
12|     //parameter constructor
13|     universe(float radius);
14|
15|     //constructor for taking in input from txt doc.
16|     universe(int numOfCelestialBodies, float radius);
17|
18|     //set radius if needed
19|     void set_radius(float radius);
20|
21|     //calculate positions based on window size.
22|     void set_position(sf::Vector2u windowSize = defaultWindowSize);
23|
24|     // Draw method for universe
```

```
25|     void virtual draw(sf::RenderTarget& target) const;
26|
27|     //for testing
28|     void print ();
29|
30|   private:
31|   double universeRadius;
32|
33|   //using a vector of shared_ptr to hold celestialBodies
34|   std::vector<std::shared_ptr<celestialBody>> celestialBodies;
35| };
36|
37|
38| #endif //UNIVERSE_H
```

Universe.cpp

```
01| #include "Universe.hpp"
02|
03| universe::universe(){
04|   return;
05| }
06|
07| universe::universe(float radius){
08|   universeRadius = radius;
09| }
10|
11| //constructor for taking in input from txt doc.
12| universe::universe(int numOfCelestialBodies, float radius){
13|
14|   //for loop to collect data for the number of celestial bodies.
15|   for(int i=0; i<numOfCelestialBodies; i++){
16|     std::shared_ptr<celestialBody> temp = std::make_shared<celestialBody>
();
17|     std::cin >> *temp;
18|
19|     //calculate initial position for all bodies as we loop through
20|     temp->set_position(radius);
21|
22|     //add the body to the vector
23|     celestialBodies.push_back(temp);
24|
25|     //used for testing
26|     //std::cout << *temp;
27|   }
28| }
29|
30| //sets the radius if we need to.
31| void universe::set_radius(float radius){
32|   universeRadius = radius;
33|   return;
34| }
35|
36| //uses an iterator to go through and set position of each celestialBody
37| void universe::set_position(sf::Vector2u windowSize){
```

```
38|    for(auto it = celestialBodies.begin(); it != celestialBodies.end();
++it){
39|       (**it).set_position(universeRadius, windowSize);
40|    }
41| }
42|
43|
44| //uses an iterator to go through and draw each celestialBody
45| void universe::draw(sf::RenderTarget& target) const{
46|    for(auto it = celestialBodies.begin(); it != celestialBodies.end();
++it){
47|       target.draw(**it);
48|    }
49| }
50|
51| //print function for testing.
52| void universe::print (){
53|    for(auto it = celestialBodies.begin(); it != celestialBodies.end();
++it){
54|       std::cout << **it;
55|    }
56| }
57|
58|
```

Celestialbody.hpp

```
01| #ifndef  CELESTIALBODY_H
02| #define  CELESTIALBODY_H
03|
04| #include <iostream>
05| #include <string>
06| #include <vector>
07| #include <SFML/System.hpp>
08| #include <SFML/Window.hpp>
09| #include <SFML/Graphics.hpp>
10|
11|
12| // Constants for the window size.
13| const sf::Vector2u defaultWindowSize(1000, 1000);
14|
15| class celestialBody: public sf::Drawable{
16| public:
17|
18|
19|    // Constructors
20|    celestialBody();
21|
22|    celestialBody(double posX, double posY, double velX, double velY,
double mass, std::string file);
23|
24|
25|    void set_position(float radius, sf::Vector2u windowSize =
defaultWindowSize); // Sets the planets positions will default to 1000x1000
screen size
26|
```

```
27|    // Overridden operator >> for inputing from a file
28|    friend std::istream& operator>> (std::istream &input, celestialBody
&body);
29|
30|    // Overriddden operator << for debugging
31|    friend std::ostream& operator<< (std::ostream &output, celestialBody
&body);
32|
33|
34|
35| private:
36|
37|    // Draw method
38|    void virtual draw(sf::RenderTarget& target, sf::RenderStates states)
const;
39|
40|    // Member variables
41|    double positionX, positionY, velocityX, velocityY, celestialMass;
42|    std::string fileName;
43|
44|    // Image related objects
45|    sf::Image celestialImage;
46|    sf::Sprite celestialSprite;
47|    sf::Texture celestialTexture;
48| };
49|
50| #endif //CELESTIALBODY_H
```

Celestialbody.cpp

```
01| #include "CelestialBody.hpp"
02|
03| //default constructor doesn't need to do anything, since the >> operator
will set everything
04| celestialBody::celestialBody(){
05|    return;
06| }
07|
08|  //sets values if given
09| celestialBody::celestialBody(double posX, double posY, double velX,
double velY, double mass,  std::string file){
10|    positionX = posX;
11|    positionY = posY;
12|    velocityX = velX;
13|    velocityY = velY;
14|    celestialMass = mass;
15|    fileName = file;
16|
17|    if(celestialImage.loadFromFile(fileName)){
18|      return;
19|    }
20|
21|    celestialTexture.loadFromImage(celestialImage);
22|    celestialSprite.setTexture(celestialTexture);
23| }
24|
```

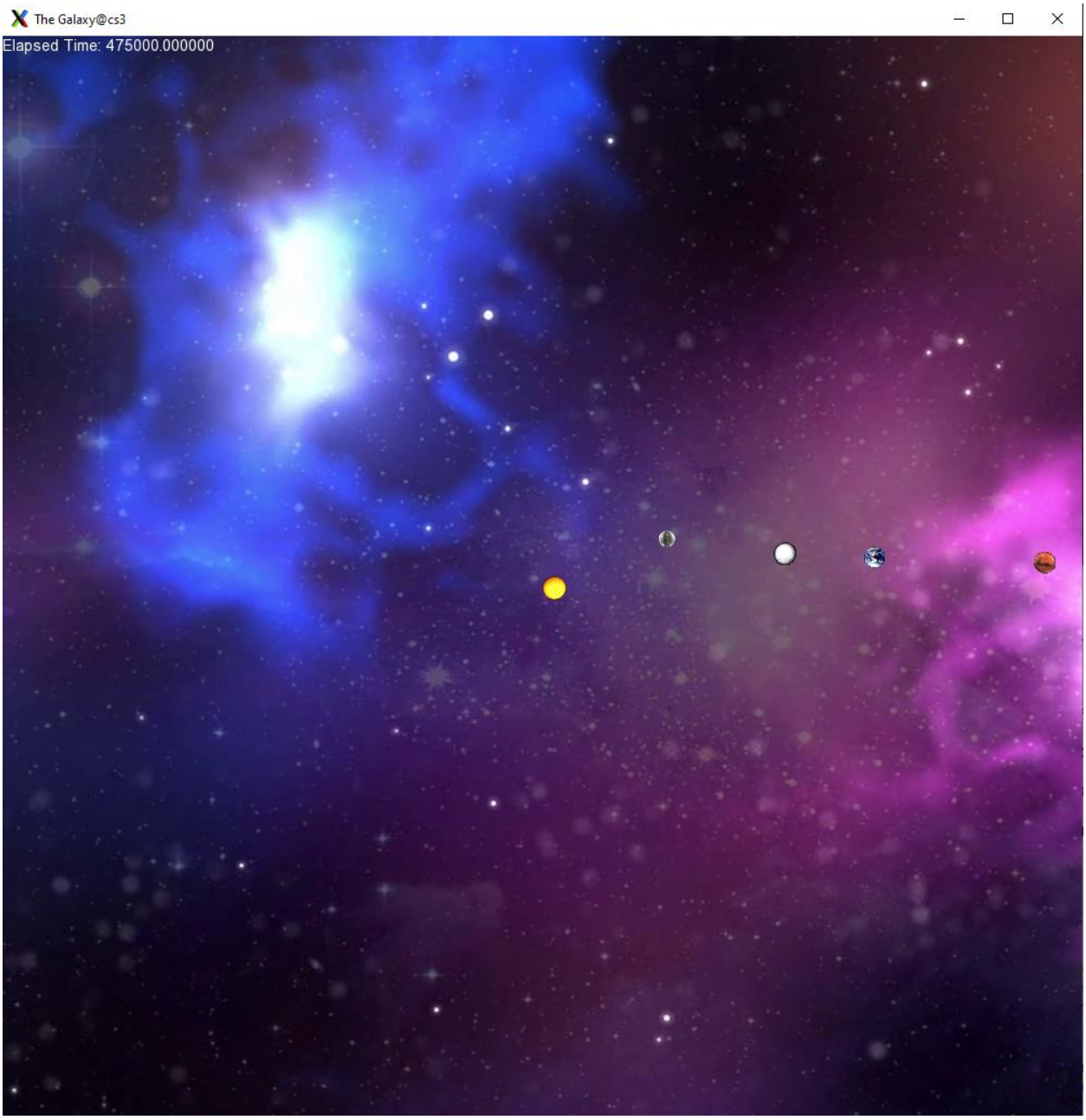
```
25|
26| void celestialBody::set_position(float radius, sf::Vector2u windowSize){
// Sets the planets positions based on window size, will default to
1000,1000.
27|
28| /*
29|   The math for this is obtain a ratio for the size of the screen. then
multiplies it by distance from center of universe(which is half of the
screen) to figure out where in relation to the center the celestialBody is.
Then offsets both x and y based of coordinates of center of the universe.
30| */
31|   positionX = ( (positionX / radius) * ( windowSize.x / 2) ) + (
windowSize.x / 2);
32|   positionY = ( (positionY / radius) * ( windowSize.y / 2) ) + (
windowSize.y / 2);
33|
34|   //apply position to sprite.
35|   celestialSprite.setPosition(positionX, positionY);
36| }
37|
38| // Overridden operator >> for inputing from a file
39| std::istream& operator>> (std::istream &input, celestialBody &body){
40|   //read in all the information
41|   input >> body.positionX >> body.positionY >> body.velocityX >>
body.velocityY >> body.celestialMass >> body.fileName;
42|
43|   //set the images and positions, like the parameter constructor.
44|    if(!body.celestialImage.loadFromFile(body.fileName)){
45|     throw std::invalid_argument("no file for celestialImage");
46|   }
47|
48|   body.celestialTexture.loadFromImage(body.celestialImage);
49|   body.celestialSprite.setTexture(body.celestialTexture);
50|
51|   return input;
52| }
53|
54| //overridden operator << for testing purposes.
55| std::ostream& operator<< (std::ostream &output, celestialBody &body)
56| {
57|   // For debugging, output all the data stored in the object.
58|   output << "File name: " << body.fileName << std::endl << "X position: "
<< body.positionX << std::endl << "Y position: " << body.positionY <<
std::endl << "X velocity: " << body.velocityX << std::endl << "Y velocity: "
<< body.velocityY << std::endl << "Mass: " << body.celestialMass <<
std::endl;
59|
60|   return output;
61| }
62|
63| // Drawable method
64| void celestialBody::draw(sf::RenderTarget& target, sf::RenderStates
states) const
65| {
66|   // draw the image
67|   target.draw(celestialSprite);
68| }
```

PS2b: Nbody Simulation (Part B)

Discussion:

In this portion of the project, I added motion to the universe that I had created in the previous portion of the project. I also added music to play in the background and a timer to show elapsed time. After the window is closed, the program also outputs the state of the Universe to the console. To simulate the motion, I had to create a function to calculate the positions of each Celestialbody and update them in the SFML window. I used Newton's law of universal gravitation to calculate the new positions of each Celestialbody and then used the same ratio as in part A to figure out where the Celestialbodies should be placed on the screen. Additionally, the elapsed time in the simulation goes by steps instead of literally second by second. Each tic of the elapsed time is equivalent to the value of the step variable in seconds. This is known as the leapfrog finite difference approximation scheme. By using the leapfrog finite difference approximation scheme, we can relatively smoothly approximate the positions as time is "elapsed."

Screenshot:



Code:

Note: Since PS2b builds off PS2a, reused files will not be included in the code section if they were not modified.

main.cpp

```
001| #include "Universe.hpp"
002| #include <SFML/Graphics.hpp>
003| #include <SFML/Audio.hpp>
004|
005| int main(int argc, char* argv[]){
006|
007|    std::string::size_type sz; //for stod use
008|
009|    //assign the parameters to doubles.
010|    double T = std::stod(argv[1], &sz);
011|    double deltaT = std::stod(argv[2], &sz);
012|    double timeElapsed = 0;
013|
014|    //std::cout << T << " " << deltaT; for testing
015|    int numPlanets;
016|    float radius;
017|    std::cin >> numPlanets >> radius;
018|
019|
020|    universe galaxy = universe(numPlanets, radius);
021|
022|
023|    //galaxy.step(deltaT);
024|    //std::cout << "HIHIHIHIHIHIHI" << std::endl;
025|    //galaxy.step(deltaT);
026|
027|    sf::RenderWindow window(sf::VideoMode(defaultWindowSize.x,
defaultWindowSize.y), "The Galaxy");
028|
029|    window.setFramerateLimit(60);
030|
031|    //create image for background
032|    sf::Image background;
033|
034|    //if load fails, throw error
035|    if(!background.loadFromFile("space.png")){
036|       throw std::invalid_argument("no file for celestialImage");
037|    }
038|
039|    //creating texture for background
040|    sf::Texture backgroundTexture;
041|    backgroundTexture.loadFromImage(background);
042|
043|    //creating sprite for background
044|    sf::Sprite backgroundSprite;
045|    backgroundSprite.setTexture(backgroundTexture);
046|
047|    //create text.
048|    sf::Font timeFont;
049|    timeFont.loadFromFile("arial.ttf");
050|
```

```
051|    sf::Text timeDisplay;
052|    timeDisplay.setFont(timeFont);
053|
054|    //make time legible
055|    timeDisplay.setCharacterSize(14);
056|    timeDisplay.setFillColor(sf::Color::White);
057|
058|    //create music (which I did not make. I found it royalty free. see
readme.)
059|    sf::Music music;
060|    if(!music.openFromFile("Joey Pecoraro - Your Favorite Place.flac")){
061|      throw std::invalid_argument("no file for music");
062|    }
063|
064|    //play music. This may cause some delay due to needing to open it.
065|    music.play();
066|    //std::cout << "music playing: " << (music.getStatus() ==
sf::SoundSource::Status::Playing) <<std::endl; for testing if music is
actually playing since i can't hear it off of the uml server.
067|
068|    while (window.isOpen()){
069|          // Process events
070|          sf::Event event;
071|          while (window.pollEvent(event)){
072|              // Close window: exit
073|              if (event.type == sf::Event::Closed){
074|                  window.close();
075|              }
076|          }
077|          window.clear();
078|
079|
080|          //draw background
081|          window.draw(backgroundSprite);
082|
083|
084|
085|          //function in universe class to draw all celestialBodies in
universe object uses target.draw() in the function.
086|          galaxy.draw(window);
087|
088|          //check to make sure elapsed time does not go over T.
089|          if(timeElapsed+ deltaT <= T){
090|            galaxy.step(deltaT);
091|            galaxy.set_position(window.getSize());
092|            timeElapsed += deltaT;
093|            timeDisplay.setString("Elapsed Time: " +
std::to_string(timeElapsed));
094|          }
095|
096|          //draw time Display onto window.
097|          window.draw(timeDisplay);
098|
099|          //std::cout << ++count<< std::endl;
100|          window.display();
101|      }
102|
```

```
103|     galaxy.print();  //prints final state of the universe.
104|
105|    return 0;
106| }
```

Universe.hpp

```
01| #ifndef  UNIVERSE_H
02| #define  UNIVERSE_H
03|
04| #include "CelestialBody.hpp"
05| #include <vector>
06| #include <memory>
07| #include <math.h>
08|
09| class universe{
10|   public:
11|     //default constructor
12|     universe();
13|
14|     //parameter constructor
15|     universe(float radius);
16|
17|     //constructor for taking in input from txt doc.
18|     universe(int numOfCelestialBodies, float radius);
19|
20|     //set radius if needed
21|     void set_radius(float radius);
22|
23|     //get radius if needed
24|     double get_radius();
25|
26|     //calculate positions based on window size.
27|     void set_position(sf::Vector2u windowSize = defaultWindowSize);
28|
29|     // Draw method for universe
30|     void virtual draw(sf::RenderTarget& target) const;
31|
32|     //for testing
33|     void print ();
34|
35|     void step(double deltaT);
36|
37|     void calculate_velocities(double deltaT);
38|
39|   private:
40|   double universeRadius;
41|
42|   //using a vector of shared_ptr to hold celestialBodies
43|   std::vector<std::shared_ptr<celestialBody>> celestialBodies;
44| };
45|
46| #endif //UNIVERSE_H
```

Universe.cpp

```
001| #include "Universe.hpp"
002|
003|
004| universe::universe(){
005|   return;
006| }
007|
008| universe::universe(float radius){
009|   universeRadius = radius;
010| }
011|
012| //constructor for taking in input from txt doc.
013| universe::universe(int numOfCelestialBodies, float radius){
014|
015|   universeRadius = radius;
016|
017|   //for loop to collect data for the number of celestial bodies.
018|   for(int i=0; i<numOfCelestialBodies; i++){
019|     std::shared_ptr<celestialBody> temp =
std::make_shared<celestialBody> ();
020|     std::cin >> *temp;
021|
022|     //calculate initial position for all bodies as we loop through
023|     temp->set_position(radius);
024|
025|     //add the body to the vector
026|     celestialBodies.push_back(temp);
027|
028|     //used for testing
029|     //std::cout << *temp;
030|   }
031| }
032|
033| //sets the radius if we need to.
034| void universe::set_radius(float radius){
035|   universeRadius = radius;
036|   return;
037| }
038|
039| //gets radius
040| double universe::get_radius(){
041|   return universeRadius;
042| }
043|
044| //uses an iterator to go through and set position of each celestialBody
045| void universe::set_position(sf::Vector2u windowSize){
046|   for(auto it = celestialBodies.begin(); it != celestialBodies.end();
++it){
047|     (**it).set_position(universeRadius, windowSize);
048|   }
049| }
050|
051|
052| //uses an iterator to go through and draw each celestialBody
053| void universe::draw(sf::RenderTarget& target) const{
```

```
054|   for(auto it = celestialBodies.begin(); it != celestialBodies.end();
++it){
055|     target.draw(**it);
056|   }
057| }
058|
059| //print function for testing.
060| void universe::print (){
061|   for(auto it = celestialBodies.begin(); it != celestialBodies.end();
++it){
062|     std::cout << **it;
063|   }
064| }
065|
066| //changes position of celestialBodies depending on velocity and time
step(deltaT).
067| void universe::step(double deltaT){
068|   this->calculate_velocities(deltaT);
069|  // std::cout << "NEW PHASE" << std::endl;
070|
071|   for(auto it = celestialBodies.begin(); it != celestialBodies.end();
++it){
072|     (**it).set_positionX((**it).get_positionX() +
((**it).get_velocityX() * deltaT));
073|     (**it).set_positionY((**it).get_positionY() +
((**it).get_velocityY() * deltaT));
074|   }
075|  // this->print();
076| }
077|
078| void universe::calculate_velocities(double deltaT){
079|   const double gravity = 6.67e-11;
080|   //nested loops to be able to compare two celestialBodies together.
second loop only goes to first iterator because all calculations can be
negated and applied to other celestialBody. This way we can go through less
of the nested loop but still hit everything
081|   for(auto it = celestialBodies.begin(); it != celestialBodies.end();
++it){
082|     for(auto it2 = celestialBodies.rbegin(); *it2 != *it; ++it2){
083|
084|       double distX = (*it2)->get_positionX() - (*it)->get_positionX();
085|       double distY = (*it2)->get_positionY() - (*it)->get_positionY();
086|       //std::cout <<distX << distY;
087|       double distSQ = pow(distX,2) + pow(distY,2);
//calculate r^2
088|       double dist = sqrt(distSQ);
//calculate r
089|       double force = (gravity* (**it).get_mass() *
(**it2).get_mass())/distSQ;  //calulate force (g*m1*m2)/r
090|       double forceX = force* (distX/dist);          //force ratio for x
091|       double forceY = force* (distY/dist);          //force ratio for y
092|       double accelXit = forceX/(**it).get_mass();        //a = F/m
093|       double accelYit = forceY/(**it).get_mass();        //a = f/m
094|       double velocityXitChange = accelXit * deltaT;      //v = deltaT*a
095|       double velocityYitChange = accelYit * deltaT;      //v = deltaT*a
096|       double accelXit2 = -1*forceX/(**it2).get_mass();  //negate for it2
because we have distances based on it, not it2
```

```
097|       double accelYit2 = -1*forceY/(**it2).get_mass();  //negate for it2
because we have distances based on it, not it2
098|       double velocityXit2Change = accelXit2 * deltaT;  //already negated
as accel was negated, so dont need to negate again.
099|       double velocityYit2Change = accelYit2 * deltaT;  //already negated
as accel was negated, so dont need to negate again.
100|       //std::cout << velocityXitChange << velocityYitChange<<
velocityXit2Change<<velocityYit2Change;
101|       (**it).set_velocityX((**it).get_velocityX() + velocityXitChange);
//set X position for it
102|       (**it).set_velocityY((**it).get_velocityY() + velocityYitChange);
//set Y position for it
103|       (**it2).set_velocityX((**it2).get_velocityX() +
velocityXit2Change);    //set X position for it2
104|       (**it2).set_velocityY((**it2).get_velocityY() +
velocityYit2Change);    //set Y position for it2
105|     }
106|   }
107| }
108|
```

Celestialbody.hpp

```
01| #ifndef  CELESTIALBODY_H
02| #define  CELESTIALBODY_H
03| #include <iostream>
04| #include <string>
05| #include <vector>
06| #include <SFML/System.hpp>
07| #include <SFML/Window.hpp>
08| #include <SFML/Graphics.hpp>
09|
10|
11| // Constants for the window size.
12| const sf::Vector2u defaultWindowSize(1000, 1000);
13|
14| class celestialBody: public sf::Drawable{
15| public:
16|
17|
18|   // Constructors
19|   celestialBody();
20|
21|   celestialBody(double posX, double posY, double velX, double velY,
double mass, std::string file);
22|
23|
24|   void set_position(float radius, sf::Vector2u windowSize =
defaultWindowSize); // Sets the planets positions will default to 1000x1000
screen size
25|
26|   // Overridden operator >> for inputing from a file
27|   friend std::istream& operator>> (std::istream &input, celestialBody
&body);
28|
29|   // Overriddden operator << for debugging
```

```
30|    friend std::ostream& operator<< (std::ostream &output, celestialBody
&body);
31|
32|    //getters and setters for X velocity
33|    void set_velocityX(double Xvelocity);
34|
35|    double get_velocityX();
36|
37|    //getters and setters for Y velocity
38|    void set_velocityY(double Yvelocity);
39|
40|    double get_velocityY();
41|
42|  //getters and setters for X position
43|    void set_positionX(double Xposition);
44|
45|    double get_positionX();
46|
47|    //getters and setters for Y position
48|    void set_positionY(double Yposition);
49|
50|    double get_positionY();
51|
52|    //getter for mass
53|    double get_mass();
54|  private:
55|
56|    // Draw method
57|    void virtual draw(sf::RenderTarget& target, sf::RenderStates states)
const;
58|
59|    // Member variables
60|    double positionX, positionY, velocityX, velocityY, celestialMass;
61|    std::string fileName;
62|
63|    // Image related objects
64|    sf::Image celestialImage;
65|    sf::Sprite celestialSprite;
66|    sf::Texture celestialTexture;
67|  };
68|
69|  #endif //CELESTIALBODY_H
```

Celestialbody.cpp

```
001|  #include "CelestialBody.hpp"
002|
003|  //default constructor doesn't need to do anything, since the >> operator
will set everything
004|  celestialBody::celestialBody(){
005|     return;
006|  }
007|
008|   //sets values if given
009|  celestialBody::celestialBody(double posX, double posY, double velX,
double velY, double mass,  std::string file){
```

```
010|   positionX = posX;
011|   positionY = posY;
012|   velocityX = velX;
013|   velocityY = velY;
014|   celestialMass = mass;
015|   fileName = file;
016|
017|   if(celestialImage.loadFromFile(fileName)){
018|     return;
019|   }
020|
021|   celestialTexture.loadFromImage(celestialImage);
022|   celestialSprite.setTexture(celestialTexture);
023| }
024|
025|
026| void celestialBody::set_position(float radius, sf::Vector2u windowSize){
// Sets the planets positions based on window size, will default to
1000,1000.
027|
028| /*
029|   The math for this is obtain a ratio for the size of the screen. then
multiplies it by distance from center of universe(which is half of the
screen) to figure out where in relation to the center the celestialBody is.
Then offsets both x and y based of coordinates of center of the universe.
030| */
031|
032|   double posX = ( (positionX / radius) * ( windowSize.x / 2) ) + (
windowSize.x / 2);
033|   double posY = ( -(positionY / radius) * ( windowSize.y / 2) ) + (
windowSize.y / 2);//negate to make it orbit counter-clockwise
034|   /*for testing
035|   std::cout <<*this<< "X pixel: " << posX << std::endl;
036|   std::cout << "Y pixel: " << posY << std::endl;
037|   std::cout << "x positoin : " << positionX  << std::endl;
038|   std::cout << "y position: " << positionY  << std::endl;
039|   std::cout << "radius " << radius  << std::endl;
040|   */
041|   //apply position to sprite.
042|   celestialSprite.setPosition(posX, posY);
043|
044| }
045|
046| //getters and setters for X velocity
047| void celestialBody::set_velocityX(double Xvelocity){
048|   this->velocityX = Xvelocity;
049| }
050|
051| double celestialBody::get_velocityX(){
052|   return this->velocityX;
053| }
054|
055| //getters and setters for Y velocity
056|
057| void celestialBody::set_velocityY(double Yvelocity){
058|   this->velocityY = Yvelocity;
059| }
```

```
060|
061| double celestialBody::get_velocityY(){
062|   return this->velocityY;
063| }
064|
065|
066|
067| //getters and setters for X position
068| void celestialBody::set_positionX(double Xposition){
069|   this->positionX = Xposition;
070| }
071|
072| double celestialBody::get_positionX(){
073|   return this->positionX;
074| }
075|
076| //getters and setters for Y position
077|
078| void celestialBody::set_positionY(double Yposition){
079|   this->positionY = Yposition;
080| }
081|
082|
083| double celestialBody::get_positionY(){
084|   return this->positionY;
085| }
086|
087| //getter for mass
088| double celestialBody::get_mass(){
089|   return this->celestialMass;
090| }
091|
092| // Overridden operator >> for inputing from a file
093| std::istream& operator>> (std::istream &input, celestialBody &body){
094|   //read in all the information
095|   input >> body.positionX >> body.positionY >> body.velocityX >>
body.velocityY >> body.celestialMass >> body.fileName;
096|
097|   //set the images and positions, like the parameter constructor.
098|    if(!body.celestialImage.loadFromFile(body.fileName)){
099|     throw std::invalid_argument("no file for celestialImage");
100|   }
101|
102|   body.celestialTexture.loadFromImage(body.celestialImage);
103|   body.celestialSprite.setTexture(body.celestialTexture);
104|
105|   return input;
106| }
107|
108| //overridden operator << for testing purposes.
109| std::ostream& operator<< (std::ostream &output, celestialBody &body)
110| {
111|   // For debugging, output all the data stored in the object.
112|   output << "File name: " << body.fileName << std::endl << "X position:
" << body.positionX << std::endl << "Y position: " << body.positionY <<
std::endl << "X velocity: " << body.velocityX << std::endl << "Y velocity: "
```

```
<< body.velocityY << std::endl << "Mass: " << body.celestialMass <<
std::endl;
113|
114|    return output;
115| }
116|
117| // Drawable method
118| void celestialBody::draw(sf::RenderTarget& target, sf::RenderStates
states) const
119| {
120|    // draw the image
121|    target.draw(celestialSprite);
122| }
123|
```

PS3: Synthesizing a Plucked String

PS3a: CircularBuffer implementation

Discussion:

I created a ring buffer using a vector. The vector makes it convenient to enqueue and dequeue items up to the capacity. I kept tract of two indexes for the head and tail as well as values for the size and capacity. Then, I used some index management to make sure that the index wraps around when it goes above capacity. I also used boost testing to do unit tests and make sure that the program is running as intended.

Console Output (Running Boost test):

Running 2 test cases...

*** No errors detected

Code:

Makefile:

```
01| CC = g++
02| CFLAGS = -std=c++14 -c -g -Og -Wall -Werror -pedantic
03| OBJ = test.o CircularBuffer.o
04| LIBS =
05| EXE = PS3a
06|
07| all: PS3a
08|
09| PS3a: $(OBJ)
10|     $(CC) $(OBJ) -o $(EXE) $(LIBS)
11|
12| CircularBuffer.o: CircularBuffer.cpp CircularBuffer.h
13|     $(CC) $(CFLAGS) -o $@ $<
14|
15| test.o: test.cpp CircularBuffer.h
16|     $(CC) $(CFLAGS) -o $@ $<
17|
18| clean:
19|     rm *.o
20|     rm $(EXE)
21|
```

test.cpp:

```
01| #include <iostream>
02| #include <stdexcept>
03|
04| #include "CircularBuffer.h"
```

```
05|
06| #define BOOST_TEST_DYN_LINK
07| #define BOOST_TEST_MODULE Main
08| #include <boost/test/included/unit_test.hpp>
09|
10|
11| BOOST_AUTO_TEST_CASE(constructors ) {
12|    // tests negative number in constructor. expects error thrown
13|    BOOST_REQUIRE_THROW(CircularBuffer cTest(-5), std::invalid_argument);
14|    // tests 0 in constructor. expects error thrown
15|    BOOST_REQUIRE_THROW(CircularBuffer cTest(0), std::invalid_argument);
16|    // tests 1 in constructor. expects error thrown
17|    BOOST_REQUIRE_THROW(CircularBuffer cTest(1), std::invalid_argument);
18|
19|    // tests an expected input into the constructor. no error should be
thrown
20|    BOOST_REQUIRE_NO_THROW(CircularBuffer cTest(10));
21|    // tests an expected input into the constructor. no error should be
thrown
22|    BOOST_REQUIRE_NO_THROW(CircularBuffer cTest(20));
23|    // tests an expected input into the constructor. no error should be
thrown
24|    BOOST_REQUIRE_NO_THROW(CircularBuffer cTest(37));
25| }
26|
27| BOOST_AUTO_TEST_CASE(ring_buffer_modification ) {
28|    CircularBuffer test(10);
29|    // check functions on empty buffer
30|    BOOST_REQUIRE_THROW(test.peek(), std::runtime_error);
31|    BOOST_REQUIRE_THROW(test.dequeue(), std::runtime_error);
32|    BOOST_REQUIRE(test.isEmpty() == true);
33|    BOOST_REQUIRE(test.isFull() == false);
34|    BOOST_REQUIRE(test.size() == 0);
35|    // add 5 elements to buffer
36|    BOOST_REQUIRE_NO_THROW(test.enqueue(5));
37|    BOOST_REQUIRE_NO_THROW(test.enqueue(6));
38|    BOOST_REQUIRE_NO_THROW(test.enqueue(7));
39|    BOOST_REQUIRE_NO_THROW(test.enqueue(8));
40|    BOOST_REQUIRE_NO_THROW(test.enqueue(9));
41|
42|    // check peek and dequeue on buffer with elements. should return/pop
head.
43|    BOOST_REQUIRE(test.size() == 5);
44|    BOOST_REQUIRE(test.peek() == 5);
45|    BOOST_REQUIRE(test.dequeue() == 5);
46|
47|    // check to make sure size went down after dequeue and that isEmpty is
false
48|    BOOST_REQUIRE(test.size() == 4);
49|    BOOST_REQUIRE(test.isEmpty() == false);
50|    BOOST_REQUIRE(test.isFull() == false);
51|
52|    // add 2 more elements to buffer
53|    BOOST_REQUIRE_NO_THROW(test.enqueue(10));
54|    BOOST_REQUIRE_NO_THROW(test.enqueue(11));
55|
56|    // double check peek and dequeue
```

```
57|    BOOST_REQUIRE(test.peek() == 6);
58|    BOOST_REQUIRE(test.dequeue() == 6);
59|
60|    // add elements to put size to capcaity
61|    BOOST_REQUIRE_NO_THROW(test.enqueue(12));
62|    BOOST_REQUIRE_NO_THROW(test.enqueue(13));
63|
64|    // Test the Size function some more
65|    BOOST_REQUIRE(test.size() == 7);
66|    BOOST_REQUIRE_NO_THROW(test.enqueue(14));
67|    BOOST_REQUIRE_NO_THROW(test.enqueue(15));
68|    BOOST_REQUIRE_NO_THROW(test.enqueue(16));
69|
70|    // check isEmpty and isFull
71|    BOOST_REQUIRE(test.isEmpty() == false);
72|    BOOST_REQUIRE(test.isFull() == true);
73|
74|    // 12 total elements added, but 2 popped off
75|    // buffer is now full, so adding another should throw error
76|    BOOST_REQUIRE_THROW(test.enqueue(17), std::runtime_error);
77| }
78|
```

CircularBuffer.h

```
01| #ifndef CIRCULARBUFFER_H
02| #define CIRCULARBUFFER_H
03|
04| #include <stdint.h>
05| #include <vector>
06|
07| class CircularBuffer{
08|   public:
09|     // required constructor listed in pdf
10|     CircularBuffer(int capacity);
11|
12|     // required functions listed in pdf
13|     int size();
14|     bool isEmpty();
15|     bool isFull();
16|     void enqueue(int16_t x);
17|     int16_t dequeue();
18|     int16_t peek();
19|
20|   private:
21|   // private member variables
22|   int bufferTail;
23|   int bufferHead;
24|   int bufferCapacity;
25|   int bufferSize;
26|   // using vector to hold the ring buffer
27|   std::vector<int16_t> buffer;
28| };
29|
30| #endif //CIRCULARBUFFER_H
```

CircularBuffer.cpp

```
01| #include "CircularBuffer.h"  // NOLINT
02| #include <stdexcept>
03|
04| CircularBuffer::CircularBuffer(int capacity) {
05|   // Have capacity <= 1 becuase algorithm requires 2 items.
06|   if (capacity <= 1) {
07|     throw std::invalid_argument
08|       ("CircularBuffer constructor: capacity must be greater than zero");
09|   }
10|   bufferCapacity = capacity;
11|   bufferSize = 0;
12|   bufferHead = 0;
13|   bufferTail = 0;
14|   buffer.resize(capacity);
15| }
16|
17| // required functions in pdf
18| int CircularBuffer::size() {
19|   return bufferSize;
20| }
21|
22| bool CircularBuffer::isEmpty() {
23|   if (bufferSize == 0) {
24|      return true;
25|   }
26|   return false;
27| }
28|
29| bool CircularBuffer::isFull() {
30|   if (bufferSize == bufferCapacity) {
31|     return true;
32|   }
33|   return false;
34| }
35|
36| void CircularBuffer::enqueue(int16_t x) {
37|   if (isFull()) {
38|     throw std::runtime_error("enqueue: can't enqueue into a full ring");
39|   }
40|
41|   buffer[bufferTail] = x;
42|
43|   // loops around if capacity is reached. indexes are 0 to capacity-1,
44|   // so if bufferTail = capacity-1, then we just inserted into the last
location
45|   if (bufferTail == bufferCapacity-1) {
46|     bufferTail = 0;
47|   } else {
48|     bufferTail++;
49|   }
50|   bufferSize++;
51| }
52|
53| int16_t CircularBuffer::dequeue() {
54|   if (isEmpty()) {
```

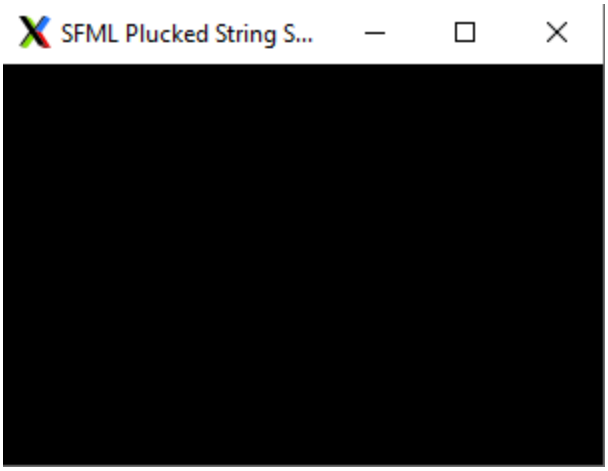
```
55|     throw std::runtime_error("dequeue: can't dequeue from an empty
ring");
56|   }
57|
58|   // this should make sure bufferHead never reaches out of index.
59|   if (bufferHead == bufferCapacity-1) {
60|     bufferHead = 0;
61|     bufferSize--;
62|     return buffer[bufferCapacity-1];
63|   }
64|
65|   // if we don't need to worry about bufferHead going out of index,
66|   // just do things normally.
67|   bufferSize--;
68|   return buffer[bufferHead++];
69| }
70|
71| int16_t CircularBuffer::peek() {
72|   if (isEmpty()) {
73|     throw std::runtime_error("peek: can't peeke from an empty ring");
74|   }
75|   // bufferHead should never get out of index, so we can just check it.
76|   return buffer[bufferHead];
77| }
78|
```

PS3b: StringSound Implementation and SFML audio output

Discussion:

I utilized the CircularBuffer to simulate the frequency of a held note. The CircularBuffer is used to create the following white noise as a note is held but started at a specific frequency based on what key is pressed. I utilized SFML to create a window and to play the simulated note. To calculate the frequency of each key, I used the formula $440 \times 2^{(i-24)/12}$. This was also the first project where I included a lambda expression, which was something new that I learned during this class.

Screenshot:



Code:

Note: Since PS3b builds off PS3a, reused files will not be included in the code section if they were not modified.

Makefile

```
01| CC = g++
02| CFLAGS = -std=c++14 -c -g -Og -Wall -Werror -pedantic
03| OBJ = KSGuitarSim.o StringSound.o CircleBuffer.o
04| LIBS = -lsfml-graphics -lsfml-system -lsfml-window -lsfml-audio
05| EXE = KSGuitarSim
06|
07| all: KSGuitarSim
08|
09| KSGuitarSim: $(OBJ)
10|     $(CC) $(OBJ) -o $(EXE) $(LIBS)
11|
12| KSGuitarSim.o: KSGuitarSim.cpp StringSound.h
13|     $(CC) $(CFLAGS) -o $@ $<
14|
15| StringSound.o: StringSound.cpp StringSound.h CircleBuffer.h
16|     $(CC) $(CFLAGS) -o $@ $<
17|
18| CircleBuffer.o: CircleBuffer.cpp CircleBuffer.h
19|     $(CC) $(CFLAGS) -o $@ $<
20|
21| clean:
22|     rm *.o
23|     rm $(EXE)
24|
```

KSGuitarSim.cpp

```
01| #include <SFML/Graphics.hpp>
02| #include <SFML/System.hpp>
```

```
03| #include <SFML/Audio.hpp>
04| #include <SFML/Window.hpp>
05|
06| #include <math.h>
07| #include <limits.h>
08|
09| #include <iostream>
10| #include <string>
11| #include <exception>
12| #include <stdexcept>
13| #include <vector>
14|
15| #include "CircleBuffer.h"
16| #include "StringSound.h"
17|
18|
19|
20| std::vector<sf::Int16> makeSamples(StringSound gs, bool dif) {
21|   std::vector<sf::Int16> samples;
22|
23|   gs.pluck();
24|   int duration = 8;  // seconds
25|   int i;
26|   for (i= 0; i < SAMPLES_PER_SEC * duration; i++) {
27|     gs.tic();
28|     samples.push_back(gs.sample());
29|   }
30|   return samples;
31| }
32|
33| int main() {
34|   sf::RenderWindow window(sf::VideoMode(300, 200), "SFML Plucked String
Sound Lite");
35|   sf::Event event;
36|
37|   double freq;
38|
39|   std::vector<std::vector<sf::Int16>> samples(37);
40|   std::vector<sf::SoundBuffer> soundBuffers(37);
41|   std::vector<sf::Sound> sounds(37);
42|
43|   std::vector<std::vector<sf::Int16>> samples2(37);
44|   std::vector<sf::SoundBuffer> soundBuffers2(37);
45|   std::vector<sf::Sound> sounds2(37);
46|
47|   // create a string with the keyboard keys
48|   std::string keyboard = "q2we4r5ty7u8i9op-[=zxdcfvgbnjmk,.;/' ";
49|
50|   //make frequencies for the keyboard.
51|   for(int i=0; i<37; i++){
52|     // Use formula in pdf to calculate frequency
53|     freq = 440*pow(2,((i-24)/12.0));
54|     StringSound temp = StringSound(freq);
55|     // use the StringSound to fill the samples vector in that index
56|     samples[i] = makeSamples(temp, false);
57|
```

```
58|     if(!soundBuffers[i].loadFromSamples(&samples[i][0],
samples[i].size(), 2, 44100)){
59|         throw std::runtime_error("Could not load soundBuffers from
samples");
60|     }
61|     sounds[i].setBuffer(soundBuffers[i]);
62|   }
63|
64|   while (window.isOpen()) {
65|     while (window.pollEvent(event)) {
66|       //check if event is unicode character (because our entire keyboard
consists of unicode characters)
67|       //better than doing a switch for each key
68|       if(event.type == sf::Event::TextEntered){
69|         // ASCII is a subset of unicode, only need to deal with ASCII
chars
70|         if(event.text.unicode < 128){
71|           // convert unicode to ascii
72|           char key = (char) (event.text.unicode);
73|
74|           for(int i = 0; i<37; i++){
75|             if(keyboard[i] == key){
76|               sounds[i].play();
77|               break;
78|             }
79|           }
80|         }
81|       }
82|       // Close window: exit
83|       if (event.type == sf::Event::Closed)
84|         window.close();
85|     }
86|     window.clear();
87|     window.display();
88|   }
89|   return 0;
90| }
91|
```

StringSound.h

```
01| #ifndef STRINGSOUND_H
02| #define STRINGSOUND_H
03|
04| #include <SFML/Graphics.hpp>
05| #include <SFML/System.hpp>
06| #include <SFML/Audio.hpp>
07| #include <SFML/Window.hpp>
08| #include <vector>
09| #include <memory>
10| #include "CircleBuffer.h"
11|
12| #define SAMPLES_PER_SEC 44100
13| #define CONCERT_A 220.0
14|
15| class StringSound{
```

```
16|     public:
17|         StringSound(double frequency);
18|         StringSound(std::vector<sf::Int16> init);
19|         void pluck();
20|         void tic();
21|         sf::Int16 sample();
22|         int time();
23|         int getBufferSize();
24|         ~StringSound();
25|     private:
26|         int ticsPassed;
27|         CircleBuffer* buffer;
28| };
29|
30| #endif //STRINGSOUND_H
31|
```

StringSound.cpp

```
01| #include "StringSound.h"
02| #include <cmath>
03| #include <random>
04| #include <exception>
05|
06| StringSound::StringSound(double frequency){
07|     ticsPassed = 0;
08|     // use lambda expression so we don't have to calculate capacity,
09|     // assign it to a variable, then use it for the constructor.
10|     //Add exception for when samples/freq <=1
11|     if(frequency >= 44100 || frequency <=0){
12|         throw std::invalid_argument
13|             ("Frequency must be between 1 and 44099");
14|     }
15|     //int value = ceil(SAMPLES_PER_SEC/frequency);
16|     buffer = new CircleBuffer([](int samples, int freq){return
ceil(samples/freq);}(SAMPLES_PER_SEC, frequency));
17| }
18|
19| StringSound::StringSound(std::vector<sf::Int16> init){
20|     buffer = new CircleBuffer(init.size());
21|     for (auto it = init.begin(); it < init.end(); it++){
22|         buffer->enqueue((int16_t) *it);
23|     }
24|
25|     ticsPassed = 0;
26| }
27|
28| void StringSound::pluck(){
29|     buffer->empty();
30|
31|     //make random number generator
32|     std::mt19937 mt(1729);
33|     std::uniform_int_distribution<int16_t> dist(-32768,32767);
34|     for(int i =0; i < buffer->capacity(); i++){
35|         buffer->enqueue(dist(mt));
36|     }
```

```
37| }
38|
39| void StringSound::tic(){
40|     /*
41|     // check if buffer size is too small for dequeue + peek
42|     if(buffer->size()<2){
43|         throw std::length_error("Buffer is too small, can't tic");
44|     }
45|     */
46|     // dequeue the first value
47|     int16_t first = buffer->dequeue();
48|
49|     // get second value for Karplus-Strong, but don't dequeue
50|     int16_t second = buffer->peek();
51|
52|     // using 0.498 instead of decay factor of 0.996 because i took the
1/2 from the average (of first and second) and multiplied it to the 0.996
53|     buffer->enqueue((sf::Int16) (0.498*(first+second)));
54|     ticsPassed++;
55| }
56|
57|
58| sf::Int16 StringSound::sample(){
59|     // check for exception if buffer is too empty
60|     if(buffer->isEmpty()){
61|         throw std::length_error("Buffer is too small, can't peek for
sample");
62|     }
63|
64|     return (sf::Int16) buffer->peek();
65| }
66|
67| int StringSound::time(){
68|     return ticsPassed;
69| }
70|
71| //made to facilitate making of frequency chirp
72| int StringSound::getBufferSize(){
73|     return buffer->size();
74| }
75|
76| StringSound::~StringSound(){
77|     //delete buffer;
78| }
79|
80|
```

PS4: DNA Sequence Alignment

Discussion:

This project introduced the idea of dynamic programming. I had already known about space and time complexity from previous computer science courses, but this was also a good refresher. I used nested vectors to make a 2D matrix so that could align the strings in the matrix and then calculate the cost of each step. My program first fills out the matrix from the bottom right corner and then to print out the optimal path, it traverses the matrix from the upper left corner. The algorithm that I used specifically was the Needleman-Wunsch method.

Console Output when run on 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

Execution time is 0.000909seconds

Edit distance = 7

Code:

main.cpp

```
01| #include <iostream>
02| #include <string>
03| #include <SFML/System.hpp>
04| #include "ED.hpp"
05|
06| int main(int argv, char** argc) {
07|   sf::Clock clock;
08|   sf::Time t;
09|
10|   std::string string1, string2;
11|   std::cin >> string1 >> string2;
12|   ED test(string1, string2);
13|   std::cout << "Edit distance = " << test.OptDistance() << "\n";
14|   std::cout << test.Alignment();
15|
16|   t = clock.getElapsedTime();
17|   std::cout << "Execution time is " << t.asSeconds() << "seconds \n";
18|   // Edit distance is reprinted for ease of looking at output
19|   std::cout << "Edit distance = " << test.OptDistance() << "\n";
20|   return 0;
21| }
22|
```

ED.hpp

```
01| #ifndef ED_H
02| #define ED_H
03|
04| #include <vector>
05| #include <string>
06|
07| class ED{
08|   public:
09|     ED(std::string stringOne, std::string stringTwo);
10|     static int penalty(char a, char b);
11|     static int min(int a, int b, int c);
12|     int OptDistance();
13|     std::string Alignment();
14|     void print();
15|   private:
16|     // 2D vector matrix, so I can use the i,j like coordinates
17|     std::vector<std::vector<int>> matrix;
18|     std::string string1;
19|     std::string string2;
20|
21| };
22|
23| #endif //ED_H
```

ED.cpp

```
001| #include "ED.hpp"
002| #include <iostream>
003| #include <exception>
004| #include <sstream>
005|
006| ED::ED(std::string stringOne, std::string stringTwo) {
007|   // store strings
008|   string1 = stringOne;
009|   string2 = stringTwo;
010|
011|   // make matrix size of string1.length+1 x string2.length+1
012|   for (int i = 0; i <= static_cast<int>(string1.length()); i++) {
013|     std::vector<int> temp;
014|     temp.resize(string2.length()+1);
015|     matrix.push_back(temp);
016|   }
017| }
018|
019| int ED::penalty(char a, char b) {
020|   return a == b ? 0 : 1;
021| }
022|
023| // return smallest value
024| int ED::min(int a, int b, int c) {
025|   // if a is smallest or equal to smalles
026|   if (a <= b && a <= c) {
027|     return a;
028|   } else if (b <= c) {  // since a is not smallest, check if b <= c
029|     return b;
030|   } else {  // return c because it must be smallest
031|     return c;
032|   }
033| }
034|
035| // fill out matrix for distances
036| int ED::OptDistance() {
037|   int m = string1.length();
038|   int n = string2.length();
039|
040|   // fill in right column
041|   for (int i = 0; i <= m; i++) {
042|     matrix[i][n] = 2* (m-i);
043|   }
044|
045|   // don't have to do when j=n becuase it was set in the previous for
loop
046|   for (int j = 0; j < n; j++) {
047|     matrix[m][j] = 2*(n-j);
048|   }
049|
050|   // start at bottom and go up.
051|   for (int i = m-1; i >= 0; i--) {
052|     for (int j = n-1; j >= 0; j--) {
053|       matrix[i][j] = min(matrix[i+1][j+1] + penalty(string1[i], //
NOLINT added for false positive
```

```
054|       string2[j]), matrix[i+1][j]+2, matrix[i][j+1]+2);
055|     }
056|   }
057|
058|   // return the optimal edit distance
059|   return matrix[0][0];
060| }
061|
062| std::string ED::Alignment() {
063|   std::stringstream returnString;
064|   int i = 0;
065|   int j = 0;
066|   int m = string1.length();
067|   int n = string2.length();
068|   int right, diag;
069|   int penaltyCost = 5;
070|
071|   // made lambda expressions for each calculated case.
072|   auto rightCase = [this](int x, int y){return matrix[x+1][y] + 2;};
073|   auto diagCase = [this](int x, int y, int penaltyCost){
074|     return matrix[x+1][y+1] + penaltyCost;
075|   };
076|   // loop to check when we hit bottom right corner
077|   while (i < m || j < n) {
078|     // make the right gap case
079|     try {
080|       // right = matrix[i + 1][j] + 2;
081|       right = rightCase(i, j);
082|     } catch (std::out_of_range e) {
083|       right = -1;
084|     }
085|
086|     // make diagonal case
087|     try {
088|       penaltyCost = penalty(string1[i], string2[j]);
089|       // diag = matrix[i+1][j+1] + penaltyCost;
090|       diag = diagCase(i, j, penaltyCost);
091|     } catch (std::out_of_range e) {
092|       diag = -1;
093|     }
094|
095|     // check if diagonal was optimal
096|     if (matrix[i][j] == diag) {
097|       returnString << string1[i] << " " << string2[j]
098|           << " " << penaltyCost << "\n";
099|       i++;
100|       j++;
101|     } else if (matrix[i][j] == right) {  // check if right was optimal
102|       returnString << string1[i] << " - 2\n";
103|       i++;
104|     } else {  // if diagonal and right weren't optimal, down gap must be
105|       returnString << "- " << string2[j] << " 2\n";
106|       j++;
107|     }
108|   }
109|
110|   return returnString.str();
```

```
111| }
112|
113| void ED::print() {
114|   for (int i = 0; i < static_cast<int>(matrix.size()); i++) {
115|     for (int j = 0; j < static_cast<int>(matrix[0].size()); j++) {
116|       std::cout << matrix[i][j] << "  ";
117|     }
118|     std::cout << std::endl;
119|   }
120| }
121|
```

PS5: Markov Model of Natural Language

Discussion:

In this project, I made a functioning Markov model based on a given string. I had not heard of a Markov model and it seems useful as a predictive algorithm. In order to organize all of the kgrams from the resulting model, I used a map to hold the kgrams and their frequencies. The map was set up so that the kgrams themselves were the keys and the frequencies were the stored value for that respective key. I think it is really interesting as a starter concept and would definitely like to see how we make predictive models for things like artificial intelligence.

Console Output:

When running TextGenerator:

./TextGenerator 2 11 < input17.txt

gagagaggcga

When running Test:

Running 6 test cases...

*** No errors detected

Code:

Makefile

```
01| CC = g++
02| CFLAGS = -std=c++11 -c -g -Og -Wall -Werror -pedantic -Iheader
03| OBJ = TextGenerator.o MModel.o
04| LIBS =
05| EXE = TextGenerator
06|
07| all: TextGenerator Test
08|
09| TextGenerator: $(OBJ)
10|     $(CC) $(OBJ) -o $(EXE) $(LIBS)
11|
12| Test: test.o MModel.o
13|     $(CC) test.o MModel.o -o Test
14|
15| MModel.o: MModel.cpp header/MModel.h
16|     $(CC) $(CFLAGS) -o $@ $<
17|
18| test.o: test.cpp header/MModel.h
19|     $(CC) $(CFLAGS) -o $@ $<
20|
21| TextGenerator.o: TextGenerator.cpp header/MModel.h
```

```
22|     $(CC) $(CFLAGS) -o $@ $<
23|
24| clean:
25|     rm *.o
26|     rm $(EXE) Test
27|
```

TextGenerator.cpp

```
01| #include "header/MModel.h"
02|
03| int main(int argc, char** argv) {
04|   // Check for number of args
05|   if (argc != 3) {
06|     std::cout << "There is an incorrect number of args. "
07|                  "There should be 3 args.\n";
08|     return -1;
09|   }
10|
11|   // convert args to ints
12|   int k = atoi(argv[1]);
13|   int l = atoi(argv[2]);
14|
15|   std::string input;
16|   std::string current;
17|
18|   // take in entirety of string
19|   while (std::cin >> current) {
20|     input += current;
21|     current = "";
22|   }
23|
24|   // make MModel
25|   MModel model(input, k);
26|
27|   // create Kgram of length K from first K chars
28|   current = input.substr(0, k);
29|
30|   // print generated string of length l starting with kgram
31|   std::cout << model.generate(current, l) << "\n";
32| }
33|
```

test.cpp

```
001| #define BOOST_TEST_DYN_LINK
002| #define BOOST_TEST_MODULE Main
003| #include <boost/test/included/unit_test.hpp>
004|
005| #include "header/MModel.h"
006|
007| BOOST_AUTO_TEST_CASE(constructor) {
008|   // tests an expected input into the constructor. no error should be
thrown
009|   BOOST_REQUIRE_NO_THROW(MModel cTest("gagggagaggcgagaaa", 0));
010|
```

```
011|   // tests an expected input into the constructor. no error should be
thrown
012|   BOOST_REQUIRE_NO_THROW(MModel cTest("gagggagaggcgagaaa", 3));
013|
014|   // tests an expected input into the constructor. no error should be
thrown
015|   BOOST_REQUIRE_NO_THROW(MModel cTest("gagggagaggcgagaaa", 5));
016|
017|   // tests an expected input into the constructor. no error should be
thrown
018|   BOOST_REQUIRE_NO_THROW(MModel cTest("gagggagaggcgagaaa", 7));
019| }
020|
021| BOOST_AUTO_TEST_CASE(Korder) {
022|   // creating MModel to run freq on with kgram 0
023|   MModel cTest("gagggagaggcgagaaa", 0);
024|
025|   // ensure kOrder() is returning correct value
026|   BOOST_REQUIRE(cTest.kOrder() == 0);
027|
028|   // creating MModel to run freq on with kgram 3
029|   MModel cTest2("gagggagaggcgagaaa", 3);
030|
031|   // ensure kOrder() is returning correct value
032|   BOOST_REQUIRE(cTest2.kOrder() == 3);
033| }
034|
035| BOOST_AUTO_TEST_CASE(freq) {
036|   // creating MModel to run freq on with kgram 0
037|   MModel cTest("gagggagaggcgagaaa", 0);
038|
039|   // test calling freq on cTest with a correct kgram
040|   BOOST_REQUIRE_NO_THROW(cTest.freq(""));
041|
042|   // test calling freq on cTest with an incorrect kgram
043|   BOOST_REQUIRE_THROW(cTest.freq("a"), std::runtime_error);
044|
045|   // double check value returned by freq
046|   BOOST_REQUIRE(cTest.freq("") == 17);
047|
048|   // test calling freq on cTest with a correct kgram
049|   BOOST_REQUIRE_NO_THROW(cTest.freq("", 'a'));
050|
051|   // test calling freq on cTest with an incorrect kgram
052|   BOOST_REQUIRE_THROW(cTest.freq("a", 'a'), std::runtime_error);
053|
054|   // double check value returned by freq
055|   BOOST_REQUIRE(cTest.freq("", 'a') == 7);
056|
057|   // double check value returned by freq
058|   BOOST_REQUIRE(cTest.freq("", 'c') == 1);
059|
060|   // double check value returned by freq
061|   BOOST_REQUIRE(cTest.freq("", 'g') == 9);
062|
063|   // double check value returned by freq when char not in input
064|   BOOST_REQUIRE(cTest.freq("", 'z') == 0);
```

```
065|
066|   // creating MModel to run freq on with kgram 3
067|   MModel cTest2("gagggagaggcgagaaa", 3);
068|
069|   // test calling freq on cTest with an incorrect kgram
070|   BOOST_REQUIRE_THROW(cTest2.freq("a"), std::runtime_error);
071|
072|   // double check value returned by freq
073|   BOOST_REQUIRE(cTest2.freq("aaa") == 1);
074|
075|   // double check value returned by freq
076|   BOOST_REQUIRE(cTest2.freq("gag") == 4);
077|
078|   // test calling freq on cTest2 with an incorrect kgram
079|   BOOST_REQUIRE_THROW(cTest2.freq("a", 'a'), std::runtime_error);
080|
081|   // test calling freq on cTest2 with a correct kgram
082|   BOOST_REQUIRE_NO_THROW(cTest2.freq("aaa", 'a'));
083|
084|   // double check value returned by freq when next char not in input
085|   BOOST_REQUIRE(cTest2.freq("aaa", 'a') == 0);
086|
087|   // double check value returned by freq
088|   BOOST_REQUIRE(cTest2.freq("gcg", 'a') == 1);
089| }
090|
091| BOOST_AUTO_TEST_CASE(kRand) {
092|   // creating MModel to run freq on with kgram 0
093|   MModel cTest("gagggagaggcgagaaa", 0);
094|
095|   // test calling kRand on cTest with an incorrect kgram
096|   BOOST_REQUIRE_THROW(cTest.kRand("a"), std::runtime_error);
097|
098|   // test calling kRand on cTest with a correct kgram
099|   BOOST_REQUIRE_NO_THROW(cTest.kRand(""));
100|
101|   // creating MModel to run freq on with kgram 3
102|   MModel cTest2("gagggagaggcgagaaa", 3);
103|
104|   // test calling kRand on cTest2 with an incorrect kgram
105|   BOOST_REQUIRE_THROW(cTest2.kRand("a"), std::runtime_error);
106|
107|   // test calling kRand on cTest2 with an correct kgram not in input
108|   BOOST_REQUIRE_THROW(cTest2.kRand("ccc"), std::runtime_error);
109|
110|   // test calling kRand on cTest2 with a correct kgram
111|   BOOST_REQUIRE_NO_THROW(cTest2.kRand("aaa"));
112| }
113|
114| BOOST_AUTO_TEST_CASE(generate) {
115|   // creating MModel to run freq on with kgram 0
116|   MModel cTest("gagggagaggcgagaaa", 0);
117|
118|   // test calling generate on cTest with an incorrect kgram
119|   BOOST_REQUIRE_THROW(cTest.generate("a", 5), std::runtime_error);
120|
121|   // test calling generate on cTest with a correct kgram
```

```
122|   BOOST_REQUIRE_NO_THROW(cTest.generate("", 5));
123|
124|   // test calling generate on cTest with a correct kgram and
125|   // checking length of return
126|   BOOST_REQUIRE(cTest.generate("", 5).length() == 5);
127|
128|   // test calling generate on cTest with a correct kgram and
129|   // checking length of return
130|   BOOST_REQUIRE(cTest.generate("", 7).length() == 7);
131|
132|   // creating MModel to run freq on with kgram 3
133|   MModel cTest2("gagggagaggcgagaaa", 3);
134|
135|   // test calling generate on cTest2 with an incorrect kgram
136|   BOOST_REQUIRE_THROW(cTest2.generate("a", 5), std::runtime_error);
137|
138|   // test calling generate on cTest with a correct kgram
139|   BOOST_REQUIRE_NO_THROW(cTest2.generate("ggg", 5));
140|
141|   // test calling generate on cTest with a correct kgram and
142|   // checking length of return
143|   BOOST_REQUIRE(cTest2.generate("aag", 5).length() == 5);
144|
145|   // test calling generate on cTest with a correct kgram and
146|   // checking length of return
147|   BOOST_REQUIRE(cTest2.generate("gcg", 7).length() == 7);
148| }
149|
150| BOOST_AUTO_TEST_CASE(overloaded_function) {
151|   // creating MModel to run freq on with kgram 0
152|   MModel cTest("gagggagaggcgagaaa", 1);
153|
154|   // redirects the constructors overloaded << to the boost test stream.
155|   boost::test_tools::output_test_stream output;
156|
157|   output << cTest;
158|
159|   // test output is equal to expected input
160|   BOOST_REQUIRE(output.is_equal("Original text: gagggagaggcgagaaa"
161|   "\nOrder: 1"
162|   "\nAlphabet: gac\n"
163|   "Markov Map: \n"
164|   "Kgram: a Frequency: 7\n"
165|   "Kgram+1: aa Frequency: 2\n"
166|   "Kgram+1: ag Frequency: 5\n"
167|   "Kgram: c Frequency: 1\n"
168|   "Kgram+1: cg Frequency: 1\n"
169|   "Kgram: g Frequency: 9\n"
170|   "Kgram+1: ga Frequency: 5\n"
171|   "Kgram+1: gc Frequency: 1\n"
172|   "Kgram+1: gg Frequency: 3\n"
173| ));
174| }
175|
```

MModel.h

```
#ifndef MMODEL_H
#define MMODEL_H

#include <string>
#include <iostream>
#include <map>

class MModel{
  public:
    MModel (std::string text, int k);
    int kOrder();
    int freq(std::string kgram);
    int freq(std::string kgram, char c);
    char kRand(std:: string kgram);
    std::string generate(std::string kgram, int L);
    friend std::ostream& operator<< (std::ostream& os, MModel model);
  private:
    std::map<std::string, int> kGramMap;
    std::string inputText;
    std::string alphabet;
    int order;

};

#endif // MMODEL_H
```

MModel.cpp

```
#include <ctime>
#include <cstdlib>
#include "header/MModel.h"


MModel::MModel(std::string text, int k) {
  srand(time(NULL));
  order = k;
  inputText = text;
  int textLength = (unsigned) inputText.length();

  // generate alphabet
  for (int i = 0; i < textLength; i++) {
    if (alphabet.find(inputText[i]) == std::string::npos) {
      alphabet += inputText[i];
    }
  }

  // create lambda expression to add key to kgram map
  auto addToKGramMap = [this](std::string key) {
    if (kGramMap.find(key) == kGramMap.end()) {
      kGramMap[key] = 1;
    } else {
      kGramMap[key] += 1;
    }
  };

```

```
028|   // generate map
029|   for (int i = 0; i < textLength; i++) {
030|     std::string temp;
031|
032|     // make kgram
033|     for (int j = i; j < i + k; j++) {
034|       temp += inputText[j % textLength];
035|     }
036|
037|     // add kgram to kGramMap
038|     addToKGramMap(temp);
039|
040|     // generate k+1
041|     temp += inputText[(i + k) % textLength];
042|
043|     // add kgram+1 to kGramMap
044|     addToKGramMap(temp);
045|   }
046| }
047|
048| // return order
049| int MModel::kOrder() {
050|   return order;
051| }
052|
053| // return frequency of kgram
054| int MModel::freq(std::string kgram) {
055|   if (kgram.length() != (unsigned) order) {
056|     throw std::runtime_error("kgram is not size k");
057|   }
058|
059|   if (order == 0) {
060|     return inputText.length();
061|   }
062|
063|   return kGramMap[kgram];
064| }
065|
066| // return frequency of c after kgram
067| int MModel::freq(std::string kgram, char c) {
068|   if (kgram.length() != (unsigned) order) {
069|     throw std::runtime_error("kgram is not size k");
070|   }
071|   if (order == 0) {
072|     std::string s;
073|     s+=c;
074|     return kGramMap[s];
075|   }
076|   return kGramMap[kgram + c];
077| }
078|
079| // return char that could come after kgram
080| char MModel::kRand(std:: string kgram) {
081|   if (kgram.length() != (unsigned) order) {
082|     throw std::runtime_error("kgram is not size k");
083|   }
084|   if (kGramMap[kgram] == 0) {
```

```
085|     throw std::runtime_error("kgram is not an existing kgram");
086|   }
087|
088|   // simulate frequency of next letter by adding more of them to string
089|   std::string nextFrequency;
090|   for (unsigned int i = 0; i < alphabet.length(); i++) {
091|     for (int j = 0; j < kGramMap[kgram + alphabet[i]]; j++) {
092|       nextFrequency += alphabet[i];
093|     }
094|   }
095|
096|   // return random char in nextFrequency
097|   return nextFrequency[rand() % nextFrequency.size()];
098| }
099|
100| // generate a string of length L following Markov chain
101| std::string MModel::generate(std::string kgram, int L) {
102|   if (kgram.length() != (unsigned) order) {
103|     throw std::runtime_error("kgram is not size k");
104|   }
105|
106|   std::string generatedString = kgram;
107|   std::string tempKGram = kgram;
108|   for (int i = order; i < L ; i++) {
109|     // generate next char
110|     char tempC = kRand(tempKGram);
111|     // add next char to return string
112|     generatedString += tempC;
113|
114|     // add next char to temkKGram
115|     tempKGram += tempC;
116|     // delete first char in tempKGram
117|     tempKGram.erase(0, 1);
118|   }
119|   return generatedString;
120| }
121|
122| // print model
123| std::ostream& operator<< (std::ostream& os, MModel model) {
124|   os << "Original text: " << model.inputText;
125|   os << "\nOrder: " << model.order << "\nAlphabet: " << model.alphabet;
126|   os << "\nMarkov Map: \n";
127|   unsigned int kOrder = (unsigned) model.kOrder();
128|   for (auto const &it : model.kGramMap) {
129|     if (it.first.length() == kOrder) {
130|       os << "Kgram: " << it.first << " Frequency: " << it.second <<
"\n";
131|     } else {
132|       os << "Kgram+1: " << it.first << " Frequency: " << it.second <<
"\n";
133|     }
134|   }
135|   return os;
136| }
137|
```

PS6: Kronos Time Clock

Discussion:

This project introduced me to regex. What I did in this project was to parse a log and figure out when the device attempted to boot and of the boot was successful. I used a regex to determine which lines were relevant to my goal, since they all had the same general format and were able to be grouped by a single regex for each task log entry. I then wrote the output related to my results in a file similar to the log file that I had parsed. If you know what the format of the data that you are looking for is, regex makes it much easier to filter out all the unnecessary noise that may accompany your important data. I am interested in building a web scraper using regex that will scrape the html code from webpages and isolate specific keywords that I may be interested in. I feel like a regex would be a good way to implement that if you can get the HTML to your C++ program.

File Output (when run using device5_intouch.log as the log file):

31063 (log.c.166) server started 2014-Jan-26 09:55:07 success elapsed time: 177000 ms

31274 (log.c.166) server started 2014-Jan-26 12:15:18 failure

31293 (log.c.166) server started 2014-Jan-26 14:02:39 success elapsed time: 165000 ms

32623 (log.c.166) server started 2014-Jan-27 12:27:55 failure

32641 (log.c.166) server started 2014-Jan-27 12:30:23 failure

32656 (log.c.166) server started 2014-Jan-27 12:32:51 failure

32674 (log.c.166) server started 2014-Jan-27 12:35:19 failure

32693 (log.c.166) server started 2014-Jan-27 14:02:38 success elapsed time: 163000 ms

33709 (log.c.166) server started 2014-Jan-28 12:44:17 failure

33725 (log.c.166) server started 2014-Jan-28 14:02:33 success elapsed time: 162000 ms

34594 (log.c.166) server started 2014-Jan-29 12:43:07 failure

34613 (log.c.166) server started 2014-Jan-29 14:02:35 success elapsed time: 164000 ms

37428 (log.c.166) server started 2014-Jan-30 12:43:05 failure

37447 (log.c.166) server started 2014-Jan-30 14:02:40 success elapsed time: 162000 ms

38258 (log.c.166) server started 2014-Jan-31 14:02:33 success elapsed time: 163000 ms

39150 (log.c.166) server started 2014-Feb-01 12:39:38 failure

39166 (log.c.166) server started 2014-Feb-01 12:42:07 failure

39182 (log.c.166) server started 2014-Feb-01 14:02:32 success elapsed time: 164000 ms

40288 (log.c.166) server started 2014-Feb-02 14:02:39 success elapsed time: 172000 ms

41615 (log.c.166) server started 2014-Feb-03 12:35:55 failure

41633 (log.c.166) server started 2014-Feb-03 12:38:22 failure

41648 (log.c.166) server started 2014-Feb-03 12:40:48 failure

41666 (log.c.166) server started 2014-Feb-03 12:43:17 failure

41684 (log.c.166) server started 2014-Feb-03 12:45:46 failure

41694 (log.c.166) server started 2014-Feb-03 14:02:34 success elapsed time: 164000 ms

Code:

Makefile

```
01| CC = g++
02| CFLAGS = -std=c++11 -c -g -Og -Wall -Werror -pedantic -Iheader
03| OBJ = PS6.o
04| LIBS = -lboost_regex -lboost_date_time
05| EXE = PS6
06|
07| all: PS6
08|
09| PS6: $(OBJ)
10|     $(CC) $(OBJ) -o $(EXE) $(LIBS)
11|
12| PS6.o: PS6.cpp
13|     $(CC) $(CFLAGS) -o $@ $<
14|
15|
16| clean:
17|     rm *.o
18|     rm $(EXE)
19|
```

PS6.cpp

```
01| #include <iostream>
02| #include <string>
03| #include <fstream>
04| #include <boost/regex.hpp>
05| #include "boost/date_time/gregorian/gregorian.hpp"
06| #include "boost/date_time/posix_time/posix_time.hpp"
07|
08| using std::cout;
09| using std::cin;
10| using std::endl;
11| using std::string;
12|
13| using boost::gregorian::date;
14| using boost::gregorian::from_simple_string;
```

```
15| using boost::gregorian::date_period;
16| using boost::gregorian::date_duration;
17|
18| using boost::posix_time::ptime;
19| using boost::posix_time::time_duration;
20| using boost::posix_time::time_from_string;
21|
22| int main(int argc, char* argv[]) {
23|   if (argc !=2) {
24|     throw std::invalid_argument("There should only be 2 arguments!");
25|   }
26|
27|   // open log file
28|   std::fstream readLog(argv[1], std::fstream::in);
29|   if (!readLog.is_open()) {
30|     throw std::runtime_error("unable to open file");
31|   }
32|
33|   // create report file
34|   string reportName(string(argv[1]) + ".rpt");
35|   std::fstream reportFile(reportName.c_str(), std::fstream::out);
36|
37|   // setup dateTime for regex
38|   string dateTime("([0-9]{4}-[0-9]{1,2}-[0-9]{1,2}) ([0-9]{2}:[0-
9]{2}:[0-9]{2})"); // NOLINT
39|
40|   // create lambda expression to automatically include
41|   // dateTime at beginning of regex
42|   auto make_regex = [dateTime](string a){
43|     return boost::regex(dateTime + a);
44|   };
45|
46|   // create regex
47|   boost::regex boot = make_regex(".*(log.c.166).*");
48|   boost::regex end = make_regex(".*oejs.AbstractConnector:Started
SelectChannelConnector@0.0.0.0:9080"); // NOLINT
49|
50|   // hold matches
51|   boost::smatch matches;
52|
53|   // create string to store line in from file
54|   string line;
55|
56|   // create line number counter
57|   int lineNumber = 1;
58|
59|   // create boolean to remember if booting
60|   bool isBooting = false;
61|
62|   // create time variables for time calculation
63|   ptime startTime, endTime;
64|
65|   // go through file until EOF
66|   while (getline(readLog, line)) {
67|     if (regex_match(line, matches, boot)) {
68|       // set start time
```

```
69|       startTime = time_from_string(matches[1].str() + " " +
matches[2].str());
70|
71|       // if already booting, we tried to start another boot so first one
failed
72|       if (isBooting) {
73|         reportFile << " failure\n";
74|       }
75|       // print line number and start time.
76|       reportFile << lineNumber << " (log.c.166) server started ";
77|       reportFile << startTime;
78|       isBooting = true;
79|
80|     } else if (regex_match(line, matches, end)) {
81|       endTime = time_from_string(matches[1].str() + " " +
matches[2].str());
82|       // only print stuff if we are booting
83|       if (isBooting) {
84|         reportFile << " success elapsed time: ";
85|         reportFile << (endTime - startTime).total_milliseconds() << "
ms\n";
86|         isBooting = false;
87|       }
88|     }
89|     // increment line number
90|     ++lineNumber;
91|   }
92|   return 0;
93| }
94|
```