ECE4122/6122 **Fall Semester, 2016**

Final Project Mandelbrot Set Display

Assigned: Nov 10, 2016 *Due: Dec 15 2016, 3:00pm*

Introduction In this assignment we will use the OpenGL graphics API to compute and display a visual image of the *Mandelbrot Set*. Once the set is displayed, we will use the mouse to select a square region from the displayed set, and recompute the set using only the selected region of the complex plane. Details of the math to compute the *Mandelbrot Set*is given in the paragraphs below.

The Mandelbrot Set The *Mandelbrot Set* is defined as the set of points in the complex plane that satisfy

$M = \{c \in C | \lim_{n\to\infty} Z_n \neq \infty\}$

where

M is the set of all complex numbers **in** the *Mandelbrot Set*.

C is the set of all complex numbers in the complex plane,

$Z_0 = c$,

$Z_{n+1} = Z_n^2 + c$

From this description it appears we have to iterate n over all values from 0 to ∞, which would take quite a bit of computation. Luckily, we can make two simplifying assumptions.

1. If the magnitude of any Z_n is greater than 2.0, then it can be proved that Z will eventually reach infinity, so if we ever get a Z_n for which the magnitude is greater then 2.0 we can stop iterating and claim that the point c is *not* in the *Mandelbrot Set*.

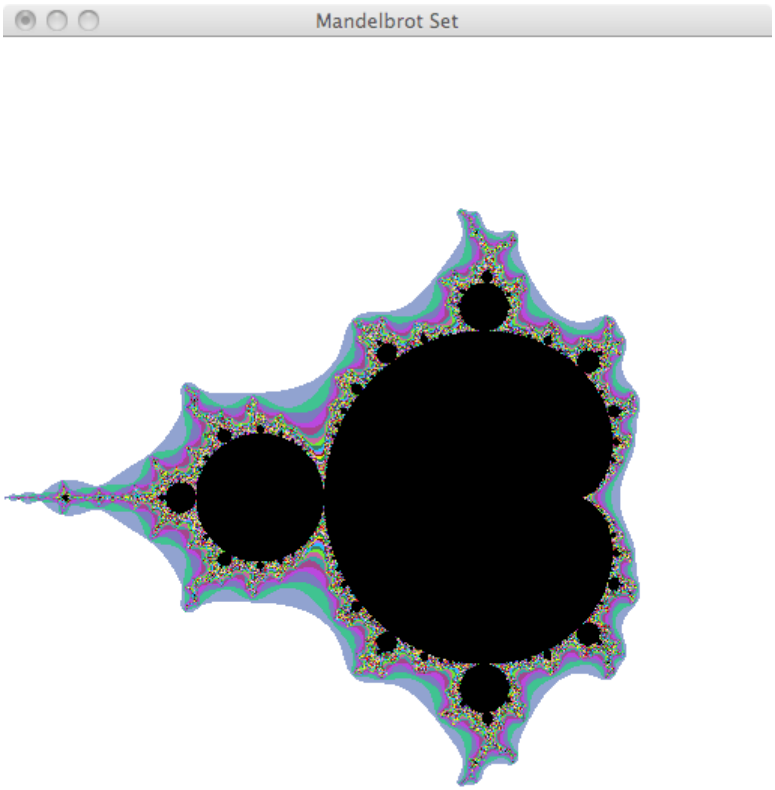
2. If we have iterated 2,000 times and still not found a Z_n with a magnitude greater than 2.0, we can again stop iterating, but this time claim the c *is* in the *Mandelbrot Set*. The value 2000 was chosen arbitrarily but seems to work pretty well for this assignment.

Displaying the *Mandelbrot Set* Start by creating a display window of 512 by 512 pixels. Then compute and display the *Mandelbrot Set*. Unfortunately, it appears in the above discussion of the math to compute the *Mandelbrot Set*, that we have to iterate all possible values of $c \in C$. Again we are lucky that we can limit the possible range of the c value as follows:

$(-2.0, -1.2) < c < (1.0, 1.8)$

This still seems to be an infinite number of possible c values. To again avoid infinite processing, simply select 512 discrete c values in both the real and imaginary ranges above, resulting in 512 * 512 total unique c values. For each c, simply iterate the Z values as shown above. It the c is in the *Mandelbrot Set*, display a black pixel at the appropriate point in the display window. If the point is *not* in the *Mandelbrot Set*(ie you found a $Z_n > 2.0$), display the pixel in a color of your choosing. However, the chosen color must be a function of the number of iterations taken to find that Z will be infinite. For example, if on the 1999^{th} iteration you found that the magnitude of Z was greater than 2.0, then the color painted must be the same for all c values that required 1999 iterations. Your result in this case will be similar to that below.

USE 16 separate threads to compute the *Mandelbrot Set*.



Graduate Students Only. Next, enable the mouse clicks and movements in OpenGL and allow the user to select a square region in the displayed *Mandelbrot Set* image. When the region is selected (ie. the mouse button released), recalculate the *Mandelbrot Set* using the minimum and maximum c range based on the selected region. Limit the selected region to be square, not rectangular. Also, again for grad students only, maintain a history of the displayed sets and allow for a keypress of `b` to return to the previous set.

Copying the Project Skeletons

1. Copy the files from the ECE6122 user account using the following command:

   ```
   /usr/bin/rsync -avu /nethome/ECE6122/MBSet .
   ```

   Be sure to notice the period at the end of the above commands.

2. Change your working directory to `MBSet`

   ```
   cd MBSet
   ```

3. Copy the provided `MBSet-skeleton.cc` to `MBSet.cc` as follows:

   ```
   cp MBSet-skeleton.cc MBSet.cc
   ```

4. Build the binaries using the provided Makefile.

5. Run your program normally:

   `./MBSet`

   This should open an X-window on your laptop with the proper Mandelbrot set display.

Turning in your Project. Use the normal `turnin-ece6122` procedure as always.