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.

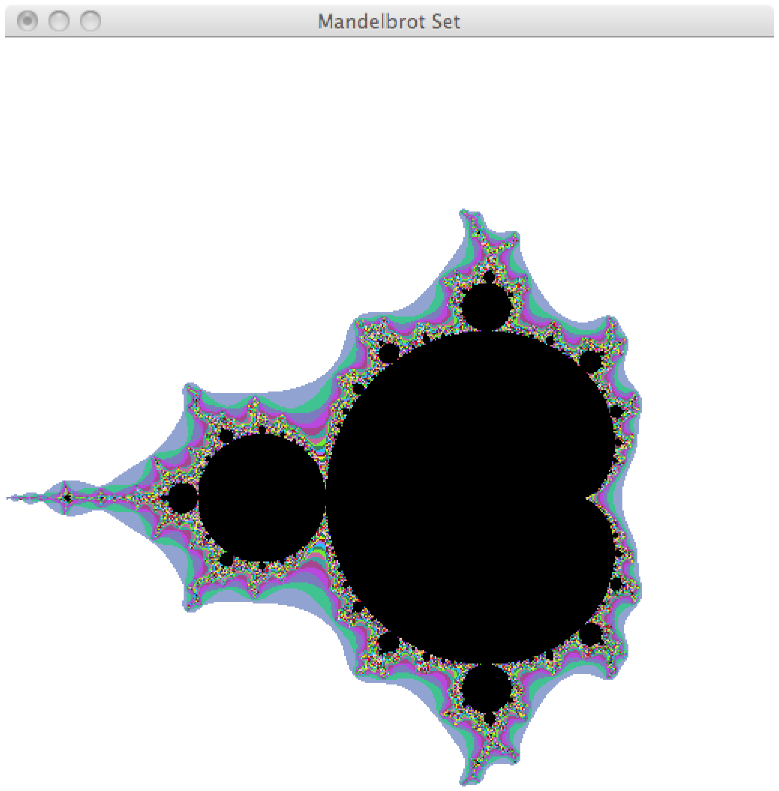
The Mandelbrot Set The *Mandelbrot Set* is defined as the set of points in the complex plane that satisfy
$M = \{c \in C | \lim_{n\to\infty} Z_n \neq \infty\}$
where
M is the set of all complex numbers **in** the *Mandelbrot Set*.
C is the set of all complex numbers in the complex plane,
$Z_0 = c$,
$Z_{n+1} = Z_n^2 + c$
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.

USing CUDA You may want to use CUDA and GPU's for this project to add a skillset to your resume; I will grade the CUDA submissions for a small number of extra credit points. Be aware that there are not very many jinx systems with GPU's so you might have trouble getting access to one.

1. Log in to the cluster using `jinx-login.cc.gatech.edu`.
2. Use the `qsub` command to gain access to one of the jinx systems with attached GPU card

   ```
   qsub -I -q class -l nodes=1:gpu
   ```
3. After a hopefully short wait you will get access to one of the GPU-Enabled systems, and you can edit and compile your program as needed. Entering `exit` will exit the GPU node back to jinx-login.
4. There is a Makefile and skeleton code in /nethome/ECE6122/MBSet-Cuda that you can copy as usual.

Turning in your Project. Use the normal `turnin-ece6122` procedure as always.
If you implemented a CUDA version then turn in two different solutions. First the MBSet as above.
In addition also turn in the CUDA version from a directory called:
MBSet-Cuda
You will have to create this directory and put all MBSet code there including the CUDA code.