

# EECS201000

## Introduction to Programming Laboratory

### Homework 2: Mandelbrot Set

Due: July 17, 2017, 8AM

## 1 GOALSCHE

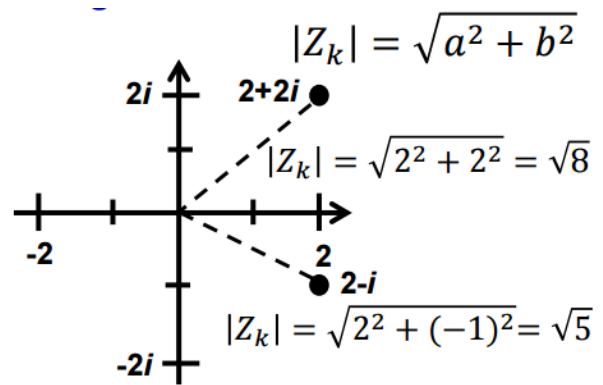
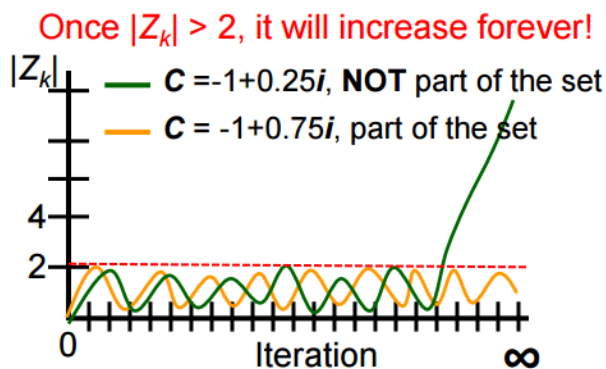
This assignment aims to get you familiar with **hybrid parallelism** (MPI + OpenMP), and **load balancing** techniques by implementing the Mandelbrot Set problem.

## 2 PROBLEM DESCRIPTION

The Mandelbrot Set is a set of complex numbers that are quasi-stable when computed by iterating the function:

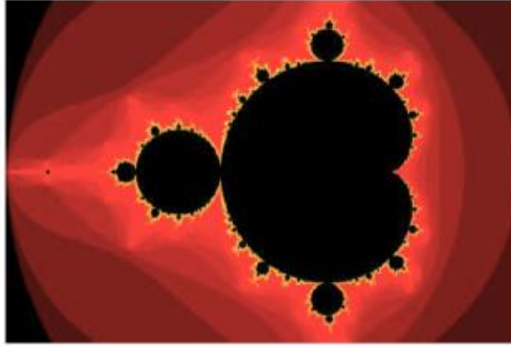
$$Z_0 = C, Z_{k+1} = Z_k^2 + C$$

- $C$  is some complex number:  $C = a + bi$
- $Z_{k+1}$  is the  $(k + 1)_{th}$  iteration of the complex number
- if  $|Z_k| \leq 2$  for any  $k$ ,  $C$  belongs to Mandelbrot Set



What exact is Mandelbrot Set?

- It is fractal: An object that display self-similarity at various scale; Magnifying a fractal reveals small-scale details similar to the larger-scale characteristics
- After plotting the Mandelbrot Set determined by thousands of iterations:



For more information, please refer to lecture notes.

### 3 INPUT / OUTPUT FORMAT

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1. The value of the points is between 0-255
2. Your program accepts 8 input parameters:

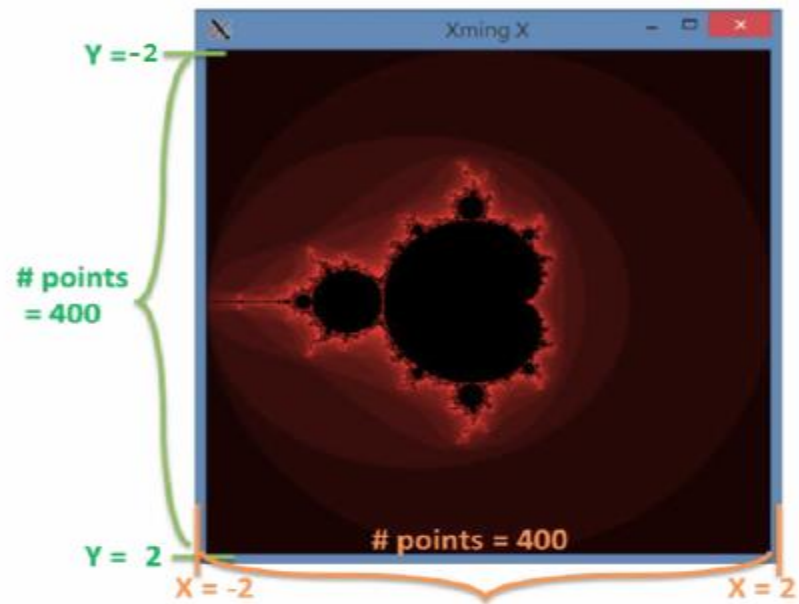
`./executable ${1} ${2} ${3} ${4} ${5} ${6} ${7} ${8}`

- `${1}`: number of threads per process [int, between 1 ~ 12]
- `${2}`: left range of real-axis [double, between -10 ~ 10]
- `${3}`: right range of real-axis [double, between -10 ~ 10]
- `${4}`: lower range of imag-axis [double, between -10 ~ 10]
- `${5}`: upper range of imag-axis [double, between -10 ~ 10]
- `${6}`: number of points in x-axis [int, between 200 ~ 4000]
- `${7}`: number of points in y-axis [int, between 200 ~ 4000]
- `${8}`: output filename

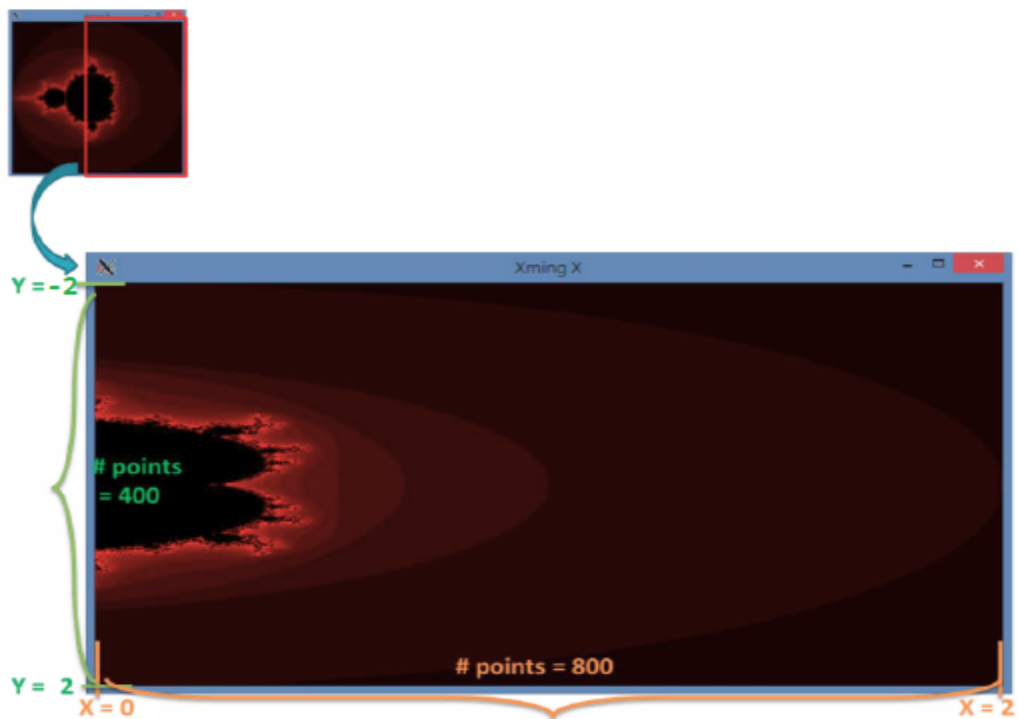
3. Output:

- The output file lists the value of each point in the plot from right to left and top to bottom.
- You may visualize the output file through X-window by running the script located at `/home/ipl2017/shared/hw2` with your output filename as the only input argument.

Example 1: `mpirun -n 2 ./HomeWork2 4 -2 2 -2 2 400 400 output_file`



Example 2: `mpirun -n 2 ./HomeWork2 4 0 2 -2 2 800 400 output_file`



## 4 OPTIMIZATION HINTS

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- Use **dynamic** load balancing algorithm
- Minimize communication overhead

## 5 GRADING

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1. **Correctness** (60%)
  - During the demo time, TA will use a lot of different combinations of parameters to test your program, and check whether the data values in your output file are correct.
2. **Performance** (30%)
  - Performance is measured by the program execution time when X-window is disabled.
  - Points are giving according to the performance ranking of your program among all the students.
3. **Demo** (10%)
  - Each student is given 5 minutes to explain your implementation followed by some questions from TA.
  - Not debugging or code modification is allowed during the demo.
  - Points are given according to your understanding and explanation of your code, and your answers of the TA questions.
4. **Late Policy**
  - 80% within 3 days, 60% afterwards.

## 6 SUBMISSION

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- Please upload the following files to **homework/HW2** directory on **apollo31** under your home directory before **7/17(Mon) 8:00AM: (The folder will be locked after deadline)**

i 、 **HW2\_{student-ID}.c**

ii 、 **Makefile**

Make sure your compile script can execute correctly and your code has no compile error in the **uploaded folder**

## 7 REMINDER

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1. We provide a sequential version of Mandelbrot Set under `/home/ipl2017/shared/hw2` for your reference.

2. Compilation:

```
mpicc HW2_{student-ID}.c -o HW2_{student-ID} -fopenmp
```

**We provide a sample makefile under `/home/ipl2017/shared/hw2` for your reference, please change ID of `MS_s105062553.c` in makefile to your ID.**

3. Since we have limited resources, please **start your work ASAP**. Do not leave it until the last day!
4. **Do NOT try to abuse the computing nodes by ssh to them directly**. If we ever find you doing that, you will get 0 point for the homework!
5. **0 will be given to cheater** (even copying code from the Internet), but discussion on code is encouraged.
6. Asking questions through iLMS is welcomed!