Fractals

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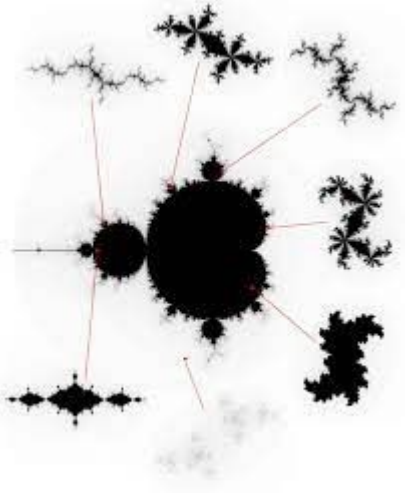
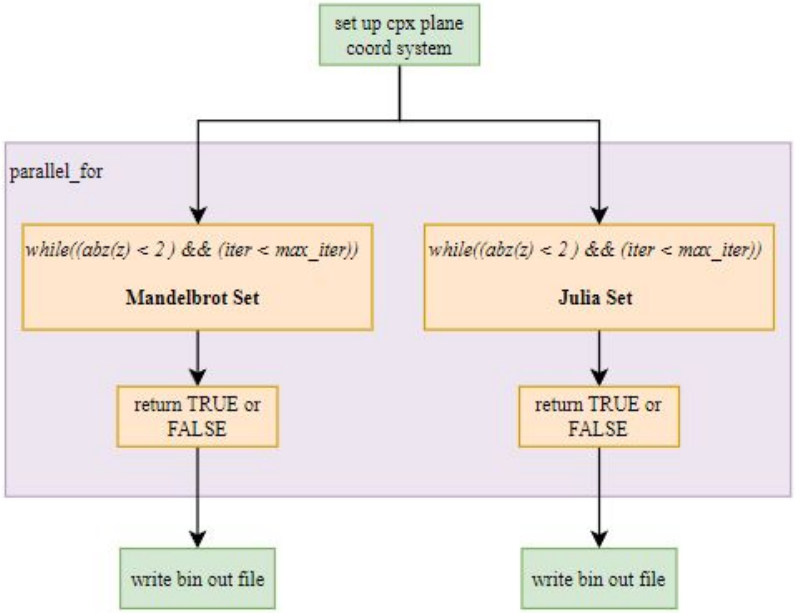
Mandelbrot & Julia Sets

- **Equation:** `f(z) = z^2 + c.`
- 2D sets defined in cpx plane where `c` is cpx num that does not diverge into infinity (i.e. greater than 2). Recursion is applied throughout desired cpx cords (Re, Im)
- **Mandelbrot:** starts at iter of z at 0;
  `c` is changing (i.e. cpx cord)
- **Julia:** starts at iter of z at 1st cpx cord;
  `c` is constant throughout all cpx cords

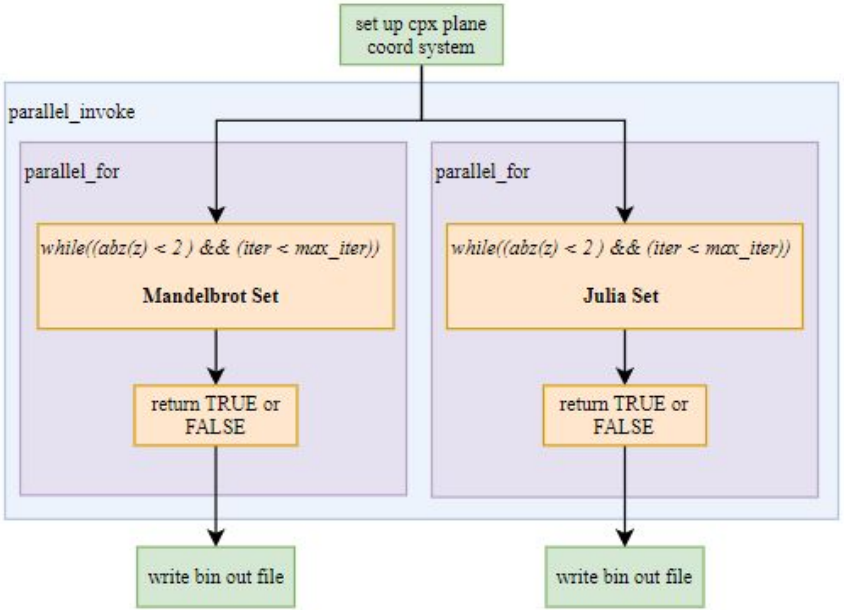


Parallelization Strategies

- PAR 1 - `parallel_for`



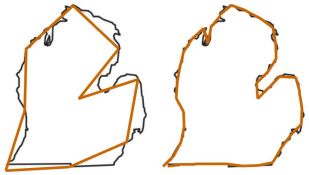
- PAR 2 - `parallel_invoke` & `parallel_for`



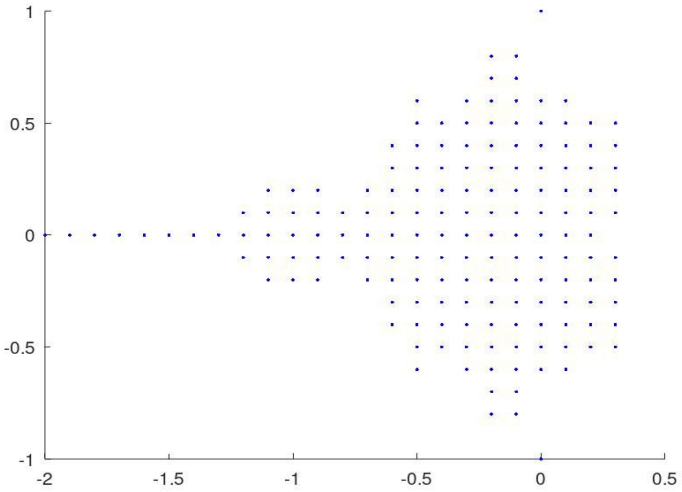
Initial Setup

RE_NUM_MIN/MAX_CORD: (-2, 1), IM_NUM_MIN/MAX_CORD: (-1, 1)			
step size	RE_RANGE_CNT	IM_RANGE_CNT	TOTAL_RANGE
1	4	3	12
0.5	7	5	35
0.25	13	9	117
0.1	31	21	651
0.01	301	201	60501
0.001	3001	2001	6005001

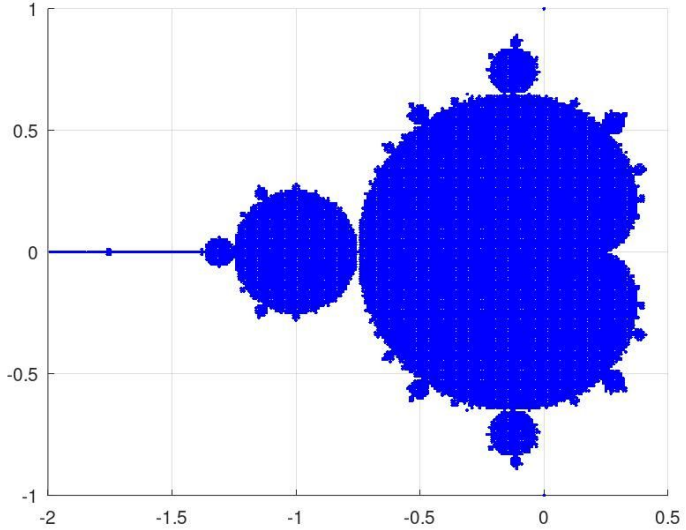
Fractal Dimensions



- *Mandelbrot Set*

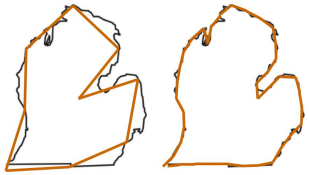


Step: 0.1 ➡ **RANGE:** 651

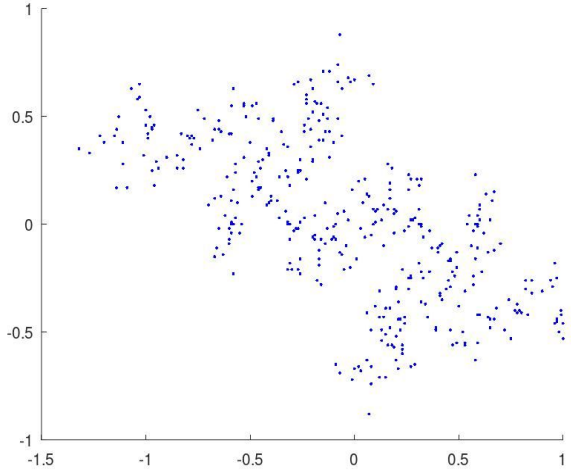


Step: 0.01 ➡ **RANGE:** 60501

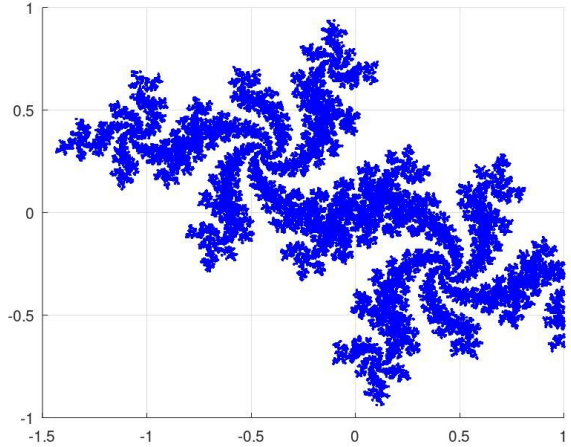
Fractal Dimensions



- *Julia Set (`c` being `-0.54 + 0.54 * I`)*



Step: 0.01 ➡ **RANGE:** 60501

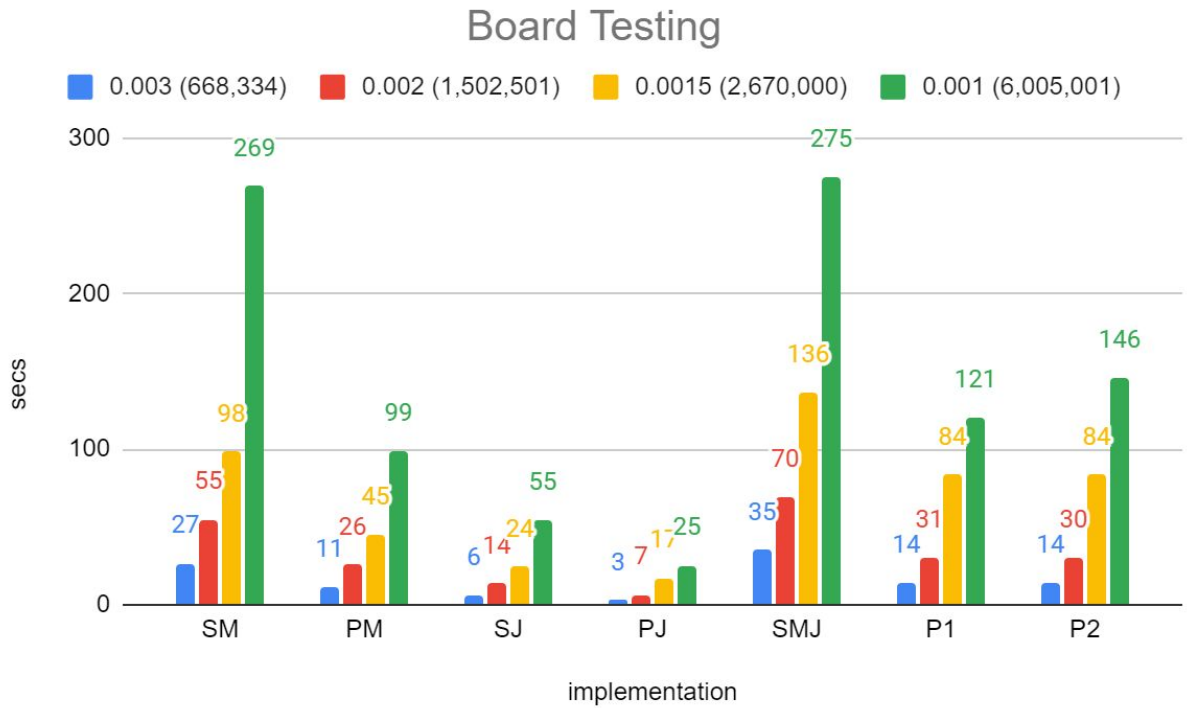


Step: 0.001 ➡ **RANGE:** 6005001

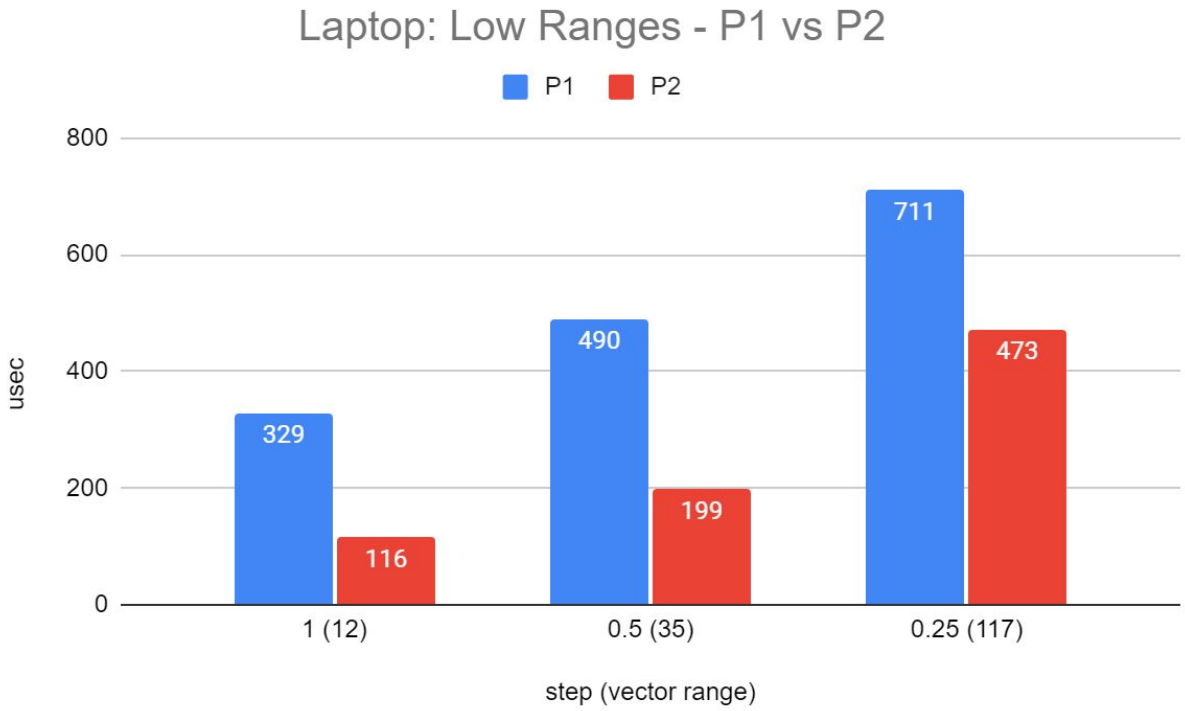
Results

```
buddy@vbox:~/SW/Final_Project/Fractals_V2$ ./fractals 1
step = 1
vector size = 12

DEBUG STATEMENTS
total_seq_m = 5
total_seq_j = 0
total_par_1_m = 5
total_par_1_j = 0
total_par_2_m = 5
total_par_2_j = 0

RESULTS
        SM      P1M     P2M     SJ      P1J     P2J
z[0]:   0       0       0       0       0       0
z[1]:   1       1       1       0       0       0
z[2]:   0       0       0       0       0       0
z[3]:   0       0       0       0       0       0
z[4]:   1       1       1       0       0       0
z[5]:   0       0       0       0       0       0
z[6]:   1       1       1       0       0       0
z[7]:   1       1       1       0       0       0
z[8]:   1       1       1       0       0       0
z[9]:   0       0       0       0       0       0
z[10]:  0       0       0       0       0       0
z[11]:  0       0       0       0       0       0
```

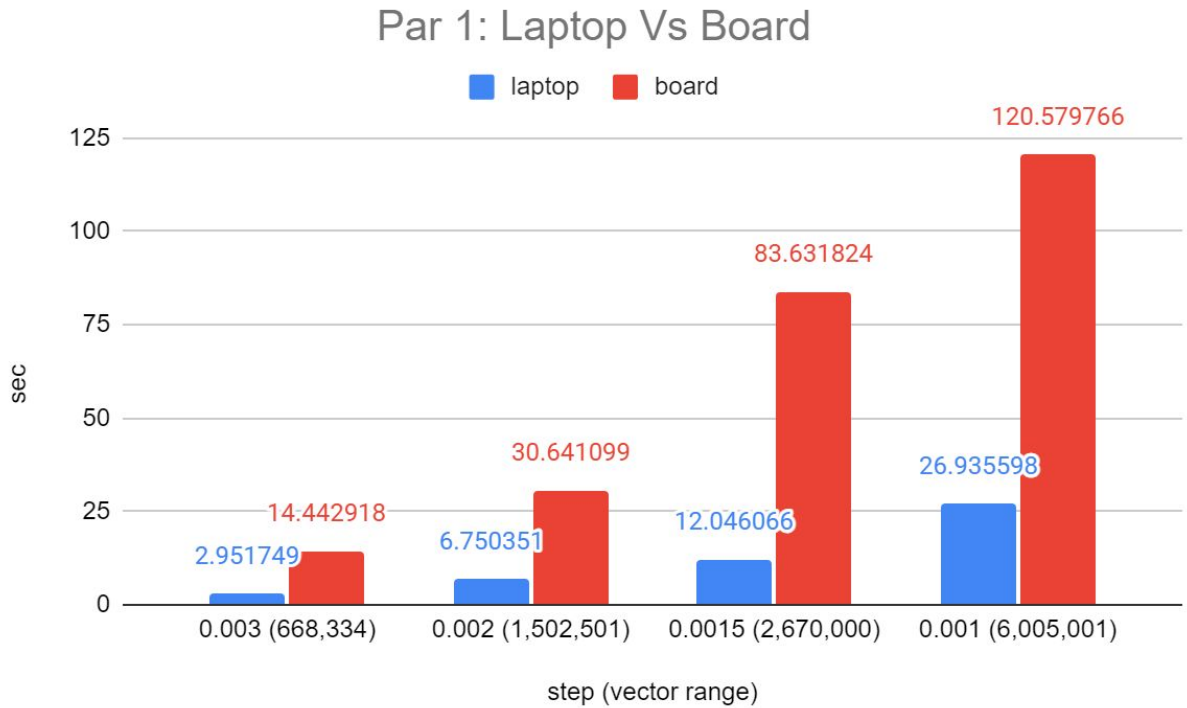
Test: All Implementations



Test: P1 vs P2 Board - Low Ranges



Test: Par 1 - Laptop vs Board



Challenges

- Cpx cords being set, i.e. at cord would be missing.
  Solution: create a vector to send to hold cords.

- Complex number compatibility issues between c & c++.
  Solution: c - `double complex Re + Im * I`
  c++ - `complex<double>(Re, Im)`

- At high step ranges, 0 would be a very small number
  Solution: not problem with code but machine

- Race conditions for TBB
  Solution: create vectors instead of variables.

References

1. Oakland University picture: slide 1
   https://www.commonapp.org/explore/oakland-university
2. Mandelbrot & Julia Set picture: slide 2
   https://paulbourke.net/fractals/juliaset/