Project III: Parallel Processing and Multi-Threading

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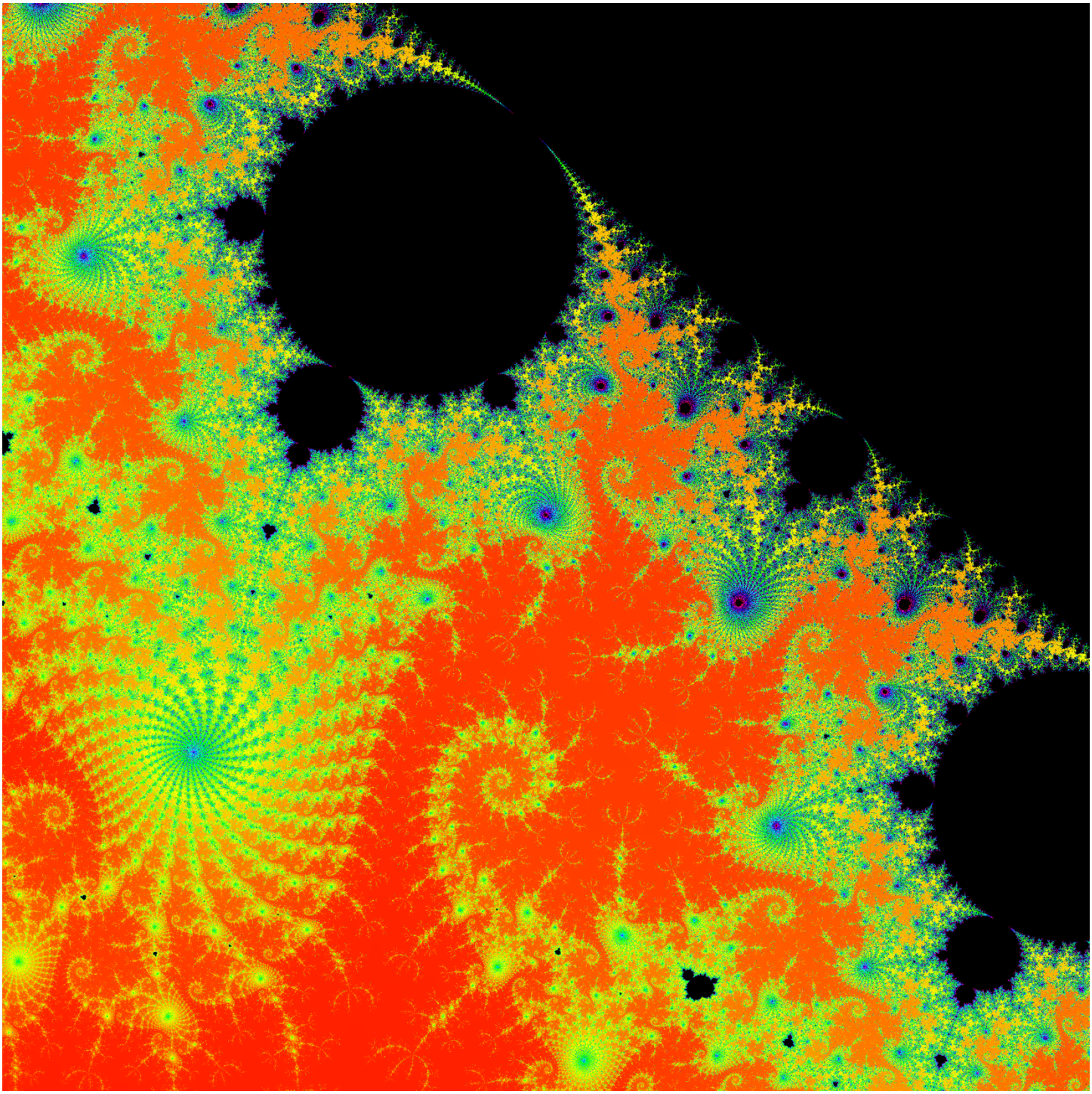


Figure 1 → ./mandel -x -0.5397949000000 -y -0.6095890009734 -s 0.00005 -m 15000 -n 250 -W 2440 -H 2440

Evaluation

- In your own words, briefly explain the purpose of the experiments and the experimental setup. Be sure to clearly state on which machine you ran the experiments, and exactly what your command line arguments were, so that we can reproduce your work in case of any confusion.

    - In this project, we are delving into the realms of parallelism using processes and threads to optimize the performance while generating Mandelbrot set images. The setup provided serves as a playground to experiment with both coarse-grained and fine-grained parallelism by modifying the 'mandel.c' code to implement multithreading. By measuring the execution time across different thread counts, we aim to evaluate how parallel processing can significantly cut down computation time in such a CPU-intensive task. All the experiments were performed in a 2021 "14" M1 MacBook Pro.
      The image I found interesting is mandel -x -0.5397949000000 -y -0.6095890009734 -s 0.0001
      The following is the result of executing → ./mandel -x -0.5397949000000 -y -0.6095890009734 -s 0.0001 -m 3500

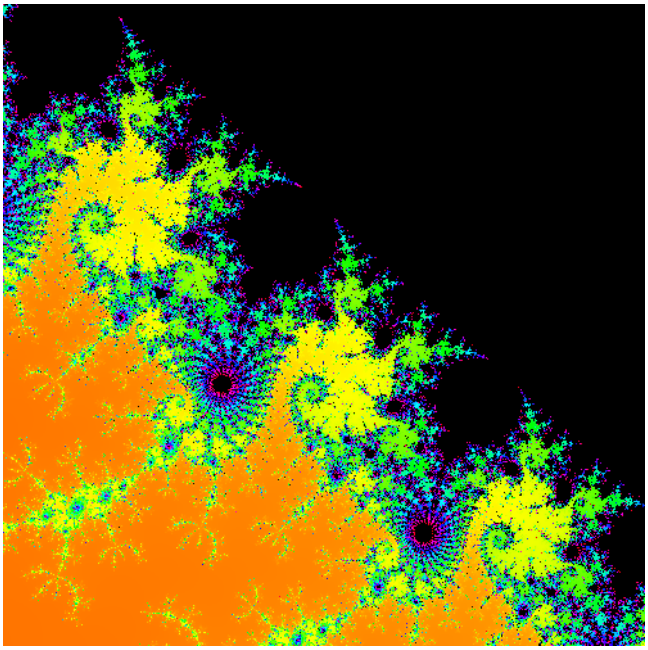


Figure 2 → mandel: x=-0.539795 y=-0.609589 scale=0.000100 max=3500 outfile=mandel.bmp threads=1 Time taken: 5.382914 seconds

- Measure and graph the execution time of mandelmovie for each of 1, 2, 3, 4, 5, and 10 processes running simultaneously. Because each of these will be fairly long running, it will be sufficient to measure each configuration only once. Make sure that you write all of your output files somewhere in /tmp to avoid any timing problems with the network file system.

```
williamduran@Williams-MacBook-Pro source % ./mandelmovie 1
mandel: x=-0.539795 y=-0.609589 scale=2.000000 max=3500 outfile=mandel1.bmp threads=1 Time taken: 1.042887 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.959186 max=3500 outfile=mandel2.bmp threads=1 Time taken: 1.090772 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.918371 max=3500 outfile=mandel3.bmp threads=1 Time taken: 1.136308 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.877557 max=3500 outfile=mandel4.bmp threads=1 Time taken: 1.198348 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.836743 max=3500 outfile=mandel5.bmp threads=1 Time taken: 1.259612 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.795929 max=3500 outfile=mandel6.bmp threads=1 Time taken: 1.345844 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.755114 max=3500 outfile=mandel7.bmp threads=1 Time taken: 1.367978 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.714300 max=3500 outfile=mandel8.bmp threads=1 Time taken: 1.476260 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.673486 max=3500 outfile=mandel9.bmp threads=1 Time taken: 1.584359 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.632671 max=3500 outfile=mandel10.bmp threads=1 Time taken: 1.571187 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.591857 max=3500 outfile=mandel11.bmp threads=1 Time taken: 1.651504 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.551043 max=3500 outfile=mandel12.bmp threads=1 Time taken: 1.733066 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.510229 max=3500 outfile=mandel13.bmp threads=1 Time taken: 1.843124 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.469414 max=3500 outfile=mandel14.bmp threads=1 Time taken: 1.951295 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.428600 max=3500 outfile=mandel15.bmp threads=1 Time taken: 2.042172 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.387786 max=3500 outfile=mandel16.bmp threads=1 Time taken: 2.153612 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.346971 max=3500 outfile=mandel17.bmp threads=1 Time taken: 2.265253 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.306157 max=3500 outfile=mandel18.bmp threads=1 Time taken: 2.409578 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.265343 max=3500 outfile=mandel19.bmp threads=1 Time taken: 2.537511 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.224529 max=3500 outfile=mandel20.bmp threads=1 Time taken: 2.710350 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.183714 max=3500 outfile=mandel21.bmp threads=1 Time taken: 2.837544 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.142900 max=3500 outfile=mandel22.bmp threads=1 Time taken: 2.977447 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.102086 max=3500 outfile=mandel23.bmp threads=1 Time taken: 3.120301 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.061271 max=3500 outfile=mandel24.bmp threads=1 Time taken: 3.275115 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.020457 max=3500 outfile=mandel25.bmp threads=1 Time taken: 3.440075 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.979643 max=3500 outfile=mandel26.bmp threads=1 Time taken: 3.621814 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.938829 max=3500 outfile=mandel27.bmp threads=1 Time taken: 3.769443 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.898014 max=3500 outfile=mandel28.bmp threads=1 Time taken: 4.031581 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.857200 max=3500 outfile=mandel29.bmp threads=1 Time taken: 4.108084 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.816386 max=3500 outfile=mandel30.bmp threads=1 Time taken: 4.220122 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.775571 max=3500 outfile=mandel31.bmp threads=1 Time taken: 4.209266 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.734757 max=3500 outfile=mandel32.bmp threads=1 Time taken: 4.240553 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.693943 max=3500 outfile=mandel33.bmp threads=1 Time taken: 4.256248 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.653129 max=3500 outfile=mandel34.bmp threads=1 Time taken: 4.235112 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.612314 max=3500 outfile=mandel35.bmp threads=1 Time taken: 4.194723 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.571500 max=3500 outfile=mandel36.bmp threads=1 Time taken: 4.123390 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.530686 max=3500 outfile=mandel37.bmp threads=1 Time taken: 4.070194 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.489871 max=3500 outfile=mandel38.bmp threads=1 Time taken: 4.017107 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.449057 max=3500 outfile=mandel39.bmp threads=1 Time taken: 3.812085 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.408243 max=3500 outfile=mandel40.bmp threads=1 Time taken: 3.591259 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.367429 max=3500 outfile=mandel41.bmp threads=1 Time taken: 3.411692 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.326614 max=3500 outfile=mandel42.bmp threads=1 Time taken: 3.240635 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.285800 max=3500 outfile=mandel43.bmp threads=1 Time taken: 3.106792 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.244986 max=3500 outfile=mandel44.bmp threads=1 Time taken: 2.951995 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.204171 max=3500 outfile=mandel45.bmp threads=1 Time taken: 2.788842 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.163357 max=3500 outfile=mandel46.bmp threads=1 Time taken: 2.377382 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.122543 max=3500 outfile=mandel47.bmp threads=1 Time taken: 2.067352 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.081729 max=3500 outfile=mandel48.bmp threads=1 Time taken: 2.350335 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.040914 max=3500 outfile=mandel49.bmp threads=1 Time taken: 2.587405 seconds
number of processes: 1 , time taken: 136.198664
williamduran@Williams-MacBook-Pro source % mandel: x=-0.539795 y=-0.609589 scale=0.000100 max=3500 outfile=mandel50.bmp threads=1 Time taken: 6.798423 seconds
```

Figure 3 → ./mandelmovie 1

```
williamduran@Williams-MacBook-Pro source % ./mandelmovie 2
mandel: x=-0.539795 y=-0.609589 scale=2.000000 max=3500 outfile=mandel1.bmp threads=1 Time taken: 1.045366 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.959186 max=3500 outfile=mandel2.bmp threads=1 Time taken: 1.087565 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.918371 max=3500 outfile=mandel3.bmp threads=1 Time taken: 1.149622 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.877557 max=3500 outfile=mandel4.bmp threads=1 Time taken: 1.196603 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.836743 max=3500 outfile=mandel5.bmp threads=1 Time taken: 1.244650 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.795929 max=3500 outfile=mandel6.bmp threads=1 Time taken: 1.302226 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.755114 max=3500 outfile=mandel7.bmp threads=1 Time taken: 1.361141 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.714300 max=3500 outfile=mandel8.bmp threads=1 Time taken: 1.424395 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.673486 max=3500 outfile=mandel9.bmp threads=1 Time taken: 1.496407 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.632671 max=3500 outfile=mandel10.bmp threads=1 Time taken: 1.571186 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.591857 max=3500 outfile=mandel11.bmp threads=1 Time taken: 1.651619 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.551043 max=3500 outfile=mandel12.bmp threads=1 Time taken: 1.736439 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.510229 max=3500 outfile=mandel13.bmp threads=1 Time taken: 1.831087 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.469414 max=3500 outfile=mandel14.bmp threads=1 Time taken: 1.930541 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.428600 max=3500 outfile=mandel15.bmp threads=1 Time taken: 2.167232 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.387786 max=3500 outfile=mandel16.bmp threads=1 Time taken: 2.270856 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.346971 max=3500 outfile=mandel17.bmp threads=1 Time taken: 2.283367 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.306157 max=3500 outfile=mandel18.bmp threads=1 Time taken: 2.410986 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.265343 max=3500 outfile=mandel19.bmp threads=1 Time taken: 2.562216 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.224529 max=3500 outfile=mandel20.bmp threads=1 Time taken: 2.704157 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.183714 max=3500 outfile=mandel21.bmp threads=1 Time taken: 2.803639 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.142900 max=3500 outfile=mandel22.bmp threads=1 Time taken: 2.936934 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.102086 max=3500 outfile=mandel23.bmp threads=1 Time taken: 3.083927 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.061271 max=3500 outfile=mandel24.bmp threads=1 Time taken: 3.241651 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.020457 max=3500 outfile=mandel25.bmp threads=1 Time taken: 3.403389 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.979643 max=3500 outfile=mandel26.bmp threads=1 Time taken: 3.580493 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.938829 max=3500 outfile=mandel27.bmp threads=1 Time taken: 3.800431 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.898014 max=3500 outfile=mandel28.bmp threads=1 Time taken: 3.975549 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.857200 max=3500 outfile=mandel29.bmp threads=1 Time taken: 4.077949 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.816386 max=3500 outfile=mandel30.bmp threads=1 Time taken: 4.169861 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.775571 max=3500 outfile=mandel31.bmp threads=1 Time taken: 4.249242 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.734757 max=3500 outfile=mandel32.bmp threads=1 Time taken: 4.276070 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.653129 max=3500 outfile=mandel34.bmp threads=1 Time taken: 4.276845 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.693943 max=3500 outfile=mandel33.bmp threads=1 Time taken: 4.300408 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.571500 max=3500 outfile=mandel36.bmp threads=1 Time taken: 4.152551 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.612314 max=3500 outfile=mandel35.bmp threads=1 Time taken: 4.229633 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.489871 max=3500 outfile=mandel38.bmp threads=1 Time taken: 3.953099 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.530686 max=3500 outfile=mandel37.bmp threads=1 Time taken: 4.059445 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.408243 max=3500 outfile=mandel40.bmp threads=1 Time taken: 3.587889 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.449057 max=3500 outfile=mandel39.bmp threads=1 Time taken: 3.804968 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.326614 max=3500 outfile=mandel42.bmp threads=1 Time taken: 3.212624 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.367429 max=3500 outfile=mandel41.bmp threads=1 Time taken: 3.385309 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.244986 max=3500 outfile=mandel44.bmp threads=1 Time taken: 2.953716 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.285800 max=3500 outfile=mandel43.bmp threads=1 Time taken: 3.101190 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.163357 max=3500 outfile=mandel46.bmp threads=1 Time taken: 2.376375 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.204171 max=3500 outfile=mandel45.bmp threads=1 Time taken: 2.792780 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.122543 max=3500 outfile=mandel47.bmp threads=1 Time taken: 2.066252 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.081729 max=3500 outfile=mandel48.bmp threads=1 Time taken: 2.347425 seconds
number of processes: 2 , time taken: 68.205257
williamduran@Williams-MacBook-Pro source % mandel: x=-0.539795 y=-0.609589 scale=0.040914 max=3500 outfile=mandel49.bmp threads=1 Time taken: 2.593666 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.000100 max=3500 outfile=mandel50.bmp threads=1 Time taken: 6.836291 seconds
```

Figure 4 → ./mandelmovie 2

```
williamduran@Williams-MacBook-Pro source % ./mandelmovie 3
mandel: x=-0.539795 y=-0.609589 scale=2.000000 max=3500 outfile=mandel1.bmp threads=1 Time taken: 1.045552 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.959186 max=3500 outfile=mandel2.bmp threads=1 Time taken: 1.088268 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.918371 max=3500 outfile=mandel3.bmp threads=1 Time taken: 1.134887 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.877557 max=3500 outfile=mandel4.bmp threads=1 Time taken: 1.219748 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.836743 max=3500 outfile=mandel5.bmp threads=1 Time taken: 1.272926 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.795929 max=3500 outfile=mandel6.bmp threads=1 Time taken: 1.326415 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.755114 max=3500 outfile=mandel7.bmp threads=1 Time taken: 1.366080 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.714300 max=3500 outfile=mandel8.bmp threads=1 Time taken: 1.433600 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.673486 max=3500 outfile=mandel9.bmp threads=1 Time taken: 1.502289 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.632671 max=3500 outfile=mandel10.bmp threads=1 Time taken: 1.623565 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.591857 max=3500 outfile=mandel11.bmp threads=1 Time taken: 1.700191 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.551043 max=3500 outfile=mandel12.bmp threads=1 Time taken: 1.796215 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.510229 max=3500 outfile=mandel13.bmp threads=1 Time taken: 1.843973 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.469414 max=3500 outfile=mandel14.bmp threads=1 Time taken: 1.943070 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.428600 max=3500 outfile=mandel15.bmp threads=1 Time taken: 2.052322 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.387786 max=3500 outfile=mandel16.bmp threads=1 Time taken: 2.133472 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.346971 max=3500 outfile=mandel17.bmp threads=1 Time taken: 2.249304 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.306157 max=3500 outfile=mandel18.bmp threads=1 Time taken: 2.379042 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.265343 max=3500 outfile=mandel19.bmp threads=1 Time taken: 2.522744 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.224529 max=3500 outfile=mandel20.bmp threads=1 Time taken: 2.670424 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.183714 max=3500 outfile=mandel21.bmp threads=1 Time taken: 2.809369 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.142900 max=3500 outfile=mandel22.bmp threads=1 Time taken: 2.983577 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.102086 max=3500 outfile=mandel23.bmp threads=1 Time taken: 3.125754 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.061271 max=3500 outfile=mandel24.bmp threads=1 Time taken: 3.284072 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.020457 max=3500 outfile=mandel25.bmp threads=1 Time taken: 3.515384 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.979643 max=3500 outfile=mandel26.bmp threads=1 Time taken: 3.716152 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.938829 max=3500 outfile=mandel27.bmp threads=1 Time taken: 3.878639 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.898014 max=3500 outfile=mandel28.bmp threads=1 Time taken: 3.954524 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.857200 max=3500 outfile=mandel29.bmp threads=1 Time taken: 4.091084 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.816386 max=3500 outfile=mandel30.bmp threads=1 Time taken: 4.174505 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.775571 max=3500 outfile=mandel31.bmp threads=1 Time taken: 4.193435 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.734757 max=3500 outfile=mandel32.bmp threads=1 Time taken: 4.227857 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.693943 max=3500 outfile=mandel33.bmp threads=1 Time taken: 4.250734 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.571500 max=3500 outfile=mandel36.bmp threads=1 Time taken: 4.124277 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.612314 max=3500 outfile=mandel35.bmp threads=1 Time taken: 4.187428 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.653129 max=3500 outfile=mandel34.bmp threads=1 Time taken: 4.235603 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.449057 max=3500 outfile=mandel39.bmp threads=1 Time taken: 3.784187 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.489871 max=3500 outfile=mandel38.bmp threads=1 Time taken: 3.952108 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.530686 max=3500 outfile=mandel37.bmp threads=1 Time taken: 4.051452 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.326614 max=3500 outfile=mandel42.bmp threads=1 Time taken: 3.234167 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.367429 max=3500 outfile=mandel41.bmp threads=1 Time taken: 3.400133 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.408243 max=3500 outfile=mandel40.bmp threads=1 Time taken: 3.599085 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.204171 max=3500 outfile=mandel45.bmp threads=1 Time taken: 2.847690 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.244986 max=3500 outfile=mandel44.bmp threads=1 Time taken: 3.013306 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.285800 max=3500 outfile=mandel43.bmp threads=1 Time taken: 3.140833 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.122543 max=3500 outfile=mandel47.bmp threads=1 Time taken: 2.143617 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.081729 max=3500 outfile=mandel48.bmp threads=1 Time taken: 2.429243 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.163357 max=3500 outfile=mandel46.bmp threads=1 Time taken: 2.460623 seconds
number of processes: 3 , time taken: 46.336647
williamduran@Williams-MacBook-Pro source % mandel: x=-0.539795 y=-0.609589 scale=0.040914 max=3500 outfile=mandel49.bmp threads=1 Time taken: 2.642832 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.000100 max=3500 outfile=mandel50.bmp threads=1 Time taken: 6.885970 seconds
```

Figure 5 → ./mandelmovie 3

```
williamduran@Williams-MacBook-Pro source % ./mandelmovie 4
mandel: x=-0.539795 y=-0.609589 scale=2.000000 max=3500 outfile=mandel1.bmp threads=1 Time taken: 1.045131 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.959186 max=3500 outfile=mandel2.bmp threads=1 Time taken: 1.088398 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.918371 max=3500 outfile=mandel3.bmp threads=1 Time taken: 1.134396 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.877557 max=3500 outfile=mandel4.bmp threads=1 Time taken: 1.182972 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.836743 max=3500 outfile=mandel5.bmp threads=1 Time taken: 1.294919 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.795929 max=3500 outfile=mandel6.bmp threads=1 Time taken: 1.335827 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.755114 max=3500 outfile=mandel7.bmp threads=1 Time taken: 1.406079 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.714300 max=3500 outfile=mandel8.bmp threads=1 Time taken: 1.465691 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.673486 max=3500 outfile=mandel9.bmp threads=1 Time taken: 1.486462 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.632671 max=3500 outfile=mandel10.bmp threads=1 Time taken: 1.559712 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.591857 max=3500 outfile=mandel11.bmp threads=1 Time taken: 1.641546 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.551043 max=3500 outfile=mandel12.bmp threads=1 Time taken: 1.725815 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.510229 max=3500 outfile=mandel13.bmp threads=1 Time taken: 1.820849 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.469414 max=3500 outfile=mandel14.bmp threads=1 Time taken: 1.919319 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.428600 max=3500 outfile=mandel15.bmp threads=1 Time taken: 2.026420 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.387786 max=3500 outfile=mandel16.bmp threads=1 Time taken: 2.135371 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.346971 max=3500 outfile=mandel17.bmp threads=1 Time taken: 2.243124 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.306157 max=3500 outfile=mandel18.bmp threads=1 Time taken: 2.373065 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.265343 max=3500 outfile=mandel19.bmp threads=1 Time taken: 2.517611 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.224529 max=3500 outfile=mandel20.bmp threads=1 Time taken: 2.662962 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.183714 max=3500 outfile=mandel21.bmp threads=1 Time taken: 2.800443 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.142900 max=3500 outfile=mandel22.bmp threads=1 Time taken: 2.935519 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.102086 max=3500 outfile=mandel23.bmp threads=1 Time taken: 3.080096 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.061271 max=3500 outfile=mandel24.bmp threads=1 Time taken: 3.237646 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.020457 max=3500 outfile=mandel25.bmp threads=1 Time taken: 3.399897 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.979643 max=3500 outfile=mandel26.bmp threads=1 Time taken: 3.576678 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.938829 max=3500 outfile=mandel27.bmp threads=1 Time taken: 3.757596 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.898014 max=3500 outfile=mandel28.bmp threads=1 Time taken: 3.928963 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.857200 max=3500 outfile=mandel29.bmp threads=1 Time taken: 4.062820 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.816386 max=3500 outfile=mandel30.bmp threads=1 Time taken: 4.146109 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.775571 max=3500 outfile=mandel31.bmp threads=1 Time taken: 4.194193 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.734757 max=3500 outfile=mandel32.bmp threads=1 Time taken: 4.230052 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.571500 max=3500 outfile=mandel36.bmp threads=1 Time taken: 4.115900 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.612314 max=3500 outfile=mandel35.bmp threads=1 Time taken: 4.185225 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.653129 max=3500 outfile=mandel34.bmp threads=1 Time taken: 4.226280 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.693943 max=3500 outfile=mandel33.bmp threads=1 Time taken: 4.251141 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.408243 max=3500 outfile=mandel40.bmp threads=1 Time taken: 3.567174 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.449057 max=3500 outfile=mandel39.bmp threads=1 Time taken: 3.787444 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.489871 max=3500 outfile=mandel38.bmp threads=1 Time taken: 3.950469 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.530686 max=3500 outfile=mandel37.bmp threads=1 Time taken: 4.052786 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.244986 max=3500 outfile=mandel44.bmp threads=1 Time taken: 2.955514 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.285800 max=3500 outfile=mandel43.bmp threads=1 Time taken: 3.103139 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.326614 max=3500 outfile=mandel42.bmp threads=1 Time taken: 3.208480 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.367429 max=3500 outfile=mandel41.bmp threads=1 Time taken: 3.377834 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.122543 max=3500 outfile=mandel47.bmp threads=1 Time taken: 2.066481 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.081729 max=3500 outfile=mandel48.bmp threads=1 Time taken: 2.347178 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.163357 max=3500 outfile=mandel46.bmp threads=1 Time taken: 2.376509 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.204171 max=3500 outfile=mandel45.bmp threads=1 Time taken: 2.786301 seconds
number of processes: 4 , time taken: 35.239620
williamduran@Williams-MacBook-Pro source % mandel: x=-0.539795 y=-0.609589 scale=0.040914 max=3500 outfile=mandel49.bmp threads=1 Time taken: 2.578120 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.000100 max=3500 outfile=mandel50.bmp threads=1 Time taken: 6.781189 seconds
```

Figure 6 → ./mandelmovie 4

```
williamduran@Williams-MacBook-Pro source % ./mandelmovie 5
mandel: x=-0.539795 y=-0.609589 scale=2.000000 max=3500 outfile=mandel1.bmp threads=1 Time taken: 1.084208 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.959186 max=3500 outfile=mandel2.bmp threads=1 Time taken: 1.086485 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.918371 max=3500 outfile=mandel3.bmp threads=1 Time taken: 1.130515 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.877557 max=3500 outfile=mandel4.bmp threads=1 Time taken: 1.223973 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.836743 max=3500 outfile=mandel5.bmp threads=1 Time taken: 1.242846 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.795929 max=3500 outfile=mandel6.bmp threads=1 Time taken: 1.295133 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.755114 max=3500 outfile=mandel7.bmp threads=1 Time taken: 1.345281 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.714300 max=3500 outfile=mandel8.bmp threads=1 Time taken: 1.423492 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.673486 max=3500 outfile=mandel9.bmp threads=1 Time taken: 1.495507 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.632671 max=3500 outfile=mandel10.bmp threads=1 Time taken: 1.563418 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.591857 max=3500 outfile=mandel11.bmp threads=1 Time taken: 1.635582 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.551043 max=3500 outfile=mandel12.bmp threads=1 Time taken: 1.725142 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.510229 max=3500 outfile=mandel13.bmp threads=1 Time taken: 1.816819 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.469414 max=3500 outfile=mandel14.bmp threads=1 Time taken: 1.914466 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.428600 max=3500 outfile=mandel15.bmp threads=1 Time taken: 2.022125 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.387786 max=3500 outfile=mandel16.bmp threads=1 Time taken: 2.128750 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.346971 max=3500 outfile=mandel17.bmp threads=1 Time taken: 2.245117 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.306157 max=3500 outfile=mandel18.bmp threads=1 Time taken: 2.379130 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.265343 max=3500 outfile=mandel19.bmp threads=1 Time taken: 2.521711 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.224529 max=3500 outfile=mandel20.bmp threads=1 Time taken: 2.666576 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.183714 max=3500 outfile=mandel21.bmp threads=1 Time taken: 2.803433 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.142900 max=3500 outfile=mandel22.bmp threads=1 Time taken: 2.939225 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.102086 max=3500 outfile=mandel23.bmp threads=1 Time taken: 3.080721 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.061271 max=3500 outfile=mandel24.bmp threads=1 Time taken: 3.240431 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.020457 max=3500 outfile=mandel25.bmp threads=1 Time taken: 3.401521 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.979643 max=3500 outfile=mandel26.bmp threads=1 Time taken: 3.578374 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.938829 max=3500 outfile=mandel27.bmp threads=1 Time taken: 3.757429 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.898014 max=3500 outfile=mandel28.bmp threads=1 Time taken: 3.931787 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.857200 max=3500 outfile=mandel29.bmp threads=1 Time taken: 4.065633 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.816386 max=3500 outfile=mandel30.bmp threads=1 Time taken: 4.149274 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.612314 max=3500 outfile=mandel35.bmp threads=1 Time taken: 4.185354 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.775571 max=3500 outfile=mandel31.bmp threads=1 Time taken: 4.195451 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.734757 max=3500 outfile=mandel32.bmp threads=1 Time taken: 4.229444 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.653129 max=3500 outfile=mandel34.bmp threads=1 Time taken: 4.230731 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.693943 max=3500 outfile=mandel33.bmp threads=1 Time taken: 4.252480 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.408243 max=3500 outfile=mandel40.bmp threads=1 Time taken: 3.566788 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.449057 max=3500 outfile=mandel39.bmp threads=1 Time taken: 3.785437 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.489871 max=3500 outfile=mandel38.bmp threads=1 Time taken: 3.951758 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.530686 max=3500 outfile=mandel37.bmp threads=1 Time taken: 4.053691 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.571500 max=3500 outfile=mandel36.bmp threads=1 Time taken: 4.121009 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.204171 max=3500 outfile=mandel45.bmp threads=1 Time taken: 2.788183 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.244986 max=3500 outfile=mandel44.bmp threads=1 Time taken: 2.957063 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.285800 max=3500 outfile=mandel43.bmp threads=1 Time taken: 3.102949 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.326614 max=3500 outfile=mandel42.bmp threads=1 Time taken: 3.208352 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.367429 max=3500 outfile=mandel41.bmp threads=1 Time taken: 3.377604 seconds
number of processes: 5 , time taken: 26.971056
williamduran@Williams-MacBook-Pro source % mandel: x=-0.539795 y=-0.609589 scale=0.122543 max=3500 outfile=mandel47.bmp threads=1 Time taken: 2.070427 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.081729 max=3500 outfile=mandel48.bmp threads=1 Time taken: 2.347189 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.163357 max=3500 outfile=mandel46.bmp threads=1 Time taken: 2.377436 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.040914 max=3500 outfile=mandel49.bmp threads=1 Time taken: 2.582702 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.000100 max=3500 outfile=mandel50.bmp threads=1 Time taken: 6.782669 seconds
```

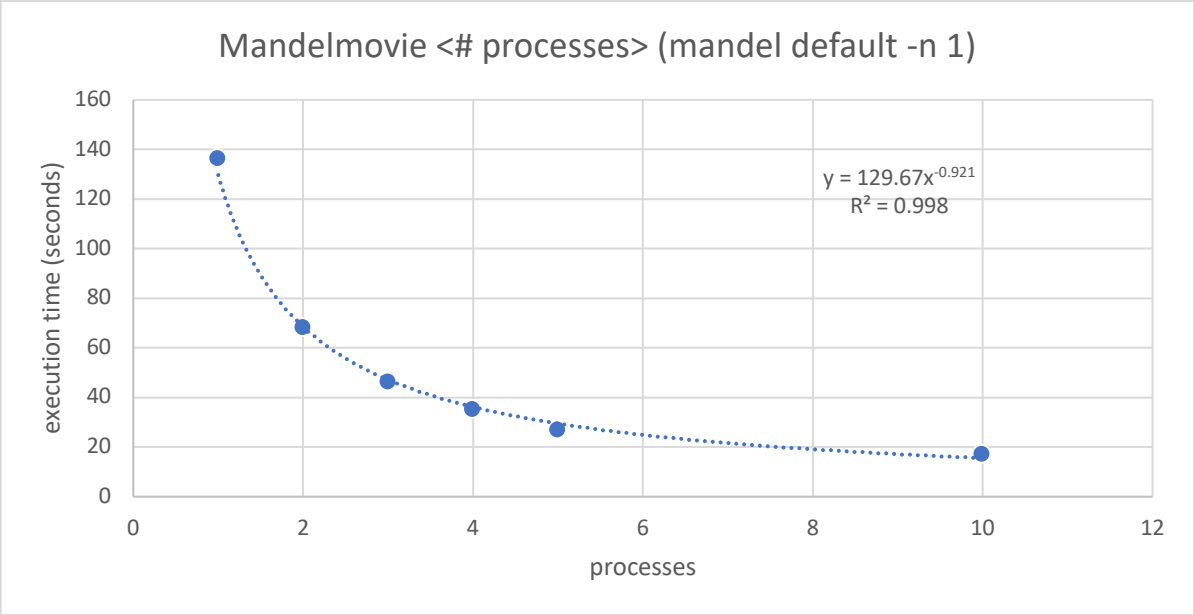
Figure 7 → ./mandelmovie 5

```
williamduran@Williams-MacBook-Pro source % ./mandelmovie 10
mandel: x=-0.539795 y=-0.609589 scale=2.000000 max=3500 outfile=mandel1.bmp threads=1 Time taken: 1.407836 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.959186 max=3500 outfile=mandel2.bmp threads=1 Time taken: 1.451700 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.918371 max=3500 outfile=mandel3.bmp threads=1 Time taken: 1.508494 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.877557 max=3500 outfile=mandel4.bmp threads=1 Time taken: 1.563509 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.836743 max=3500 outfile=mandel5.bmp threads=1 Time taken: 1.622372 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.795929 max=3500 outfile=mandel6.bmp threads=1 Time taken: 1.686793 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.755114 max=3500 outfile=mandel7.bmp threads=1 Time taken: 1.742729 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.714300 max=3500 outfile=mandel8.bmp threads=1 Time taken: 1.811140 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.673486 max=3500 outfile=mandel9.bmp threads=1 Time taken: 1.857394 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.632671 max=3500 outfile=mandel10.bmp threads=1 Time taken: 1.937292 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.591857 max=3500 outfile=mandel11.bmp threads=1 Time taken: 2.200732 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.551043 max=3500 outfile=mandel12.bmp threads=1 Time taken: 2.327103 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.510229 max=3500 outfile=mandel13.bmp threads=1 Time taken: 2.468382 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.469414 max=3500 outfile=mandel14.bmp threads=1 Time taken: 2.550940 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.428600 max=3500 outfile=mandel15.bmp threads=1 Time taken: 2.675145 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.387786 max=3500 outfile=mandel16.bmp threads=1 Time taken: 2.803874 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.346971 max=3500 outfile=mandel17.bmp threads=1 Time taken: 2.902512 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.306157 max=3500 outfile=mandel18.bmp threads=1 Time taken: 3.040106 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.265343 max=3500 outfile=mandel19.bmp threads=1 Time taken: 3.160918 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.224529 max=3500 outfile=mandel20.bmp threads=1 Time taken: 3.289493 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.183714 max=3500 outfile=mandel21.bmp threads=1 Time taken: 3.909802 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.142900 max=3500 outfile=mandel22.bmp threads=1 Time taken: 4.076915 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.102086 max=3500 outfile=mandel23.bmp threads=1 Time taken: 4.241709 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.061271 max=3500 outfile=mandel24.bmp threads=1 Time taken: 4.421441 seconds
mandel: x=-0.539795 y=-0.609589 scale=1.020457 max=3500 outfile=mandel25.bmp threads=1 Time taken: 4.533865 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.979643 max=3500 outfile=mandel26.bmp threads=1 Time taken: 4.796716 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.938829 max=3500 outfile=mandel27.bmp threads=1 Time taken: 4.888631 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.898014 max=3500 outfile=mandel28.bmp threads=1 Time taken: 5.074954 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.857200 max=3500 outfile=mandel29.bmp threads=1 Time taken: 5.248684 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.816386 max=3500 outfile=mandel30.bmp threads=1 Time taken: 5.290520 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.408243 max=3500 outfile=mandel40.bmp threads=1 Time taken: 5.326984 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.449057 max=3500 outfile=mandel39.bmp threads=1 Time taken: 5.643053 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.489871 max=3500 outfile=mandel38.bmp threads=1 Time taken: 5.843292 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.530686 max=3500 outfile=mandel37.bmp threads=1 Time taken: 5.942192 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.571500 max=3500 outfile=mandel36.bmp threads=1 Time taken: 6.015519 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.612314 max=3500 outfile=mandel35.bmp threads=1 Time taken: 6.062150 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.775571 max=3500 outfile=mandel31.bmp threads=1 Time taken: 6.080697 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.734757 max=3500 outfile=mandel32.bmp threads=1 Time taken: 6.134994 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.653129 max=3500 outfile=mandel34.bmp threads=1 Time taken: 6.164336 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.693943 max=3500 outfile=mandel33.bmp threads=1 Time taken: 6.180810 seconds
number of processes: 10 , time taken: 16.978963
williamduran@Williams-MacBook-Pro source % mandel: x=-0.539795 y=-0.609589 scale=0.122543 max=3500 outfile=mandel47.bmp threads=1 Time taken: 3.030588 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.081729 max=3500 outfile=mandel48.bmp threads=1 Time taken: 3.365819 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.163357 max=3500 outfile=mandel46.bmp threads=1 Time taken: 3.455286 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.040914 max=3500 outfile=mandel49.bmp threads=1 Time taken: 3.665898 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.204171 max=3500 outfile=mandel45.bmp threads=1 Time taken: 3.882951 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.244986 max=3500 outfile=mandel44.bmp threads=1 Time taken: 4.030121 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.285800 max=3500 outfile=mandel43.bmp threads=1 Time taken: 4.210764 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.326614 max=3500 outfile=mandel42.bmp threads=1 Time taken: 4.248079 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.367429 max=3500 outfile=mandel41.bmp threads=1 Time taken: 4.444194 seconds
mandel: x=-0.539795 y=-0.609589 scale=0.000100 max=3500 outfile=mandel50.bmp threads=1 Time taken: 7.851534 seconds
```

Figure 8 → ./mandelmovie 10

Mandelmovie <# processes> (mandel default -n 1)	
processes	execution time (seconds)
1	136.198664
2	68.205257
3	46.336647
4	35.23962
5	26.971056
10	16.978963

Table 1 → Mandelmovie <# processes> (mandel default -n 1)



- Explain the shape of the curve. What is the optimal number of processes? Why? Is it possible to have too many processes? Why?

  - Curve Analysis:
    - The graph depicts an exponential decay in execution time with an increase in processes. The most substantial reduction was evident in the initial addition of processes. However, the benefits lessened as more processes were added.

  - Optimal Processes:
    - While the exact optimal number is contingent upon specific goals, it's evident that beyond 5 processes, the reduction in execution time is not as pronounced. The jump from 1 to 2 processes yielded a significant decrease, whereas the shift from 5 to 10 was notably less impactful.

  - Limitations with Increasing Processes:
    - Introducing too many processes can lead to inefficiencies due to:
      - Overhead in process management.
      - Competition for shared resources.
      - Inherent sequential components in the program, as dictated by Amdahl's Law.
  - Conclusion:
    - Although parallelization via multiple processes can enhance performance, there's a threshold beyond which the advantages decline. It's crucial to strike a balance to achieve optimal efficiency.

- For the following two configurations, measure and graph the execution time of multithreaded mandel using 1, 2, 3, 4, 5, 10, 50, and 100 threads. The execution time of these experiments may be upset by other things going on in the machine. So, repeat each measurement five times, and use the fastest time achieved.
    - A: mandel -x -.5 -y .5 -s 1 -m 2000

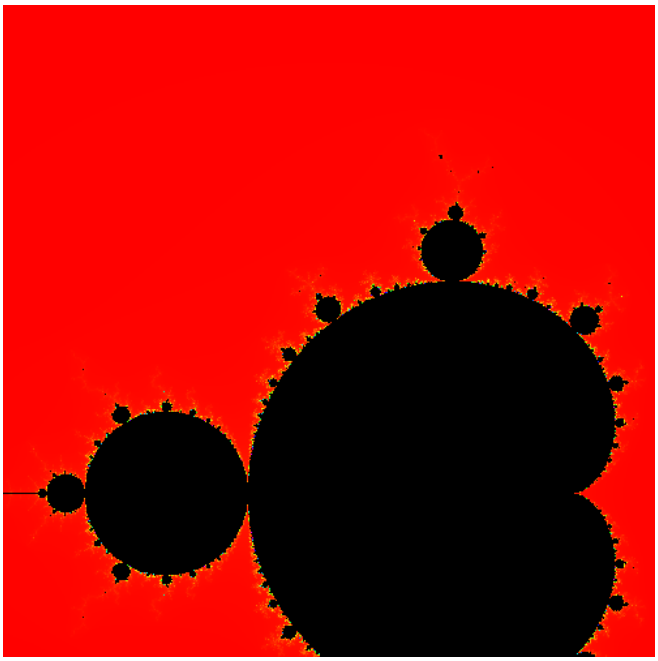


Figure 9 → ./mandel -x -.5 -y .5 -s 1 -m 2000

    - B: mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000

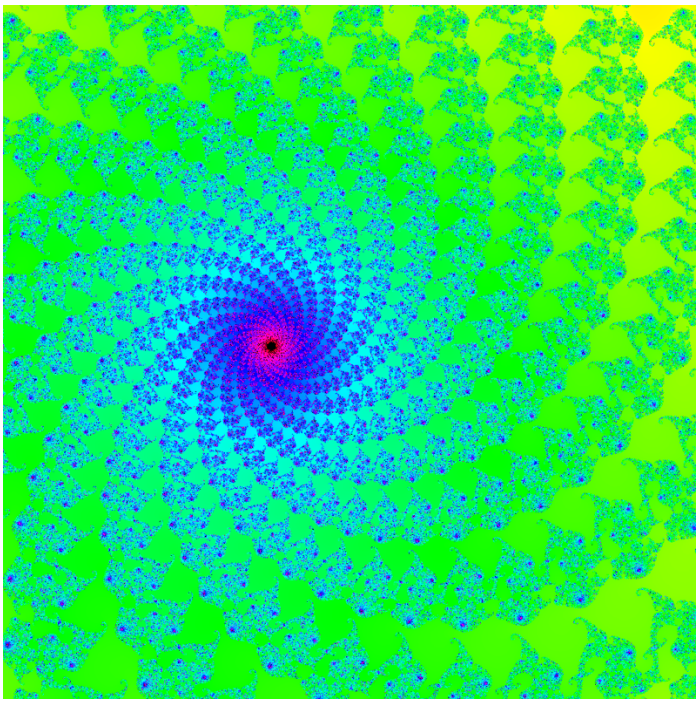


Figure 10 → mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000

- A: mandel -x -.5 -y .5 -s 1 -m 2000

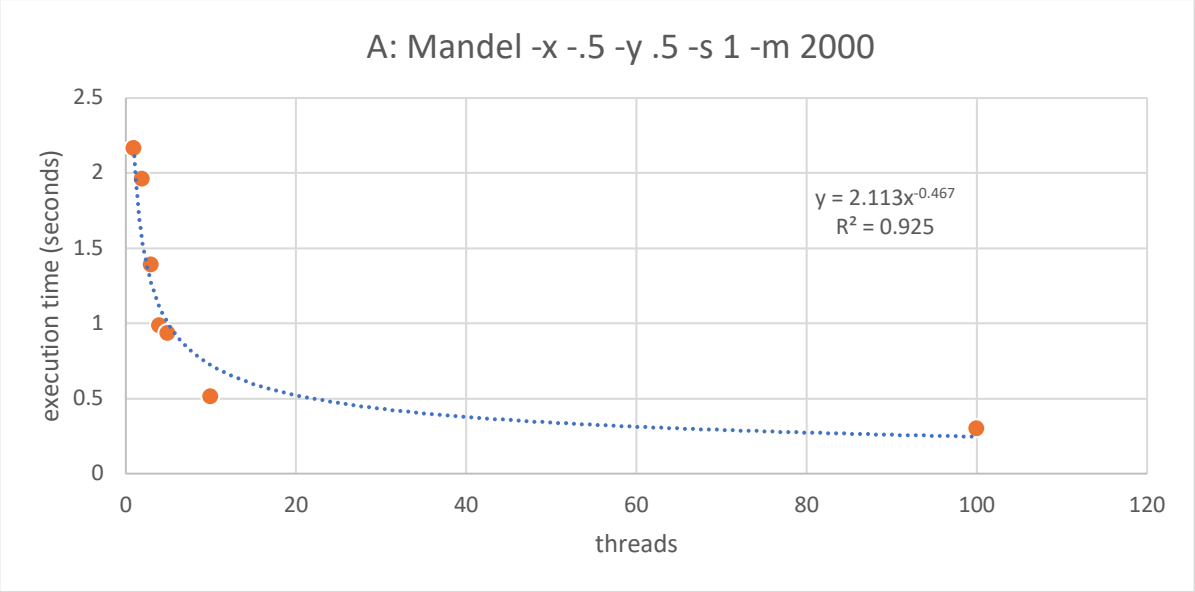
```
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 1
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=1 Time taken: 2.162131 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 1
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=1 Time taken: 2.161344 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 1
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=1 Time taken: 2.161917 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 1
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=1 Time taken: 2.173248 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 1
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=1 Time taken: 2.163516 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 2
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=2 Time taken: 1.950613 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 2
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=2 Time taken: 1.952811 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 2
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=2 Time taken: 1.955627 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 2
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=2 Time taken: 1.953376 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 2
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=2 Time taken: 1.965733 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 3
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=3 Time taken: 1.380537 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 3
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=3 Time taken: 1.380538 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 3
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=3 Time taken: 1.380212 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 3
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=3 Time taken: 1.382699 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 3
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=3 Time taken: 1.380813 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 4
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=4 Time taken: 0.982973 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 4
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=4 Time taken: 0.982573 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 4
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=4 Time taken: 0.982542 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 4
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=4 Time taken: 0.983348 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 4
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=4 Time taken: 0.983104 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 5
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=5 Time taken: 0.932907 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 5
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=5 Time taken: 0.936736 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 5
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=5 Time taken: 0.933211 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 5
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=5 Time taken: 0.933006 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 5
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=5 Time taken: 0.931026 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 10
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=10 Time taken: 0.506999 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 10
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=10 Time taken: 0.507906 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 10
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=10 Time taken: 0.514960 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 10
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=10 Time taken: 0.511470 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 10
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=10 Time taken: 0.508876 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 100
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=100 Time taken: 0.301970 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 100
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=100 Time taken: 0.300087 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 100
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=100 Time taken: 0.300842 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 100
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=100 Time taken: 0.298936 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x -.5 -y .5 -s 1 -m 2000 -n 100
 mandel: x=-0.500000 y=0.500000 scale=1.000000 max=2000 outfile=mandel.bmp threads=100 Time taken: 0.293768 seconds
 williamduran@Williams-MacBook-Pro source %
```

Figure 11 → ./mandel -x -.5 -y .5 -s 1 -m 2000

- A: mandel -x -.5 -y .5 -s 1 -m 2000

A: Mandel -x -.5 -y .5 -s 1 -m 2000	
threads	execution time (seconds)
1	2.161344
2	1.958613
3	1.388212
4	0.982542
5	0.931026
10	0.506999
100	0.293768

Table 2 → A: mandel -x -.5 -y .5 -s 1 -m 2000



- Curve Analysis:
  - The curve demonstrates an exponential decrease in execution time as the number of threads increases. Initially, the benefits from adding more threads are substantial, but as we continue to increase the thread count, the execution time's reduction rate decreases, hinting at a diminishing return.

- Optimal Number of Threads:
  - For Configuration A, the most significant improvement in execution time is observed when moving from 1 to 10 threads. Beyond 10 threads, the decrease in execution time is less pronounced, indicating that increasing the number of threads further might not offer substantial benefits. Thus, in this context, 10 threads can be considered as the optimal number.

- In conclusion, while multi-threading provides performance enhancements, it's essential to identify the optimal number of threads to achieve the best results without unnecessary overhead. For this specific task and based on the data, using 10 threads would be the most efficient choice.

- B: mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000

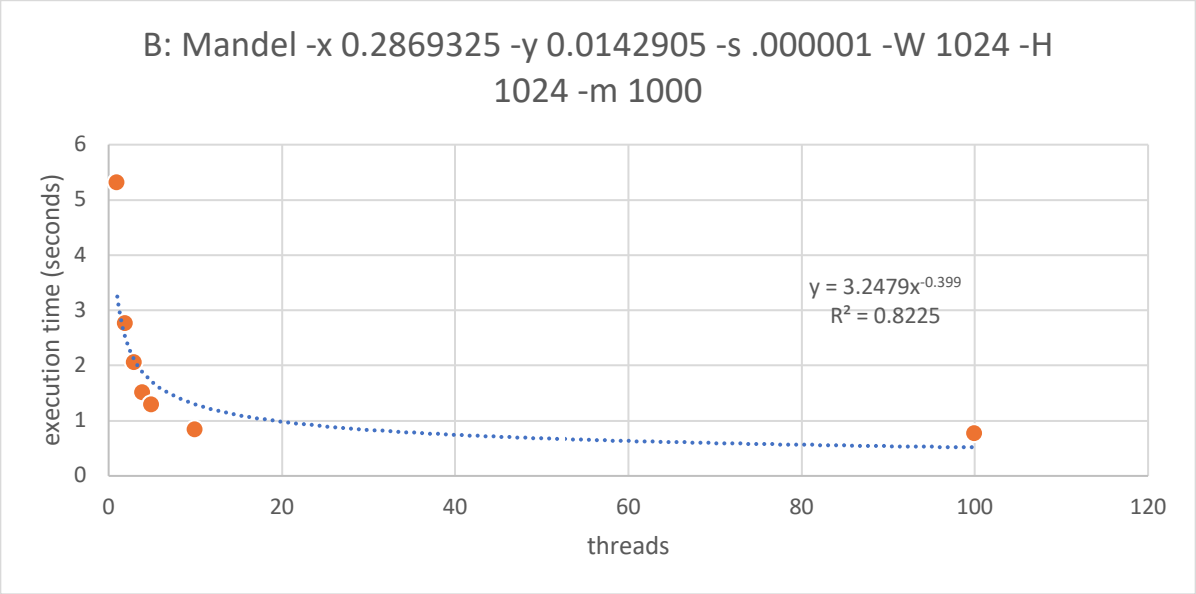
```
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 1
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=1 Time taken: 5.318685 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 1
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=1 Time taken: 5.306587 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 1
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=1 Time taken: 5.310802 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 1
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=1 Time taken: 5.306489 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 1
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=1 Time taken: 5.311819 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 2
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=2 Time taken: 2.755652 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 2
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=2 Time taken: 2.755431 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 2
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=2 Time taken: 2.757418 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 2
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=2 Time taken: 2.755670 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 2
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=2 Time taken: 2.757150 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 3
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=3 Time taken: 2.041666 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 3
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=3 Time taken: 2.039220 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 3
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=3 Time taken: 2.043985 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 3
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=3 Time taken: 2.042593 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 3
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=3 Time taken: 2.039805 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 4
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=4 Time taken: 1.501214 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 4
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=4 Time taken: 1.507083 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 4
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=4 Time taken: 1.505357 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 4
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=4 Time taken: 1.505338 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 4
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=4 Time taken: 1.530215 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 5
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=5 Time taken: 1.308313 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 5
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=5 Time taken: 1.282665 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 5
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=5 Time taken: 1.295853 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 5
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=5 Time taken: 1.293835 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 5
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=5 Time taken: 1.299793 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 10
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=10 Time taken: 0.826947 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 10
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=10 Time taken: 0.861683 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 10
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=10 Time taken: 0.821996 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 10
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=10 Time taken: 0.827152 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 10
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=10 Time taken: 0.822603 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 100
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=100 Time taken: 0.791055 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 100
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=100 Time taken: 0.810970 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 100
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=100 Time taken: 0.756909 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 100
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=100 Time taken: 0.757014 seconds
[williamduran@Williams-MacBook-Pro source % ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000 -n 100
 mandel: x=0.286932 y=0.014290 scale=0.000001 max=1000 outfile=mandel.bmp threads=100 Time taken: 0.779090 seconds
 williamduran@Williams-MacBook-Pro source %
```

Figure 12 → ./mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000

- B: mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000

B: Mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000	
threads	execution time (seconds)
1	5.306489
2	2.755431
3	2.03922
4	1.501214
5	1.282665
10	0.821996
100	0.756909

Table 3 → B: mandel -x 0.2869325 -y 0.0142905 -s .000001 -W 1024 -H 1024 -m 1000



- Curve Analysis:
  - The curve exhibits a power-law decrease in execution time as the number of threads increases. There's a pronounced drop in execution time when moving from 1 thread to a higher number of threads. However, as we further increase the thread count, the decrease in execution time becomes more gradual. This suggests that the benefits from additional threads diminish as the thread count increases.

- Optimal Number of Threads:
  - For Configuration B, the most significant reduction in execution time occurs between 1 and 10 threads. Beyond 10 threads, the improvement is less substantial, although there's still a noticeable decrease up to 100 threads. However, considering the diminishing returns and potential overhead associated with managing a large number of threads, using 10 threads seems to offer a balance between performance gain and computational efficiency.

- In summary, Configuration B shows that while increasing threads can reduce execution time, there's a point of diminishing returns. Based on the data presented, 10 threads appear to be the optimal choice for this task.

- Differences in Curve Shapes:
    - Curve A has a more pronounced decrease in execution time with increasing threads initially, followed by a plateau. Curve B, on the other hand, has a gentler decrease and starts plateauing earlier.
    - The difference in curve shape could be attributed to various factors:
        - Nature of the computation: The area of the Mandelbrot set being computed might have different complexities. The commands point to different regions of the Mandelbrot set to be computed, which can have varying levels of detail and complexity.
        - The size of the image to be computed: besides of the level of detail of the specific region of the Mandelbrot set that is computed for each command, there is also the size difference, where command B computes an image of 1024 by 1024 pixels whereas command A computes the default 500 by 500 pixels size. Here is a picture that compares the difference in size:

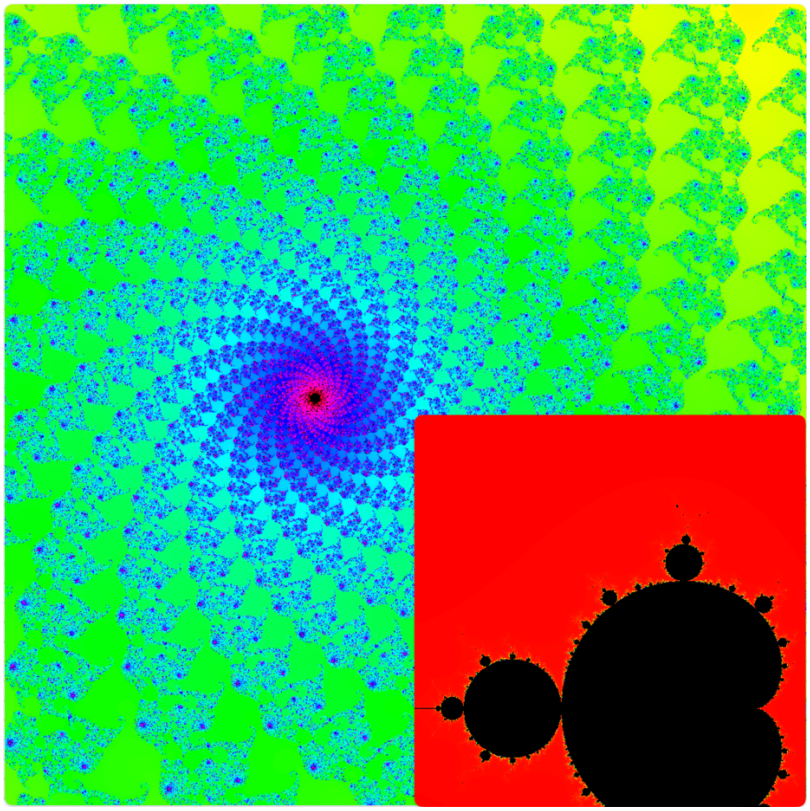


Figure 13 → 1024x1024 px vs. 500x500 px

- Conclusion:
    - The findings from the project accentuate the nuanced nature of parallel processing and multi-threading. Both techniques significantly expedite computation, with a notable decrease in execution time as processes and threads increase. However, the diminishing returns beyond certain points (5 processes or 10 threads) underscore a trade-off between performance gain and computational efficiency. While the optimal setup may vary depending on specific goals and machine configurations, a balanced approach, avoiding excessive parallelism, emerges as a prudent strategy for exploiting the benefits of parallel processing in generating Mandelbrot set images efficiently.