DISTRIBUTED GAME OF LIFE

Jack Dunfey

CSE 633

University at Buffalo The State University of New York

What is the Game of Life?

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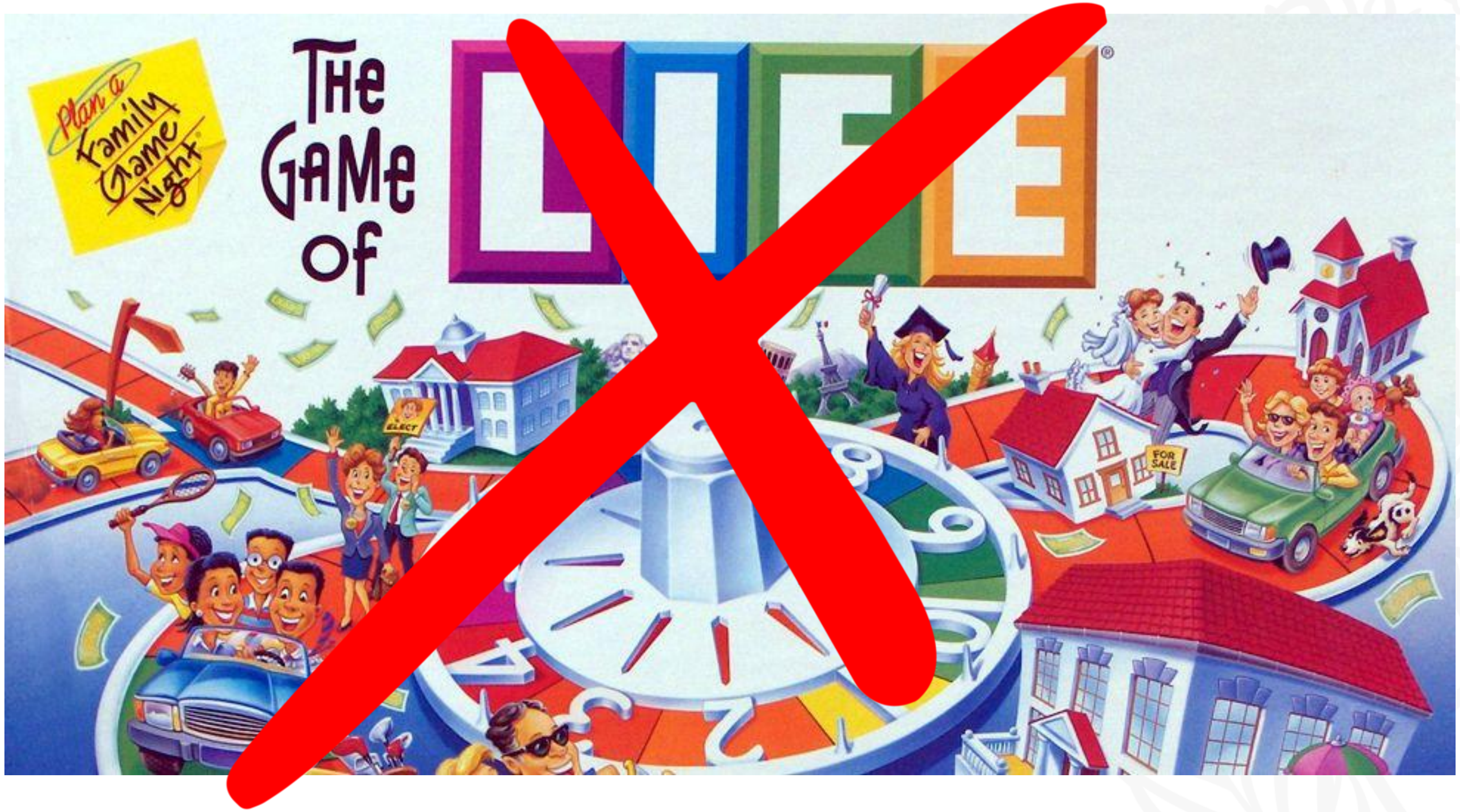
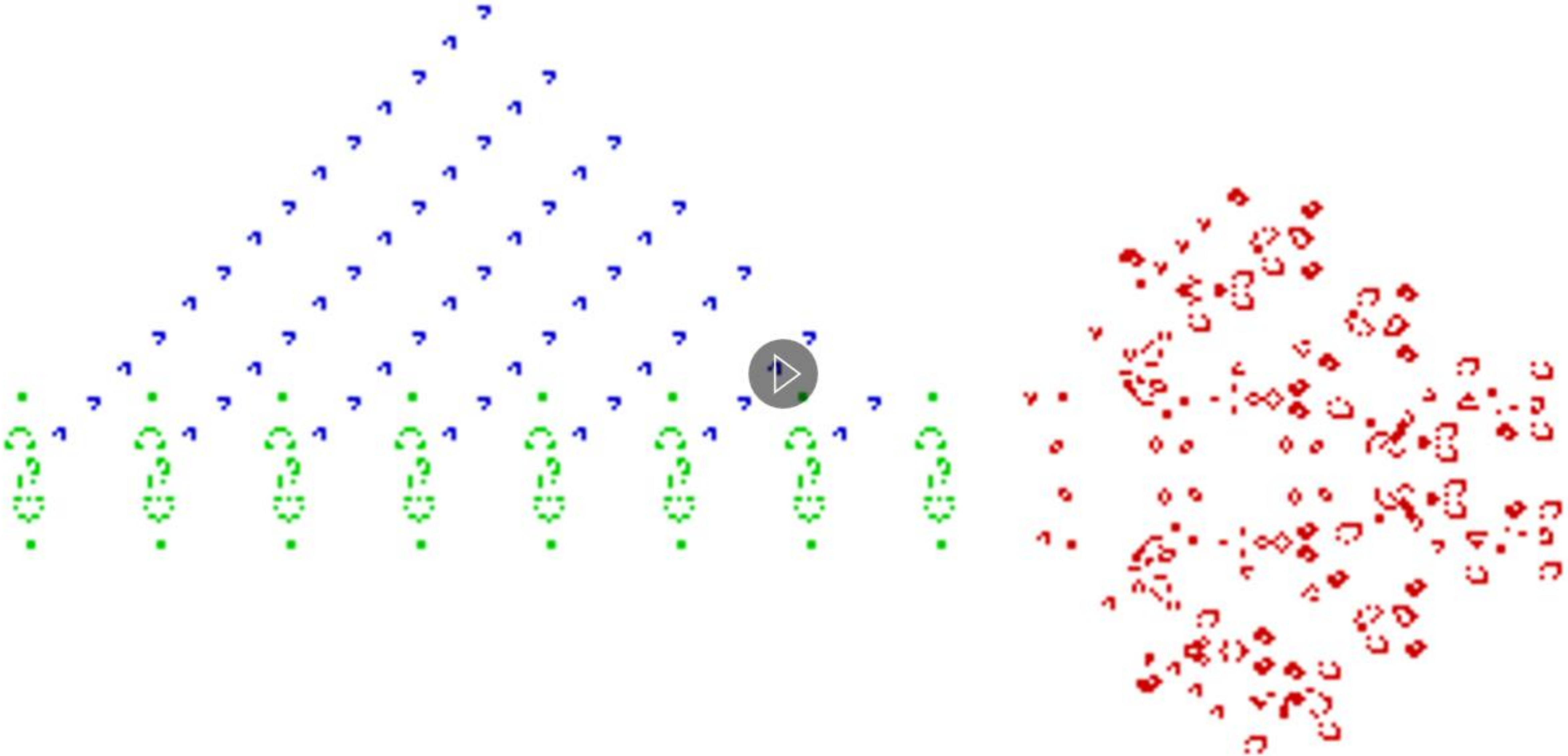
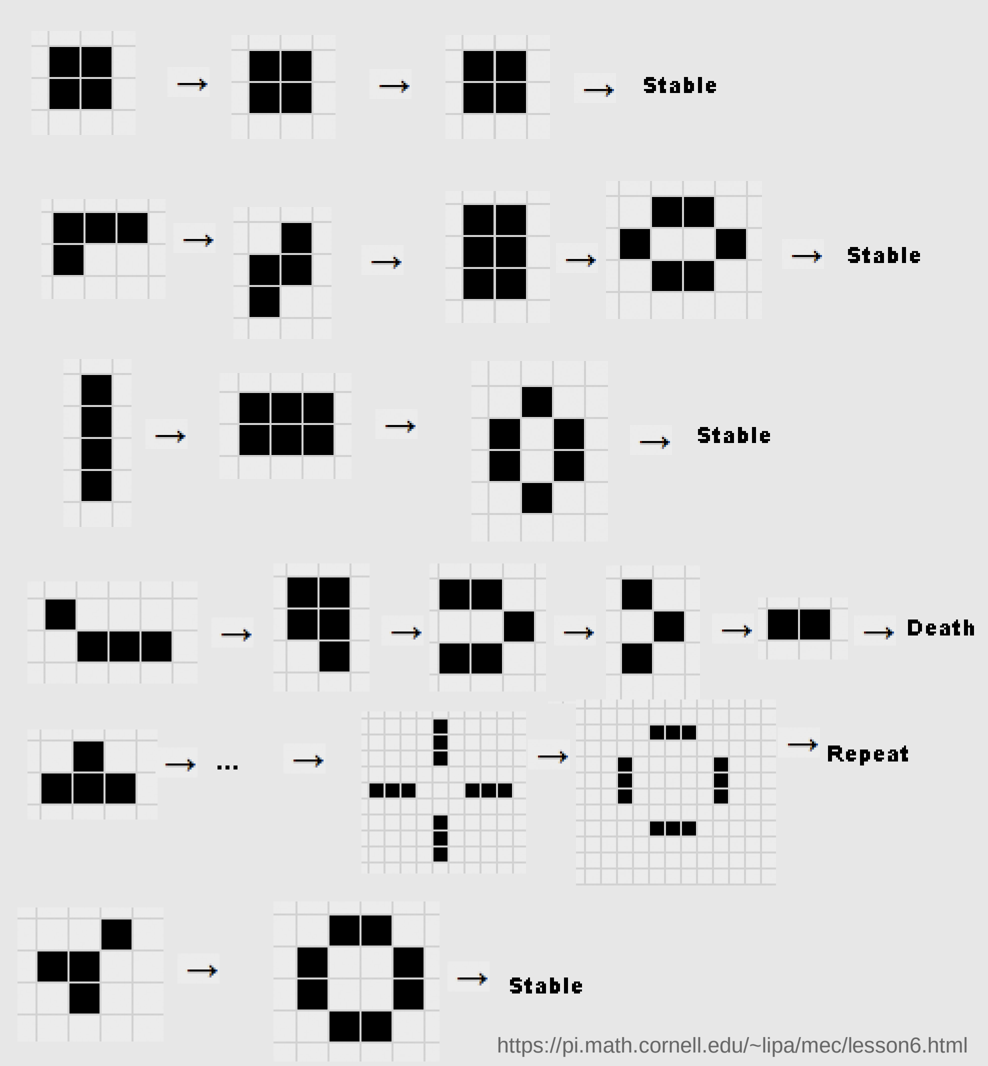




What is Conway’s Game of Life?

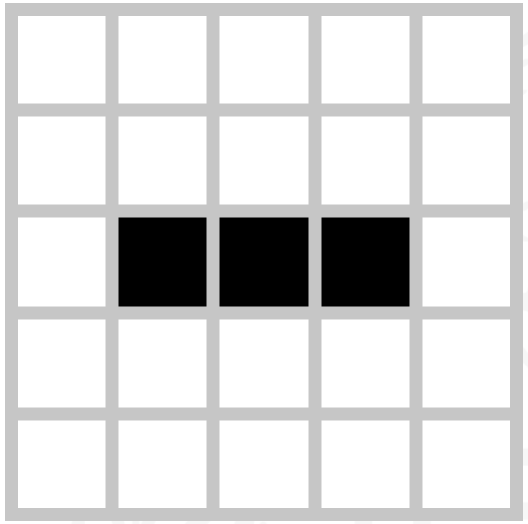
- A 0-player game
- Three rules for determining cell evolution
  - If alive,
    - Remain alive if there are **2 or 3** living neighbors
    - Otherwise, die
  - If dead,
    - Become alive if there are **exactly 3** living neighbors
    - Otherwise, remain dead

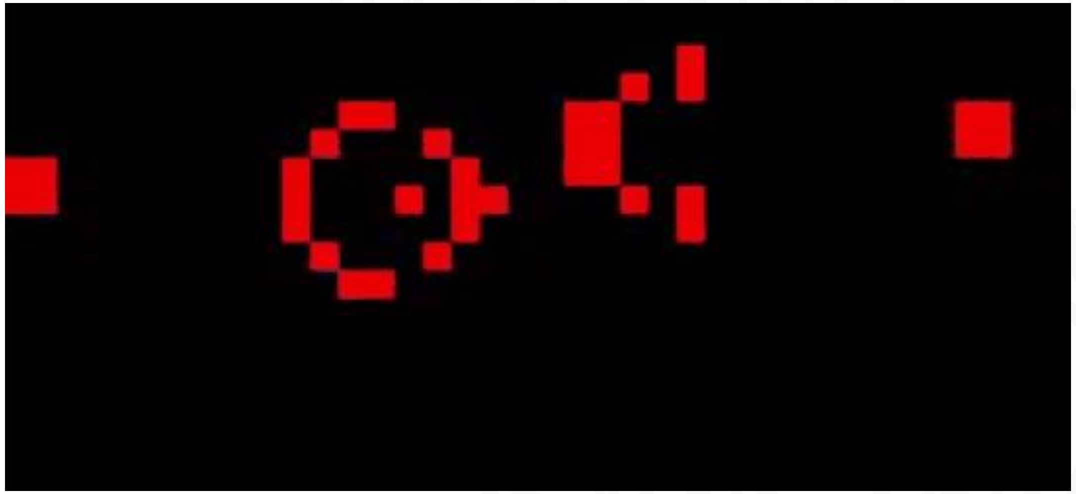


https://pi.math.cornell.edu/~lipa/mec/lesson6.html

What is Conway’s Game of Life? (Cont’d)

- Stable: a pattern that is a configuration of cells such that there are no changes between generations
- Oscillator: a pattern that repeatedly alternates between a fixed number of states
- Spaceships: a pattern that translates itself across the grid





PARALLELIZATION

w/ MPI

Motivation

- Large grids require O(n^2) time to process
- Dividing this up reduces this runtime to O(n^2/p)

Challenges

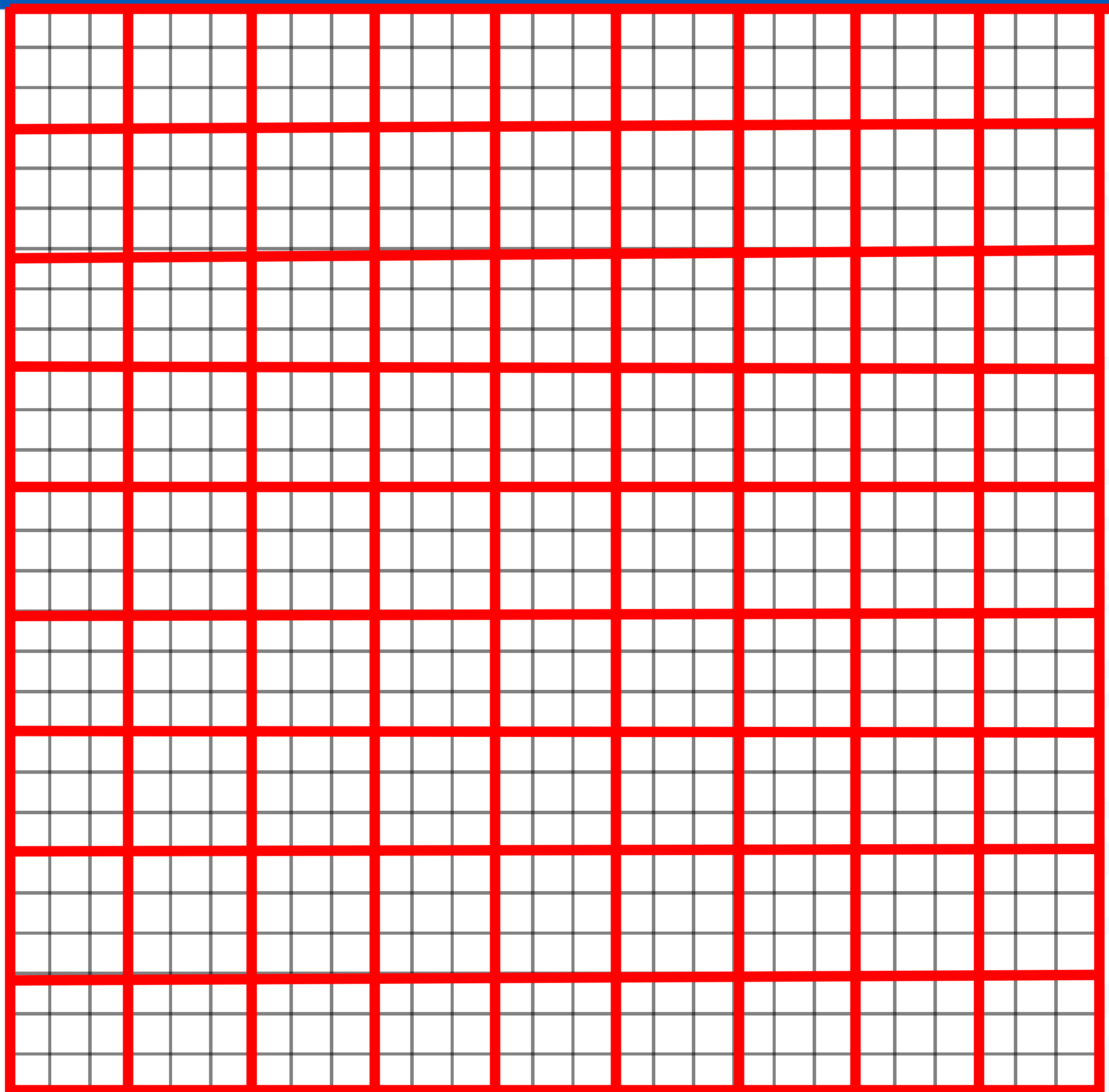
- Temporal dependencies
- Current solution:
  - Buffered non-blocking communication
  - Nodes will work independently as soon as they have all the data they need for as many generations as possible
  - Could be made faster with use of assumptions

Dividing up the Grid

27x27 grid (729 cells)

Divided amongst 81 tasks gives 9 squares per task

NOTE: The grid must be divisible by a square number of processors

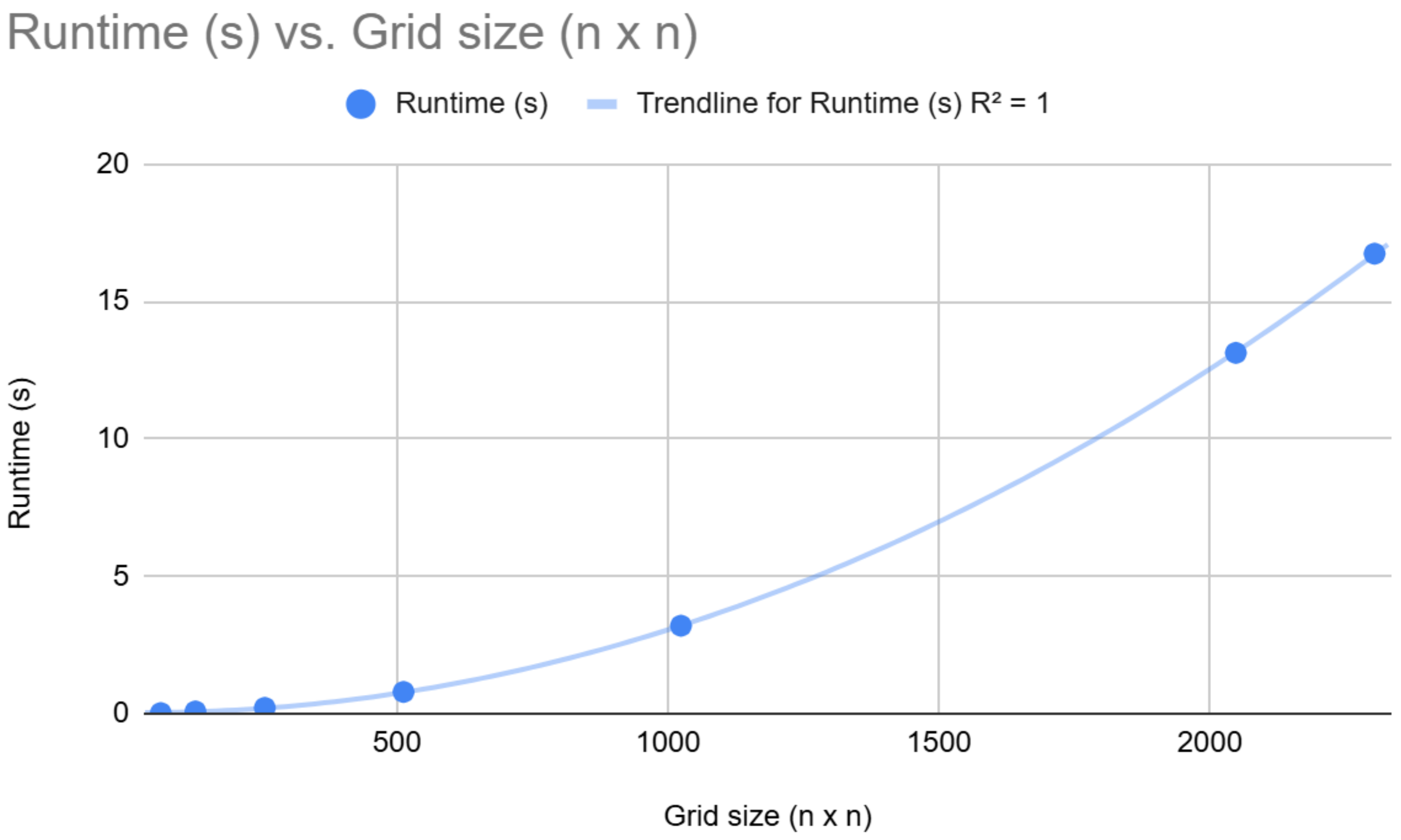


RESULTS

Sequential Runtime

1000 Generations

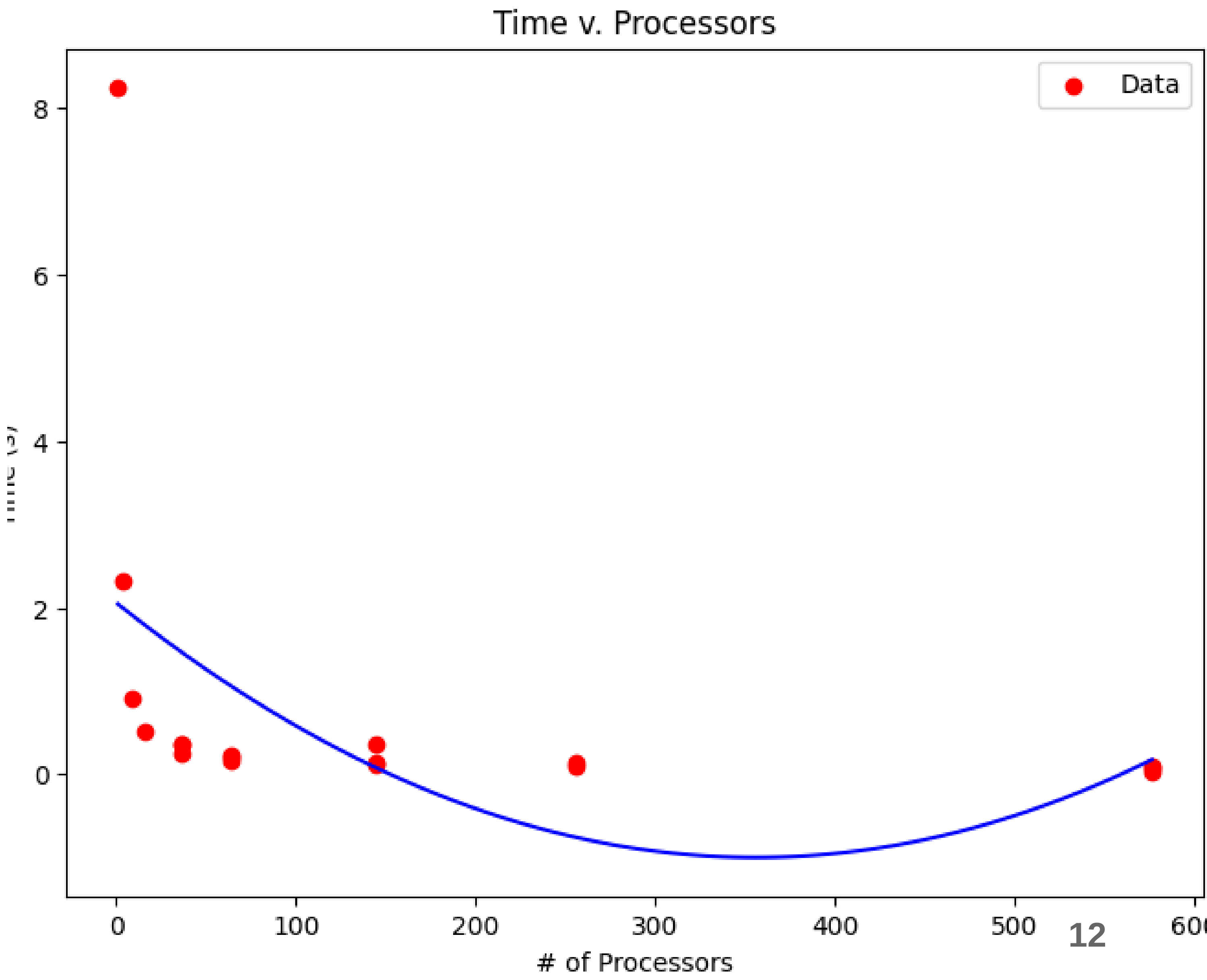
Grid size (n x n)	Runtime (s)
64	0.02
128	0.08
256	0.21
512	0.79
1024	3.20
2048	13.13
2304	16.74



Large Grid Runtime

- 1000 Generations
- 2304 x 2304 grid

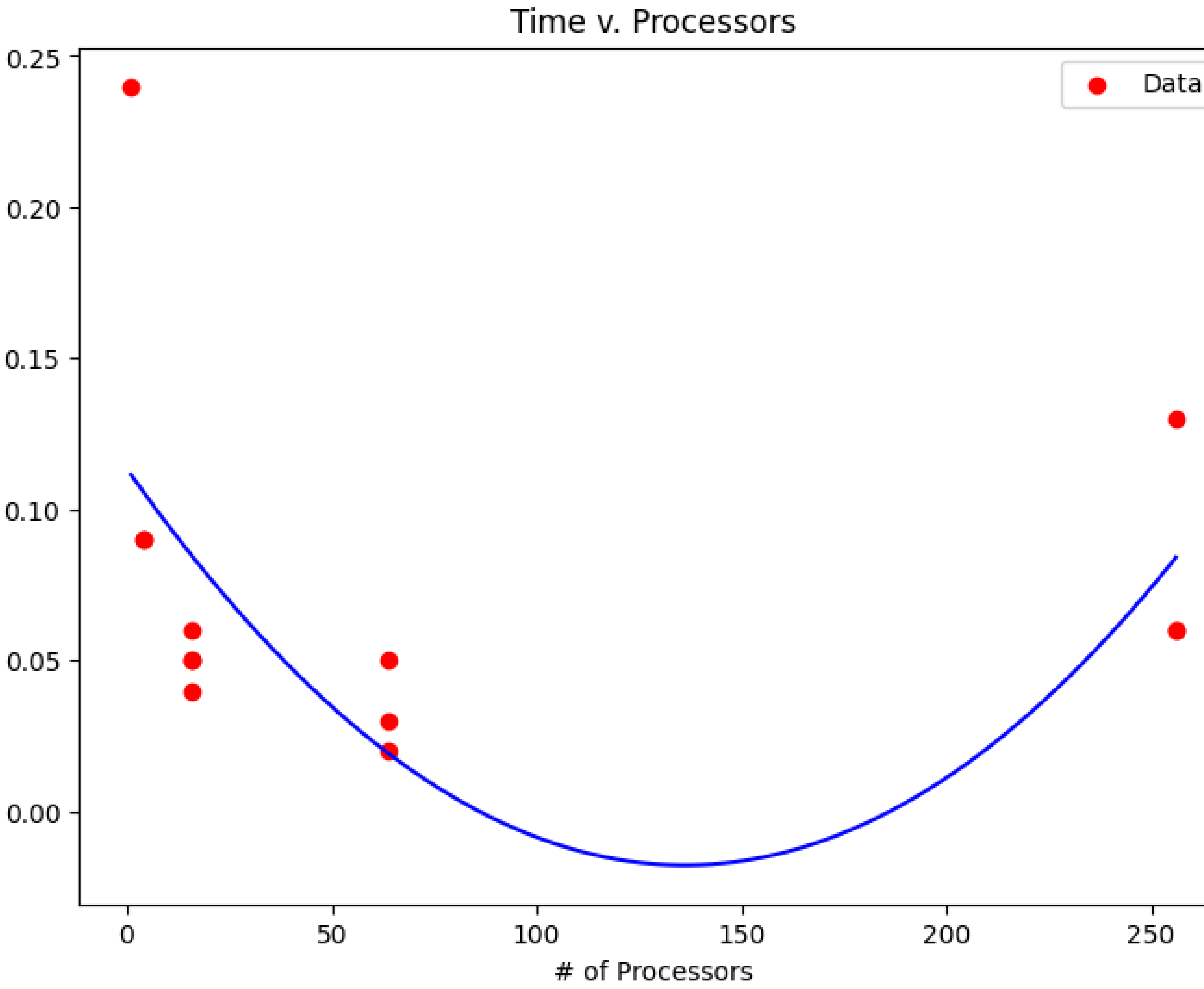
Number of Processors	Mean Execution Time (s)
1	8.25
4	2.32
9	0.92
16	0.52
36	0.32
64	0.20
144	0.20
256	0.11
576	0.07



Medium Grid Runtime

- 1000 Generations
- 256 x 256 grid

Number of Processors	Mean Execution Time (s)
1	0.24
4	0.09
16	0.05
64	0.03333
256	0.08333



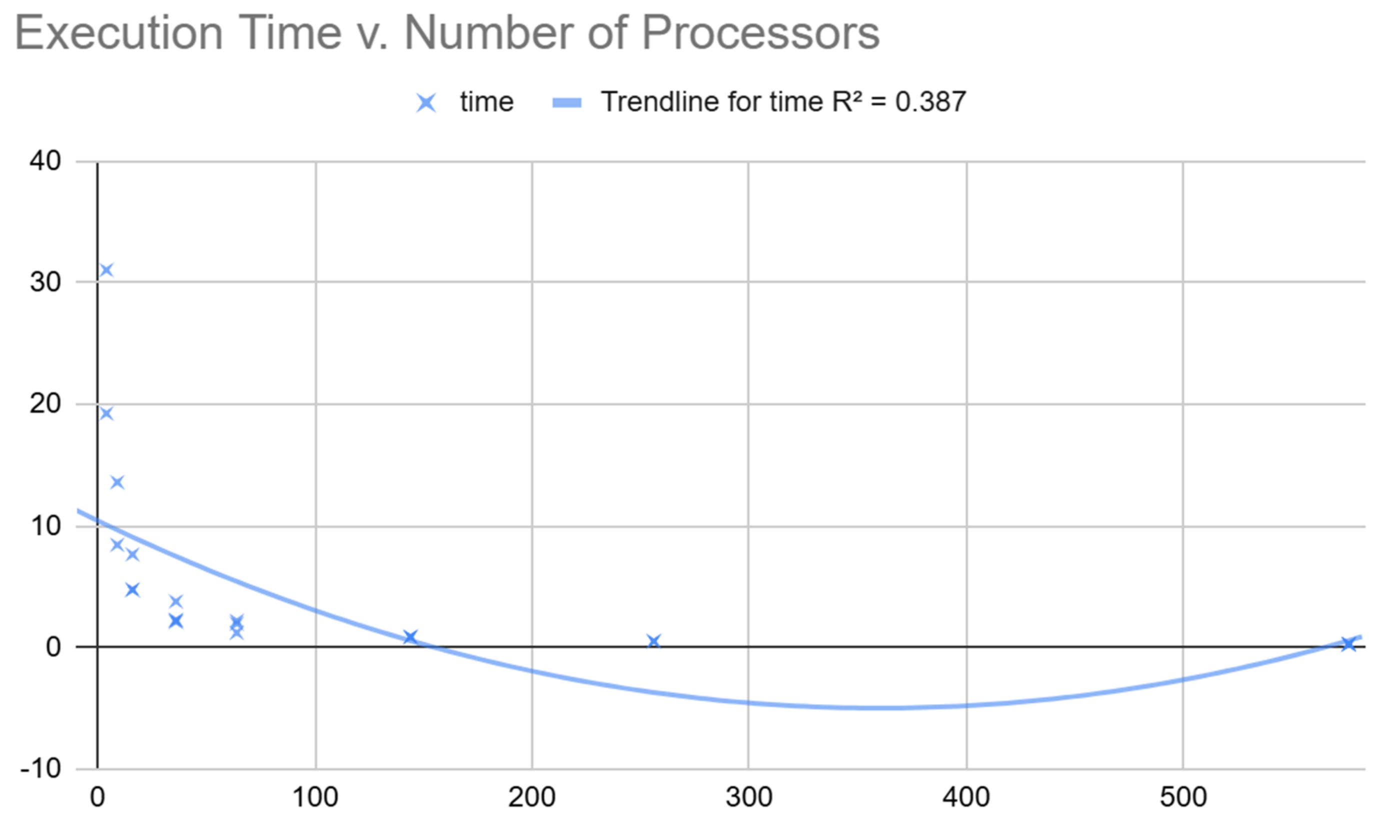
PARALLELIZATION

w/ MPI

Large Grid Runtime

- 1000 Generations
- 2304 x 2304 grid

Number of Processors	Mean Execution Time (s)
1	76.350
4	25.155
9	11.025
16	5.727
36	2.598
64	1.793
144	0.880
256	0.520
576	0.282



Medium Grid Runtime

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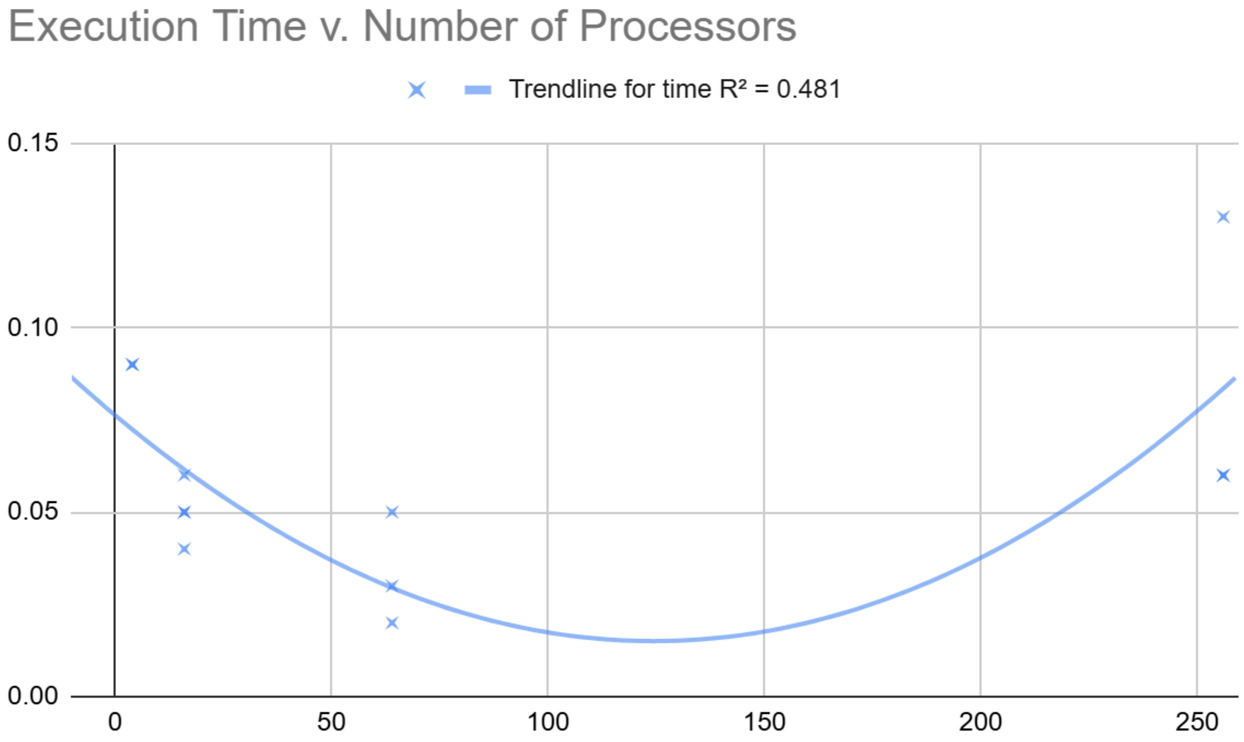
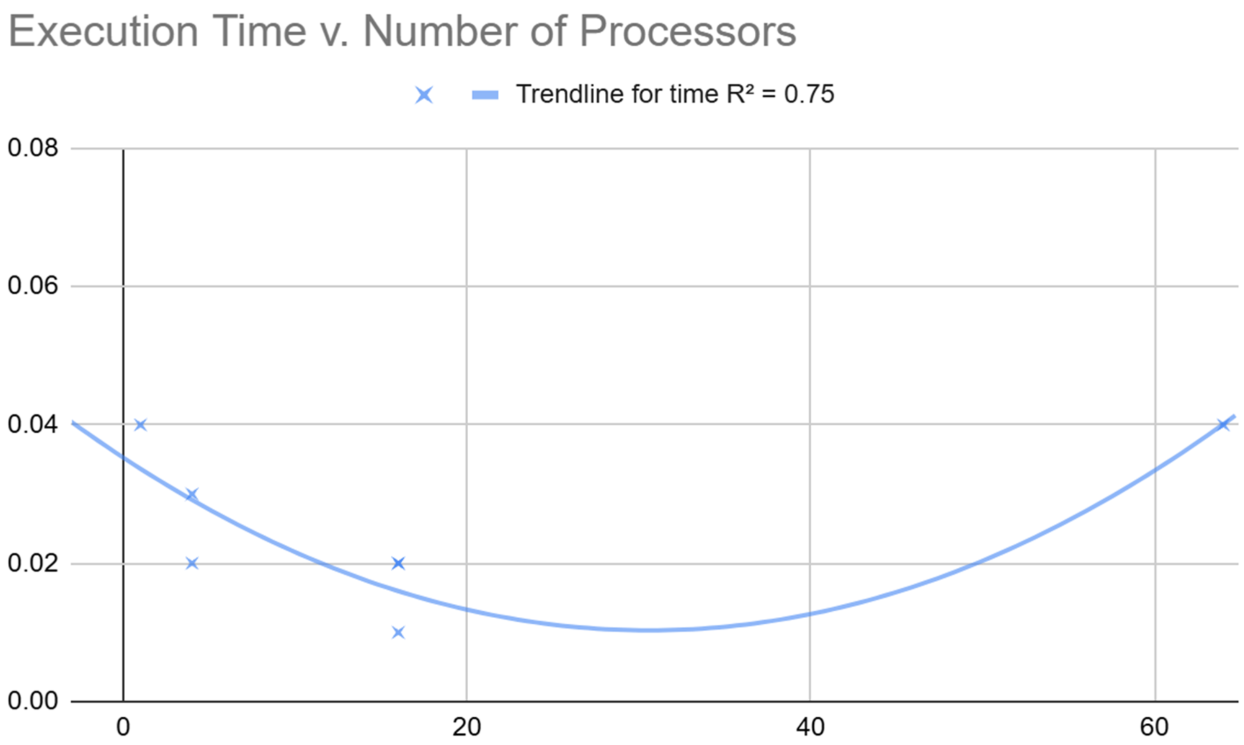


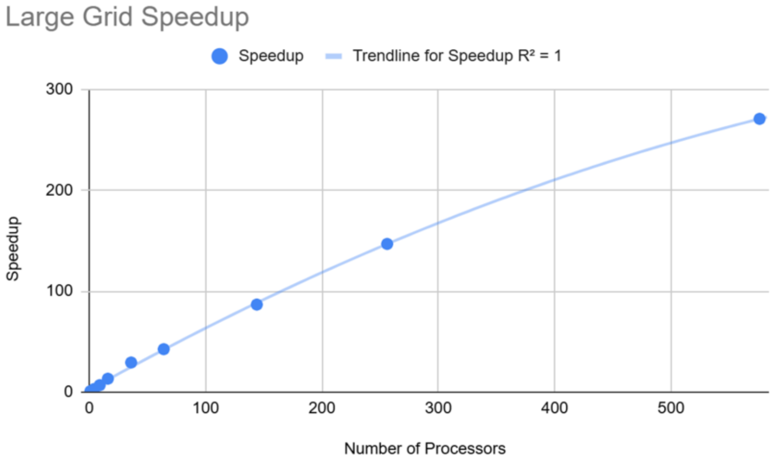
Small Grid Runtime

- 1000 Generations
- 64 x 64 grid

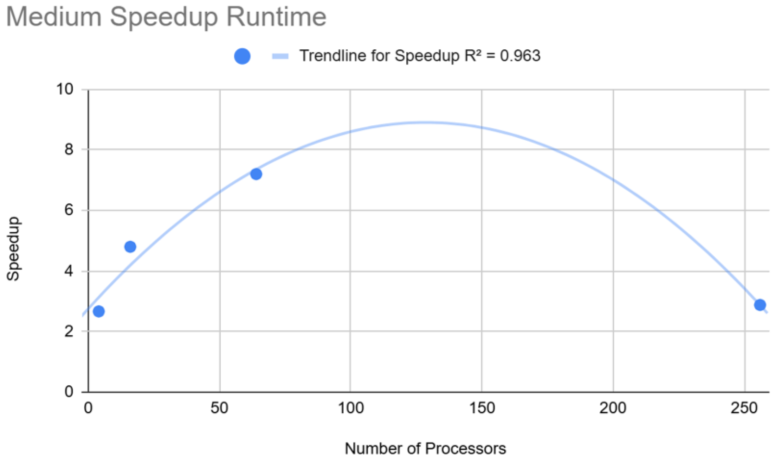
Number of Processors	Mean Execution Time (s)
4	0.025
16	0.017
64	0.04



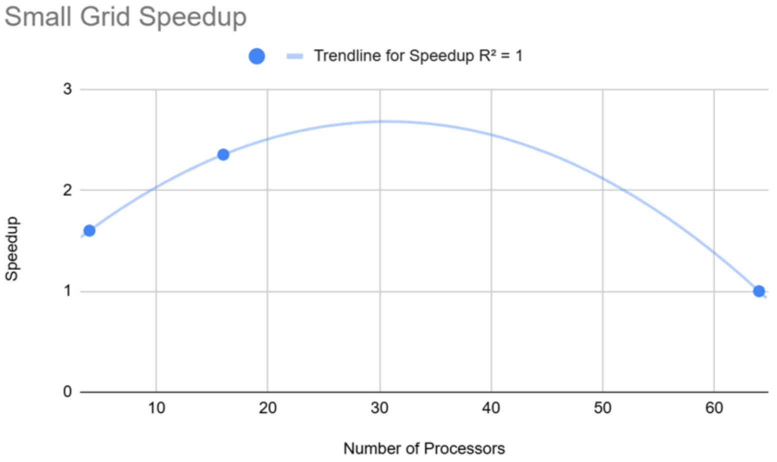
Speed-Up Graphs



Large Grid Speedup



Medium Speedup Runtime



Small Grid Speedup

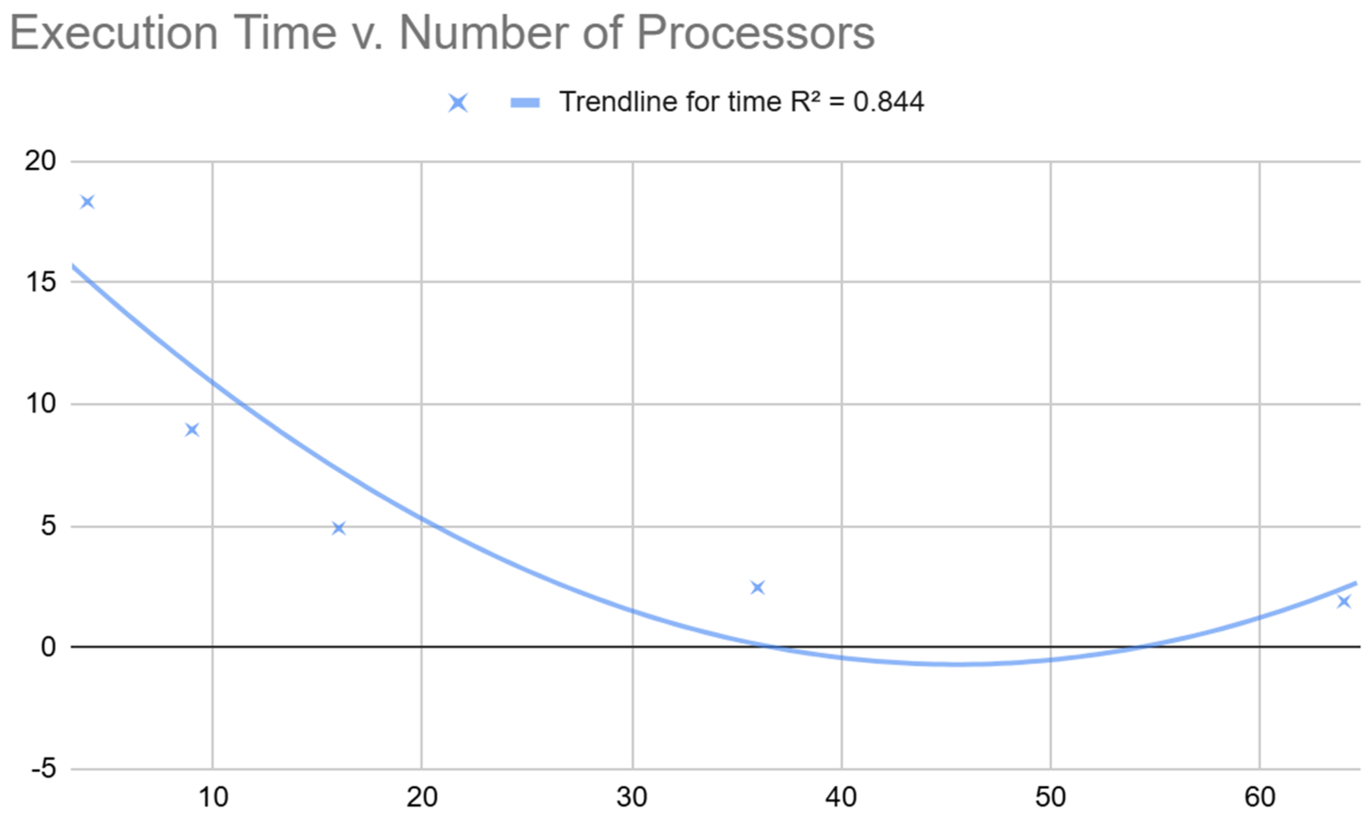
PARALLELIZATION

w/ OpenMP

Large Grid Runtime

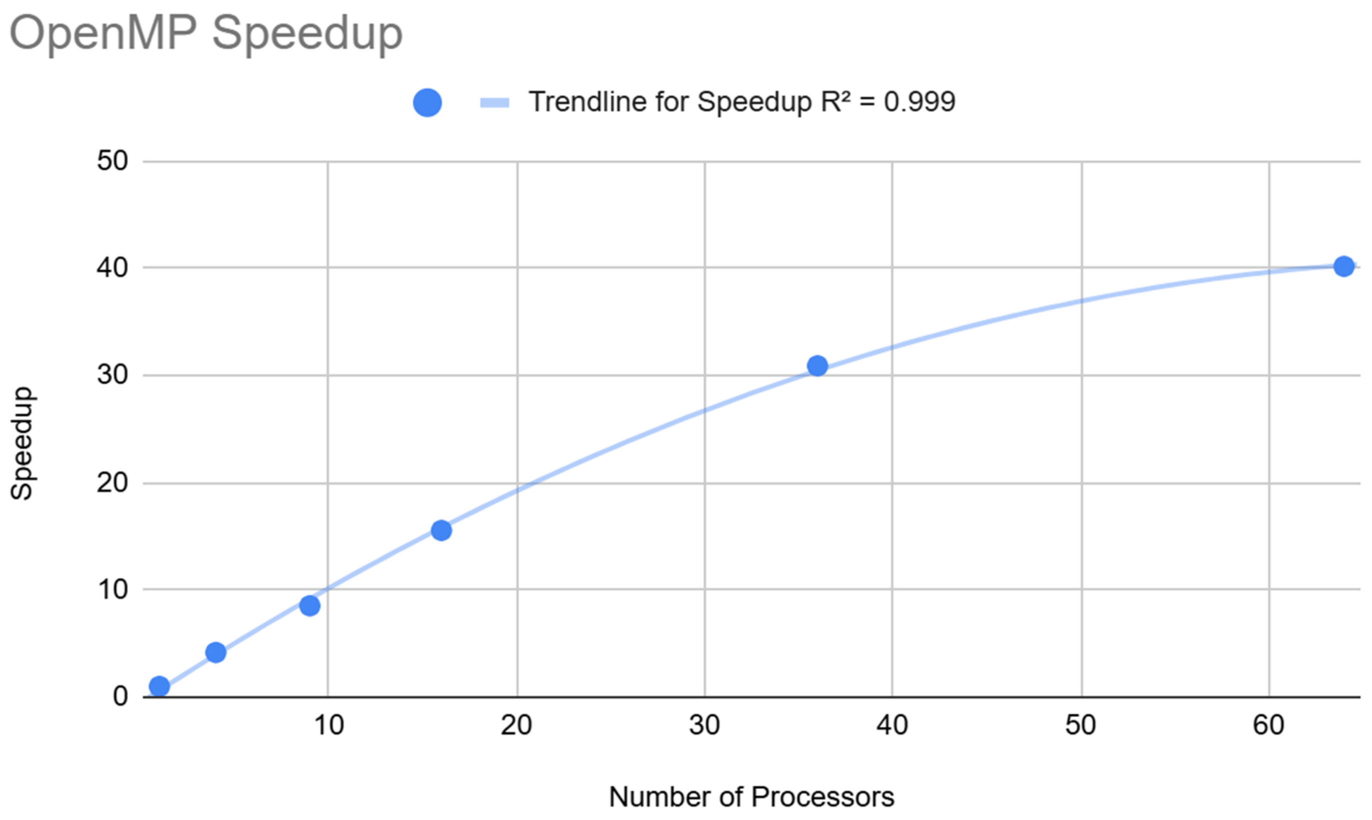
- 1000 Generations
- 2304 x 2304 grid

Number of Processors	Mean Execution Time (s)
1	72.15
4	18.33
9	8.96
16	4.91
36	2.47
64	1.90



Speed-Up

Number of Processors	Speed-Up (Relative)
1	1
4	3.936
9	3.491
16	14.695
36	29.211
64	27.99331104



PARALLELIZATION

w/ MPI + OpenMP

Large Grid Complete Data

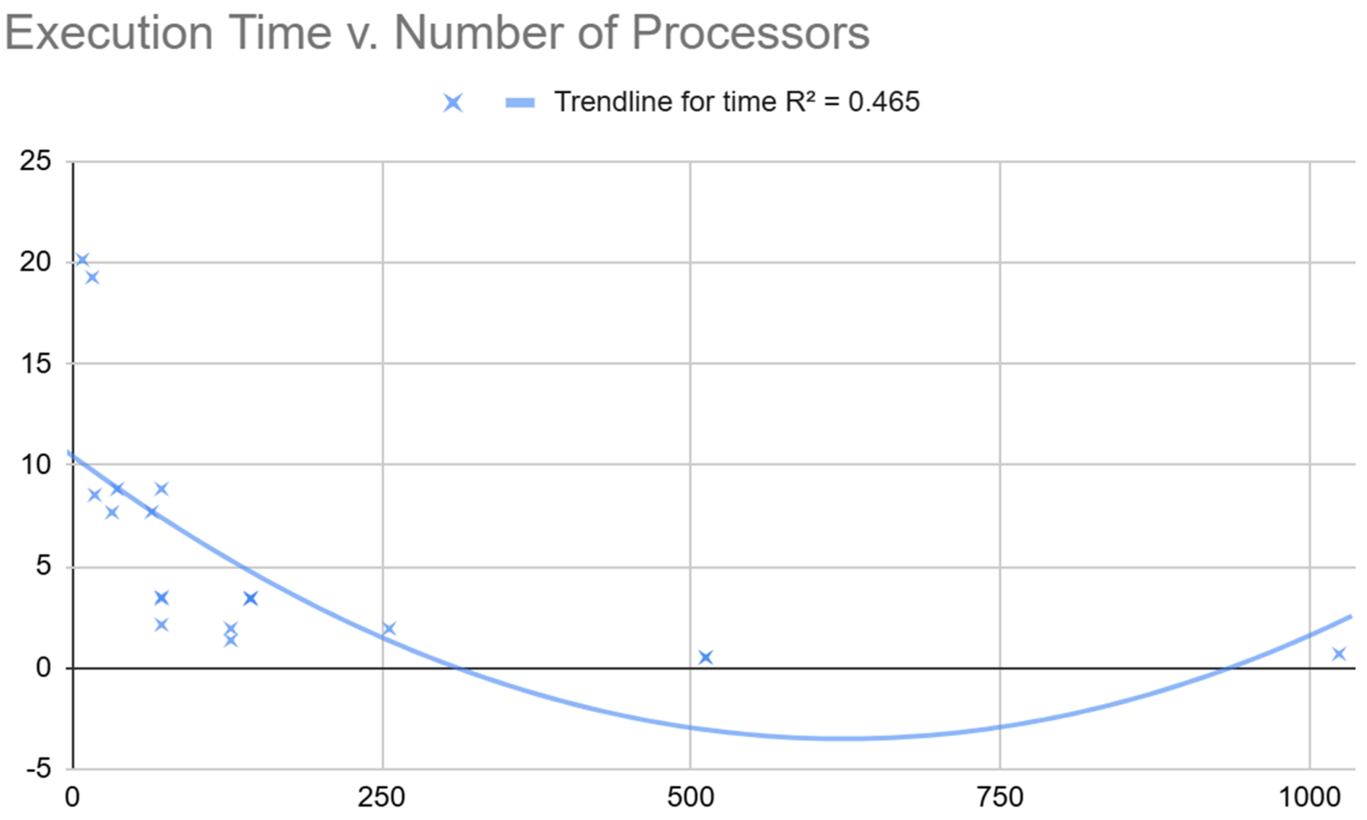
- 1000 Generations
- 2304 x 2304 grid

Nodes	Tasks per Node	CPUs per Task	Total Tasks	Time (s)
2	2	2	8	20.14
2	2	4	16	19.27
3	3	2	18	8.53
2	8	2	32	7.67
3	3	4	36	8.82
2	8	4	64	7.69
6	6	2	72	2.13
4	9	2	72	3.49
3	3	8	72	8.83
3	12	2	72	3.42
8	8	2	128	1.36

Large Grid Runtime

- 1000 Generations
- 2304 x 2304 grid

Number of Processors	Mean Execution Time (s)
8	20.140
16	19.270
18	8.530
32	7.670
36	8.820
64	7.690
72	4.468
128	1.650
256	1.930
512	0.515
1024	0.690



Large Grid Runtime

- 1000 Generations
- 2304 x 2304 grid

Number of Processors	Mean Execution Time (s)
8	20.140
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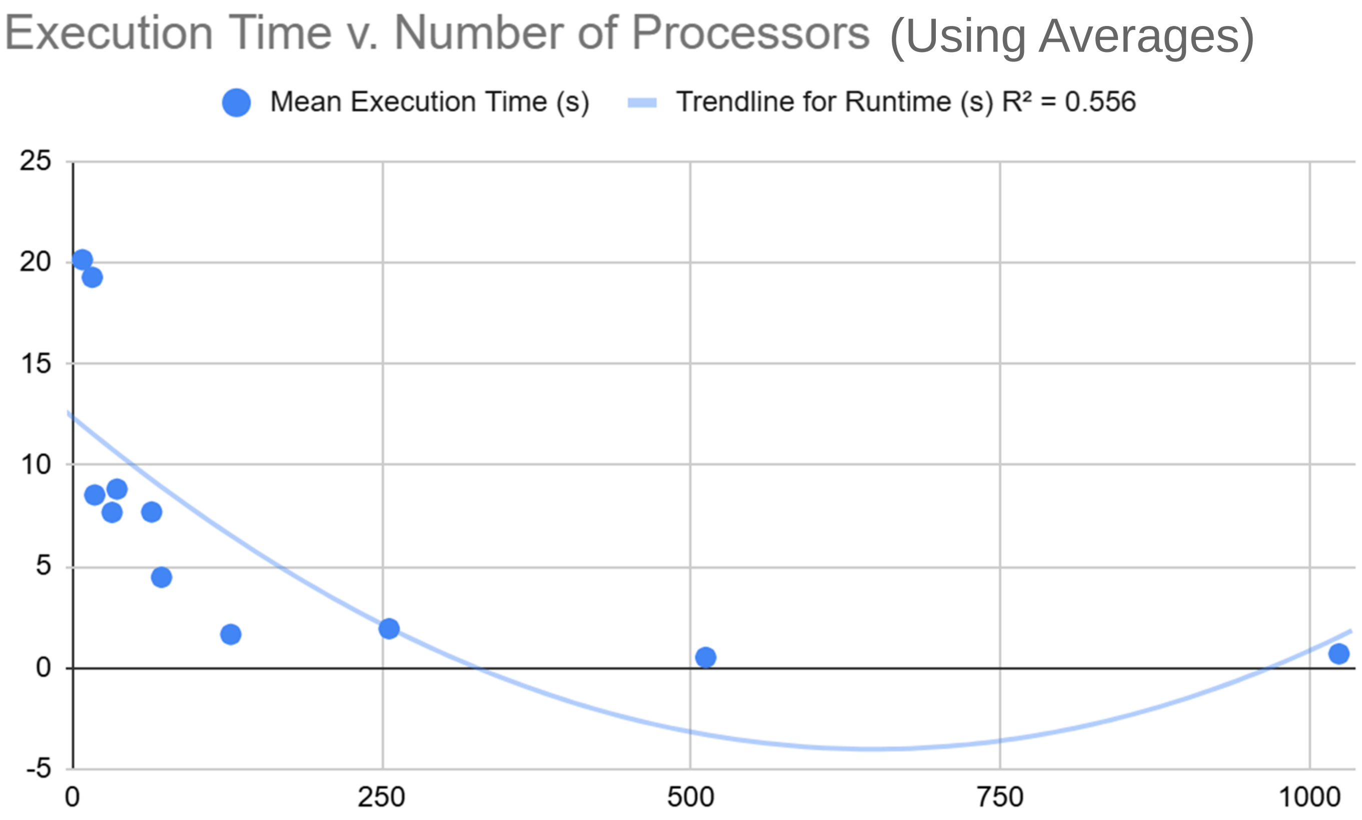
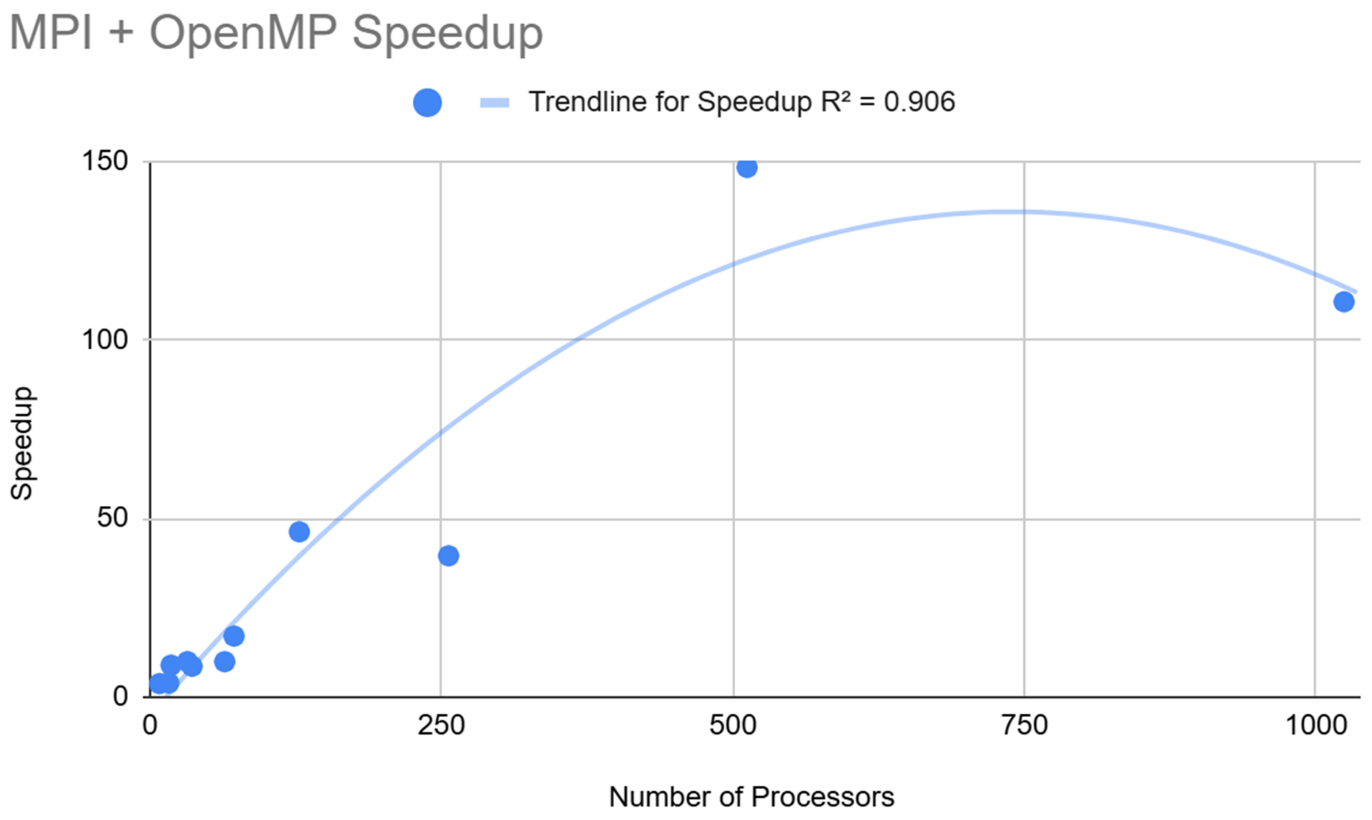


Speed-Up

Number of Processors	Speed-Up (Relative)
1	1.000
8	0.831
16	0.869
18	1.962
32	2.183
36	1.898
64	2.177
72	3.747
128	10.145
256	8.674
512	32.505
1024	24.261



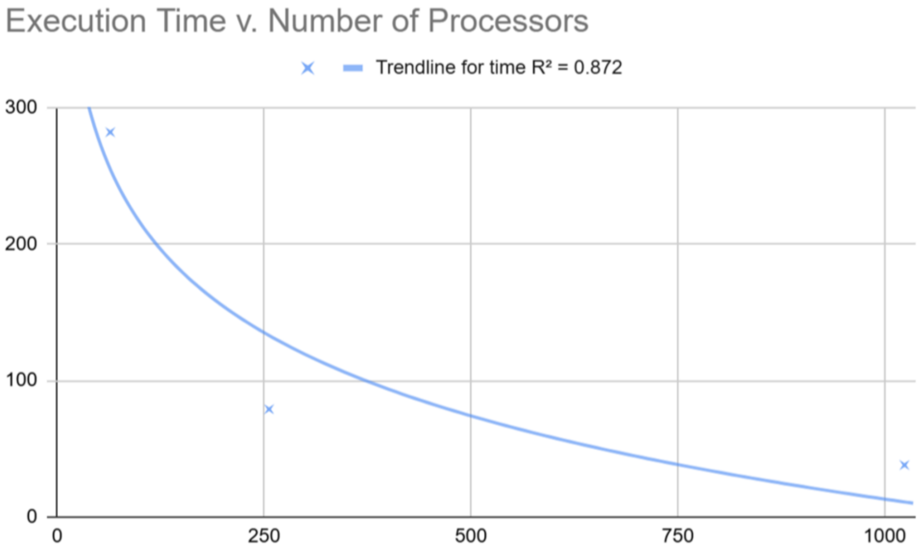
Alternative Motivation (Space > Time)

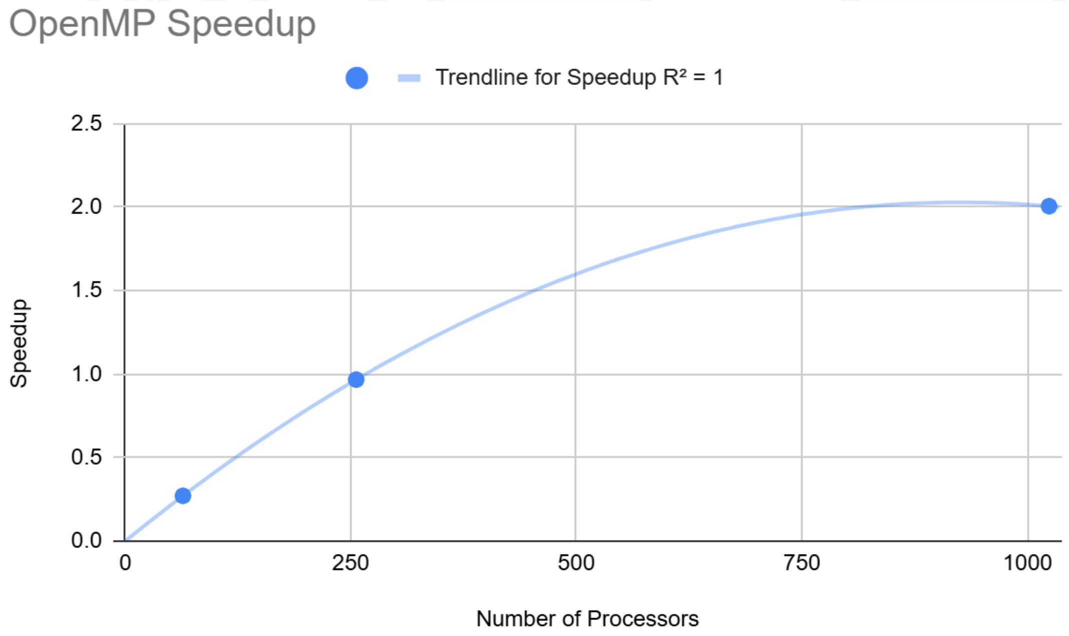
- Sometimes the grid can become so large it cannot fit into the memory of a single machine
- For example, a 65536 x 65536 grid will take up 4 GB (4,294,967,296 bytes)
  + program memory

Number of Processors	Mean Execution Time (s)
1	Out Of Memory
4	Out of Memory
16	Out of Memory
64	281.89
256	78.96
1024	38.07

Alternative Motivation (Space > Time)

Processors	Execution Time (s)
1	Out Of Memory
4	Out of Memory
16	Out of Memory
64	281.89
256	78.96
1024	38.07


Execution Time v. Number of Processors
× Trendline for time R² = 0.872


OpenMP Speedup
● Trendline for Speedup R² = 1
Speedup
Number of Processors