Parallel and Distributed Computing

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Introduction

This report is presented in order to elaborate and describe the serial and parallel programing aspects followed during the implementation in order to optimize the flow of the program. The quantitative results and comparisons are also included. The objective of this project is to implement the given problem with a program which executes serially and convert that program into a parallel one with OpenMP such that we get the same final results with optimized time efficiency. When you follow the report you will encounter section 1 with serial programing methodology followed by parallel programing methodology in section 2. Section 3 will give the results and comparisons. Finally the section 4, contains the conclusion with result justification.

Section 1: Serial Programing Methodology

There are two possible ways of implementation identified, and below Figure 1 and Figure 2 describes both of them. For our implementation we have selected the method in Figure 2 and the reason for the selection has been described in the next Section.

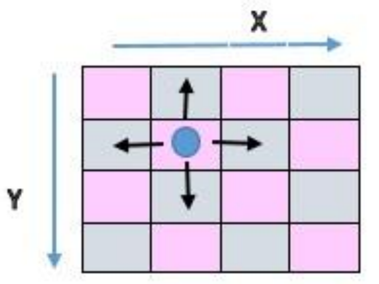


Figure 1: The processing cell (Red) checks adjacent cells and decide where it can moves to any of it. (Assume red cell contains a Wolf or a Squirrel) Processing occur to the X direction.

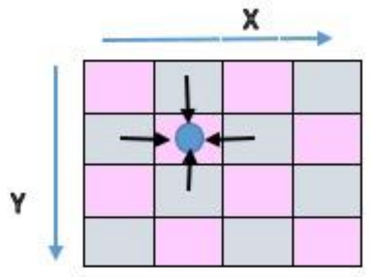


Figure 2: The processing cell (Red) checks adjacent cells and decide which of adjacent cells can come on to it. (Assume red cell is an empty cell) Processing occur to the X direction.

Section 2: Parallel Programing Methodology

In this case we are keeping two maps in the memory, where first map is the source map which will be initialized with the values which are given by input file. Meantime the second map is a temporary copy of the same data structure but it will be initially empty.

When we process the source map according to the way shown in Figure 2, the updates are made in the temporary copy in a certain sub generation (i.e.: Red sub generation). Once a sub generation is completed the changes made into the temporary map will be populated to the source map and temporary map will be cleaned again. Likewise the program executes for all the generations and gives the final result.

Methodology Selection Description

1. Parallel execution in method described in Figure 1.
   In the parallel execution, a race condition will be occurred when T1 (Thread 1) and T2 (Thread 2) both sees a movable position in the source map and tries to update the corresponding temporary map's memory location. The whole sub generation is parallelized so that there is a high probability of getting many thread conflicts which will lead to a poor performance of the parallelized version.

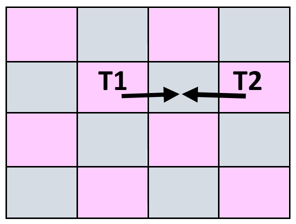


Figure 3

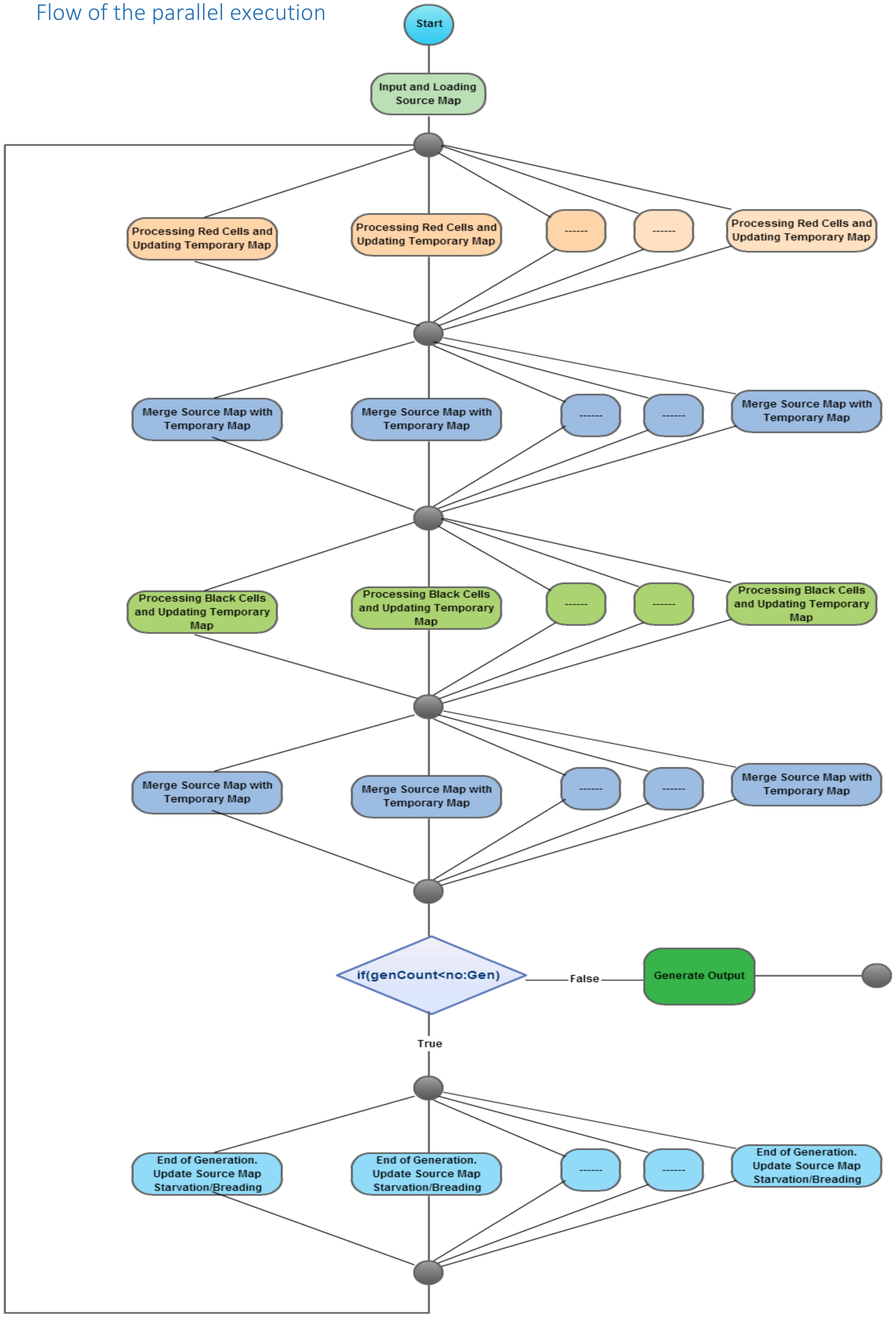
2. Parallel execution in method described in Figure 2.
   In this method, the processing cell and adjacent cells will be read from the source map and relevant updates will be applied to the corresponding cells in the temporary map. Due to the deterministic behavior of the active elements (wolfs and squirrels) this method of updating the temporary map do not encounter any race conditions. Therefore each FOR loops those are responsible for a certain sub generation can be parallelized without any dependencies and this method makes the parallel execution much efficient.

Load balancing

In order to analyze how load distribution among threads could affect overall execution time, we have profiled our parallel code by giving different chunk sizes to various scheduling mechanisms including row and column wise processing. The test has been conducted by choosing row wise processing of map because column wise processing did not contribute more influence to the parallel execution. Ex: High rate of cache misses, this rate will be increased when map size grows. For the experiment we used a map with size 30 and first half of the map was filled with elements (i.e. Wolves, Squirrels) while the latter half of the map is empty. Below table provides the total execution time of each thread within a sub generation (execT) and the time spent by each thread for its assigned load by parallel FOR (bodyT) in different scheduling configurations obtained from OpenMP profiler. According to the following statistics we could observe that the most effective load balanced configuration was Dynamic scheduling with chunk (size=1).

Scheduling Configuration	**Sub Generation**	**T0 (bodyT)**	**T1 (bodyT)**	**T2 (bodyT)**	**T3 (bodyT)**	**T0,T1,T2,T4 execT**
No configuration	Red	3.59	4.44	2.83	1.69	5.47
No configuration	Black	3.37	3.7	2.71	1.7	4.77
Static chunk (size=20)	Red	9.64	2.67	0.04	0.04	11.57
Static chunk (size=20)	Black	8.71	2.69	0.05	0.04	10.63
Static chunk (size=13)	Red	3.5	4.36	2.82	1.69	5.41
Static chunk (size=13)	Black	3.28	3.66	2.71	1.69	4.69
Static chunk (size=10)	Red	4.96	4.62	2.74	0.04	6.34
Static chunk (size=10)	Black	4.63	3.9	2.74	0.04	5.96
Static chunk (size=5)	Red	3.64	4.01	2.62	2.29	5.22
Static chunk (size=5)	Black	3.55	3.73	2.05	2.05	5.06
Static chunk (size=1)	Red	3.34	3.53	2.73	3.23	4.43
Static chunk (size=1)	Black	3.05	3.27	2.52	2.79	4.13
Dynamic chunk (size=20)	Red	2.9	3.67	1.7	3.2	9.29
Dynamic chunk (size=20)	Black	2.84	4.13	1.82	3.68	10.25
Dynamic chunk (size=13)	Red	4.01	2.2	2.9	2.6	5.47
Dynamic chunk (size=13)	Black	3.54	3	3.34	3.2	5.79
Dynamic chunk (size=10)	Red	2.72	3.13	2.97	3.05	4.38
Dynamic chunk (size=10)	Black	4.51	2.27	3.22	2.87	5.88
Dynamic chunk (size=5)	Red	2.97	3.15	3.39	3.41	4.64
Dynamic chunk (size=5)	Black	2.72	3.13	2.97	3.05	4.38
Dynamic chunk (size=1)	Red	3.39	3.4	3.4	3.39	4.19
Dynamic chunk (size=1)	Black	3.12	3.12	3.12	3.1	3.89

Flow of the parallel execution



Start
Input and Loading Source Map
Processing Red Cells and Updating Temporary Map
Processing Red Cells and Updating Temporary Map

Processing Red Cells and Updating Temporary Map
Merge Source Map with Temporary Map
Merge Source Map with Temporary Map

Merge Source Map with Temporary Map
Processing Black Cells and Updating Temporary Map
Processing Black Cells and Updating Temporary Map

Processing Black Cells and Updating Temporary Map
Merge Source Map with Temporary Map
Merge Source Map with Temporary Map

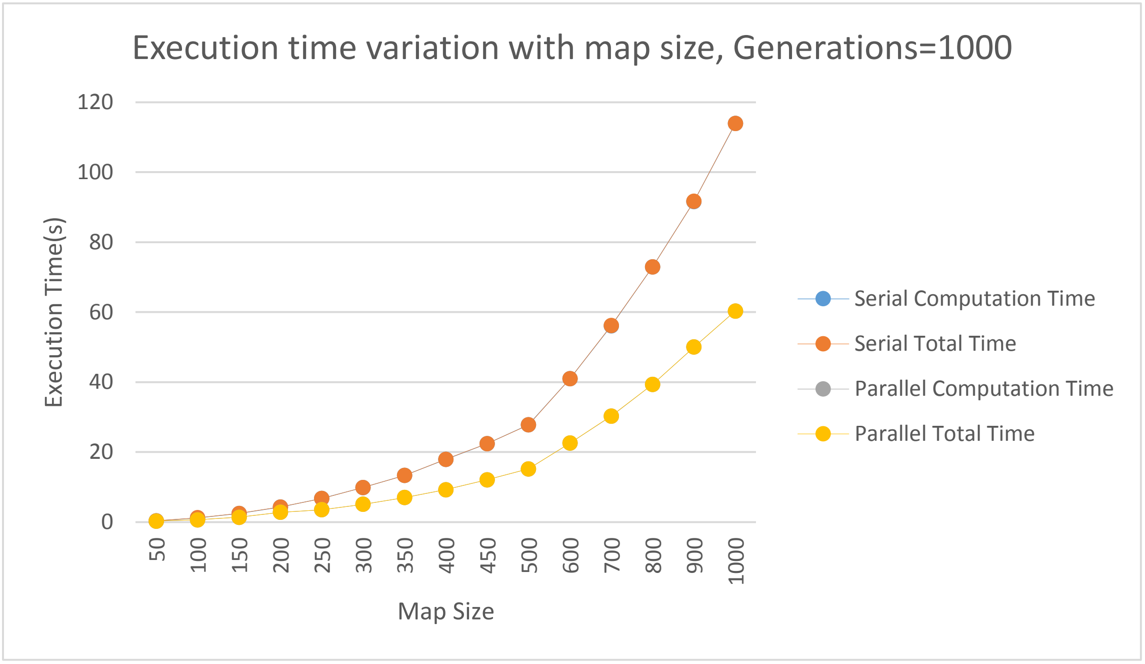
Merge Source Map with Temporary Map
if(genCount<no:Gen)
False
Generate Output
True
End of Generation. Update Source Map Starvation/Breading
End of Generation. Update Source Map Starvation/Breading

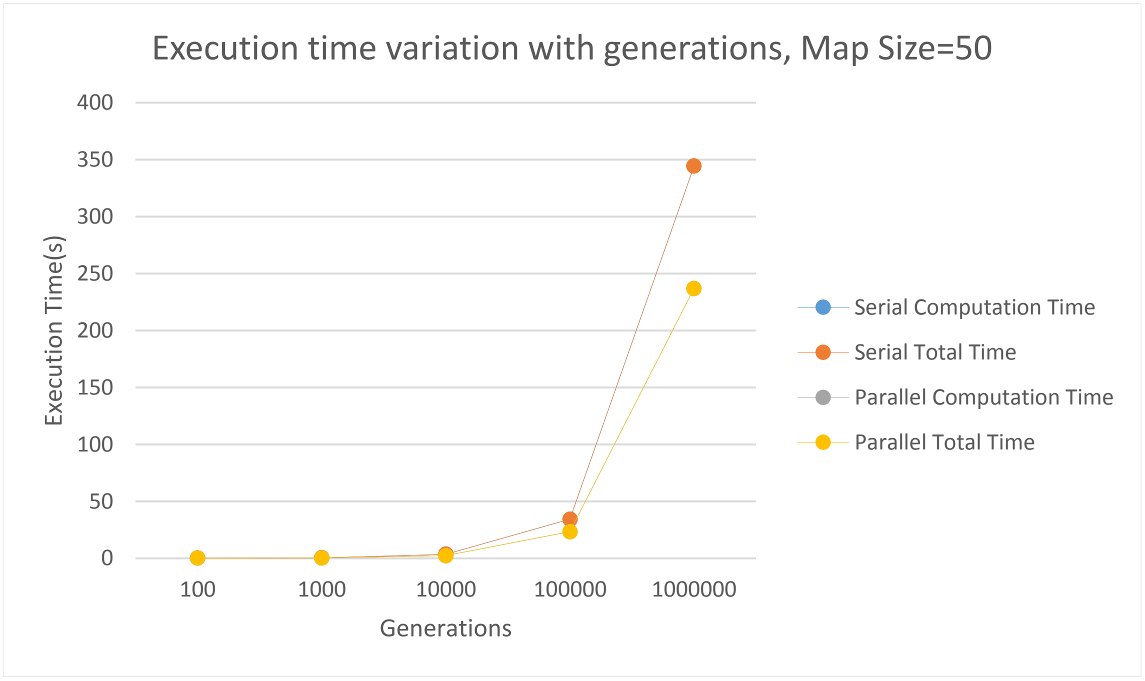
End of Generation. Update Source Map Starvation/Breading

Section 3: Results

Below graphs show the execution time of each serial and parallel programs spent during the processing of the map. One graph was populated by keeping the generation count a constant and changing the map size, while the other graph was populated by keeping the map size constant and changing the number of generations.

- Test machine configuration is, 2 CPUs (4 Thread), 4GB Memory, x86_64 architecture.





Section 4: Conclusion

According the above results we can conclude that the parallel execution time has become almost half of the serial execution time when the number of iterations increase, which we were expecting to see in a 2 core CPU with OpenMP implementation. Moreover the load balancing with dynamic scheduling configuration with chunk size of 1 has provided the most efficient load distribution which was also an expected result, because of following two reasons

1. The parallel execution was free from race conditions which includes map creation and contiguous memory allocation.
2. Since generations are growing, the uncertainty (evolution of the agents across the map) of agents' movements.

We have observed, the lower the chunk size, has produced significantly lower execution time over other chunk sizes which we have chosen and also the load was balanced uniformly among threads.