Project 1 INF236

Markus Ragnhildstveit, hef005

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Contents

I decided to run the performance tests on my computer, because the results I got on lyng was so inconsistent. My computer has 4 cores with 2 hyperthreads on each core. So a total of 8 hyperthreads.

1 1D

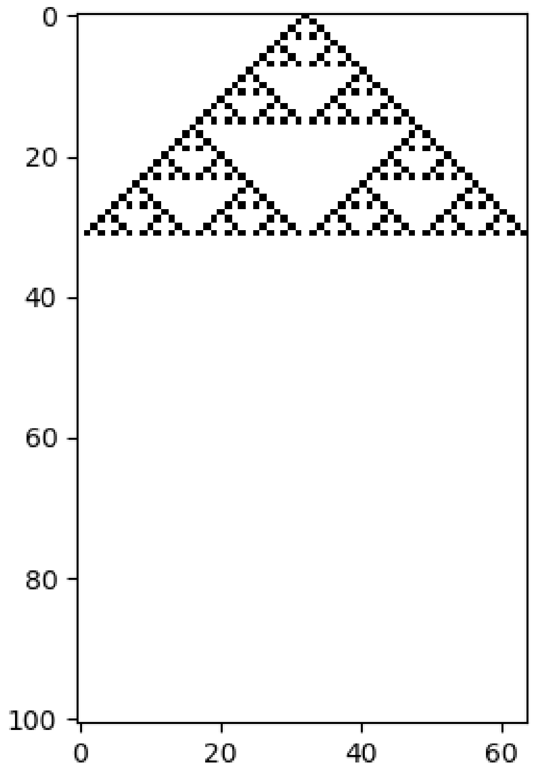


Figure 1: 100 iteration with $0^{32}10^{31}$ as initial configuration.

1.1 How to run the program

To run the sequential program, it needs the following arguments: rulefile kx.txt numOfIt. Where rulefile can be any rulefile, but the only available is mod2.txt. Also x in kx.txt can be 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 or 20. E.g. k10.txt. numOfIt is the number of iterations, which can be any number over 0.
To run the parallel program, it needs the following arguments: rulefile kx.txt numOfIt. Where rulefile can be any rulefile, but the only available is mod2.txt. Also x in kx.txt can be 10, 11,

12, 13, 14, 15, 16, 17, 18, 19 or 20. E.g. k10.txt. numOfIt is the number of iterations, which can be any number over 0.

1.2 Table

k\n	1	2	4	8	16	32	64	128
10	2.14s	1.58s	1.84s	2.16s	3.69s	5.89s	10.52s	21.96s
11	3.83s	3.26s	3.09s	3.86s	5.46s	7.47s	12.73s	24.79s
12	9.39s	6.95s	6.73s	7.55s	9.32s	11.17s	16.84s	30.2s
13	27.27s	17.3s	16.58s	18.14s	19.59s	35.68s	30.84s	51.16s

When running with 100000 iterations, I was not able to run with k larger than 13 because of limited memory. So I decided to run only 1000 iterations when k was larger than 13.

k\n	1	2	4	8	16	32	64	128
14	0.28s	0.22s	0.22s	0.28s	0.29s	0.32s	0.44s	0.66s
15	0.56s	0.44s	0.42s	0.49s	0.53s	0.59s	0.72s	1.05s
16	1.14s	0.87s	0.87s	1.02s	1.04s	1.32s	1.38s	1.82s
17	3.22s	1.85s	1.88s	2.2s	2.17s	2.49s	2.41s	3.33s
18	5.28s	4.81s	3.59s	4.19s	4.36s	4.4s	4.73s	6.87s
19	12.08s	8.81s	9.59s	9.85s	9.41s	9.68s	10.78s	14.02s
20	39.32s	22.54s	21.39s	23.48s	25.1s	24.73s	25.62s	33.54s

I noticed that the antivirus started to process when the data started, so this may have affected the results. We can however see that the optimal number of processes is close to the number of cores my machine has. I noticed that the gather function was what made 2 processes almost as fast as 4 or 8 processes, since with 2 there is less time consumption with fewer processes. I took the time before and after gather, called time1 and time2, which you can find in the result1D.csv.

1.3 How I parallelized my program

To parallelize my 1D program I first had to get the initial config and lookup table. this is done only in process 1 to avoid multiple reads to files. Then process 1 needs to calculate how big part of the config each process will get. This is done by dividing the number of cells in the config by the number of processes, but also by looking at the rest. To send each process a part of the config, I use MPI_ Scatterv.
When running each iteration each process will send and receive the neighbouring cells so their local config can be calculated. This is done by making even numbered processes send first and odd numbered receive first.
In the start when I gathered, I had a for-loop which gathered each iteration independently, but I noticed this took very long time when the number of processes increased. I then change to only using 1 gather, but the data became unorganized. To fix this when e.g. reading to a file, I had to locate the index which was the start for each process's history. You can find this in the writeToFile function.

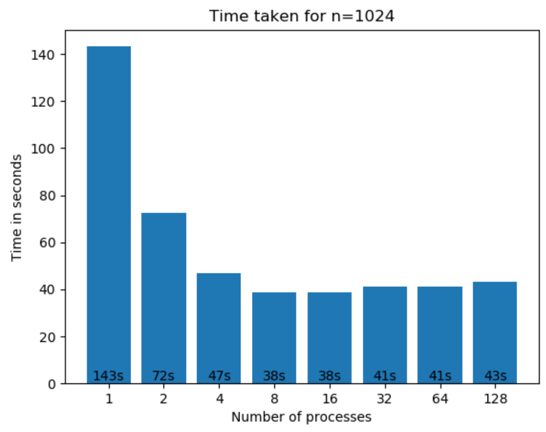
2 2D

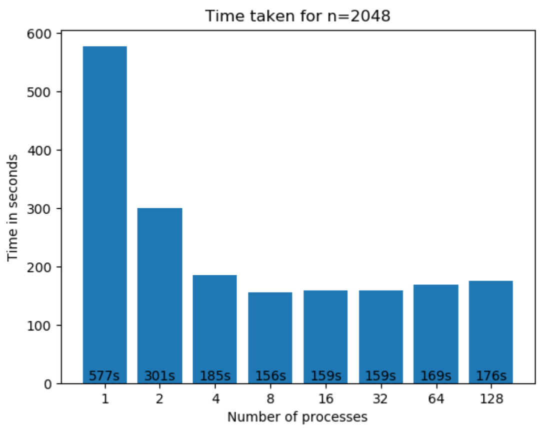
2.1 How to run

To run the sequential program, it needs the arguments as follow: gameOfLife.txt config_n.txt numOfIt. Where n is the size of n, the only supported n for this program is 3, 5, 20 and 1024. And where numOfIt is the number of iterations, which can be any number over 0.
To run the parallel program, it needs the arguments as follow: gameOfLife.txt n numOfIt. Where n is the size of the config. it can be any integer over 3, since it gets generated in the program. numOfIt is the number of iterations, it can be any number over 0.

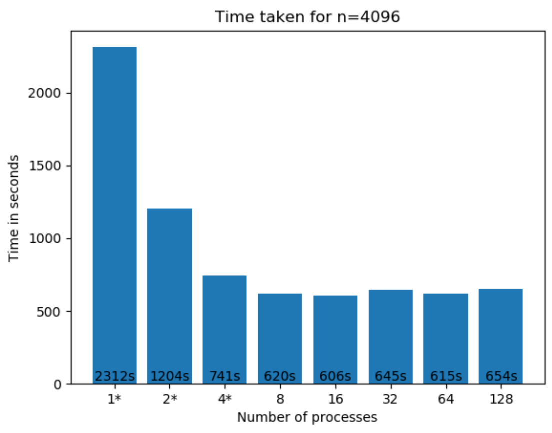
2.2 How I parallelized my program

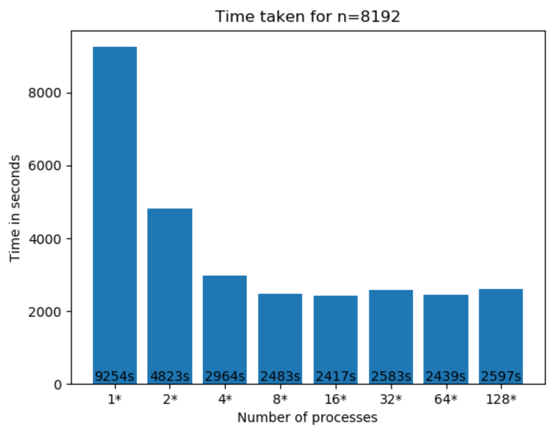
I wanted it to work for any combination of n and p, so I decided to use Scatterv and Gatherv as I did in 1D. Instead of dividing the number of cells, I divided the height between the processes, so that it would be easier to send and receive when running the iterations. The reason I divided the height instead of the width, was that then only 1 scatter was necessary.
When running each iteration, send and receive the first and last row with the corresponding neighbour. To avoid deadlock, I make the even number processes send first and then receive, while odd number number processes will receive first and the send. If there is an odd number of processes, process 0 has to receive first from process n-1 to avoid deadlock. To get neighbours of a cell, I check the row position +-1 and column position +-1. If the row is either first or last, some of the neighbours needs to be find from the array which saves the data received from neighbouring processes.
When gathering the configuration together again, it can be done the same way it is scattered.





Numbers with a star * is estimation using linear regression using execution time from both less iterations and smaller n. I do this because i noticed it was a linearly increasing in time used when I look at the number of elements processed (n*n) and number of iterations. It looks like the model thinks that processes with more than 8 will be faster when n is increasing, but this is likely only noise. We can see that 8 processes is the fastest for the real data I have. This corresponds to the number of hyperthreads my machine has, which has 4 cores and 2 hyperthreads per core. Looking at larger values for n is going to take unnecessary long time, with 1 process and n=65536 estimated to use 164.5 hours to complete.
The data used to create the bars are in the table under:





	1	2	4	8	16	32	64	128
1024	2.39m	1.21m	47.03s	38.6s	38.65s	41.37s	41.25s	43.26s
2048	9.62m	5.03m	3.1m	2.6m	2.66m	2.65m	2.83m	2.95m
4096	38.54m*	20.08m*	12.36m*	10.35m	10.11m	10.76m	10.26m	10.9m
8192	2.57h*	1.34h*	49.4m*	41.39m*	40.29m*	43.06m*	40.66m*	43.29m*
16384	10.28h*	5.36h*	3.29h*	2.76h*	2.68h*	2.87h*	2.7h*	2.88h*
32768	41.14h*	21.44h*	13.17h*	11.04h*	10.73h*	11.48h*	10.8h*	11.51h*
65536	164.54h*	85.78h*	52.68h*	44.14h*	42.9h*	45.94h*	43.2h*	46.03h*

The raw data can be found in report.csv.

3 Branching

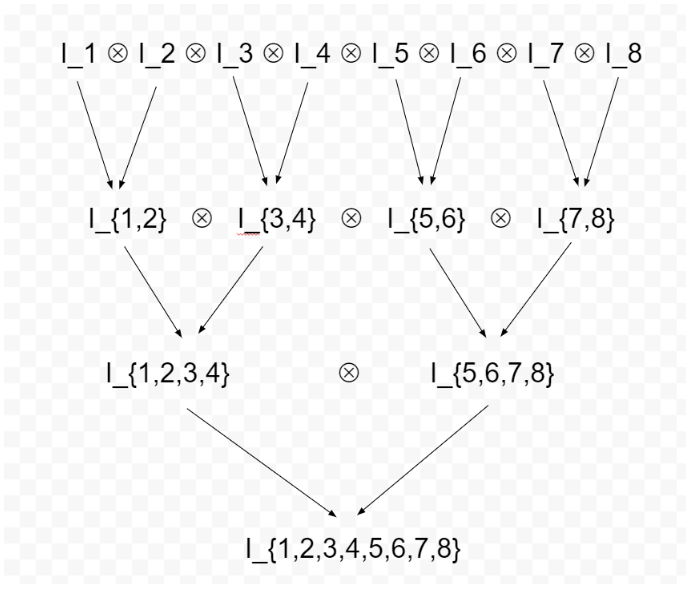
I felt like it was hard to understand how the program should work without example, but I implemented with some assumptions that I thought was correct.

3.1 How to run

To run the sequential program, it needs the following arguments: rulefile a. Where rulefile is any file with rules, but the only available file is branchingmod3.txt. And a is the binary string, e.g. 1010 when branchingmod3.txt is used.
To run the parallel program, it needs the following arguments: rulefile a. Where rulefile is any file with rules, but the only available file is branchingmod3.txt. And a is the binary string, e.g. 1010 when branchingmod3.txt is used. It is possible to run the program with generating if you uncomment line 40, 60 and 61. And comment out line 42, 58 and 59.

3.2 Problem 2

The reason that it is possible to compute val(P, a) is that the operation is associative, so the result could be calculated in this order for an example with size 8:


I_1 ⊗ I_2 ⊗ I_3 ⊗ I_4 ⊗ I_5 ⊗ I_6 ⊗ I_7 ⊗ I_8
I_{1,2} ⊗ I_{3,4} ⊗ I_{5,6} ⊗ I_{7,8}
I_{1,2,3,4} ⊗ I_{5,6,7,8}
I_{1,2,3,4,5,6,7,8}

As we can see the problem length halves each iteration. In the first iteration needs 4 processes which has 2 numbers each. Next iteration 2 processes is needed, and last only 1 process is needed. Since the problem halves each iteration, it will finish in $O(log_2(m)) = O(log(m))$ time.

3.3 How I parallelized my program

To parallelize the program, I made process 0 parse the rule file and convert the assignment argument to an int array. The rules with their sizes was broadcasted to all processes. I then scattered the array between each process with scatterv. First each process calculates the result of its own array.
To calculate the results each processed had with each other, I used MPI_Reduce. To reduce I needed to create my own MPI operation (similar to how MPI_SUM works in the background). This function is called valmpi. In this function, the only way to also receive the operation lookup table, I needed to merge the result and operation lookuptable into 1 array, and send it into the MPI_Reduce function. So when MPI_Reduce was done, the end result would be the first element in the received array.
I do have a bug in the parallel program when using the operation lookup table, but I did not have time to fix it.