Programming techniques : Project 3

Raphaël Javaux

0.1 Sequential optimisations

0.1.1 Neighbourhood coordinates lookup tables

To avoid to compute the neighbours coordinates in the *toroidal square world* at each iteration, I used two lookup tables to precompute the coordinates of, respectively, the previous column/row and the next column/row for each column/row. This gave an **1.4x** speedup to the algorithm by removing four conditional expressions.

0.1.2 Board of bytes instead of booleans

By storing the game's board state in an array of *bytes*, with cells labelled with *1* for *alive* and *0* for *dead*, I was able to replace the inspection of cell status by an eight terms addition, removing as many conditional expressions. This gave me an additional **5x** speedup.

0.2 Programming languages

In addition to the required Java tests, I written my **sequential** generation algorithm in two additional programming languages :

- In *C* because of its very competitive compilers (GCC 4.8 was used) and the similar syntax to Java which enabled me to almost copy-paste the algorithm ;
- In *Haskell* because this functional language provides automatic and deterministic array parallelisation (parallelisation of a function is a compile time option and is guaranteed by the compiler to give the same result as the sequential execution).

Both versions implement exactly the same algorithm as the Java sequential one, except that the Haskell's is able to execute itself in parallel automatically.

1 Results

These results have been collected on a dual Intel 2Ghz haxa-cores hyper-threaded machine, giving 24 logical cores for 12 physical cores. Each of the following results is obtained by computing the mean execution time of an hundred repeated executions. *As the naive strategy (spawn a new thread for each cell) wasn't able to scale up to a board of more than a thousand cells, it was removed from my tests.*

Figure 1 shows the *number of cells which can be generated per second* by each method given a certain amount of threading on a large board. Notice that the block segmentation is only able to use square numbers of threads and that the board size must also be a multiple of 144 (the *least common multiple* of 1, 4, 9 and 16).
The sequential C algorithm is awfully fast, probably because the C compiler is smart enough to use vectorial instructions while others aren't.
The linear segmentation is the most effective parallel strategy (it's also the one used by Haskell internally). The column segmentation is deadly ineffective because of being cache unfriendly. Haskell scales in an almost perfect speedup until reaching the number of physical cores, which makes me hint that the benchmark is not bounded by the memory bandwidth, even on this 24-cores machine.

Figure 2 shows the impact of different board sizes on the cell throughput, given the most efficient number of threads for each method for each size.
The *performance index* is calculated for each method by comparing the best performance obtained to the speed of the sequential Java implementation. The *parallel speedup* is the maximum speedup obtained with the method when compared to a mono-thread execution. Parallel implementations shine as well as the number of cells in the board increase. The sequential C implementation almost loose half its speed when the size of the board exceeds the CPU cache whereas the sequential Java implementation has stable, but poor, performances. Haskell is able to benefit from parallelism even on very small boards and quickly takes the lead over the sequential C algorithm on larger boards.

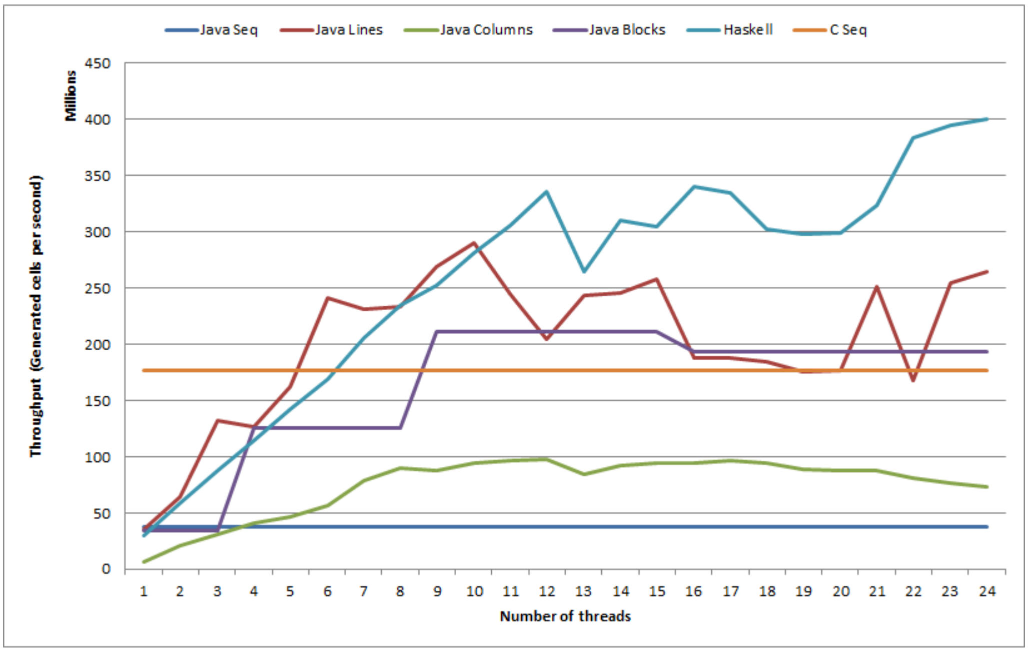
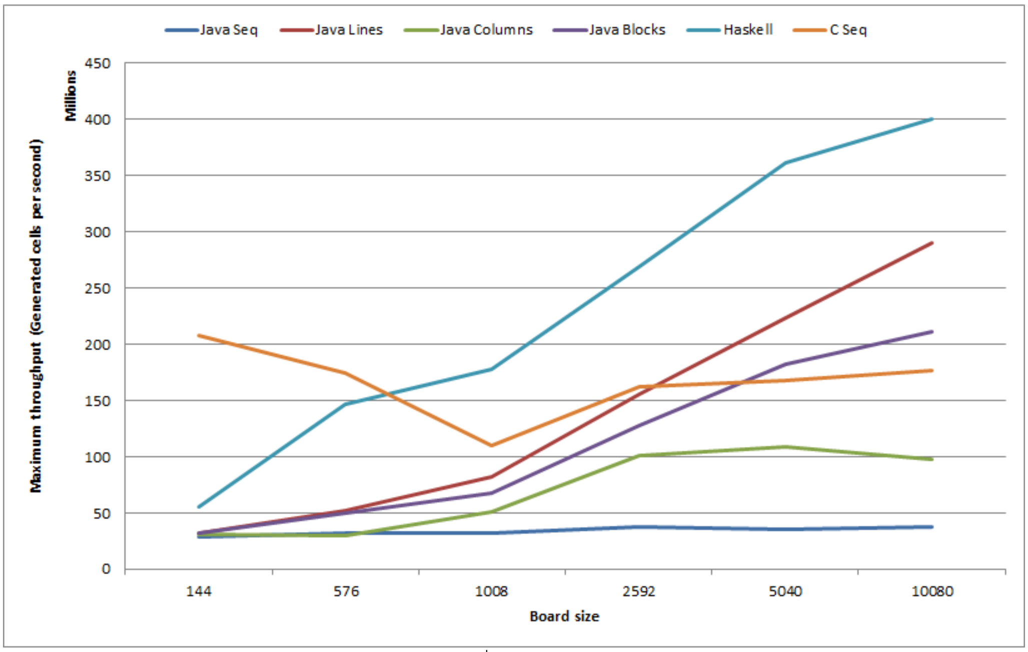


Figure 1: Cell generation rate on a 10,080 x 10,080 board



		144	576	1008	2592	5040	10080
Java Seq	Performance index	1	1	1	1	1	1
Java Lines	Performance index	1	1.6	2.6	4.2	6.3	7.8
	Parallel speedup	1	1.4	2.5	4.3	6.5	8.1
	Threads	1	5	9	9	6	10
Java Columns	Performance index	1	0.9	1.6	2.7	3.1	2.6
	Parallel speedup	1	1	2	5	8.8	**14.5**
	Threads	1	1	8	7	11	11
Java Blocks	Performance index	1	1.6	2.1	3.4	5.1	5.7
	Parallel speedup	1	1.4	2.1	3.7	5.6	6.1
	Threads	1	4	4	9	9	15
Haskell	Performance index	1.9	4.6	**5.5**	**7.2**	**10.1**	**10.7**
	Parallel speedup	**2.3**	**9.7**	**7.2**	**9.1**	**12.2**	13.3
	Threads	**4**	**18**	**22**	**20**	**24**	**24**
C Seq	Performance index	**7.1**	**5.5**	3.4	4.4	4.7	4.7

Figure 2: Maximum cell generation rate on different board sizes