Conway's Game of Life Coursework

Conway's Game of Life Explanation (Q1)

Game of Life is a cellular automata designed by Conway in 1970. It is a zero-player game and the only input provided is the initial state of the game board. The state of the board is updated at each iteration of the game in a cell-by-cell basis. The decision of the state of each cell in the next iteration depends on the number of cells that are alive in its 8-neighbourhood and on the state of each cell in particular. Therefore:

1) If a cell is alive and has exactly two or three neighbours alive it will be alive in the next iteration. Otherwise, it dies.

2) If a cell is dead and has exactly three neighbours alive it will be alive in the next iteration. Otherwise, it remains dead.

Build Instructions

$ ./build.sh

Code Organisation

The code has been organised in several folders:
- inc: contains the header files (.h or .hpp).
- src: contains the code files (.c or .cpp).
- test: contains all the required headers and code files for the unit tests (i.e. catch and test.cpp, which is the file that contains all the tests).
- doc: contains all the documentation of the project including this report.

- bin: contains the two binary files produced by this project, the app and the tests.

Run Unit Tests

Execute the following commands in the main directory of the project in order to check the correctness of the code.

$ bin/GameOfLifeTest

Run the Program

After the program and the tests have been compiled, execute this command to run the program:
$ build/src/GameOfLife –input test/input.txt –output output.txt –niter 100
$ build/src/GameOfLife –random 100 –output output.txt –niter 100

Parallelisation

The code has been parallelised using OpenMP. The part of the code that has been parallelised is the method evolve() of the Board class since each cell is updated based exclusively on the previous state of the cells in its neighbourhood, which does not change while the other cells are being updated.

```
// Code that executes Conway's rules and updates the board
#pragma omp parallel for
for (uint32_t i = 0; i < m_rows; i++) {
   for (uint32_t j = 0; j < m_cols; j++) {
      uint32_t nAlive = aliveNeighbours(i, j);
      if (m_board[i][j].isAlive()) { // If cell is alive
         if (nAlive == 2 || nAlive == 3)
            newBoard.cell(i, j, true);
         else
            newBoard.cell(i, j, false);
          }
          else {                          // If cell is not alive
         if (nAlive == 3)
            newBoard.cell(i, j, true);
```

```
            else
                newBoard.cell(i, j, false);
        }
    }
}
```

Results

Video uploaded to YouTube demonstrating Game of Life:

https://www.youtube.com/watch?v=949ciYmRyhE

This video has been generated running this program with the following command:

$ ./GameOfLife –random 100 –niter 500 –output output.txt

Then, the file output.txt is converted into a video with the following command:

$ python extras/txt_to_video.py output.txt video.mp4

Speed tests comparing the execution time with and without OpenMP:

OS : MAC OS X 10.9.5
Machine : Intel Core i7 2.5GHz 16GB 1600MHz DDR3 (4 cores)
Benchmark : Unix 'time' command
Iterations : 100
Board sizes tested: 100x100, 1000x1000, 2000x2000

Each test has been executed three times.

Without OpenMP:

GameOfLife -r 100 -n 100 -o output.txt 0.27s user 0.02s system 99% cpu 0.294 total
GameOfLife -r 100 -n 100 -o output.txt 0.27s user 0.01s system 99% cpu 0.286 total
GameOfLife -r 100 -n 100 -o output.txt 0.28s user 0.01s system 99% cpu 0.293 total

GameOfLife -r 1000 -n 100 -o output.txt 26.30s user 0.37s system 99% cpu 26.676 total
GameOfLife -r 1000 -n 100 -o output.txt 26.68s user 0.39s system 99% cpu 27.066 total
GameOfLife -r 1000 -n 100 -o output.txt 26.54s user 0.39s system 99% cpu 26.936 total

GameOfLife -r 2000 -n 100 -o output.txt 105.65s user 1.52s system 99% cpu 1:47.20 total
GameOfLife -r 2000 -n 100 -o output.txt 106.05s user 1.57s system 99% cpu 1:47.67 total
ameOfLife -r 2000 -n 100 -o output.txt 105.97s user 1.58s system 99% cpu 1:47.57 total

With OpenMP:

GameOfLife -r 100 -n 100 -o output.txt 0.50s user 0.02s system 375% cpu 0.138 total
GameOfLife -r 100 -n 100 -o output.txt 0.50s user 0.02s system 356% cpu 0.147 total
GameOfLife -r 100 -n 100 -o output.txt 0.50s user 0.02s system 382% cpu 0.138 total

GameOfLife -r 1000 -n 100 -o output.txt 60.73s user 0.44s system 570% cpu 10.729 total
GameOfLife -r 1000 -n 100 -o output.txt 60.02s user 0.43s system 564% cpu 10.714 total
GameOfLife -r 1000 -n 100 -o output.txt 62.75s user 0.44s system 568% cpu 11.124 total

GameOfLife -r 2000 -n 100 -o output.txt 282.59s user 1.80s system 607% cpu 46.848 total
GameOfLife -r 2000 -n 100 -o output.txt 284.56s user 1.79s system 611% cpu 46.810 total
GameOfLife -r 2000 -n 100 -o output.txt 286.03s user 1.82s system 611% cpu 47.105 total

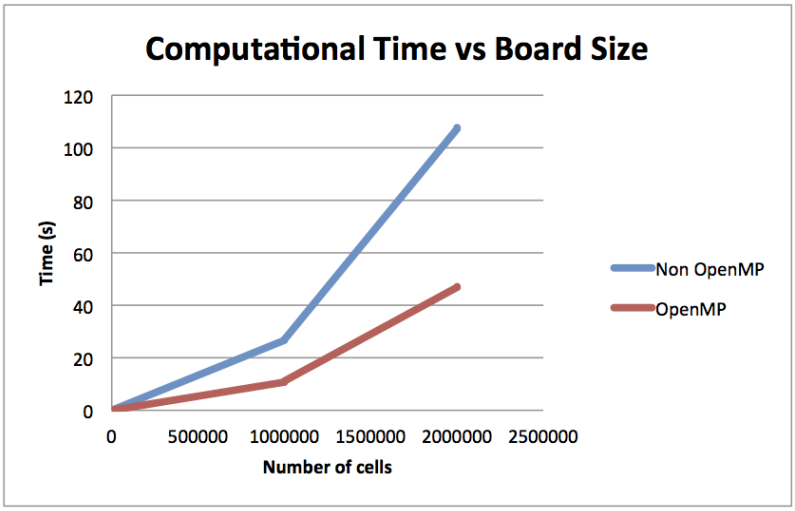
Summary (without OpenMP):

100x100: 0.294s, 0.286s, 0.293s

1000x1000: 26.676s, 27.066s, 26.936s
2000x2000: 107.20s, 107.67s, 107.57s

Summary (with OpenMP):

100x100: 0.138s, 0.147s, 0.138s
1000x1000: 10.729s, 10.714s, 11.124s
2000x2000: 46.848s, 46.810s, 47.105s



N	Non OpenMP	OpenMP
10000	0.294	0.138
10000	0.286	0.147
10000	0.293	0.138
1000000	26.676	10.729
1000000	27.066	10.714
1000000	26.936	11.124
2000000	107.2	46.848
2000000	107.67	46.81
2000000	107.57	47.105

Conclusions

The speedup achieved with OpenMP for a boards of 100x100, 1000x1000 and 2000x2000 are 206.38%, 299.99% and 229.07% respectively.