Game of Life: Profiling Report

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1 Introduction

This report intends to give some insights about the profiling of the code we developed to implement Conway's Game of Life. The results that are reported here were all obtained using the same initial configuration, the "Diehard" one, and have been computed on a whole run of the application (until automatic exit).

2 Profiling using `gprof`

`gprof` enables us to profile our application by computing the total execution time spent in each function, as well as the corresponding percentage of the total running time. The results we obtained when starting from the Diehard configuration are shown below:

```
Flat profile:

Each sample counts as 0.01 seconds.
  %   cumulative   self              self     total
 time   seconds   seconds    calls  us/call  us/call  name
100.14      0.01     0.01      131    76.45    76.45  printFieldToSubwindow
  0.00      0.01     0.00     3031     0.00     0.00  check_dimensions
  0.00      0.01     0.00      240     0.00     0.00  createField
  0.00      0.01     0.00      240     0.00     0.00  freeField
  0.00      0.01     0.00      130     0.00     0.00  calculateNextState
  0.00      0.01     0.00      130     0.00     0.00  cleanMenu
  0.00      0.01     0.00      130     0.00     0.00  convolution_2D
  0.00      0.01     0.00      130     0.00     0.00  getNewDimensions
  0.00      0.01     0.00      130     0.00     0.00  getStats
  0.00      0.01     0.00      130     0.00     0.00  handlePossibles
  0.00      0.01     0.00      109     0.00     0.00  updateFieldWithNextState
  0.00      0.01     0.00        1     0.00     0.00  clearField
  0.00      0.01     0.00        1     0.00     0.00  drawSquare
  0.00      0.01     0.00        1     0.00     0.00  enditall
  0.00      0.01     0.00        1     0.00     0.00  getPredefinedFigure
  0.00      0.01     0.00        1     0.00     0.00  initall
  0.00      0.01     0.00        1     0.00     0.00  mymove
  0.00      0.01     0.00        1     0.00     0.00  printMenu
  0.00      0.01     0.00        1     0.00     0.00  readfileAndPrint
  0.00      0.01     0.00        1     0.00     0.00  resetWindow
  0.00      0.01     0.00        1     0.00     0.00  setPaddingAndReals
  0.00      0.01     0.00        1     0.00     0.00  startGame

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```

It can be seen that the function that is called the most is the function `checl_dimensions`. This is not surprising, since it is called for every live cell, each time a new state is computed. In terms of execution time, the functions used to compute the value of the cells take almost the same amount of time. Most of the execution time is spent to display the field graphically to the `ncurses` window.

The `gprof` tool also creates the call graph, which represents for each function its parents (functions that call it) and its children (functions that it calls).

```
     Call graph

granularity: each sample hit covers 2 byte(s) for 11.10% of 0.09 seconds

granularity: each sample hit covers 2 byte(s) for 99.86% of 0.01 seconds

index % time    self  children    called     name
                0.01    0.00     131/131         main [2]
[1]    100.0    0.01    0.00     131         printFieldToSubwindow [1]
-----------------------------------------------
                                                <spontaneous>
[2]    100.0    0.00    0.01                 main [2]
                0.01    0.00     131/131         printFieldToSubwindow [1]
                0.00    0.00     130/130         calculateNextState [6]
                0.00    0.00     130/130         getStats [10]
                0.00    0.00     130/130         cleanMenu [7]
                0.00    0.00     130/130         handlePossibles [11]
                0.00    0.00       1/1           startGame [23]
                0.00    0.00       1/1           getPredefinedFigure [16]
                0.00    0.00       1/1           clearField [13]
                0.00    0.00       1/1           mymove [18]
                0.00    0.00       1/1           enditall [15]
                0.00    0.00       1/240         freeField [5]
-----------------------------------------------
                0.00    0.00    3031/3031        convolution_2D [8]
[3]      0.0    0.00    0.00    3031         check_dimensions [3]
-----------------------------------------------
                0.00    0.00       1/240         startGame [23]
                0.00    0.00     109/240         calculateNextState [6]
                0.00    0.00     130/240         convolution_2D [8]
[4]      0.0    0.00    0.00     240         createField [4]
-----------------------------------------------
                0.00    0.00       1/240         main [2]
                0.00    0.00     239/240         calculateNextState [6]
[5]      0.0    0.00    0.00     240         freeField [5]
-----------------------------------------------
                0.00    0.00     130/130         main [2]
[6]      0.0    0.00    0.00     130         calculateNextState [6]
                0.00    0.00     239/240         freeField [5]
                0.00    0.00     130/130         convolution_2D [8]
                0.00    0.00     130/130         getNewDimensions [9]
                0.00    0.00     109/240         createField [4]
                0.00    0.00     109/109         updateFieldWithNextState [12]
-----------------------------------------------
                0.00    0.00     130/130         main [2]
[7]      0.0    0.00    0.00     130         cleanMenu [7]
-----------------------------------------------
                0.00    0.00     130/130         calculateNextState [6]
[8]      0.0    0.00    0.00     130         convolution_2D [8]
                0.00    0.00    3031/3031        check_dimensions [3]
```

```
                0.00    0.00     130/240         createField [4]
-----------------------------------------------
                0.00    0.00     130/130         calculateNextState [6]
[9]      0.0    0.00    0.00     130         getNewDimensions [9]
-----------------------------------------------
                0.00    0.00     130/130         main [2]
[10]     0.0    0.00    0.00     130         getStats [10]
-----------------------------------------------
                0.00    0.00     130/130         main [2]
[11]     0.0    0.00    0.00     130         handlePossibles [11]
-----------------------------------------------
                0.00    0.00     109/109         calculateNextState [6]
[12]     0.0    0.00    0.00     109         updateFieldWithNextState [12]
-----------------------------------------------
                0.00    0.00       1/1           main [2]
[13]     0.0    0.00    0.00       1         clearField [13]
-----------------------------------------------
                0.00    0.00       1/1           resetWindow [21]
[14]     0.0    0.00    0.00       1         drawSquare [14]
                0.00    0.00       1/1           setPaddingAndReals [22]
-----------------------------------------------
                0.00    0.00       1/1           main [2]
[15]     0.0    0.00    0.00       1         enditall [15]
-----------------------------------------------
                0.00    0.00       1/1           main [2]
[16]     0.0    0.00    0.00       1         getPredefinedFigure [16]
                0.00    0.00       1/1           readfileAndPrint [20]
-----------------------------------------------
                0.00    0.00       1/1           startGame [23]
[17]     0.0    0.00    0.00       1         initall [17]
-----------------------------------------------
                0.00    0.00       1/1           main [2]
[18]     0.0    0.00    0.00       1         mymove [18]
-----------------------------------------------
                0.00    0.00       1/1           resetWindow [21]
[19]     0.0    0.00    0.00       1         printMenu [19]
-----------------------------------------------
                0.00    0.00       1/1           getPredefinedFigure [16]
[20]     0.0    0.00    0.00       1         readfileAndPrint [20]
-----------------------------------------------
                0.00    0.00       1/1           startGame [23]
[21]     0.0    0.00    0.00       1         resetWindow [21]
                0.00    0.00       1/1           drawSquare [14]
                0.00    0.00       1/1           printMenu [19]
-----------------------------------------------
                0.00    0.00       1/1           drawSquare [14]
[22]     0.0    0.00    0.00       1         setPaddingAndReals [22]
-----------------------------------------------
                0.00    0.00       1/1           main [2]
[23]     0.0    0.00    0.00       1         startGame [23]
                0.00    0.00       1/1           resetWindow [21]
                0.00    0.00       1/1           initall [17]
                0.00    0.00       1/240         createField [4]
-----------------------------------------------

 This table describes the call tree of the program, and was sorted by
 the total amount of time spent in each function and its children.
```

[...]

Index by function name

---

3 Profiling using `Valgrind`'s tool `Memcheck`

Using `Memcheck`, one can check for memory leaks in the code. The `LEAK SUMMARY` indicates whether there are any leaks in the memory, i.e. if some heap blocks are not freed when the program exits. In particular, we want to ensure that no block falls in the category `definitely lost` (no pointer can be found), `indirectly lost` (a pointer exists but cannot be accessed) or `possibly lost` (the pointer does not indicate the beginning of the block). The `still reachable` blocks are blocks that are not (and could be) freed before exiting but for which a start-pointer can be found, so they are usually not considered a problem.

```
valgrind --tool=memcheck --leak-check=full ./conway
==5210== Memcheck, a memory error detector
==5210== Copyright (C) 2002-2015, and GNU GPL'd, by Julian Seward et al.
==5210== Using Valgrind-3.11.0 and LibVEX; rerun with -h for copyright info
==5210== Command: ./conway
==5210==
==5210==
==5210== Process terminating with default action of signal 27 (SIGPROF)
==5210==    at 0x538DE0F: write_gmon (gmon.c:354)
==5210==    by 0x538E589: _mcleanup (gmon.c:422)
==5210==    by 0x52BEFF7: __run_exit_handlers (exit.c:82)
==5210==    by 0x52BF044: exit (exit.c:104)
==5210==    by 0x52A5836: (below main) (libc-start.c:325)
==5210==
==5210== HEAP SUMMARY:
==5210==     in use at exit: 134,198 bytes in 178 blocks
==5210==   total heap usage: 2,912 allocs, 2,734 frees, 202,196 bytes allocated
==5210==
==5210== LEAK SUMMARY:
==5210==    definitely lost: 0 bytes in 0 blocks
==5210==    indirectly lost: 0 bytes in 0 blocks
==5210==      possibly lost: 0 bytes in 0 blocks
==5210==    still reachable: 134,198 bytes in 178 blocks
==5210==         suppressed: 0 bytes in 0 blocks
==5210== Reachable blocks (those to which a pointer was found) are not shown.
==5210== To see them, rerun with: --leak-check=full --show-leak-kinds=all
==5210==
==5210== For counts of detected and suppressed errors, rerun with: -v
==5210== ERROR SUMMARY: 0 errors from 0 contexts (suppressed: 0 from 0)
Profiling timer expired
```

One can see in the results presented above that our code does not generate memory leaks. We tested it with several initial configurations, and covering the three exit scenarios: user-triggered exit (using escape key), automatic exit when evolution stops, automatic exit when all cells die. In all cases, no blocks are lost. No other error are raised by the profiling tool.

4 Profiling using `perf`

We also ran perf tool to profile the code. The main part of the graph are represented below. One can see that within the `conway` application, the function `printFieldToSubwindow` is the one that requires most execution time, as we saw using `gprof`.

```
# Samples: 197  of event 'cycles:pp'
# Event count (approx.): 78860815
#
# Children      Self  Command  Shared Object      Symbol
# ........  ........  .......  .................  ........................................
#
    42.83%     0.00%  conway   libc-2.23.so       [.] __libc_start_main
             |
             ---__libc_start_main
                |
                |--41.66%-- main
                |          |
                |          |--16.14%-- printFieldToSubwindow
                |          |          |
                |          |           --0.93%-- __GI___libc_write
                |          |                     entry_SYSCALL_64_fastpath
                |          |                     sys_write
                |          |                     vfs_write
                |          |                     |
                |          |                     ...
                |          |
                |          |--9.11%-- calculateNextState
                |          |          |
                |          |          |--8.07%-- convolution_2D
                |          |          |
                |          |           --1.04%-- createField
                |          |
                |          ...--2.88%-- 0x180ea
                |
                 --0.59%-- handlePossibles

    42.83%     0.00%  conway   [unknown]          [.] 0x0aa6258d4c544155
             |
             ---0xaa6258d4c544155
                __libc_start_main
                |
                |--41.66%-- main
                |          |
                |          |--16.14%-- printFieldToSubwindow
                |          |          |
                |          |           --0.93%-- __GI___libc_write
                |          |                     entry_SYSCALL_64_fastpath
                |          |                     sys_write
                |          |                     vfs_write
                |          |                     |
                |          |                     |--0.60%-- rw_verify_area
                |          |                     |
                |          |                      --0.34%-- __vfs_write
                |          |
                |          |
                |          |--9.11%-- calculateNextState
```

```
            |          |          |
            |          |          |--8.07%-- convolution_2D
            |          |          |
            |          |           --1.04%-- createField
            |          |
            ...        ...
            |
             --0.59%-- handlePossibles

41.66%     0.00%  conway   conway             [.] main
          |
          ---main
             |
             |--16.14%-- printFieldToSubwindow
             |          |
             |           --0.93%-- __GI___libc_write
             |                     entry_SYSCALL_64_fastpath
             |                     sys_write
             |                     vfs_write
             |                     |
             |                     ...
             |
             |--9.11%-- calculateNextState
             |          |
             |          |--8.07%-- convolution_2D
             |          |
             |           --1.04%-- createField
             |
             ...


16.14%     15.21%  conway   conway             [.] printFieldToSubwindow
          |
          |--15.21%-- 0xaa6258d4c544155
          |          __libc_start_main
          |          main
          |          printFieldToSubwindow
          |
           --0.93%-- printFieldToSubwindow
                     __GI___libc_write
                     entry_SYSCALL_64_fastpath
                     sys_write
                     vfs_write
                     |
                     |--0.60%-- rw_verify_area
                     |
                      --0.34%-- __vfs_write
                                tty_write
                                n_tty_write
                                pty_write
                                tty_flip_buffer_push
                                queue_work_on
                                __queue_work
                                insert_work
                                wake_up_process
                                try_to_wake_up
                                wq_worker_waking_up
```

```
    13.17%     0.00%  conway   [unknown]          [.] 0x0027002600250024
               |
               ---0x27002600250024
                  |
                  |--9.78%-- waddch
                  |
                  |--1.51%-- 0x15d71
                  |
                  |--0.90%-- 0x15d70
                  |
                  |--0.55%-- 0x71ec
                  |
                  |--0.37%-- 0x15d68
                  |
                   --0.06%-- __nanosleep
                             |
                             |

    11.78%    11.78%  conway   libncurses.so.5.9  [.] waddch
               |
               |--9.78%-- 0x27002600250024
               |          waddch
               |
                --2.00%-- 0xaa6258d4c544155
                          __libc_start_main
                          main
                          waddch
[...]
```
