CSE 633 Parallel Algorithms

Cellular Automata

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Simple Automaton: Conway’s Game of Life
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- exactly three neighbours, becomes alive,
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**Short:**

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Single Core Implementation

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step()
    for each row j
        for each row i
            c ← countN(j, i)
            buffer[j][i] ← rule(c)
        swap(world, buffer)
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countN() calculates the count of alive neighbours of the cell in row `j` and column `i`, rule() implements Conway’s Game Of Life Rule.

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Single Core Input Size Benchmark

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```c
void step() {
    #pragma omp for
    for (int j = 0; j < HEIGHT; j++) {
        for (int i = 0; i < WIDTH; i++) {
            int c = countN(i, j);
            buffer[j][i] = world[j][i] ? (c == 2 || c == 3) : c == 3;
        }
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Speedup of 30.4 on the 32 core machine
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- communication at the borders needed
- synchronization after each step
Result Verification

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- Output result state on command line (for small boards)
- Comparison to (single-core) reference implementation (`golly`)
- Calculation of well-known patterns
Open MPI Input Size Benchmark

Compared to the OpenMP implementation, the Open MPI implementation shows a much worse speedup, even on a single machine. This is due to the message passing, which can be done through a network of nodes, but significantly slows down things.
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test case: different board sizes, 4 generations of f-pentomino

- single core walltime
- walltime for 2, 3 and 4 cores
- speedup for 2, 3 and 4 cores
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- Runtime still linear

**Graph Description:**
- Time axis (x-axis) represents input size.
- Speedup for 2, 3, and 4 cores.
- Single core walltime.
- Walltime for 2, 3, and 4 cores.
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- speedup much worse than with OpenMP
- multi-process MPI runtime varies more than single-process runtime

**Test case:** different board sizes, 4 generations of f-pentomino

![Graph showing walltime and speedup for 1, 2, 3, and 4 cores](chart.png)
Open MPI Process Number Benchmark

At CCR, the maximum speedup we can achieve with a OpenMP implementation is 32. With the Open MPI implementation, we can achieve greater speedups. For example, by using 32 2-core nodes, we can achieve up to 50 times the single-core speed. 

![Graph showing time and speedup against number of processes with a test case: board 16192x16192, 16 generations of f-pentomino]
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It’s remarkable that for the first 8 tests, which all took place on a single machine with 8 cores, the speedup is almost optimal (that is, 7.96 when using 8 cores).
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Also, the current implementation does not consider how the nodes are connected.

- improve runtime by splitting the game’s board into a grid which mirrors the structure of the cluster, in order to minimize waiting times
Conclusion and Future Work

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- Also, improving the MPI implementation by considering the grid structure will give better speedup
- Engine should be extended in a way that can simulate other cellular automaton