The Game of Life

Concurrent Computing Coursework

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Functionality and Design

Our solution was built up by initially creating a single threaded solution to the problem. This version iterates through the board bitwise, and for each bit gathers all the 'neighbours' for the cells (the 8 directly adjacent cells). From this, the logic is applied and the cell is updated if necessary. This is repeated for the desired number of turns.

From this, we created a multi-threaded solution. We split the board up into strips and passed each strip to a worker. However, each worker would also need information from the lines directly above and below its strip of cells (called *halo lines*). We decided to pass these halo lines wrapped around the strips, so that the workers are able to calculate each cell correctly. Once they have completed their strip, they return it to the `distributor` function. The function reconstructs the world and begins the process again for the desired number of turns.

One problem that we ran into was that we were passing the world by means of pointer. This led to problems due to premature changes being applied to the board. To solve this, we used channels to pass the board to the workers.

The processing of the program is currently unable to be cancelled, and therefore we added the ability to quit, pause processing, and show the current state of the board with key presses. Alongside this, we also implemented an output of the number of alive cells every two seconds using a *ticker*.

Following this, we added the ability to allow the number of workers to support all multiples of two, rather than powers of two alone. Initially, this proved difficult, since at least one worker would receive a smaller strip than the others, and consequently meant that some workers would finish sooner than others. This resulted in a **deadlock** situation, because the world reconstructing function expected all strips to be of equal size, and therefore it was blocked when the final strip was smaller than expected. To work around this, we made each worker apart from the final one work on the same number of lines, and the final worker simply had the remainder. Then, to reconstruct the world, we processed the final worker output separately from the rest.

Finally, passing the entire world between each turn is time consuming, because in reality, the only information that needs to be passed between the workers are the *halo lines*. Additionally, there is no reason to reconstruct the entire world each turn. Implementing this proved to be problematic, as sometimes the workers would get out of sync with one another. To rectify this, we implemented a *master* thread, which served as a hard limit on the speed of the other threads to ensure that the threads would not exceed one another. We passed in a new structure with `masterTurns` via pointer, which contains the current turn of the master thread.

A further problem was to implement the key presses

Tests, Experiments, and Critical Analysis

Stage 1a — Single Thread

Benchmark	Baseline result (ns/100 turns)	Our result	% Difference
128x128x2-12	73689886	2021400726	36%
128x128x4-12	538915394	2010389496	26%
128x128x8-12	261671491	2009465802	17%

Benchmark	Baseline CPU usage	Our CPU usage	% Difference
128x128x2-12	185%	100%	185%
128x128x4-12	298%	100%	298%
128x128x8-12	425%	100%	425%

Average bench: 135.048s

Stage 1b — Divide and Conquer

Benchmark	Baseline result (ns/100 turns)	Our result	% Difference
128x128x2-12	736946012	1704893591	43%
128x128x4-12	537751669	1273465510	42%
128x128x8-12	362735057	1004595662	36%

Benchmark	Baseline CPU usage	Our CPU usage	% Difference
128x128x2-12	185%	188%	98%
128x128x4-12	298%	271%	109%
128x128x8-12	425%	348%	122%

Average bench: $90.460s$

Stage 2a — User Interaction

Benchmark	Baseline result (ns/100 turns)	Our result	% Difference
128x128x2-12	736121962	1699574829	43%
128x128x4-12	537944647	1256970618	42%
128x128x8-12	361777916	994380759	36%

Benchmark	Baseline CPU usage	Our CPU usage	% Difference
128x128x2-12	185%	188%	98%
128x128x4-12	296%	273%	108%
128x128x8-12	426%	343%	124%

Average bench: 88.539s

Stage 2b — Periodic Events

Benchmark	Baseline result (ns/100 turns)	Our result	% Difference
128x128x2-12	735806211	1718965842	42%
128x128x4-12	532913881	1277891763	41%
128x128x8-12	361377377	998142692	36%

Benchmark	Baseline CPU usage	Our CPU usage	% Difference
128x128x2-12	185%	190%	97%
128x128x4-12	299%	274%	109%
128x128x8-12	424%	347%	122%

Average bench: 94.175s

Stage 3 — Division of Work

Benchmark	Baseline result (ns/100 turns)	Our result	% Difference
128x128x2-12	736951655	1730991762	42%
128x128x4-12	537184229	1264782083	42%
128x128x8-12	363069928	987918516	36%

Benchmark	Baseline CPU usage	Our CPU usage	% Difference
128x128x2-12	184%	190%	96%
128x128x4-12	299%	274%	109%
128x128x8-12	425%	347%	122%

Average bench: 90.832s

Stage 4 — Cooperative Problem Solving

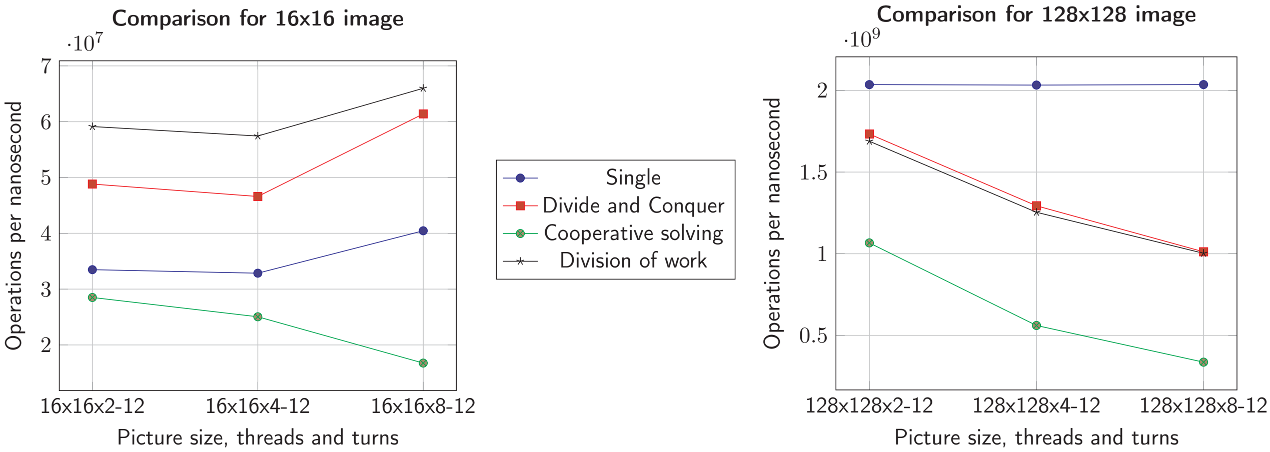
Table 1: Benchmark comparison for Stage 4

Benchmark	Baseline result (ns/100 turns)	Our result	% Difference
128x128x2-12	735620822	716510865	102%
128x128x4-12	530949831	483555762	109%
128x128x8-12	361530673	333119799	108%

Average bench: 41.679s

Table 2: CPU usage for Stage 4

Benchmark	Baseline CPU usage	Our CPU usage	% Difference
128x128x2-12	185%	289%	64%
128x128x4-12	299%	425%	70%
128x128x8-12	425%	667%	63%



Conclusions

For smaller image sizes, the single thread solution outperforms the initial divide and conquer method. This is because of the large overhead cost of splitting the image up and reconstructing the world after each turn. However, for larger images, the divide and conquer algorithm does improve on the times set by the single thread, because the cost of reconstructing the world and splitting the threads is constant and does not rely on the size of the image.