

PREPARED FOR SUBMISSION TO UNIVERSITY OF CAMBRIDGE

C2: Advanced Research Computing - Coursework Assignment

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Contents

1	Introduction	1
2	Selection of Solution Algorithm and Prototyping	1

1 Introduction

Conway's Game of Life...

2 Selection of Solution Algorithm and Prototyping

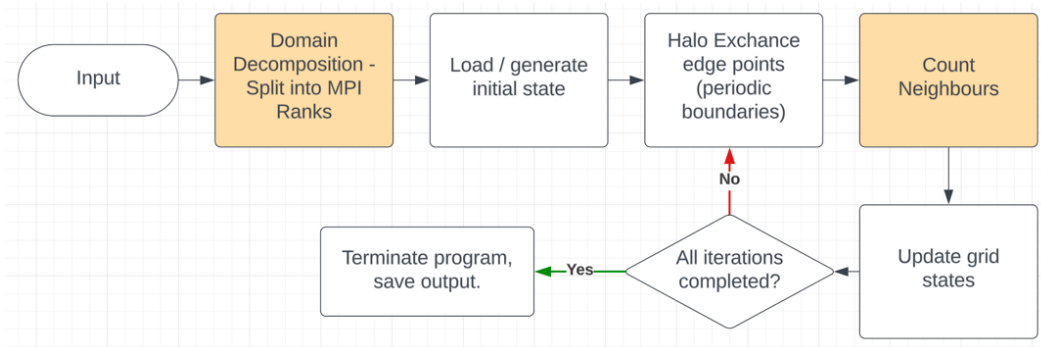


Figure 1: A high-level flow chart depicting the algorithm. The key points for efficiency considerations are highlighted in orange, the considerations are discussed in the main text.

Fig.(1) shows the high-level algorithm being used to simulate Conway's Game of Life. The key points of consideration for efficiency are highlighted in orange. Domain decomposition can be done by either strips or blocks. Strips has the advantage that it is simpler to implement but will have more memory needing to be passed between boundaries, with the opposite being true for blocks. In the case of the neighbour counting algorithm, there are a couple of possible implementations.

- **Simple convolution.** Loop through each cell, and count the number of neighbours. This is equivalent to a 3x3 convolution with the below kernel.

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 1 \end{bmatrix} \quad (2.1)$$

This requires $9N^2$ multiplication operations and $8N^2$ addition operations, yielding a total of $17N^2$ operations.

- **Separable kernel.** If the following kernel is used instead,

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \quad (2.2)$$

then the kernel becomes separable. This means that the kernel can be split into two 1D identical kernels $\begin{bmatrix} 1 & 1 & 1 \end{bmatrix}$ and applied in two passes which yields $3N^2$ multiplication operations and $2N^2$ addition operations per pass, yielding a total of $10N^2$ operations [1]. After another N^2 addition operations, to correct for replacing the central 0 with a 1, the total number of operations becomes $11N^2$. Therefore, the separable kernel method yields a theoretical speedup of $17/11 \approx 1.5$.

The simple convolution method introduces the issue of strided memory access when counting the 6 neighbours that are not horizontally adjacent to the current cell. Therefore, when implementing the simple convolution method, column-wise decomposition would be preferred as it would reduce the number of cache misses. This is because an $N \times N$ grid split into P strips would yield a $N/P * \text{sizeof}(\text{int})$ byte distance between a cell and its vertical neighbour whereas the same grid split into P columns would yield a $N * \text{sizeof}(\text{int})$ byte distance, and P blocks would yield a distance of $\sqrt{P} * \text{sizeof}(\text{int})$ (assuming P is a square number and N is perfectly divisible by P).

However, the separable kernel method does not have this issue as the data is contiguous on the horizontal pass, and the data can be made contiguous for the vertical pass by transposing the grid. Therefore, it does not matter which decomposition method is used for the separable kernel method.

References

- [1] Steve Eddins, *Steve on Image Processing with MATLAB*. Available at: <https://blogs.mathworks.com/steve/2006/10/04/separable-convolution/> [Accessed: 8-Mar-2024].