Implementing the Game of Life in parallel

Conway’s Game of Life

- You implemented a serial version of the Game of Life in a previous programming course

- Reminder of the rules
  - Each cell has eight neighbours (vertical, horizontal and diagonal)
  - If a living cell has fewer than 2 neighbours it dies (not enough to breed)
  - If a living cell has 2 or 3 neighbours it survives
  - If a living cell has 4 or more neighbours it dies (over population)
  - If a dead cell has exactly 3 neighbours a living cell is born there

A simple C++ serial implementation

```
#include <iostream>
#include <sstream>
#include <fstream>
#include <cstdlib>
#include <time.h>
#include <vector>

using namespace std;

//Note that this is a serial implementation with a periodic grid
vector<vector<bool>> grid, new_grid;
int imax, jmax;
int max_steps = 100;

int num_neighbours(int ii, int jj)
{
	int ix, jx;
	int cnt = 0;
	for (int i=-1;i<=1;i++)
		for (int j = -1; j <= 1; j++)
			if (i != 0 || j != 0)
			{
				ix = (i + ii + imax) % imax;
				jx = (j + jj + jmax) % jmax;
				if (grid[ix][jx]) cnt++;
			}
	return cnt;
}
```

```
void grid_to_file(int it)
{
	stringstream fname;
	fstream f1;
	fname << "output" << "_" << it << ".dat";
	f1.open(fname.str().c_str(), ios_base::out);
	for (int i = 0; i < imax; i++)
	{
		for (int j = 0; j < jmax; j++)
			f1 << grid[i][j] << "\t";
		f1 << endl;
	}
	f1.close();
}

void do_iteration(void)
{
	for (int i = 0; i < imax; i++)
		for (int j = 0; j < jmax; j++)
		{
			new_grid[i][j] = grid[i][j];
			int num_n = num_neighbours(i, j);
			if (grid[i][j])
			{
				if (num_n != 2 && num_n != 3)
					new_grid[i][j] = false;
			}
			else if (num_n == 3) new_grid[i][j] = true;
		}
	grid.swap(new_grid);
}
```

A simple C++ serial implementation (cont)

```
int main(int argc, char *argv[])
{
	srand(time(NULL));
	imax = 100;
	jmax = 100;
	grid.resize(imax, vector<bool>(jmax));
	new_grid.resize(imax, vector<bool>(jmax));

	//set an initial random collection of points - You could set an initial pattern
	for (int i = 0; i < imax; i++)
		for (int j = 0; j < jmax; j++) grid[i][j] = (rand() % 2);

	for (int n = 0; n < max_steps; n++)
	{
		cout << "it: " << n << endl;
		do_iteration();
		grid_to_file(n);
	}

	return 0;
}
```

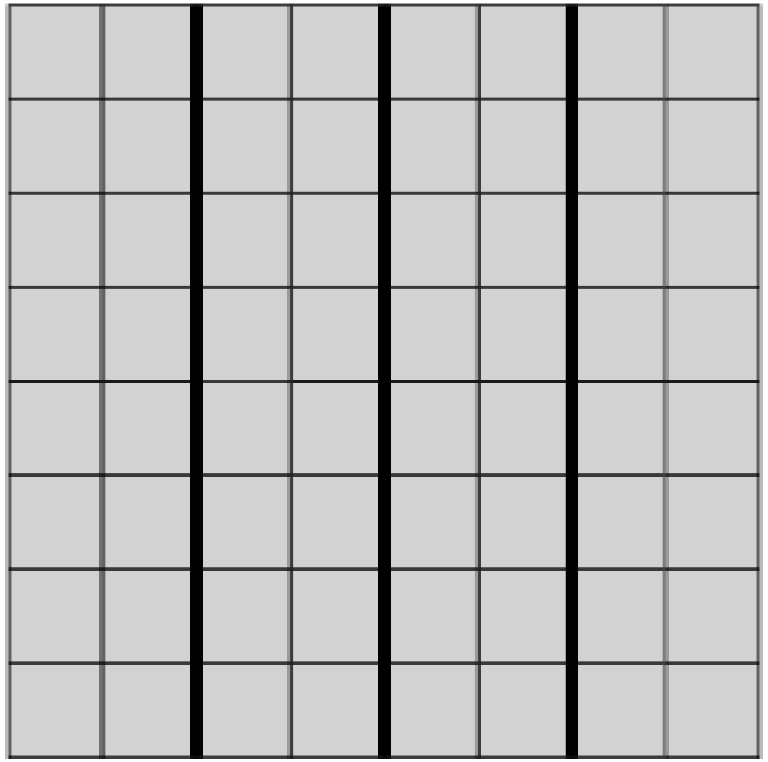
The Output

Parallelise the Game of Life Decomposition strategy

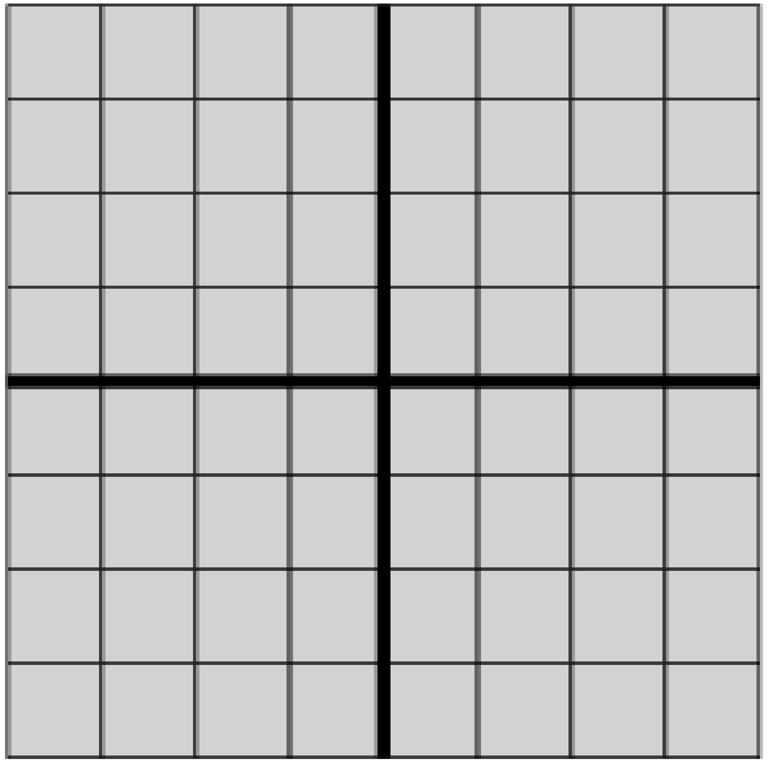
- Best decomposition tactic will be Domain Decomposition
  - Easiest to implement domain decomposition is to divided the domain into vertical or horizontal stripes
    - Only need to communicate with a maximum of two neighbouring processes
    - …,but lots of data needs to be exchanged as the edge length will be large relative to the area of the domain
  - More efficient is to divide the domain into rectangles that are as close to square as possible
    - Less data to exchange, same number of grid cell calculations
- This is exactly the same decomposition strategy as you would use for any other solution on a grid
  - E.g. Finite Difference or Finite Volume of a square grid

Domain Decomposition Strategies

- Striped decomposition



- Grid decomposition



What about the data?

- In order to make best use of the scalability of the problem each process should only store its portion of the grid
  - Don’t allocate a grid of the full size of the problem!
  - This makes the problem far more scaleable – If you double the size of the system and the number of processes, the amount of memory required by each process remains the same
- In order for the new value in a cell to be calculated it needs to know all its neighbours
  - A process needs to obtain a layer of “ghost” cells from its neighbours for the points all the way around the edge of the domain
  - Easiest way to achieve this storage is to make the size of the grid 2 points wider and higher than the size of the domain that the process is responsible for

Communication strategy

- The best communication strategy to use will be peer-to-peer
- For the striped decomposition you just communicated with two other process
  - If ordered logically you communicate with the process with an id one higher and one lower than the id of the current process
  - A line of cells at the top and bottom of each region needs to be sent
- For a grid the communication needs to be with all the neighbouring processes
  - Line of cells sent to the vertical and horizontal neighbours
  - Single corner point sent to the diagonal neighbours
  - You might notice that the communication pattern required is exactly the same as that in Worksheet 2 – Exercise 3

Other notes…

- As this is going to be run peer to peer it is more efficient to have each process write an output file rather than transferring the data back to a single process

- You should therefore also write a separate post-processing code to combine these outputs
  - This can be in Python if you wish so that you can make use of the easy ability to do graphical output