

# Message-Passing Programming

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Cellular Automaton Exercise

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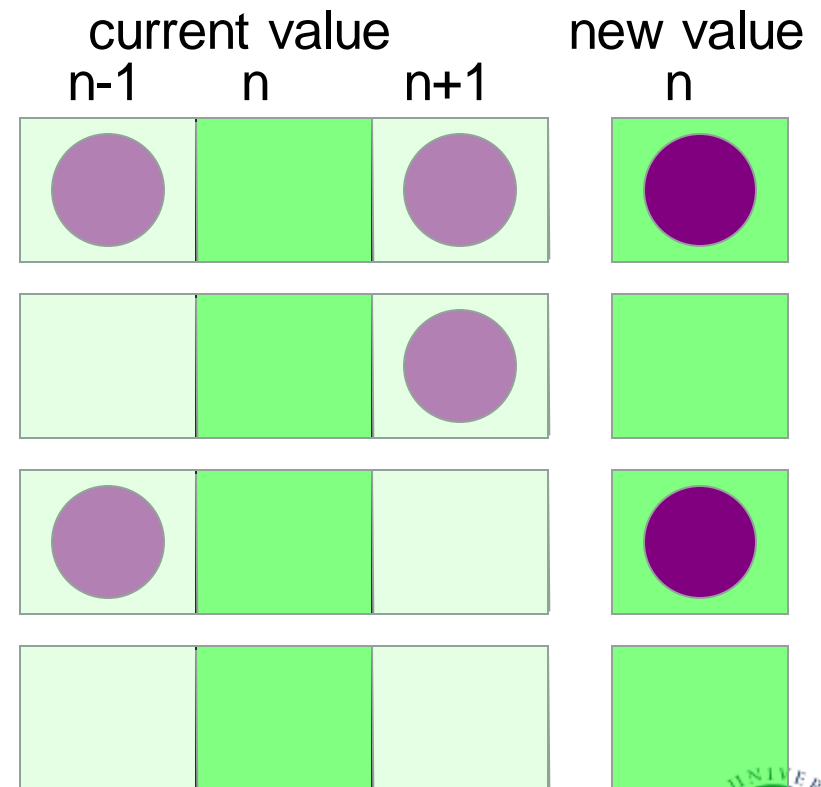
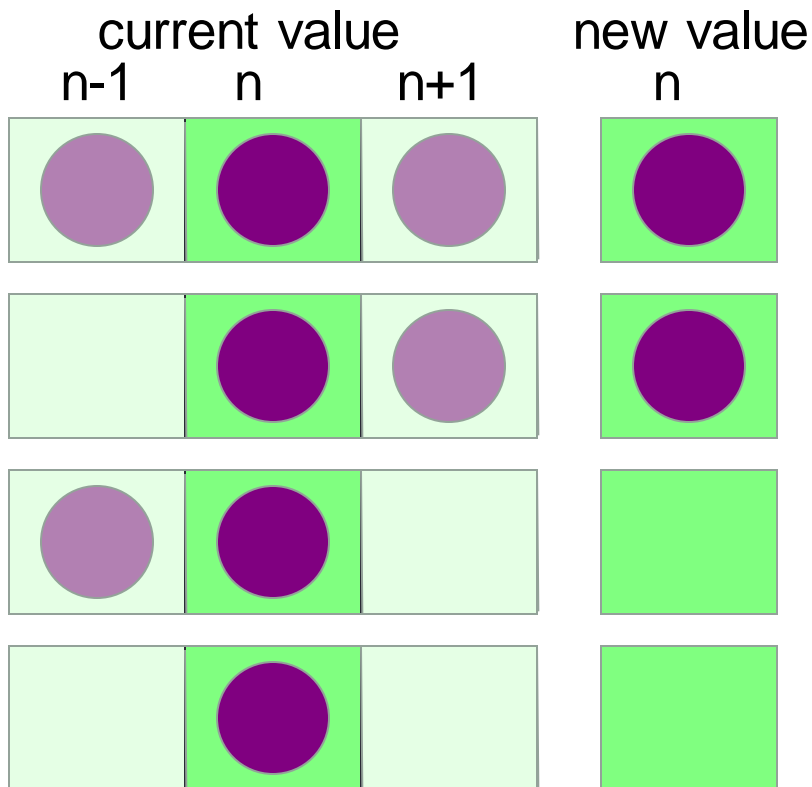
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# Traffic simulation

- Update rules depend on:
  - state of cell
  - state of nearest neighbours in both directions



# State Table

- If  $R^t(i) = 0$ , then  $R^{t+1}(i)$  is given by:

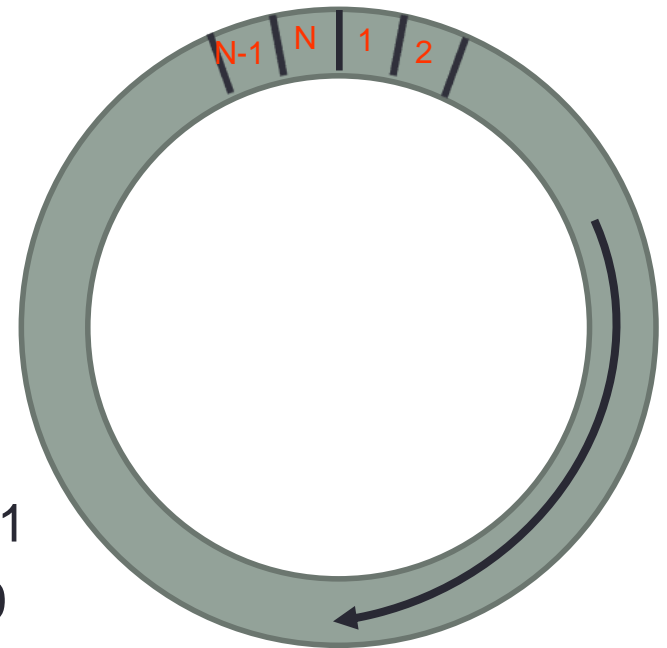
	$R^t(i-1) = 0$	$R^t(i-1) = 1$
$R^t(i+1) = 0$	0	1
$R^t(i+1) = 1$	0	1

- If  $R^t(i) = 1$ , then  $R^{t+1}(i)$  is given by:

	$R^t(i-1) = 0$	$R^t(i-1) = 1$
$R^t(i+1) = 0$	0	0
$R^t(i+1) = 1$	1	1

# Boundary conditions

- What happens if a car falls off the end of the road?
  - when does a car appear at the start?
- Consider a roundabout
  - periodic boundary conditions:
    - up from last cell  $N$  is first cell 1
    - down from first cell 1 is last cell  $N$
- Implement with *ghost* or *halo* cells
  - road has  $N+2$  cells 0, 1, 2, ...,  $N-1$ ,  $N$ ,  $N+1$
  - copy cell 1 to cell  $N+1$  and cell  $N$  to cell 0
  - then update cells 1 to  $N$  as normal

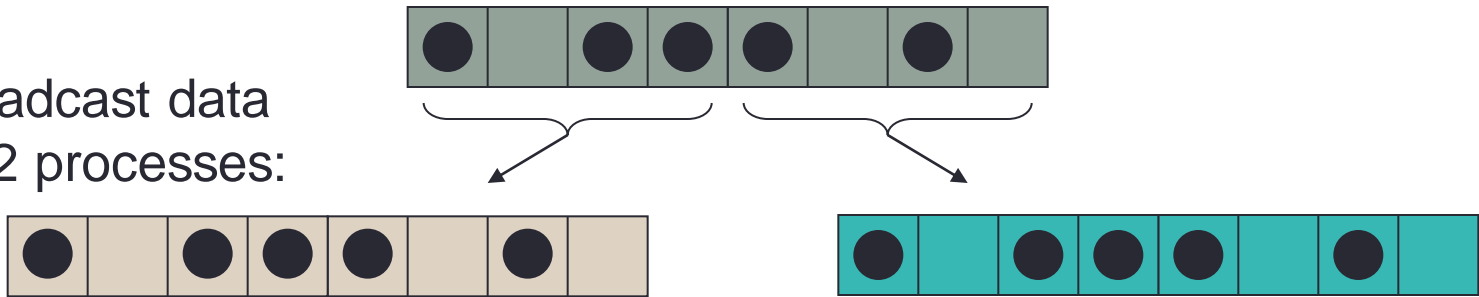


# Pseudo Code

```
declare arrays old(i) and new(i), i = 0,1,...,N,N+1
initialise old(i) for i = 1,2,...,N-1,N (eg randomly)
loop over iterations
    set old(0) = old(N) and set old(N+1) = old(1)
    loop over i = 1,...,N
        if old(i) = 1
            if old(i+1) = 1 then new(i) = 1 else new(i) = 0
        if old(i) = 0
            if old(i-1) = 1 then new(i) = 1 else new(i) = 0
    end loop over i
    set old(i) = new(i) for i = 1,2,...,N-1,N
end loop over iterations
```

# Parallelisation Strategy (1)

Broadcast data  
to 2 processes:



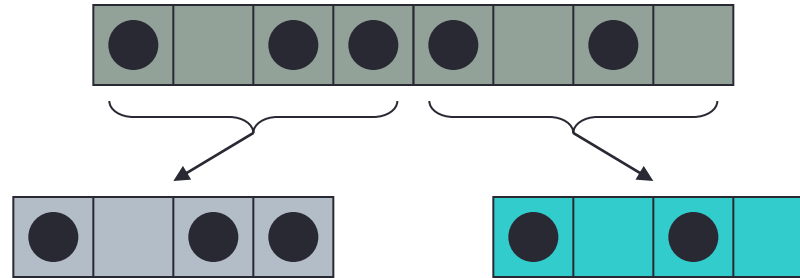
Split calculation  
between 2 processes:



- Globally resynchronise all data after each move
  - a **replicated data** strategy
- Every process stores the entire state of the calculation
  - e.g. any process can compute total number of moves

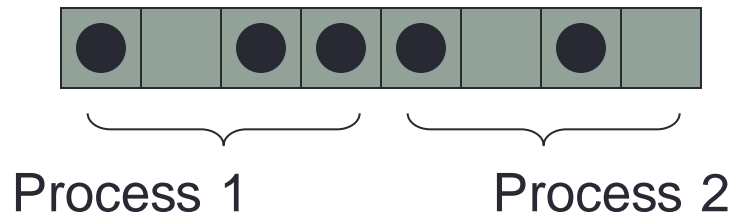
# Parallelisation Strategy (2)

Scatter data  
between 2 processes:  
**distributed data** strategy



- Internal cells can be updated independently.
- Must communicate with neighbouring processes to update edge cells.
- Sum local number of moves on each process to obtain total number of moves at each iteration.

Split calculation  
between 2 processes:



- Each process must know which part of roadway it is updating.
- Synchronise at completion of each iteration and obtain total number of moves.



# Parallelisation

- Load balance not an issue
  - updates take equal computation regardless of state of road
  - split the road into equal pieces of size  $N/P$
- For each piece
  - rule for cell  $i$  depends on cells  $i-1$  and  $i+1$
  - the  $N/P - 2$  interior cells can be updated independently in parallel
  - however, the edge cells are updated by other processors
    - similar to having separate rules for boundary conditions
- Communications required
  - to get value of edge cells from other processors
  - to produce a global sum of the number of cars that move

# Message Passing Parallelisation



2 processes,  
add halos



copy data  
to halos



update  
interior cells



local moves = 1

local moves = 2

global moves = 3