UNIVERSITY OF KENT

Lazy Cellular Automata with Communicating Processes

Adam Sampson, Peter Welch and Fred Barnes

{ats1,P.H.Welch,F.R.M.Barnes}@kent.ac.uk

University of Kent

http://www.cs.kent.ac.uk/

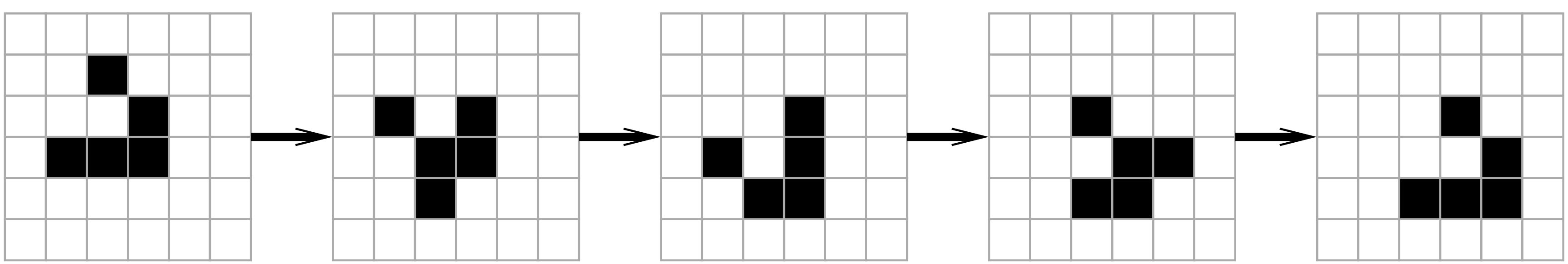
UNIVERSITY OF KENT

Introduction

- The **T**heory **U**nderpinning **N**anotech **A**ssemblers project needs to use PC clusters to simulate large numbers of autonomous entities
- . . . which we're modelling as CAs for now
- We're using the occam-π and JCSP languages – based on CSP extended with some ideas from the π-calculus
- Let's look at Life as an example. . .

Life

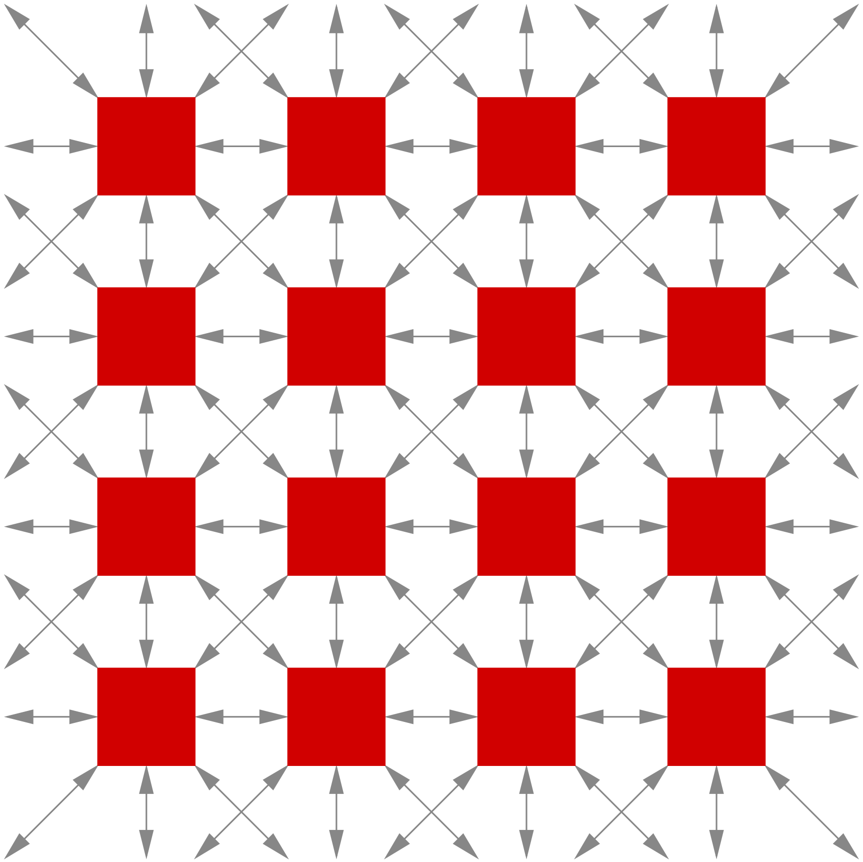
- Infinite grid of cells, each alive or dead
- On each generation step, examine self and 8 adjacent cells
- Alive and 2 or 3 live neighbours $\longrightarrow$ alive
- Dead and exactly 3 live neighbours $\longrightarrow$ alive
- Otherwise $\longrightarrow$ dead
- Interesting emergent behaviour – e.g. the “glider”:



(Black cells are alive.)

The Simple Parallel Approach

- One process per cell, connected in a grid



UNIVERSITY OF KENT

The Simple Parallel Approach

```
proc cell
  while true
    par i = 0 for 8
      ...  send state to neighbour[i]
      ...  read state from neighbour[i]
    ...  compute new state
```

UNIVERSITY OF KENT

Problems and Solutions, 1

- Inefficient
- 16 communications per cell per generation
- Most of the time the state hasn't changed
- . . . so we only want to communicate changes
- We need a new way of synchronising generation steps

Barriers

- Barriers synchronise a set of processes
- Processes sync on the barrier, and block until *all* the enrolled processes are trying to sync. . .
- . . . at which point they all proceed happily
- We can use a barrier for our generation tick

The Barrier Approach

```
proc cell
  ...  exchange initial state with
       neighbours (as before)
  while true
    ...  compute new state
    if my state has changed
      par i = 0 for 8
        ...  send state to neighbour[i]
             down buffered channel
    sync barrier
    ...  check buffered channels
         for changes from neighbours
```

UNIVERSITY OF KENT

Problems and Solutions, 2

- This is still inefficient
- All cells have to run and synchronise every generation, even if nothing around them has changed
- . . . so we want them to “sleep” when possible
- Make them resign from the barrier

UNIVERSITY OF KENT

The Lazy Approach

```
proc cell
  ... exchange initial state
  while true
    ... compute new state
    if my state has changed
      par i = 0 for 8
        ... send state to neighbour[i]
    else
      resign barrier
        ... wait for a change to be received
    sync barrier
    ... check for changes
```

UNIVERSITY OF KENT

Problems and Solutions, 3

- This is *still* inefficient
- Lots of channels – can use one shared channel per cell
- Lots of sleeping processes
- . . . so let's only create processes for the active cells
- Use FORKing and a shared state array
- Use phases to control access to the array

UNIVERSITY OF KENT

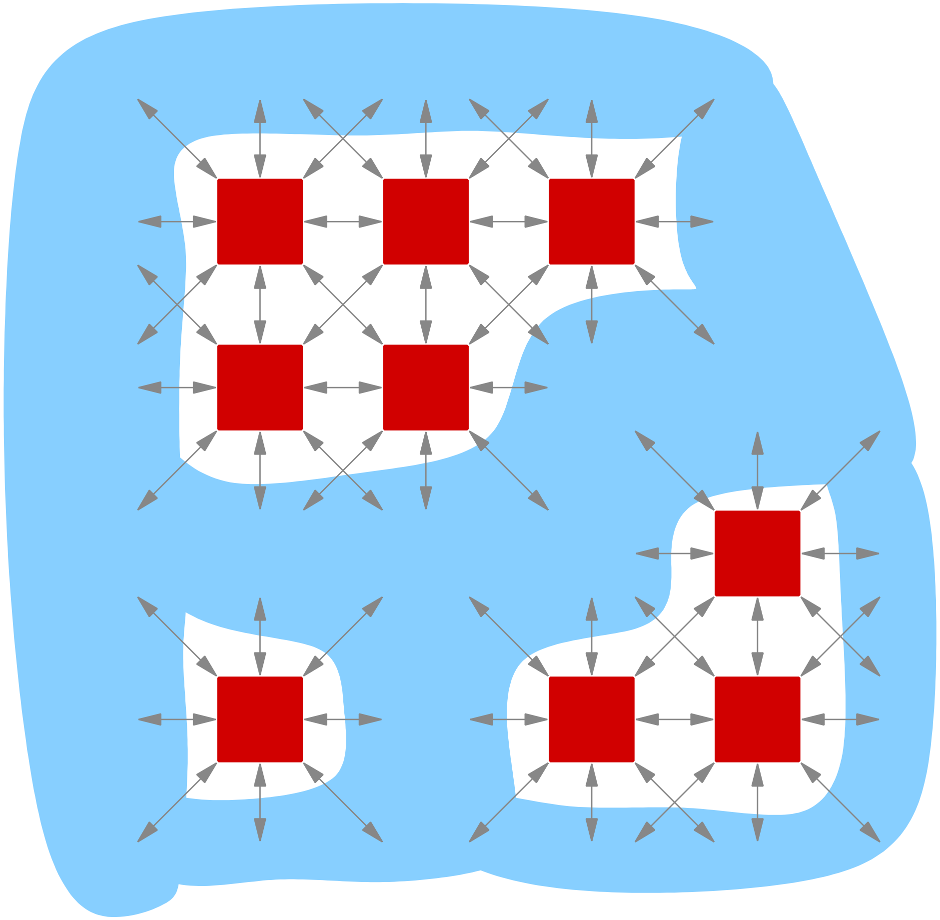
The Just-in-Time Approach

```
proc cell
  running := true
  while running
    phase 1  -- state array is constant
    ...  read neighbour state from array
    ...  compute my new state
    if my state has changed
      ...  fork new cell processes for
           the affected neighbours
           (if not already running)
    else
      running := false
    phase 2  -- update state array
    ...  write my new state to array
```

But Wait A Minute...

- Using shared memory isn't very occam-ish
- Plus we've still got a big array in memory
- . . . so use FORKing, but still connect cells with channels
- Use mobile channels to dynamically build the active bits of the network

The Dynamic Approach



Clumps of active cells, connected by mobile channels, floating in the ether

UNIVERSITY OF KENT

Zooming In A Bit

- No particular reason why each process should only simulate one cell
- Make each process simulate a block of cells
- Can take advantage of existing fast sequential code
- . . . or mix-and-match parallel approaches

UNIVERSITY OF KENT

Conclusion

- A number of approaches for simulating CAs in CPA environments
- Same approaches could be applied to other simulation tasks (FEA, CFD)
- Applications for new functionality in occam-π
- See the paper for more details – ask us if you'd like a copy of the demo code

And Finally

Any questions?