Homeostatic architectures for robust spatial computing

David H. Ackley
Lance Williams
University of New Mexico
Computer Science

The Robust Physical Computation Group

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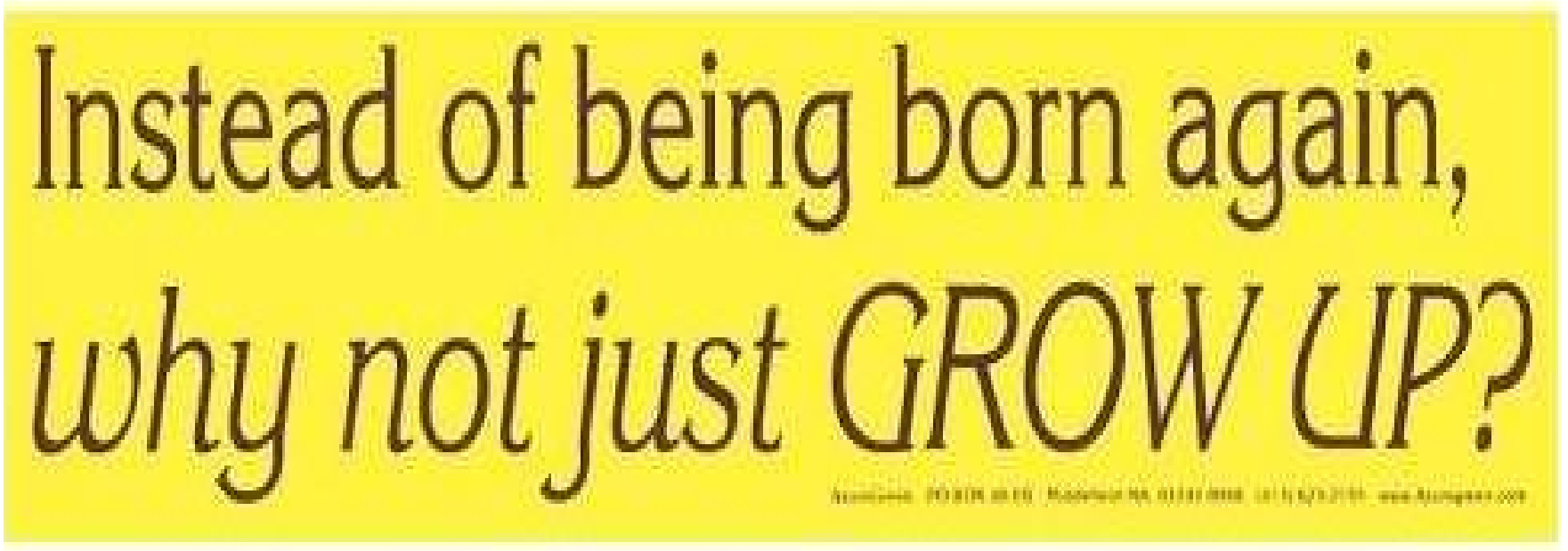
Plan

- Advocacy /
  - **We have a problem**
  - **How we got into this mess**
  - **Robust spatial computing**
- Research /
  - **The movable feast machine**
  - **Homeostatic computation**
  - **Demos**
- Call to action / **Test to failure**

Our security train wreck

- First bug costs the machine
- Non-solutions:
  - Blaming the user / user education
  - Blaming the developer / fixing the last bug
- Solutions:
  - Blame von Neumann

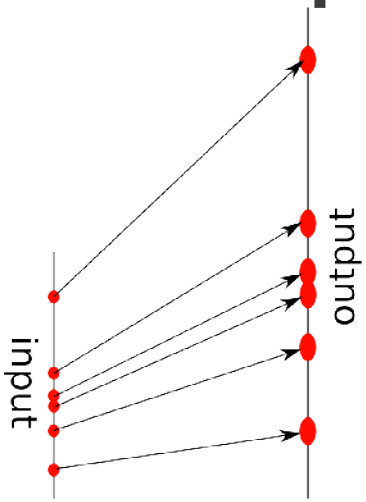
Computation must be born again



► *OK, our answer **might** be wrong*

How we got into this mess

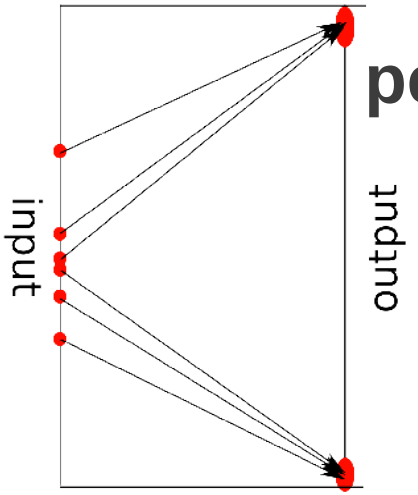
Digital hardware is *massively* redundant



Ideal linear amplifier ->
No information loss

One person's analog signal..

..is another person's digital noise.



Ideal non-linear amplifier ->
Massive information loss

The Original Deal:

Hardware shall be *reliable*

Software shall be *efficient*

(* Computation shall be serial)

Architecture matters: Space

- CPU + RAM
- Von Neumann's lament
- Strategy: Let space be space
  - Consequences: Fungibility, scalability

Architecture matters: Time

- Scalability issue: The light cone
- Robustness issue: **Single** source clocking
- Design issue: Who waits for whom?
  - Vs Nakamura (1974), Toffoli (1987), Nehaniv (2002)
- **Synchronous design begs the question**

Architecture matters: Correctness

- Who’s kidding whom?
- If not correctness?
- **Best effort is better than correct**

Indefinite scalability

- A single, clean, architectural criterion implying:
  - Spatial computing
  - Robust computation
- Perhaps a tad ambitious

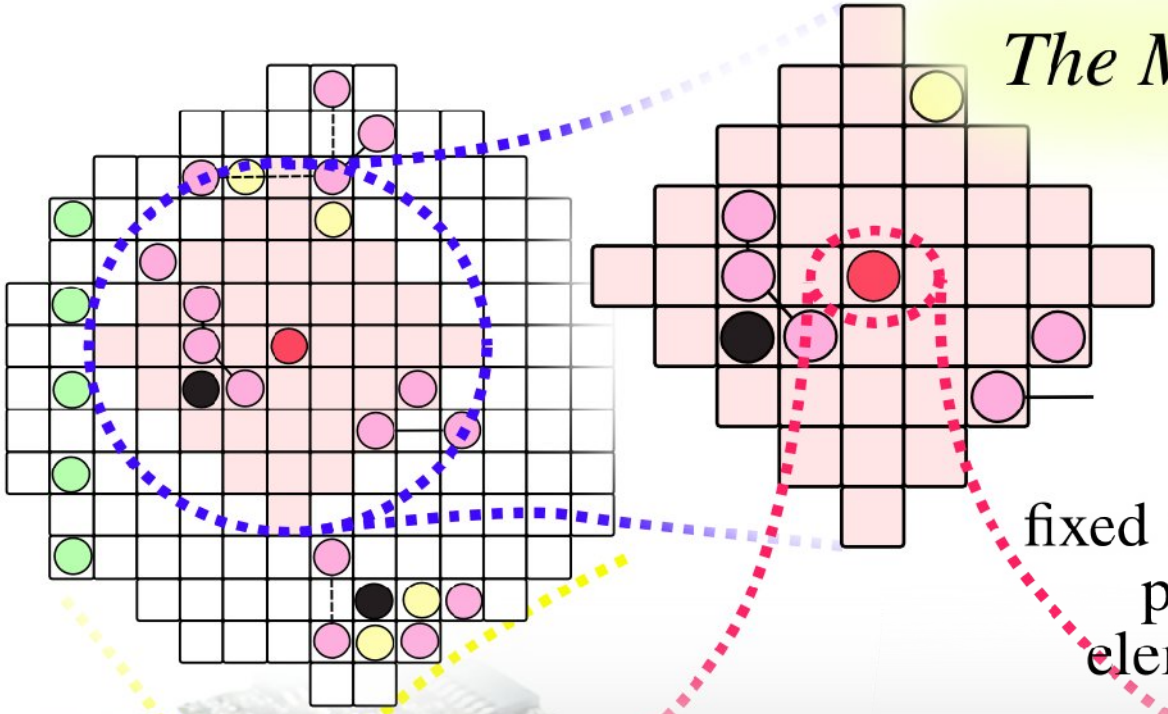
Indefinite scalability
Let space be space, let time be time

- Sacrificing:
  - ✗ Fixed-width addresses, unique node names.
  - ✗ Logarithmic global communication cost
  - ✗ Single source clocking, phase synchronization
  - ✗ 'Times' – run time, load time, power on time..
- Embracing:
  - ✔Opportunistic reproduction for ||ism & robustness
  - ✔Movability for configuration, manifest destiny, ...
  - ✔Multilevel robustness: Up *to* the end-user

Living Computation

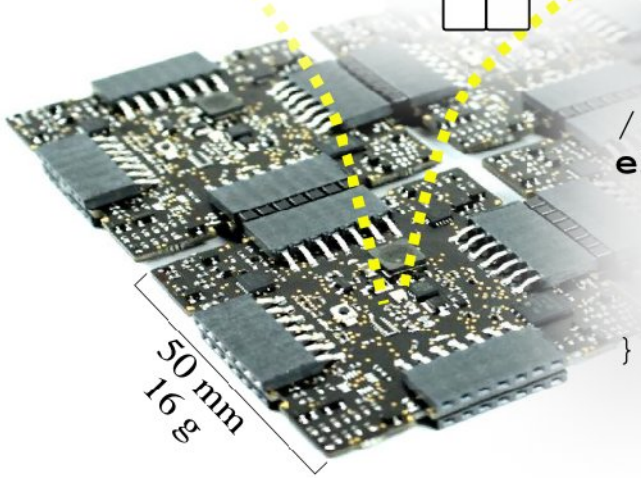
- Impossible working conditions:
  - Program inputs might be late, missing, wrong
  - Program execution might be faulty
- Become livable if
  - Program outputs can be wrong, late, missing
- Because:
  - Others are duplicating/checking your work
- Efficiency and robustness are mortal enemies

An example: Software engineering as artificial chemistry



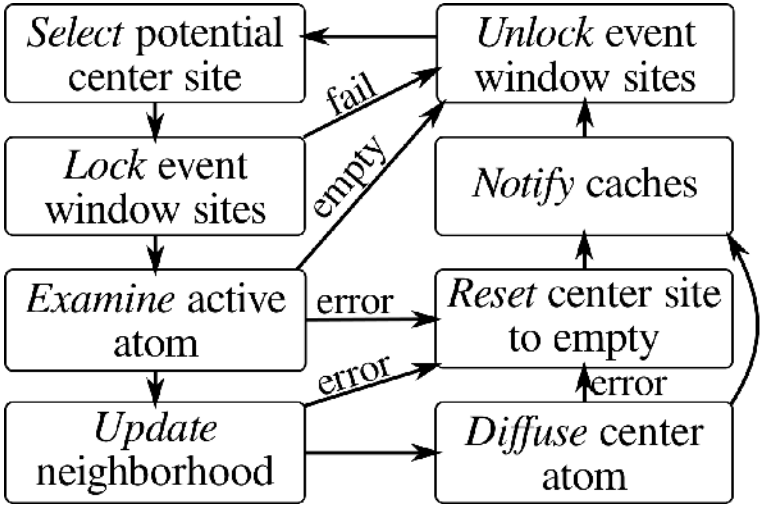
The Movable Feast Machine

spatial computing
relative addressing
local connectivity
indefinitely scalable
fixed size atoms/sites for mobility
parallel asynchronous update
element-oriented programming




```
/* DReg: Dynamic Regulator.  */
element DReg() = 0xdba {
  if n:anyAt(1), n is Empty, odds(1,1000) then n = DReg;
  if n is Empty, odds(1,200) then n = Res;
  if n is DReg, odds(1,10) then n = Empty; // limit DRegs
  if odds(1,100) then n = Empty;
}
```

Processing



- Typical parameters:
  - 64 bits per site; 16 bit header + 48 bonds and or state
  - Event window radius 4 L0 distance
  - Bonds are symmetric and relative

- Hardware packs as many disjoint event windows into space-time as possible

- Software defines a set of types with atomic formats and behavioral rules; initial conditions

Movable feast machine
Sites & atoms

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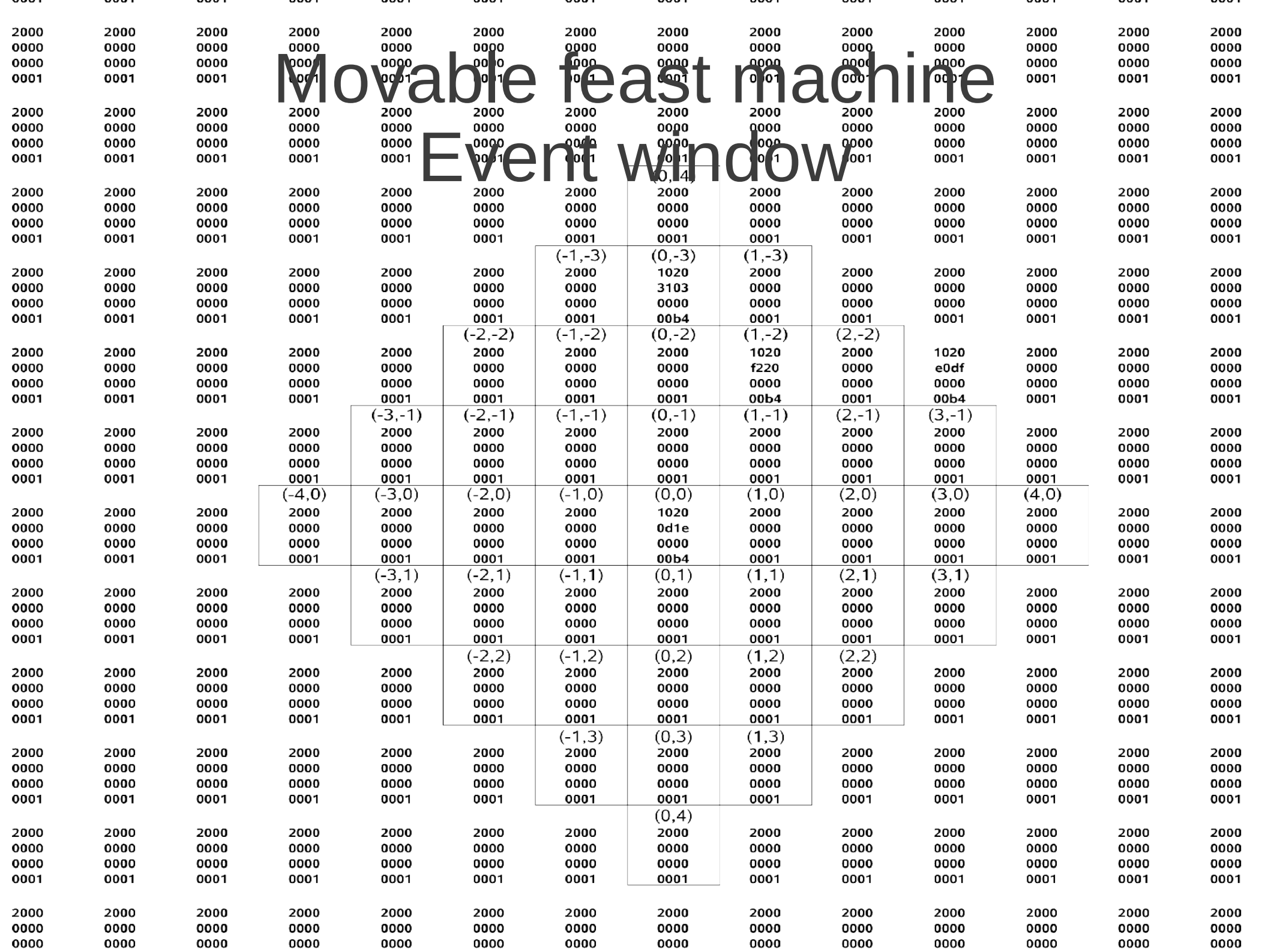
Movable feast machine
Event window
(0,4)
(-1,-3)
(0,-3)
(1,-3)
(-2,-2)
(-1,-2)
(0,-2)
(1,-2)
(2,-2)
(-3,-1)
(-2,-1)
(-1,-1)
(0,-1)
(1,-1)
(2,-1)
(3,-1)
(-4,0)
(-3,0)
(-2,0)
(-1,0)
(0,0)
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(2,0)
(3,0)
(4,0)
(-3,1)
(-2,1)
(-1,1)
(0,1)
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(-2,2)
(-1,2)
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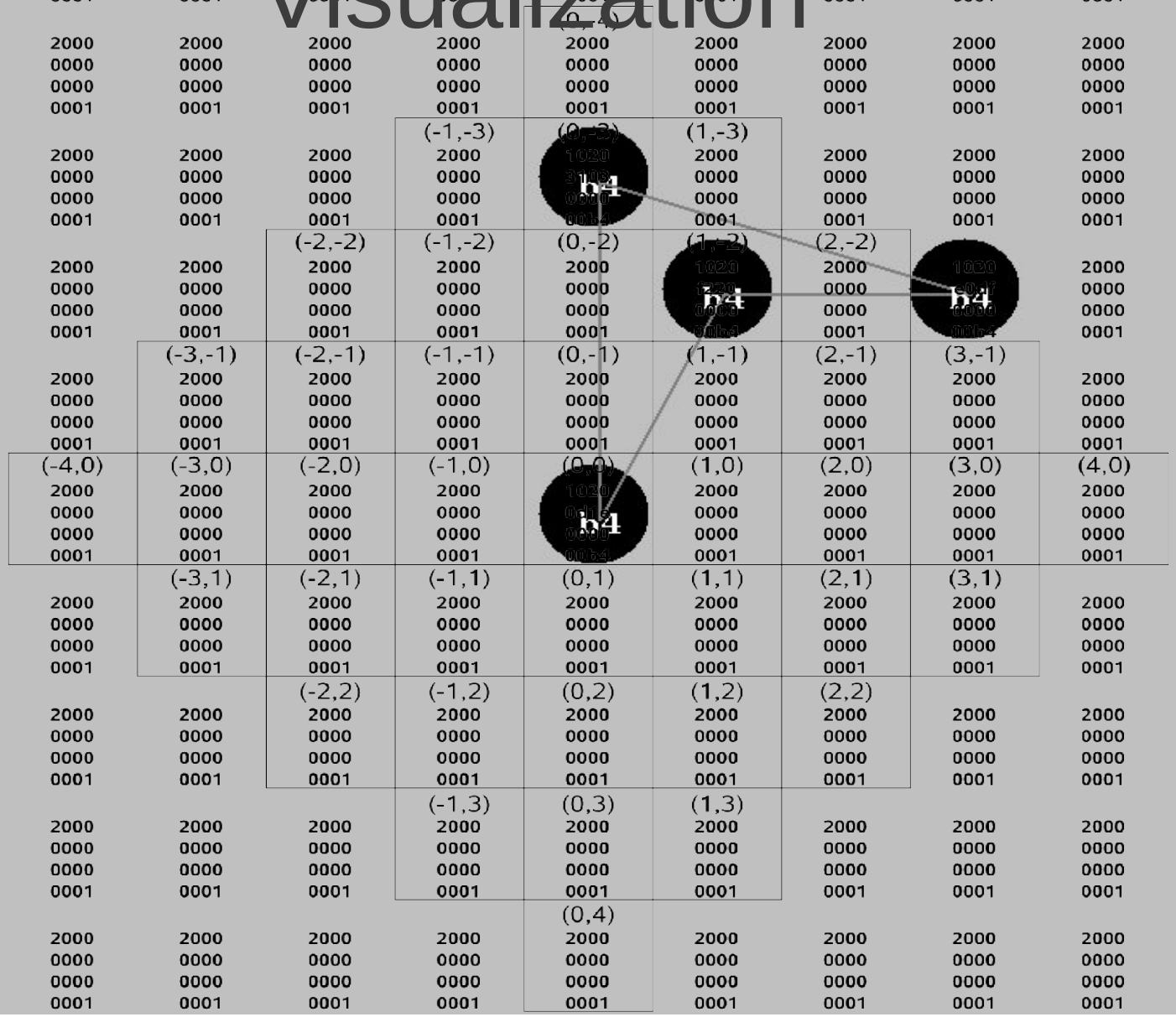
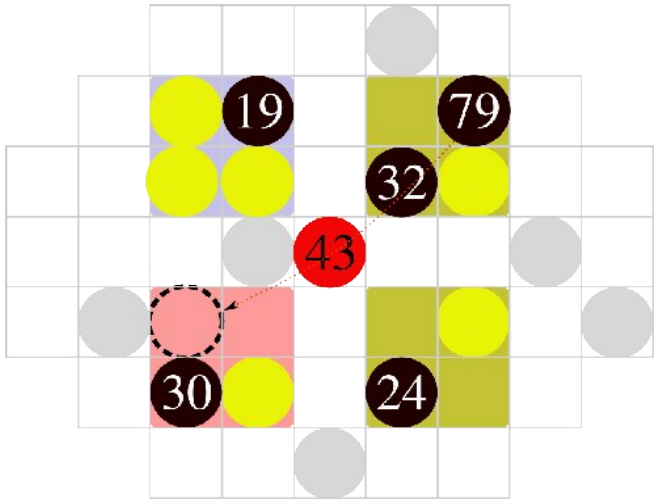
(1,3)
(0,4)

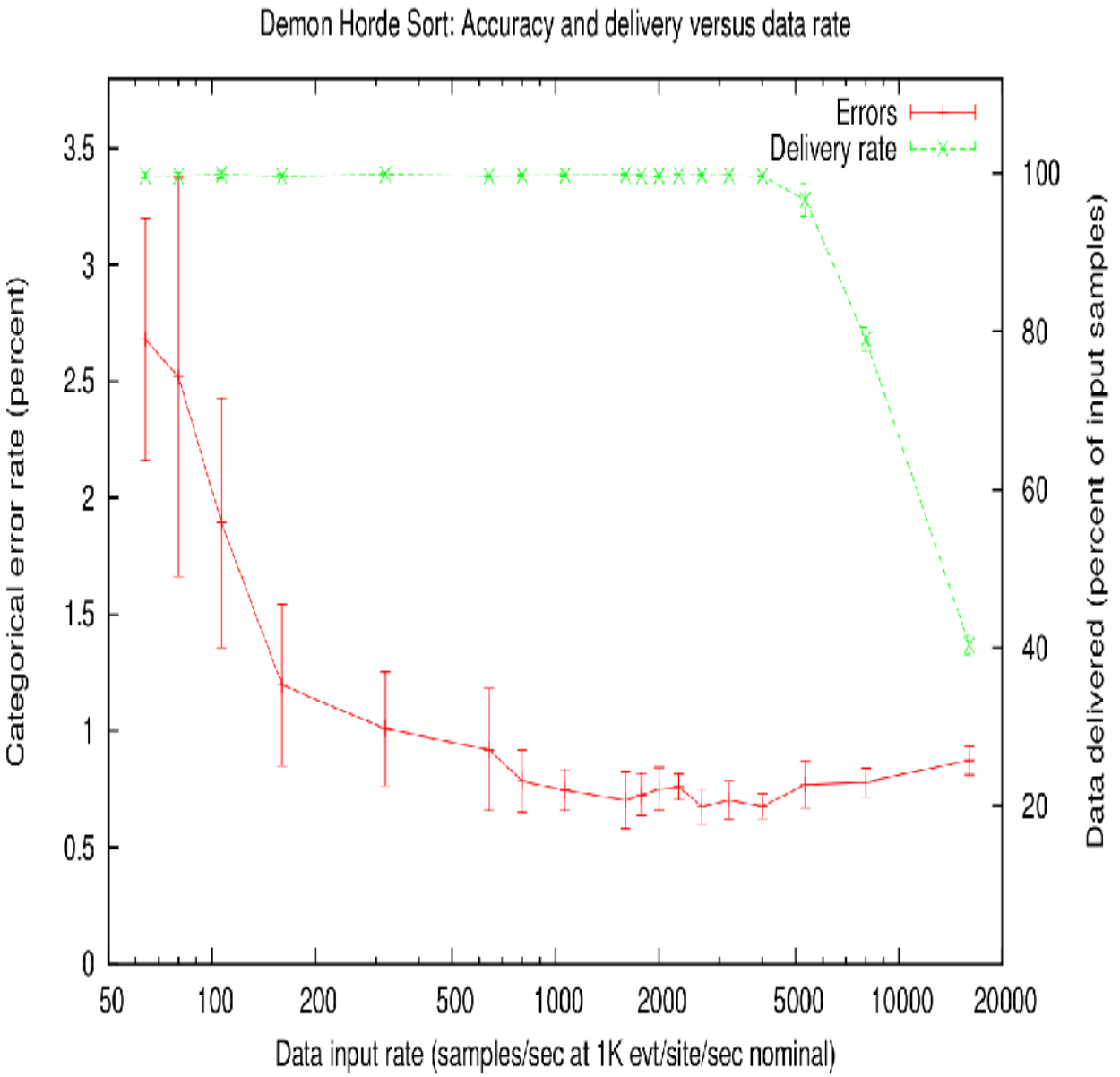
Movable feast machine Visualization



Demon Horde Sorting: Robust Computation Example



- Task: Flow sort endless data stream
  - It’s impossible
- 'Maxwell's Demon' sorting elements maintained in homeostasis by DReg
- Surprise: Quality vs data rate..



Call to action

Computation shall be

As robust as possible

As efficient as necessary

As correct as a Google search