Spatial Sorting Algorithms for Parallel Computing in Networks

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2011 October 3

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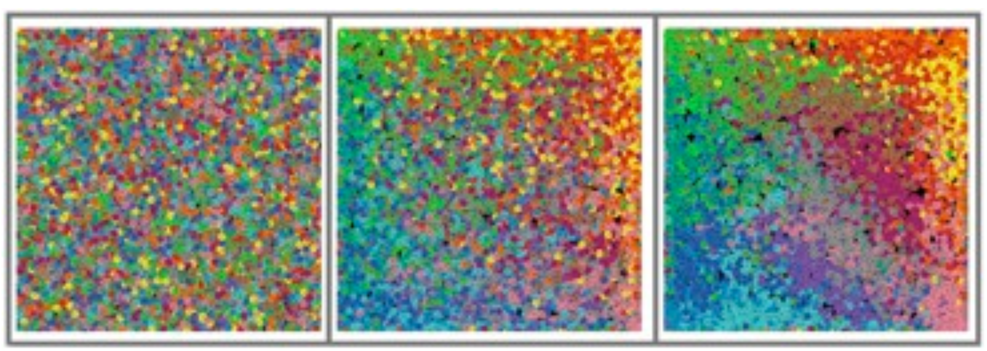
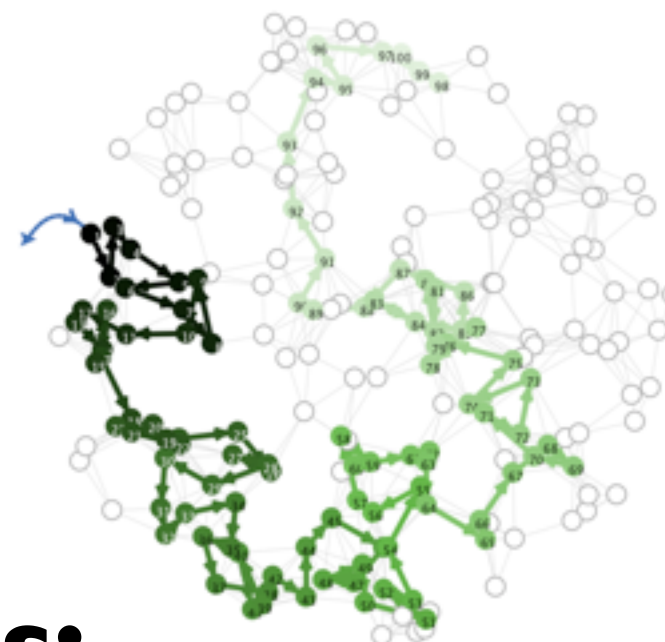
Emerging Computing Models and Technologies

Overview

- Bubble sort as a particle system
- Insertion sort in a random network



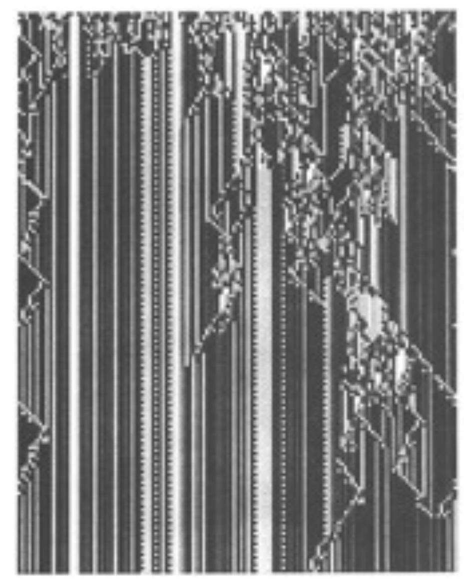


Hypothesis:
Spatial abstractions can help structure parallel computation.

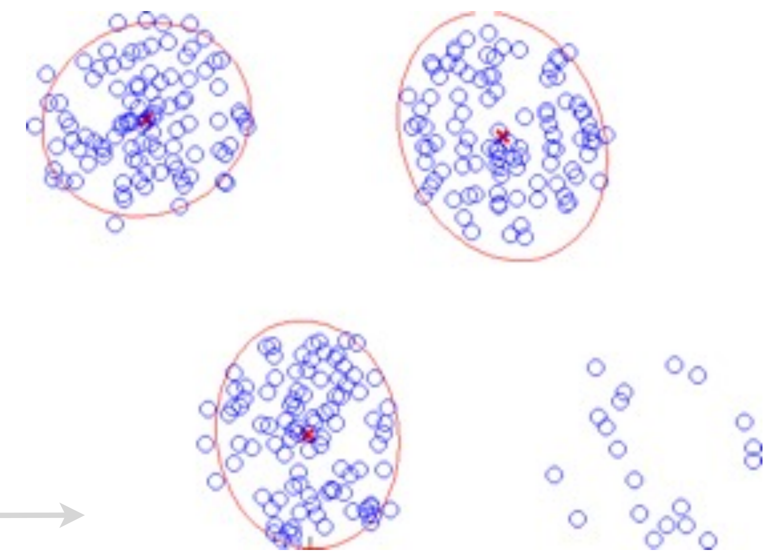
Collision Sort

related work

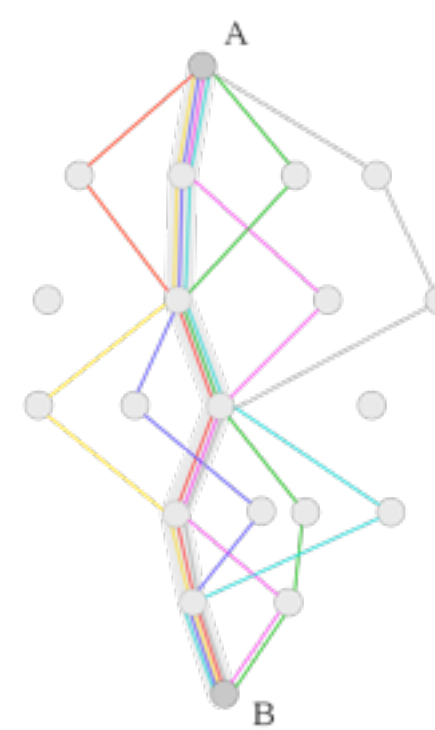
- Cellular automata
  (e.g. Lindgren and Nordahl 1990)



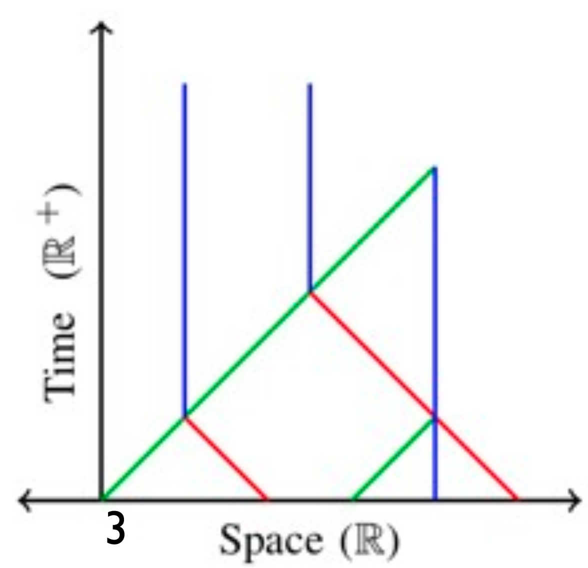
- Agent-based systems
  - Particle swarm optimization
    (Kennedy and Eberhart 1995)



  - Ant colony optimization
    (Dorigo 1992)

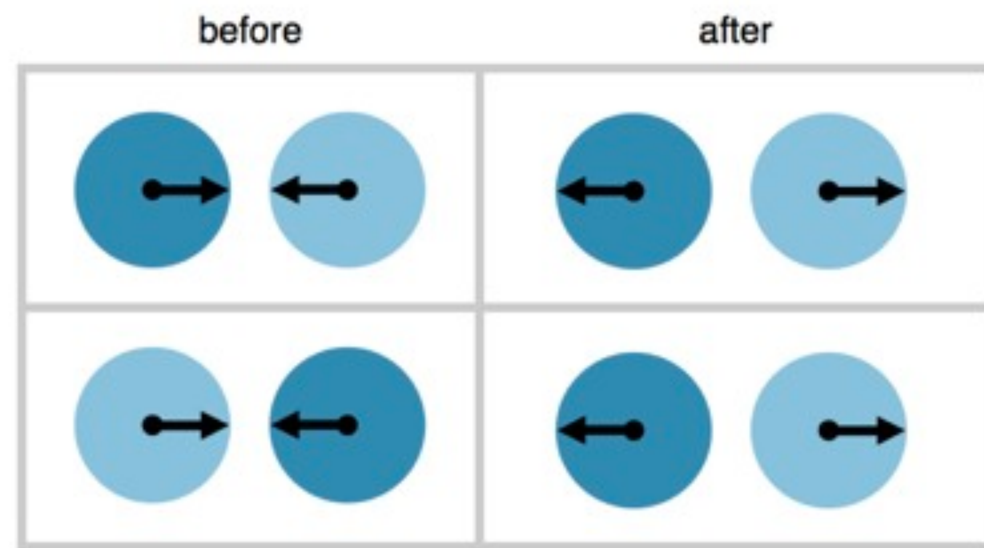


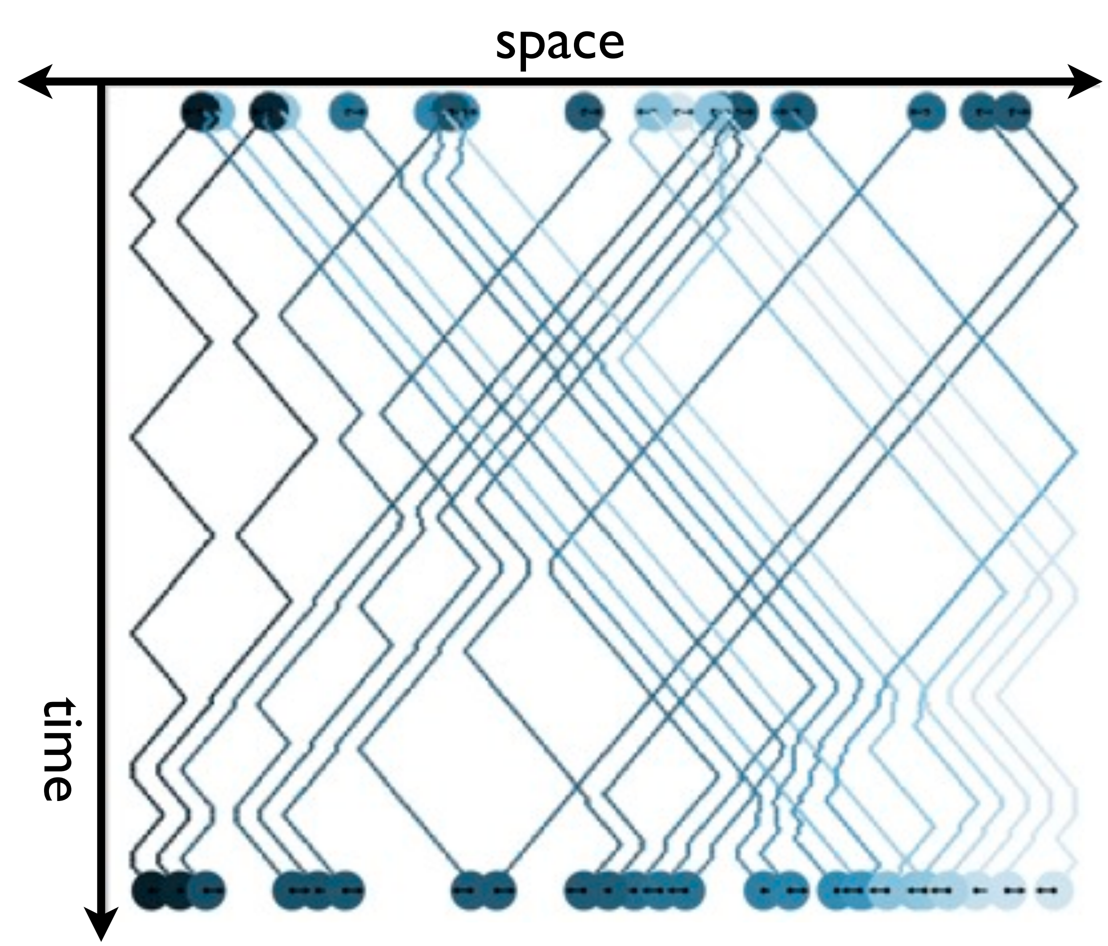
- Continuous Signal Machines (Duchier, Durand-Lose, and Senot, SASO 2010)



Collision Sort

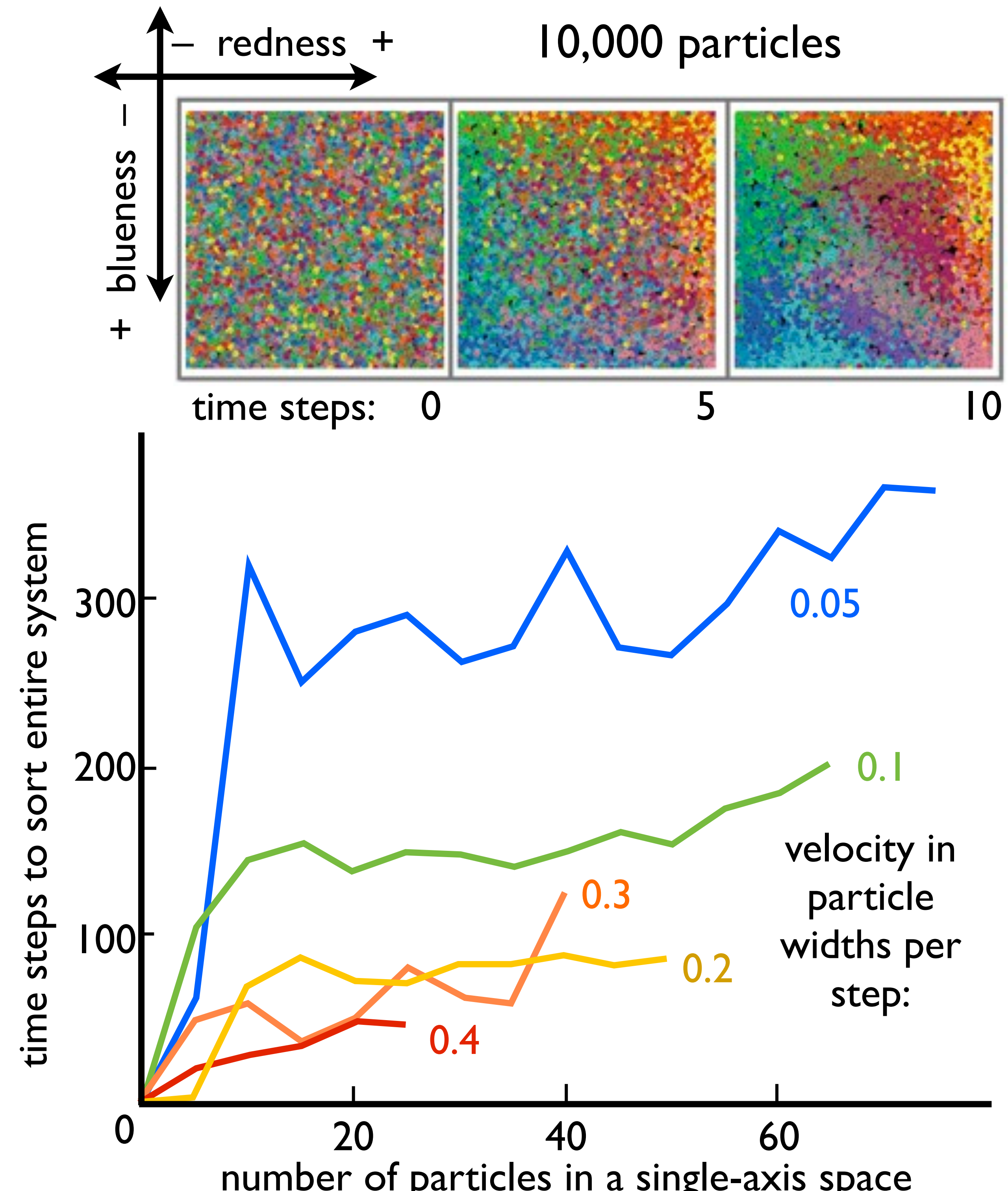
- Represent data as particles in a simulated continuous space
- "Bubbles" are conditional collisions
- The space may be partitioned like CA for parallel processing





Collision Sort

- Simultaneous multi-axis sorting is a natural extension
- Absolute positioning may be non-deterministic without global synchrony
- Performance depends on factors beyond particle count: speed, size of space...

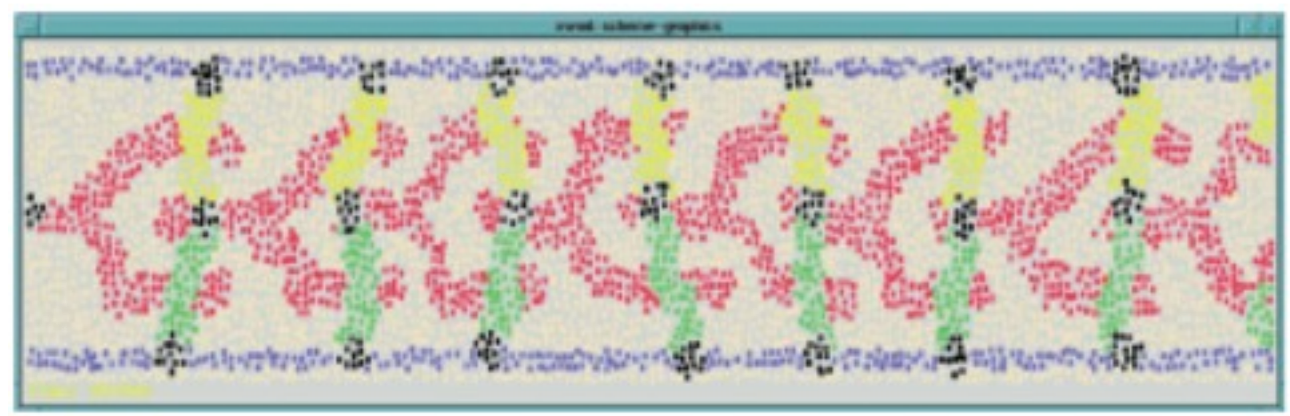


Insertion Sort

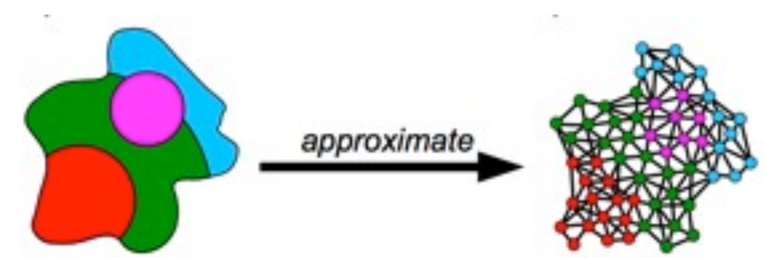
(as a developmental dataflow program
in an amorphous spatial computer)

related work

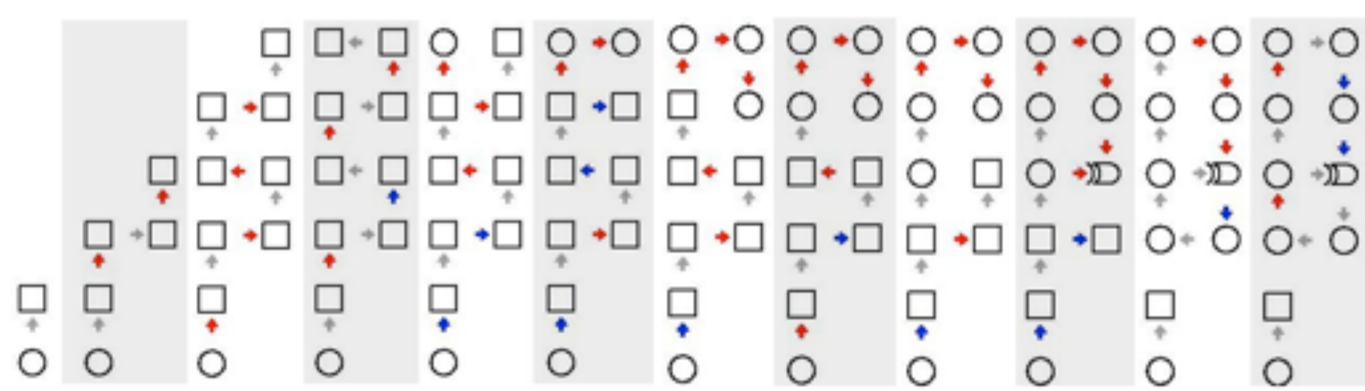
- Growing Point Language
(Coore 1999)



- Proto
(e.g. Bachrach, Beal 2006)

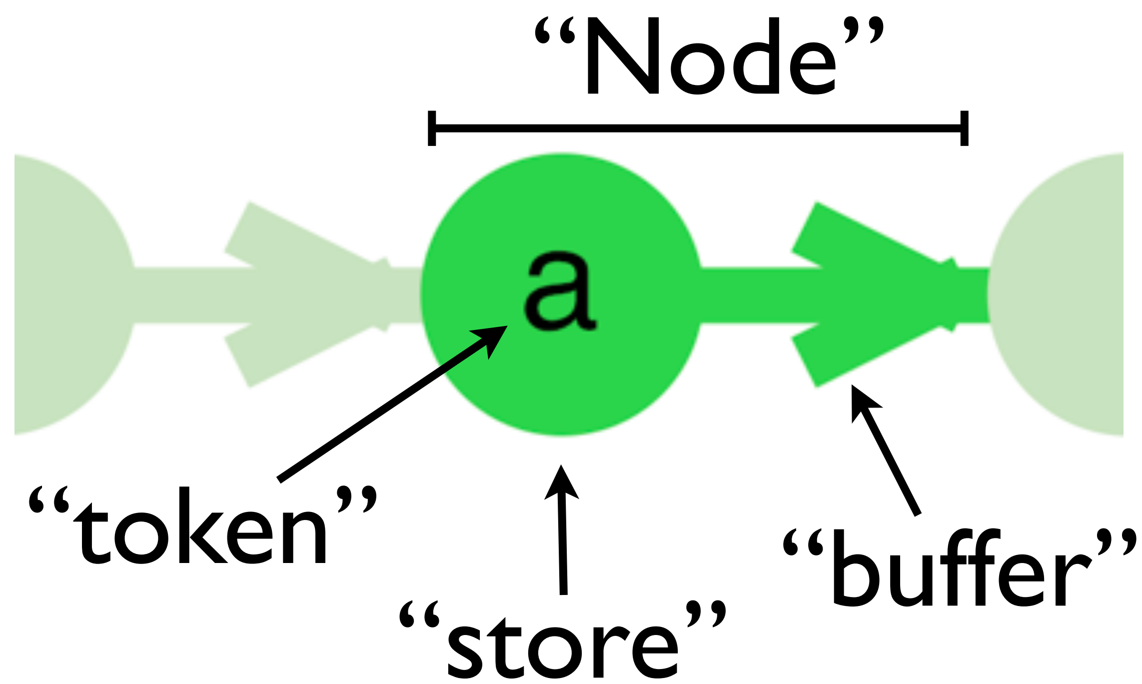


- Reconfigurable Asynchronous
Logic Automata
(Gershenfeld et al 2010)

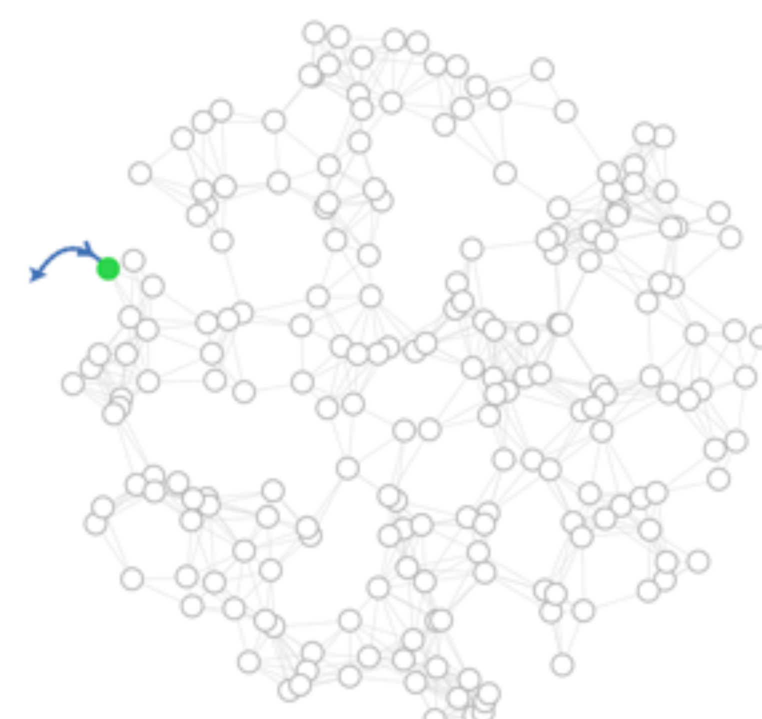


Insertion Sort

spatial computer **assumptions** and terminology

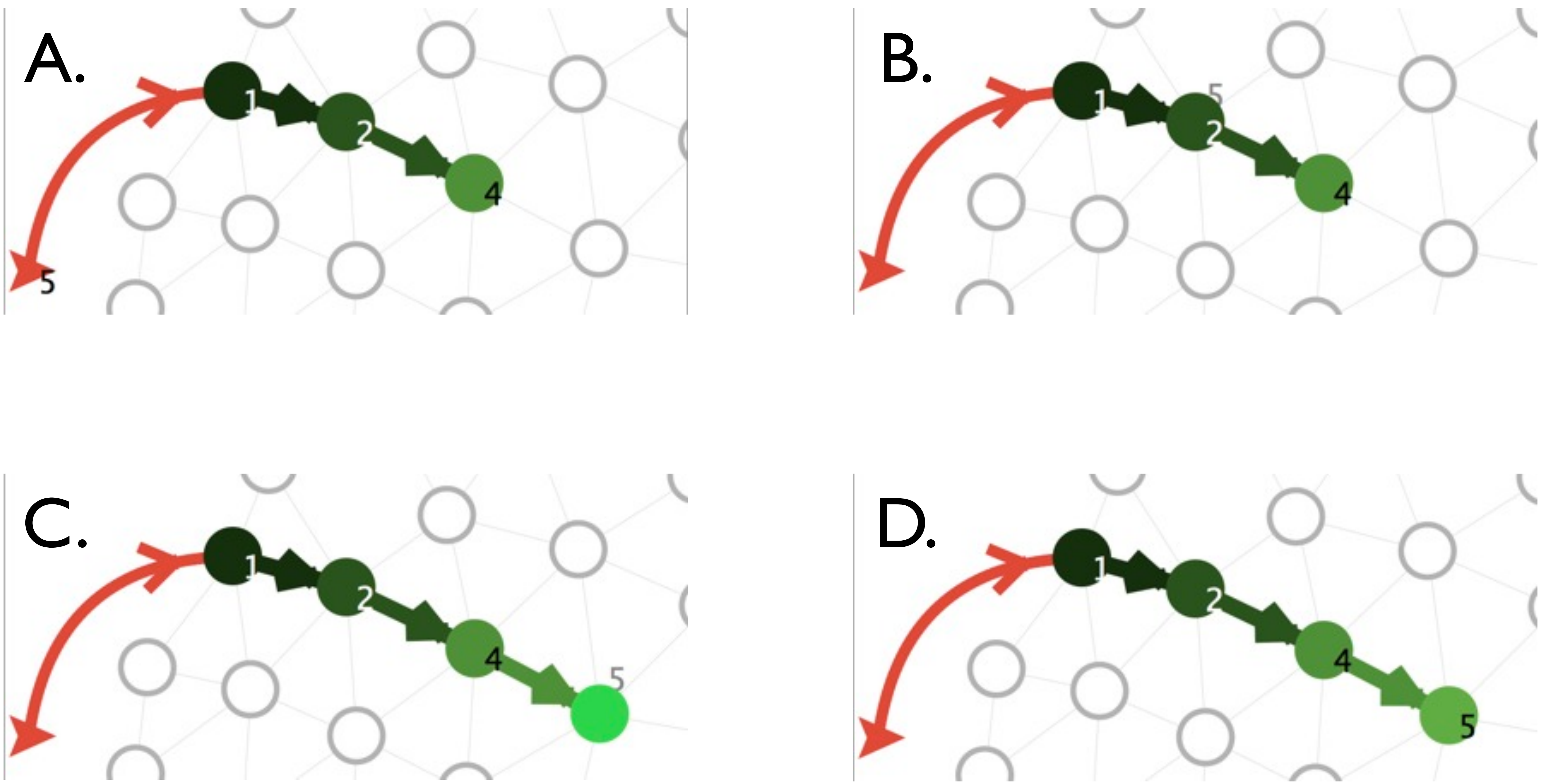


- There are more nodes than items to be sorted
- Nodes are functionally identical
  - all run the same program
  - very limited local storage
  - no access to global information
- Nodes don't move
- Sufficient local connectivity
- Atomic transactions



Insertion Sort

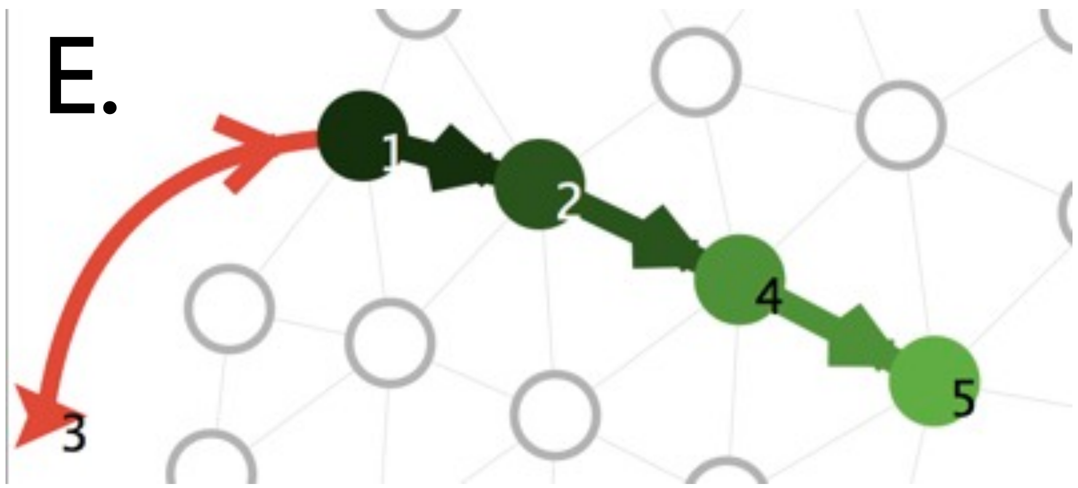
example sequence: **extension**



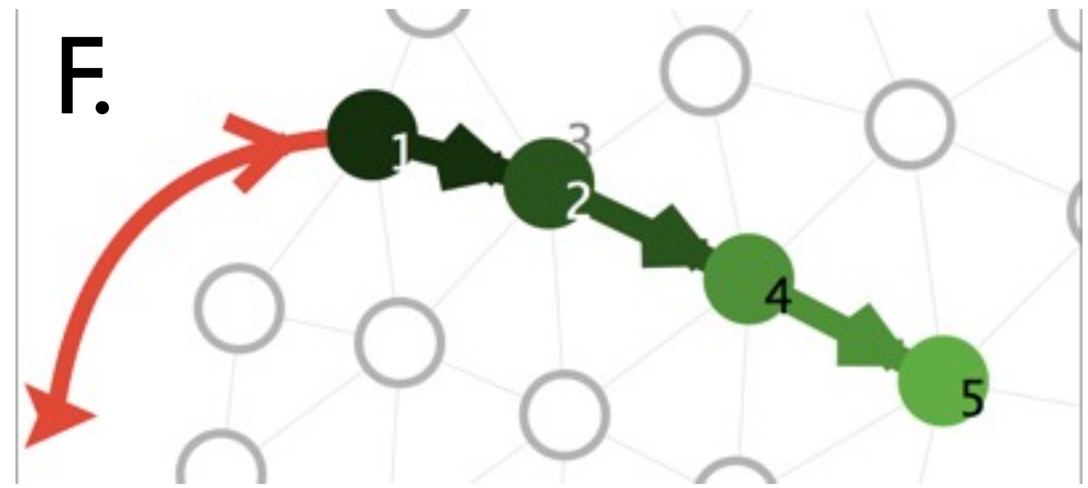
Insertion Sort

example sequence: **swelling**

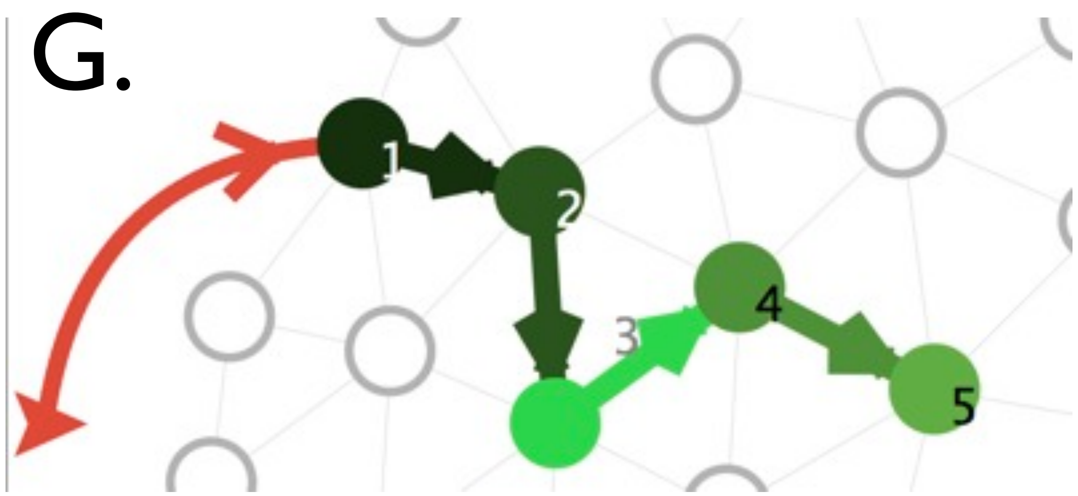
E.



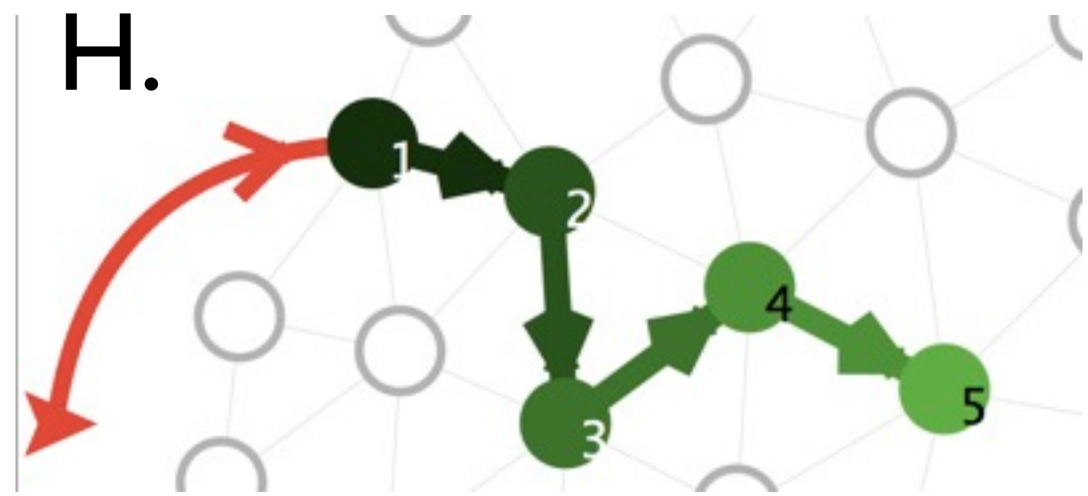
F.

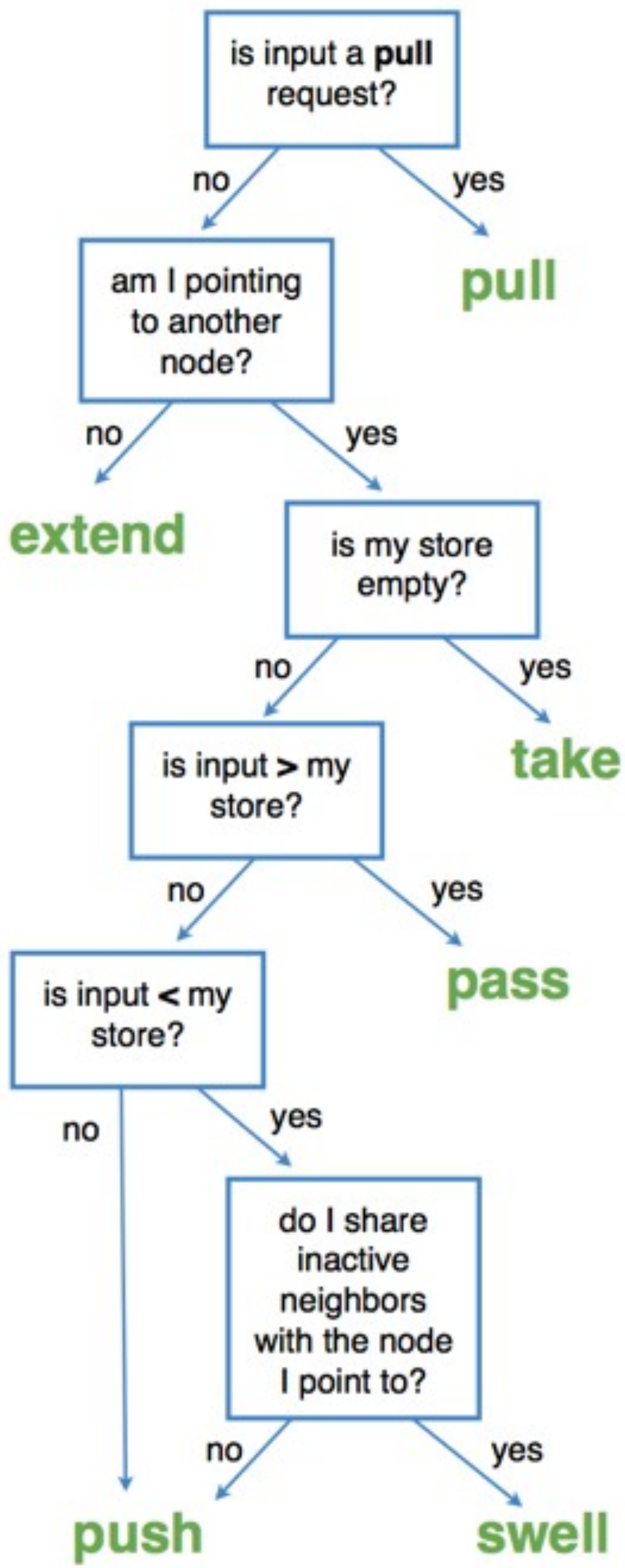


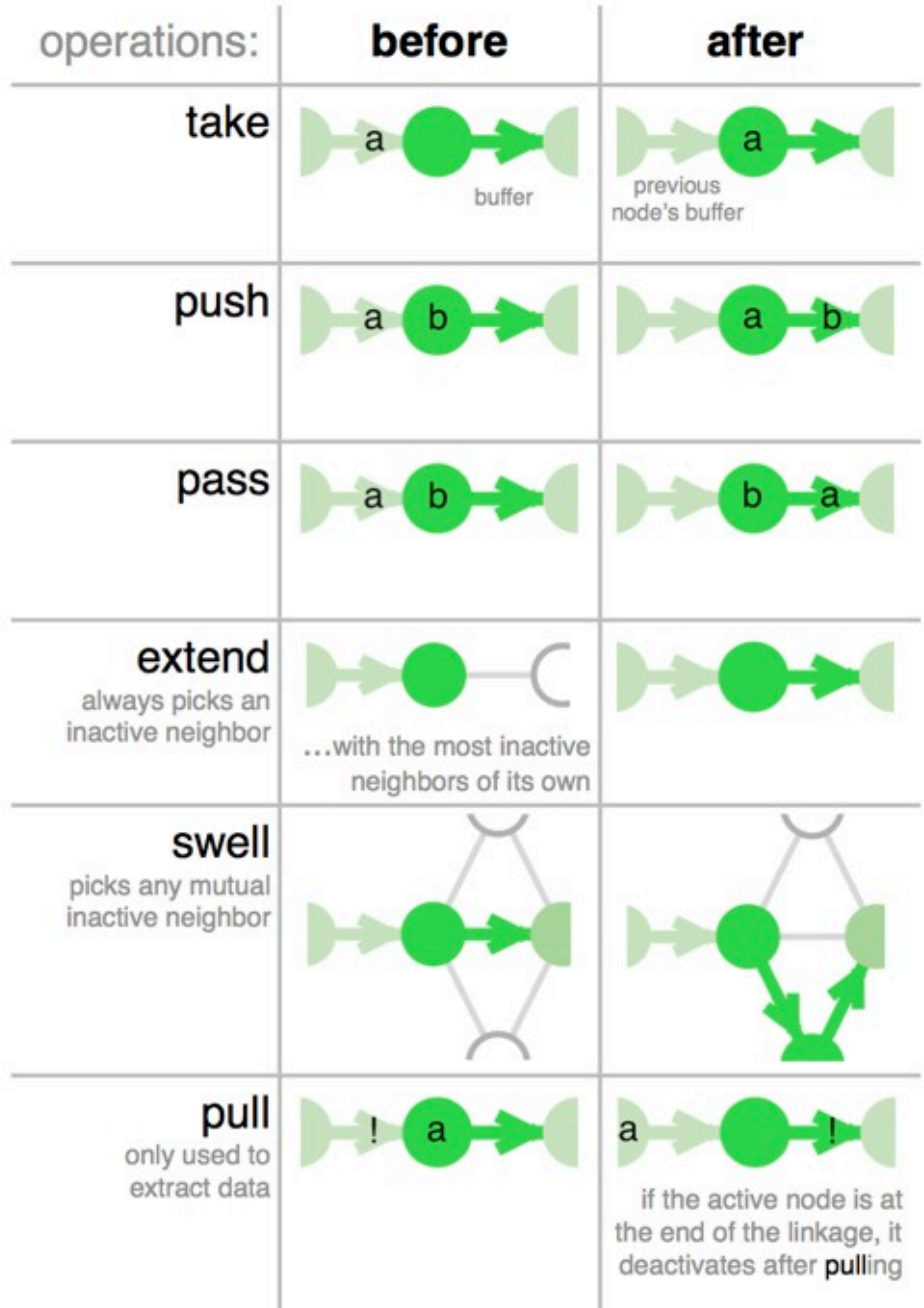
G.



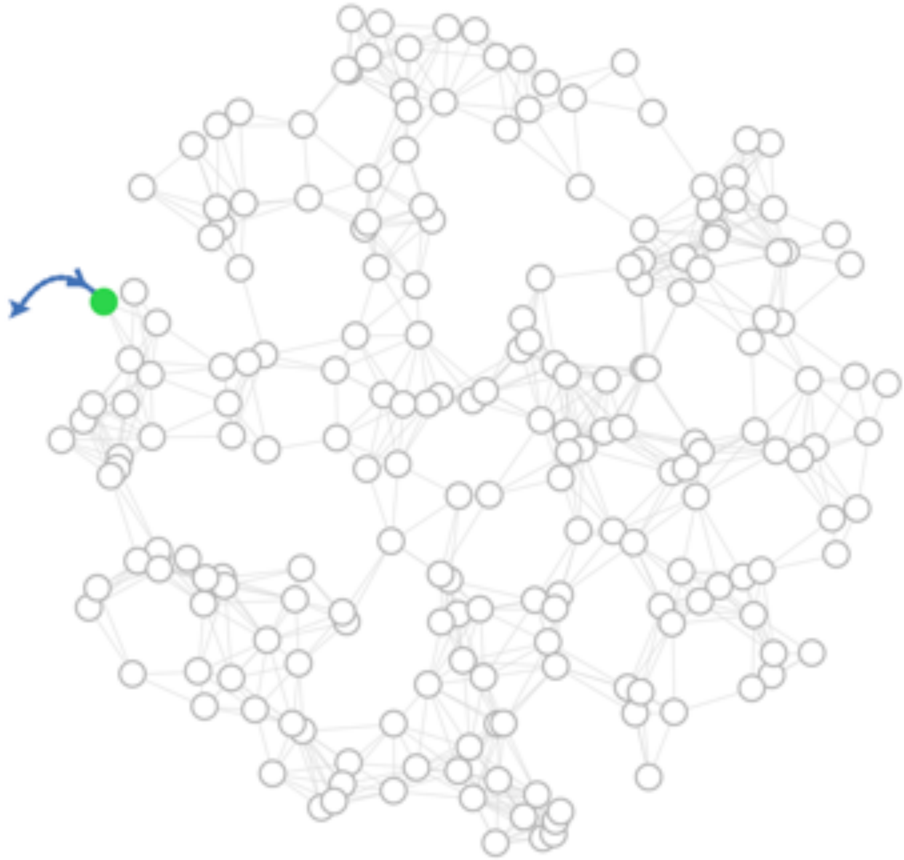
H.



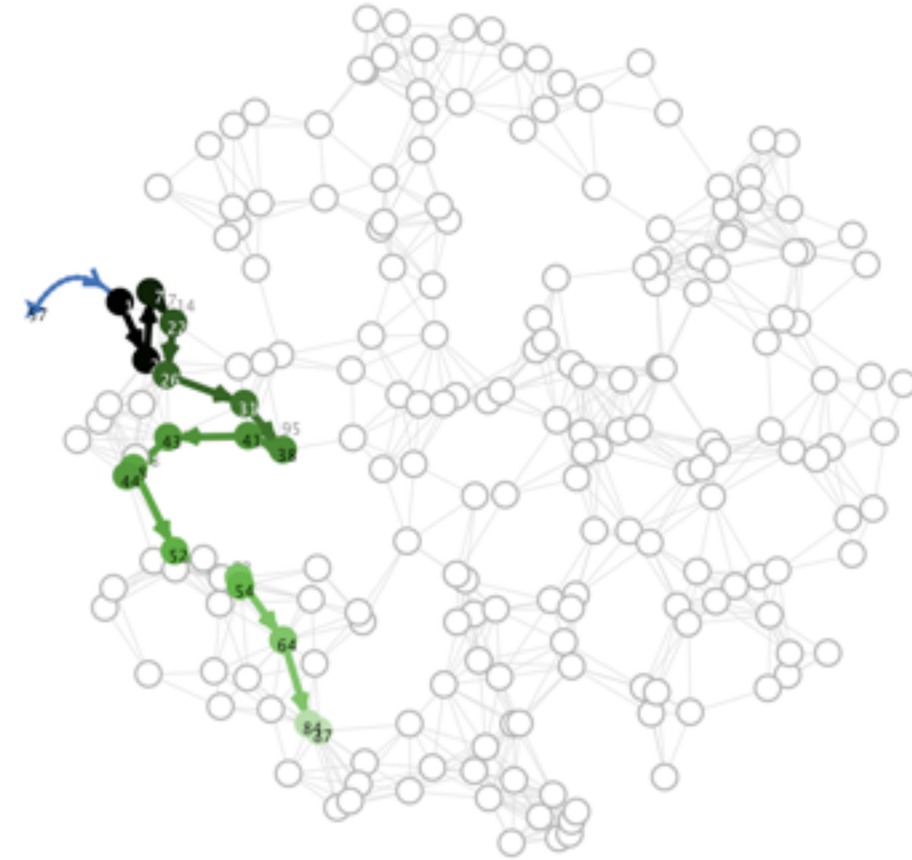

is input a **pull** request?
no
yes
pull
am I pointing to another node?
no
yes
extend
is my store empty?
no
yes
take
is input **>** my store?
no
yes
pass
is input **<** my store?
no
yes
do I share inactive neighbors with the node I point to?
no
yes
push
swell


operations:
before
after
take
a
buffer
a
previous node's buffer
push
a
b
a
b
pass
a
b
b
a
extend
always picks an inactive neighbor
...with the most inactive neighbors of its own
swell
picks any mutual inactive neighbor
pull
only used to extract data
!
a
a
!
if the active node is at the end of the linkage, it deactivates after **pull**ing

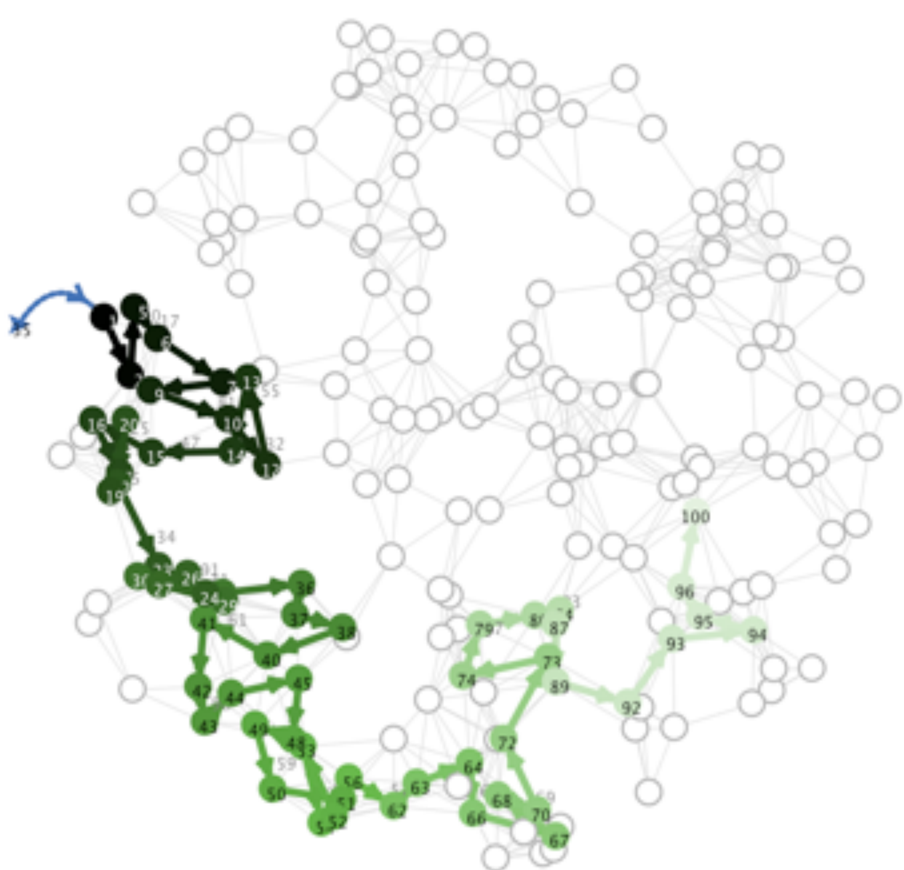
1.



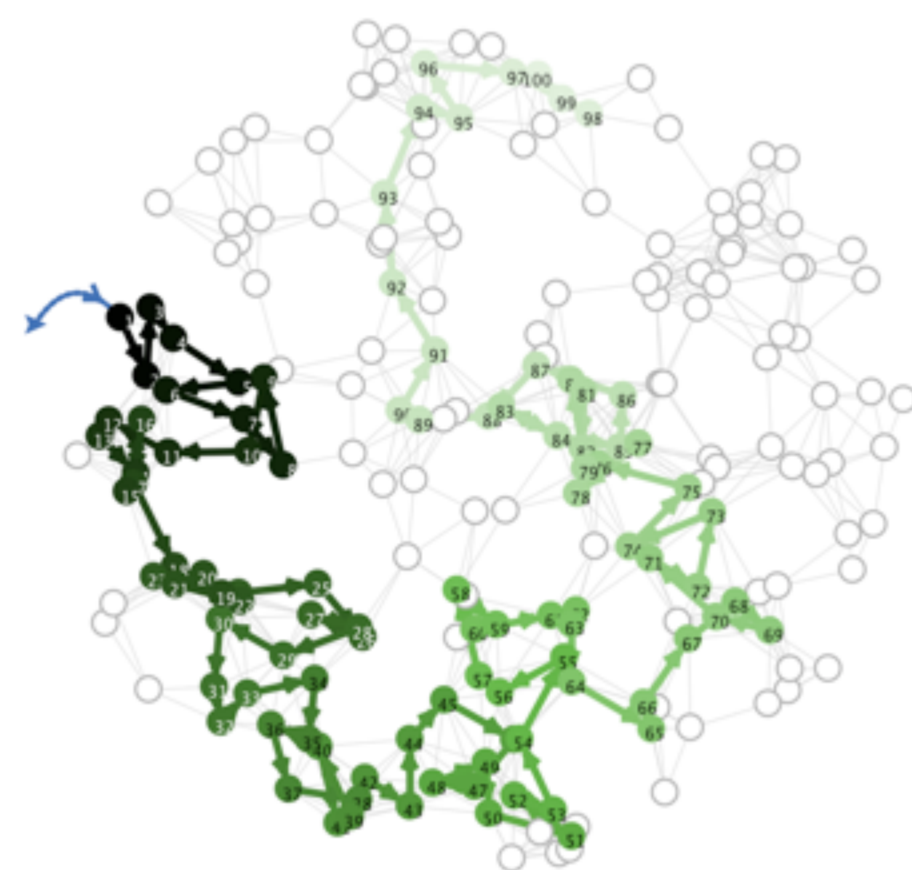
2.



3.

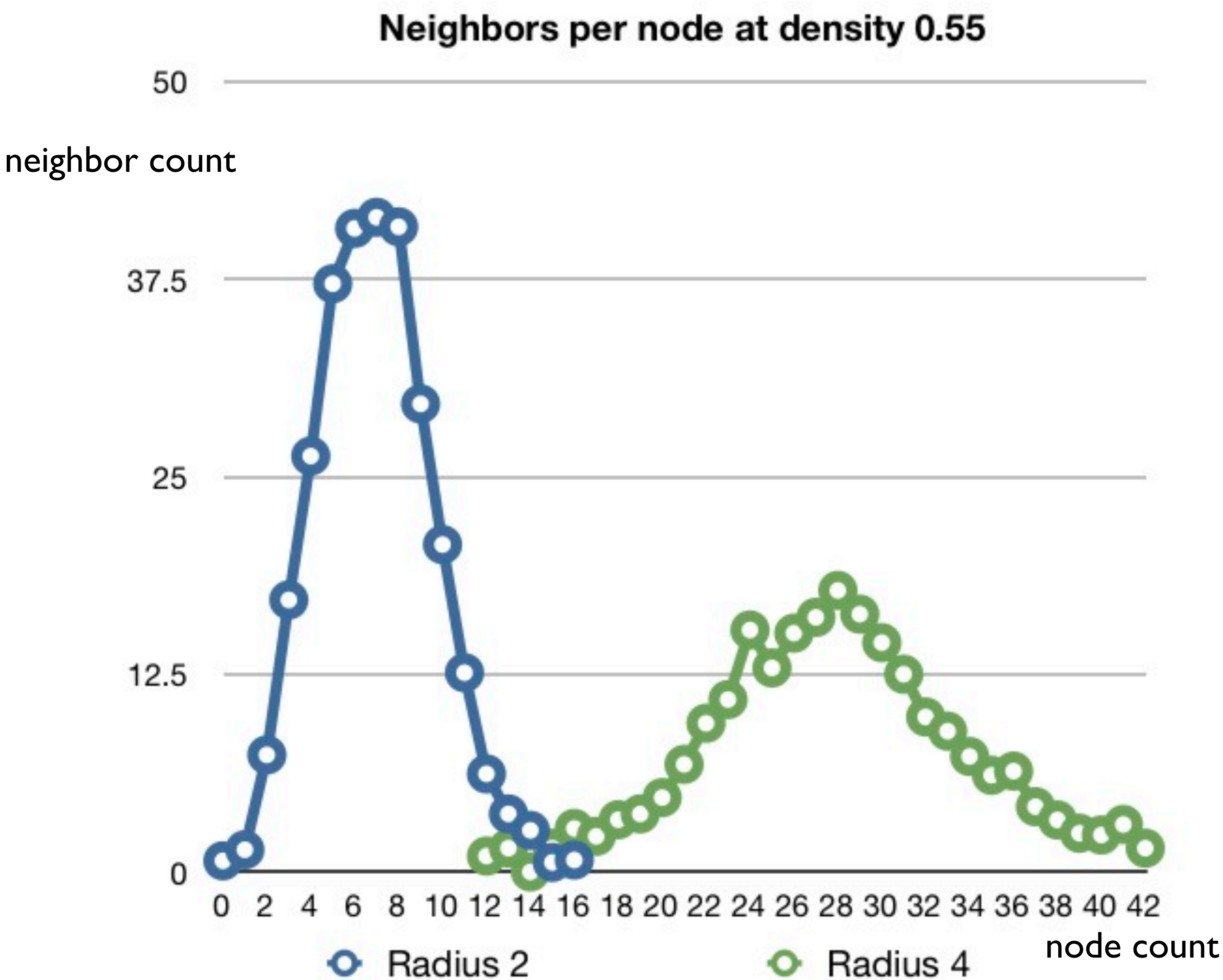


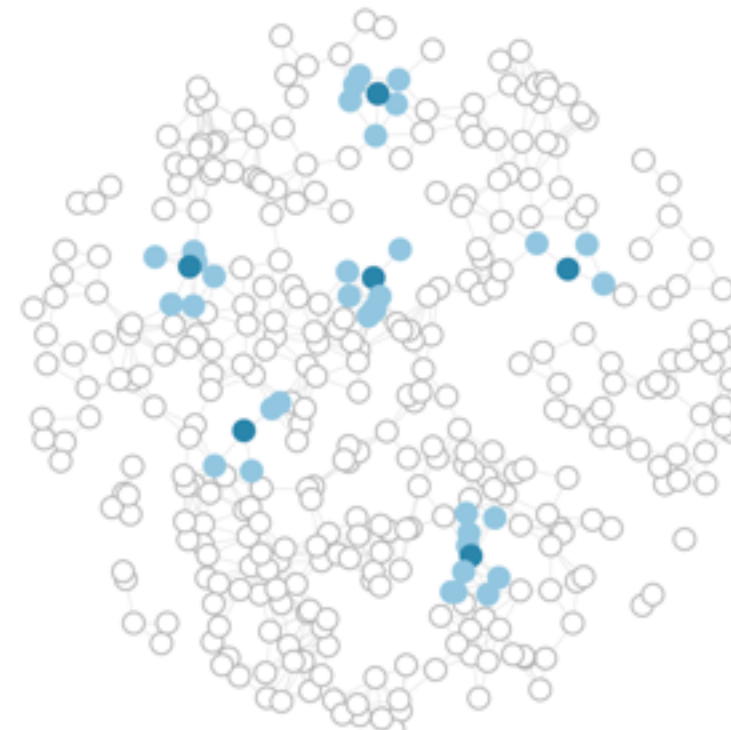
4.

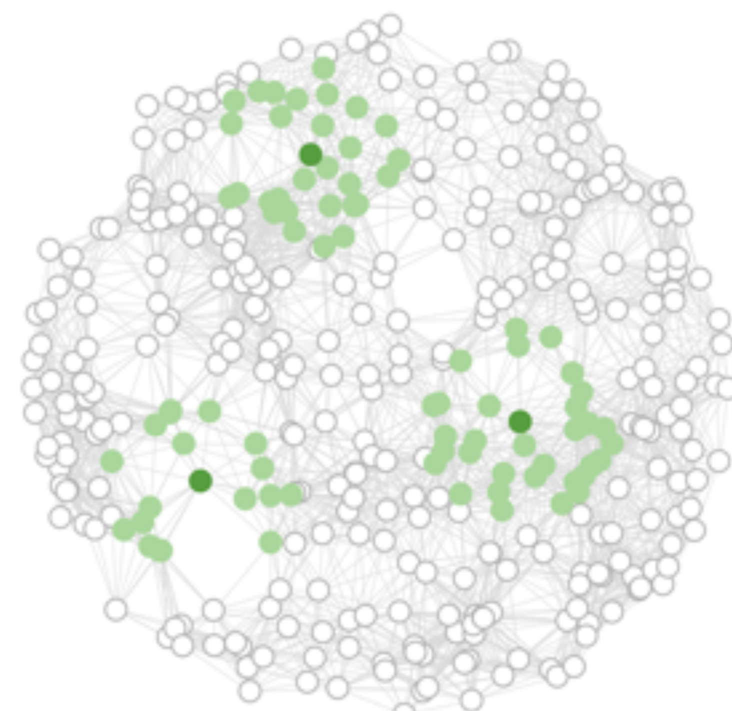


Insertion Sort

amorphous network approximates a 2D manifold

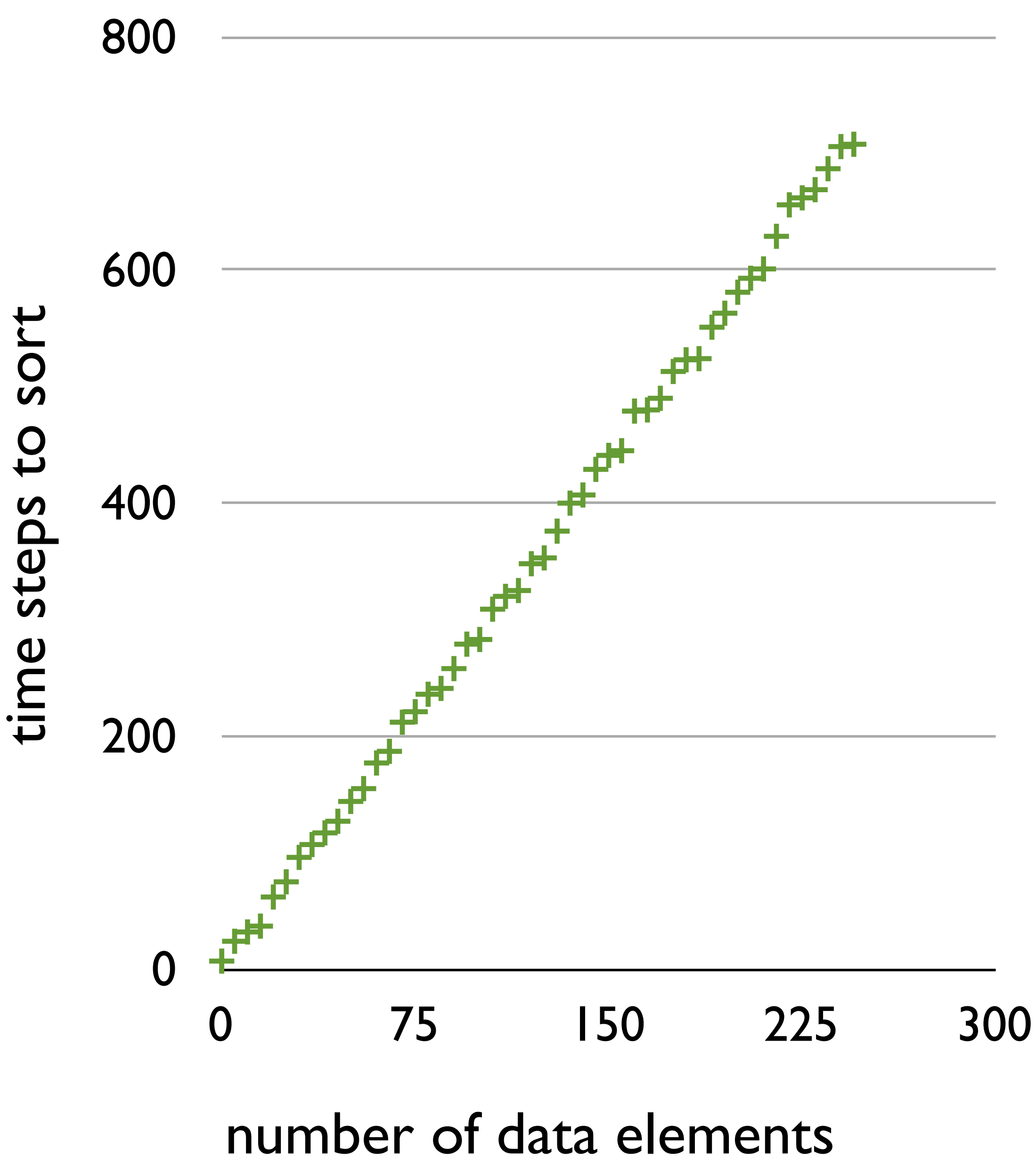






Insertion Sort

performance and limitations



- Parallel execution yields O(n) time complexity
- Growth process can get overcrowded or stuck
- No allowance for node failure in this model
- Linear linkage may be a less efficient use of space than (e.g.) spanning trees

Conclusions

- Spatial abstractions can help organize large-scale, fine-grained parallel computations
- Spatial programs may, but need not, map directly to physical computers
- Random networks can do useful work

Thanks to the Maseeh College of Engineering and Computer Science
Undergraduate Research and Mentoring Program

All software models are available:

http://cs.pdx.edu/~orhai

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