Targeting Influential Nodes for Recovery in Bootstrap Percolation on Hyperbolic Networks

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Overview

Agent based modelling of dynamic processes on complex networks

- Spatial effect of a network on the spread of a process
- Hyperbolic random geometric graphs
- Bootstrap percolation
- Introducing Bootstrap Percolation with Recovery
- Introducing recovery delays percolation, and the effect is more significant if we target nodes of high degree centrality over random selection.

Bootstrap Percolation

The process where an activity spreads if the number of your active neighbours is greater than a tipping point.

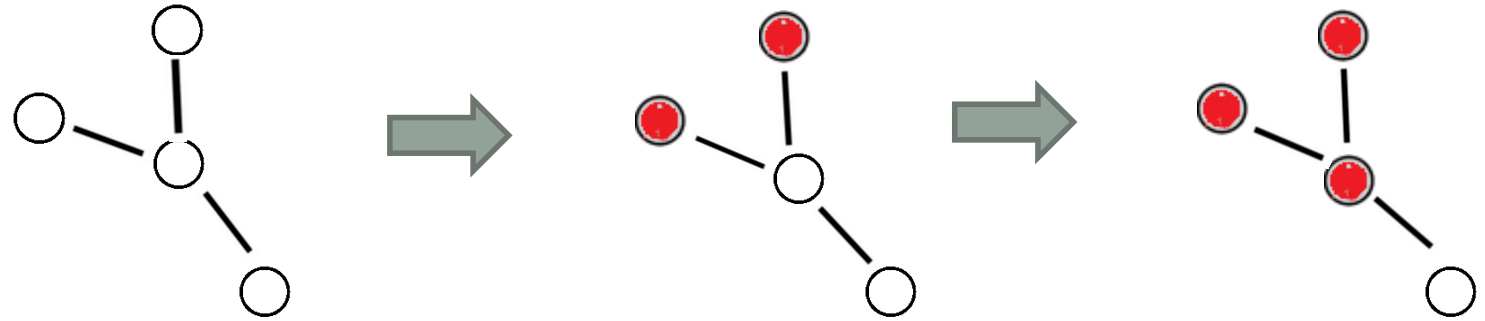
Can be used to model social reinforcement:

Spread of opinions
Voter dynamics
Adoption of new trends

Viral marketing

Simulating bootstrap percolation

- Bootstrap Percolation
  - Activation Threshold
  - Selection of active seed set
  - Update Rule

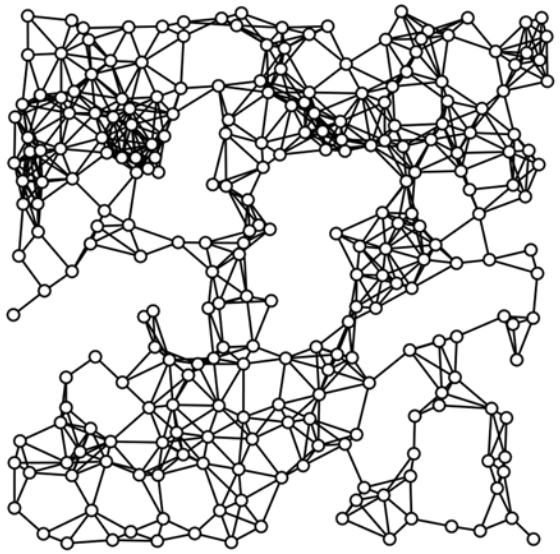


Conceptual Framework for Bootstrap Percolation with Recovery

- Standard Bootstrap
  - Inactive to Active
- Bootstrap Percolation with recovery
  - Inactive to Active
  - Active to Inactive
    - Targeted percentage of Active nodes of highest degree centrality
    - Percentage of randomly selected Active nodes
- Motivation
  - Small scale random attack in network, which nodes can we target to obstruct the spread of activity

Random Geometric Graphs

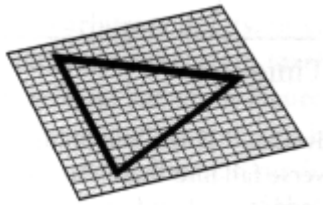
- Distance Graphs
  - Spread of Forest Fire



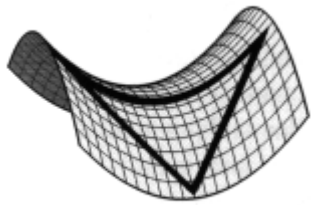
- Wireless ad-hoc and sensor networks

Different Geometric Spaces

Euclidean disc



Flat Curvature

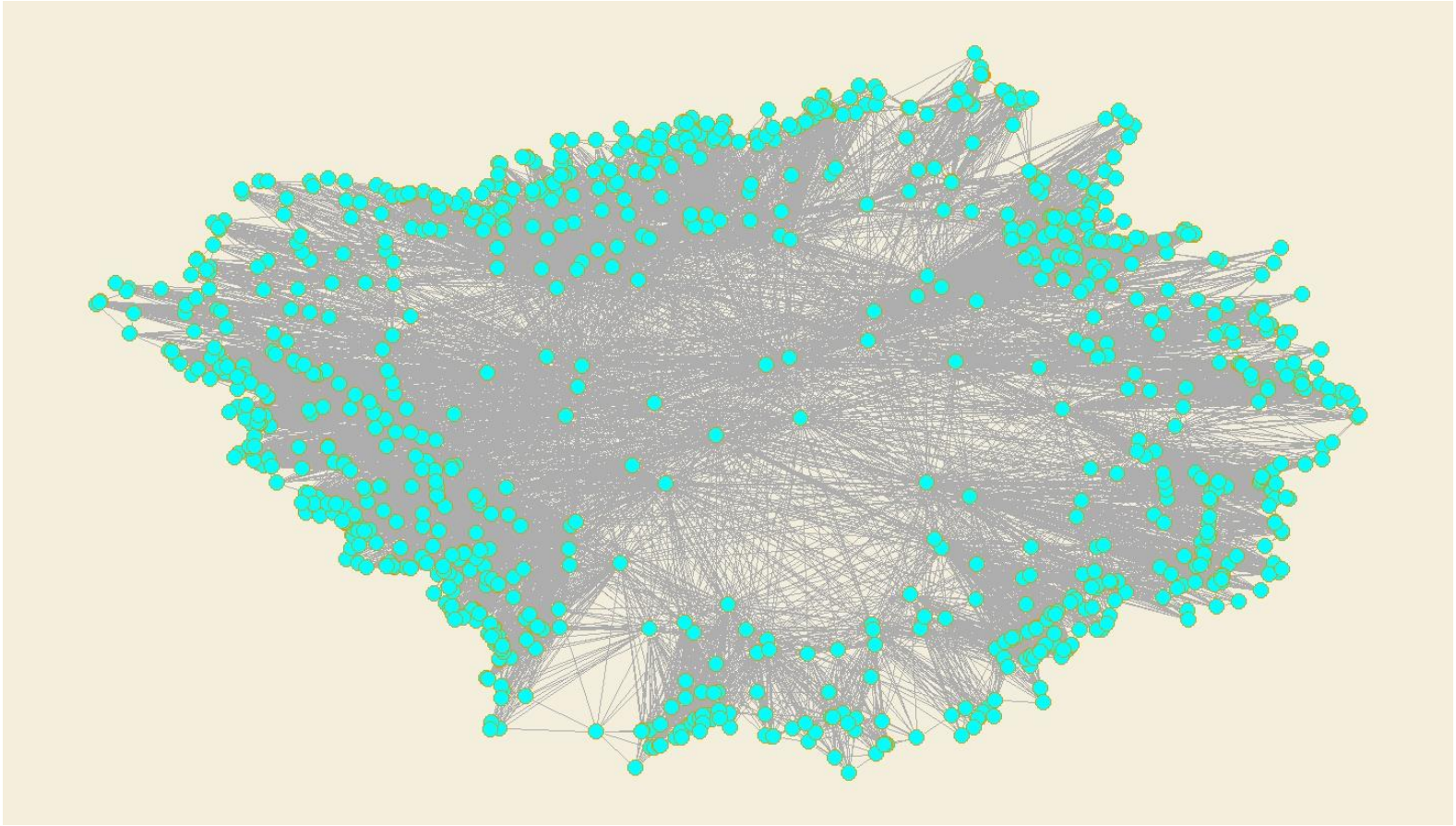


Negative Curvature

Hyperbolic disc

M.C. Escher Circle Limit IV 1960

Hyperbolic Random Geometric Graphs

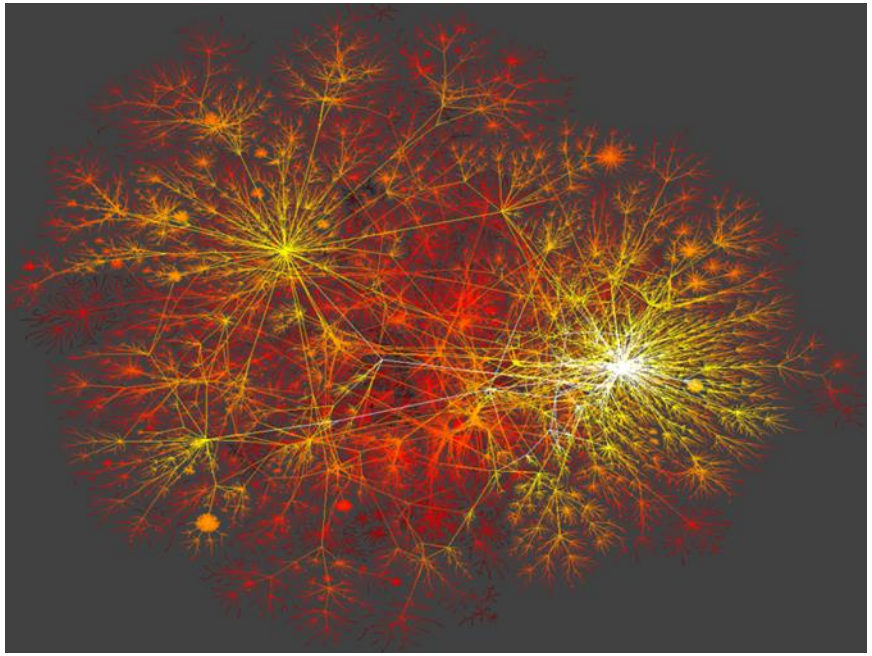


Hyperbolic random geometric graph, with edge density of 0.036

Krioukov et al., Hyperbolic Geometry of Complex Networks, 2010

Application of Hyperbolic Geometric Graph Models

Modelling the internet graph



Snapshot of Internet connectivity K.C. Claffy www.caida.org

Research Questions

- In Bootstrap Percolation: As we increase the number of edges in the hyperbolic graphs, is it possible to identify a threshold between the complete spread of activity and the failure to percolate?
- If we modify the rules in Bootstrap Percolation and allow “recovery” from active to inactive state, will this impact the spread of activity?
- If we selectively target active nodes with high degree centrality, will this have a greater impact?

Experimental Set-Up

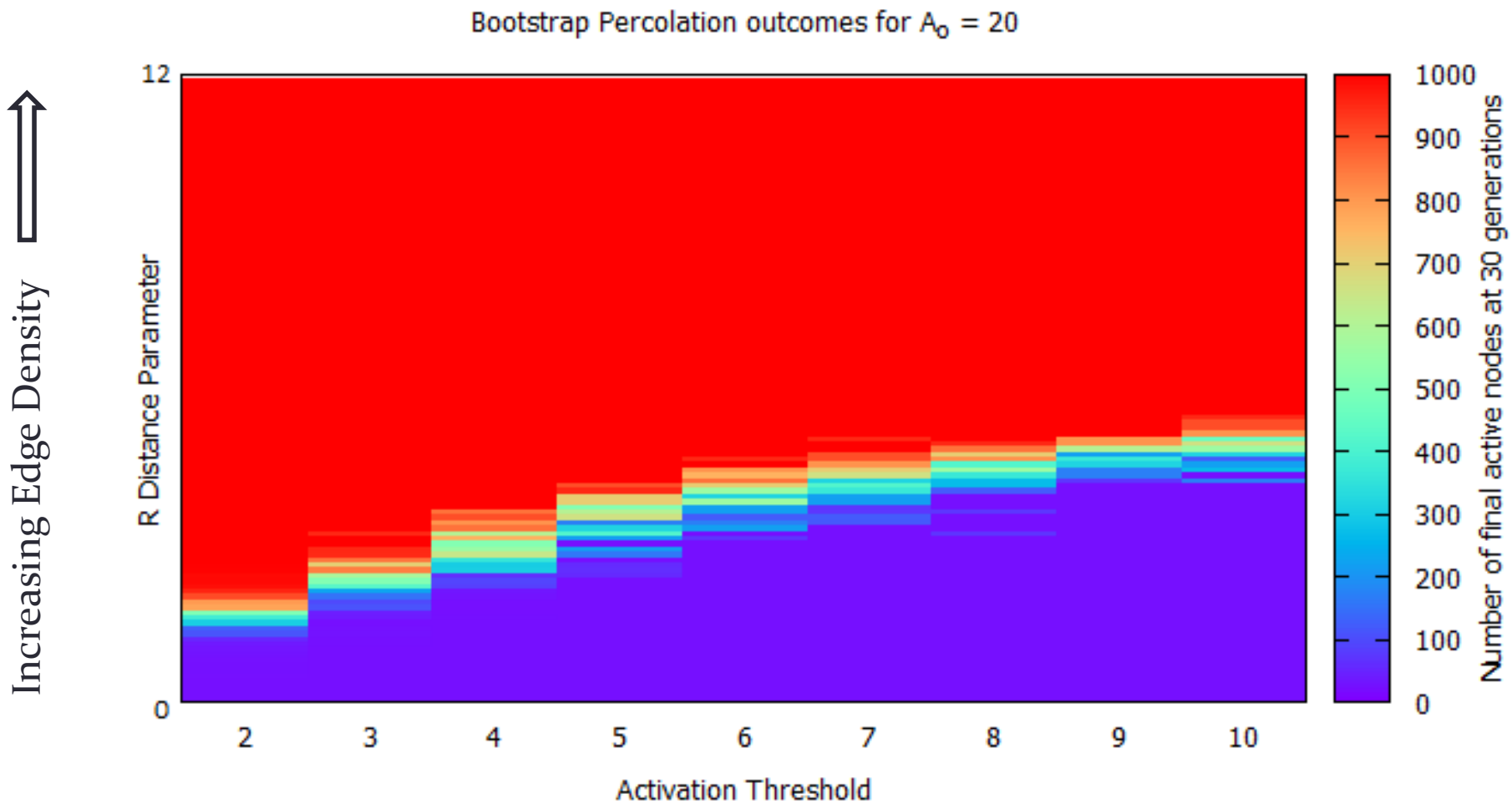
- Utilising the same set of hyperbolic geometric graphs for all simulations (1000 nodes)

- Agent based modelling of Bootstrap Percolation
  - 20 random seeds
  - Activation Threshold 2 … 10
  - Repeat activation mechanism at each time step until equilibrium
  - Count number of Final Active Nodes

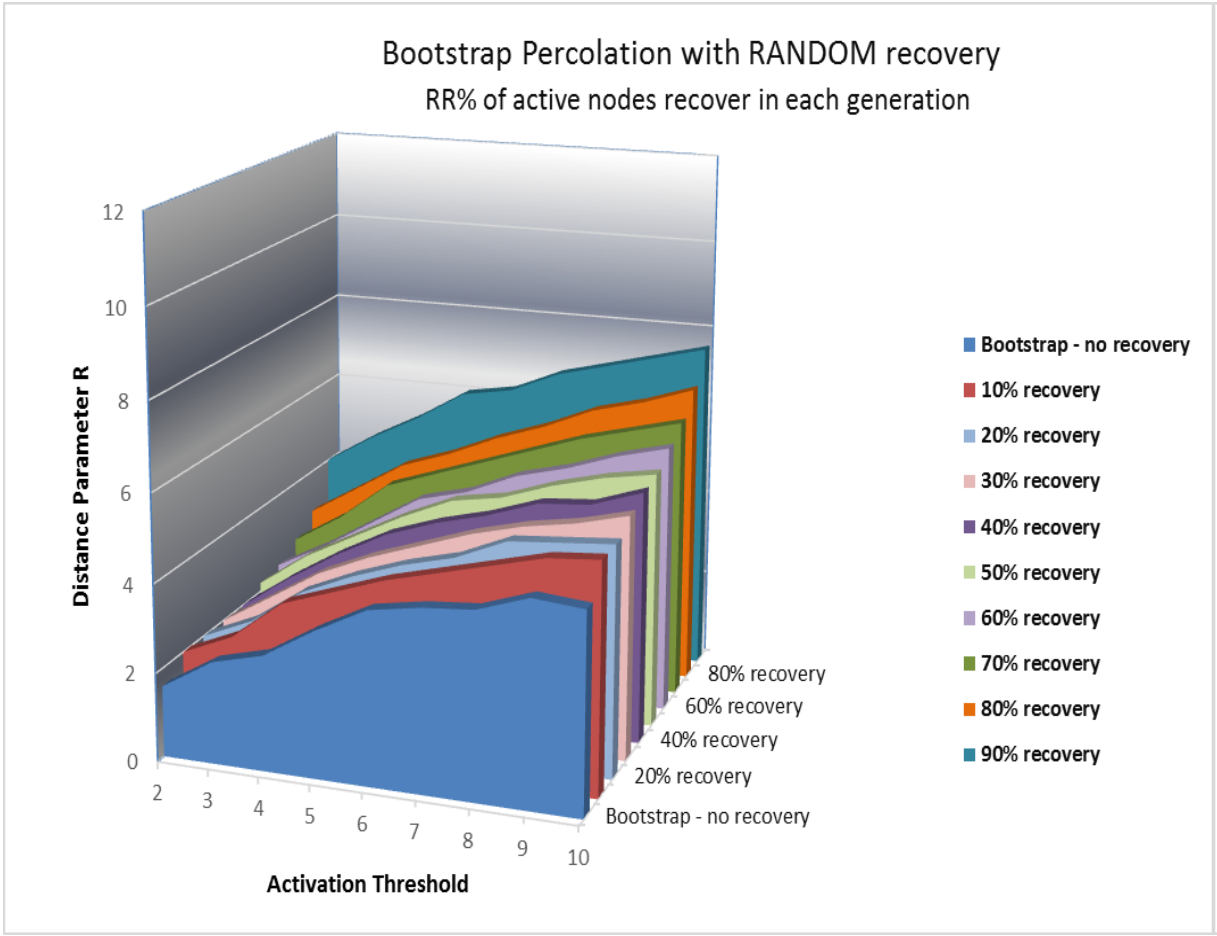
- Agent based modelling of Bootstrap Percolation with Recovery

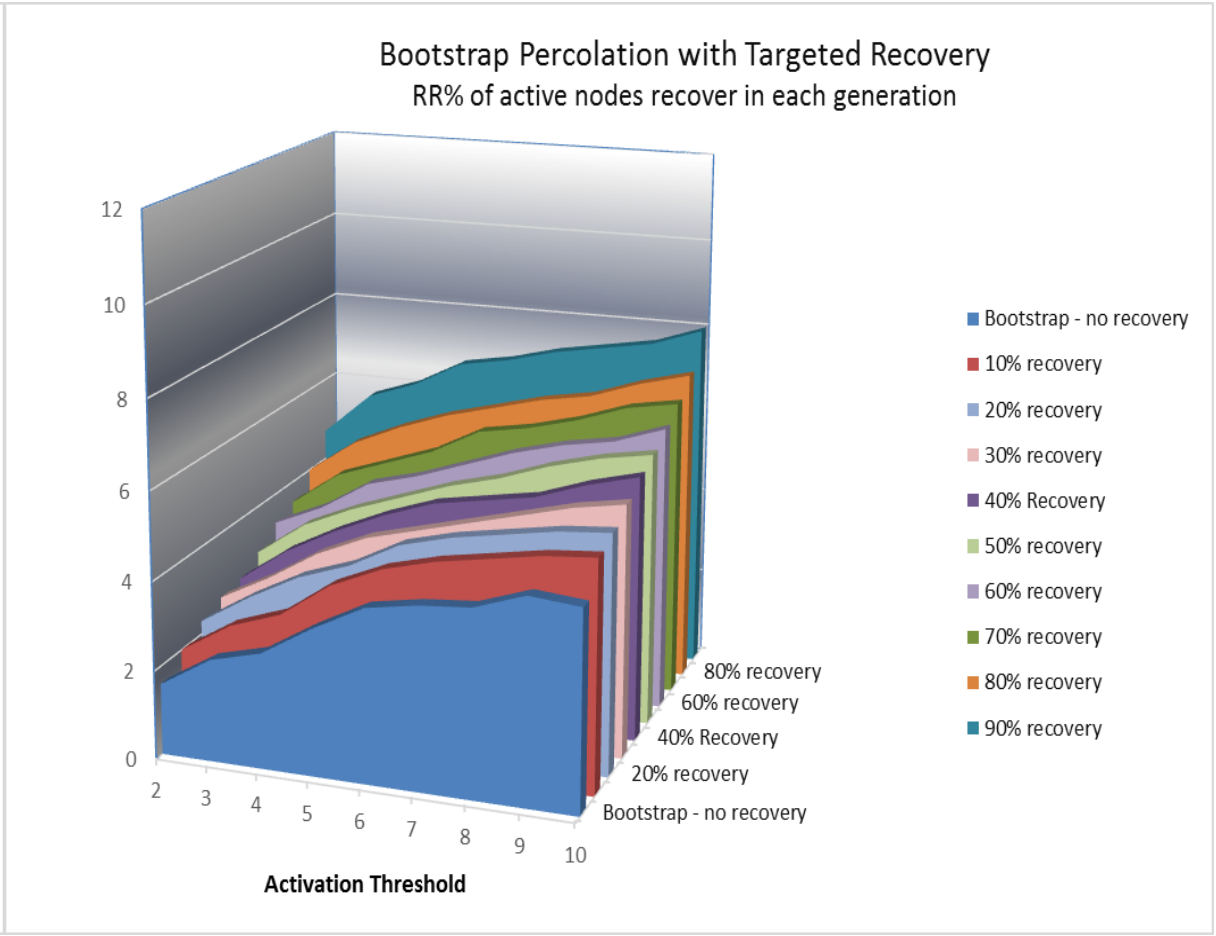
  Activation followed by % recovery at each time step (10 – 90%)
  - Targeted recovery based on top ranked node degree centrality
  - Random recovery

Results: Bootstrap Percolation



Results: Bootstrap with Recovery





Current Work

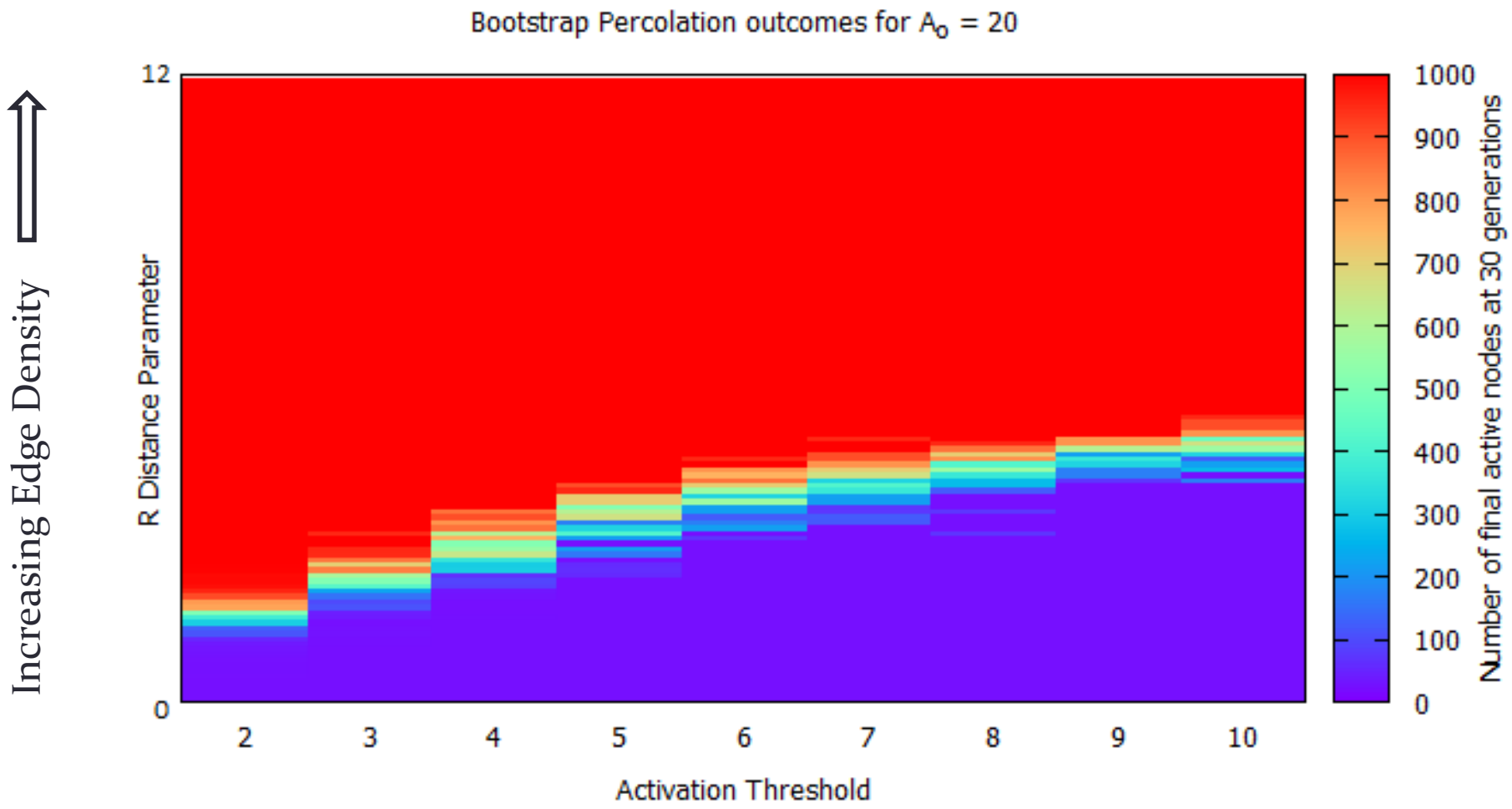
- Selectively target nodes with highly skewed graph properties for recovery

In the hyperbolic graphs:

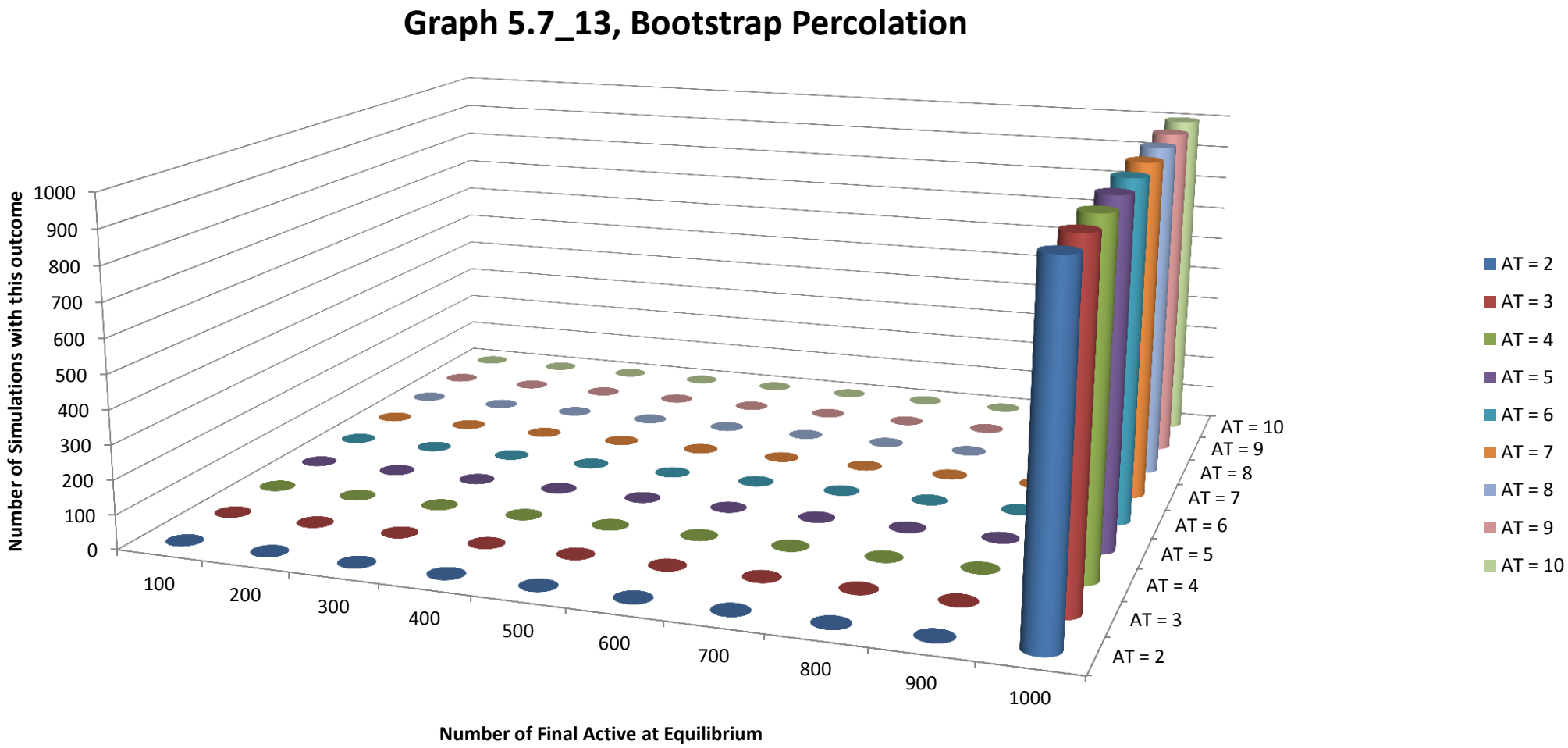
  - centralisation measures
  - clustering coefficients

Immunisation of nodes with certain properties, to observe the effect on the spread of the activity

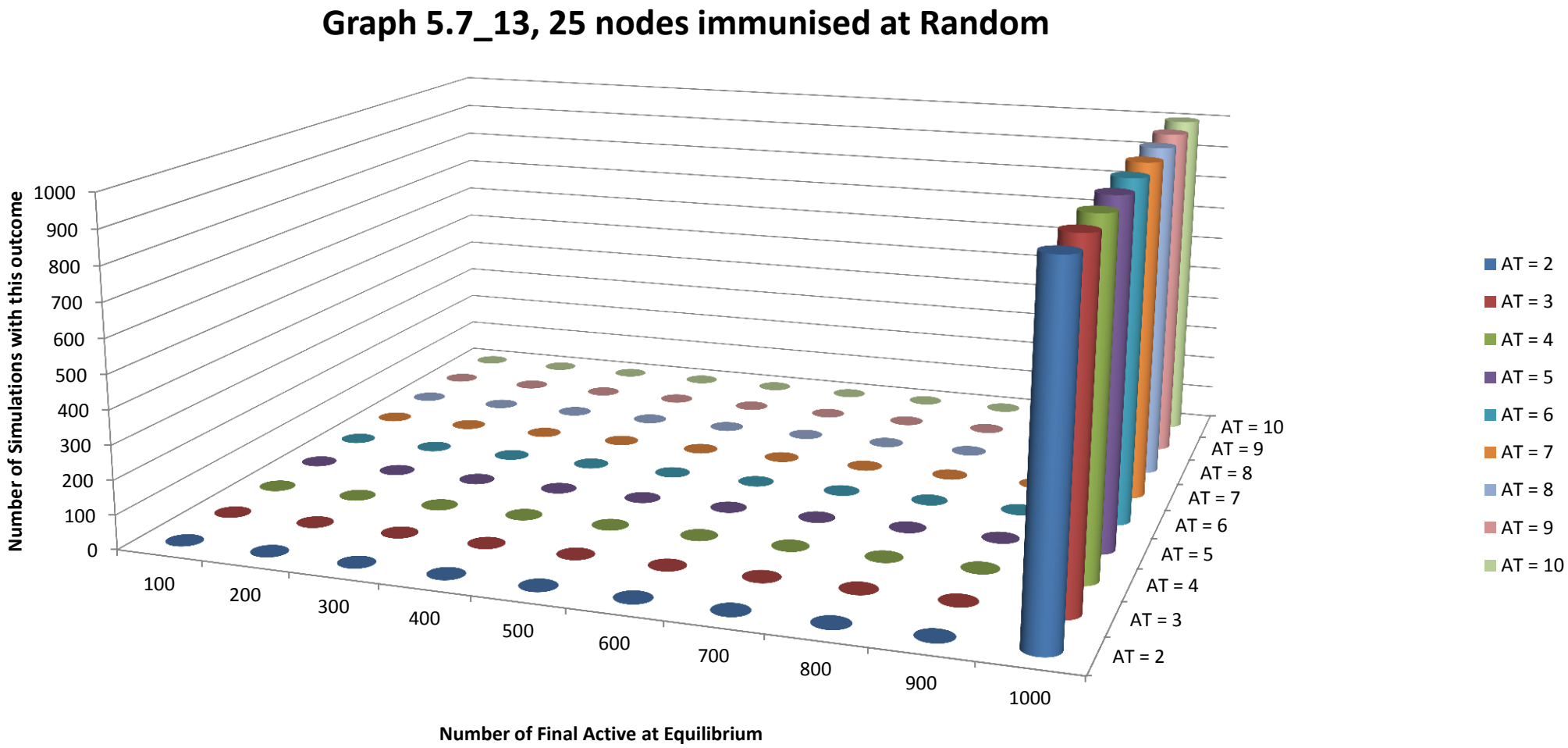
Recap: Bootstrap Percolation



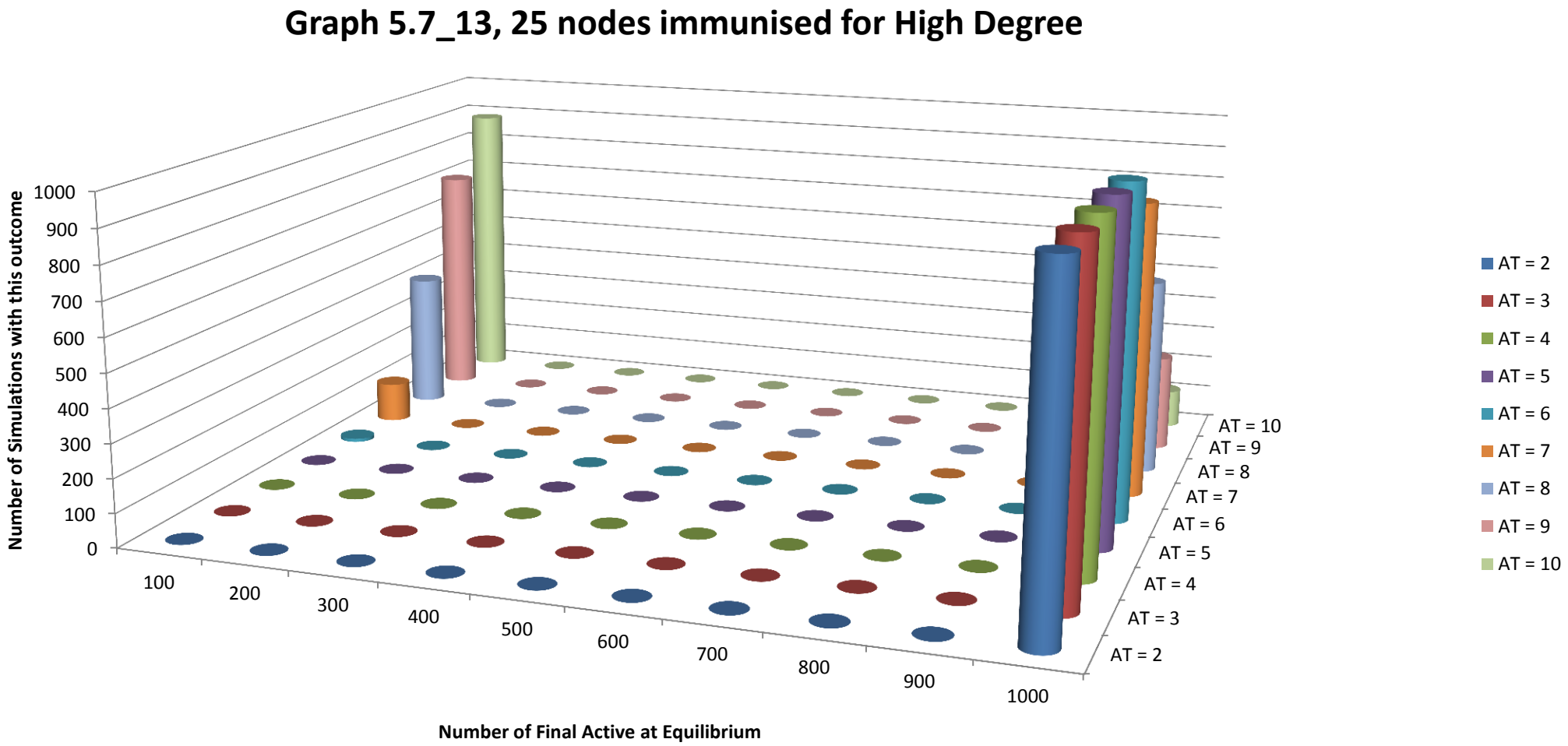
Bootstrap Percolation



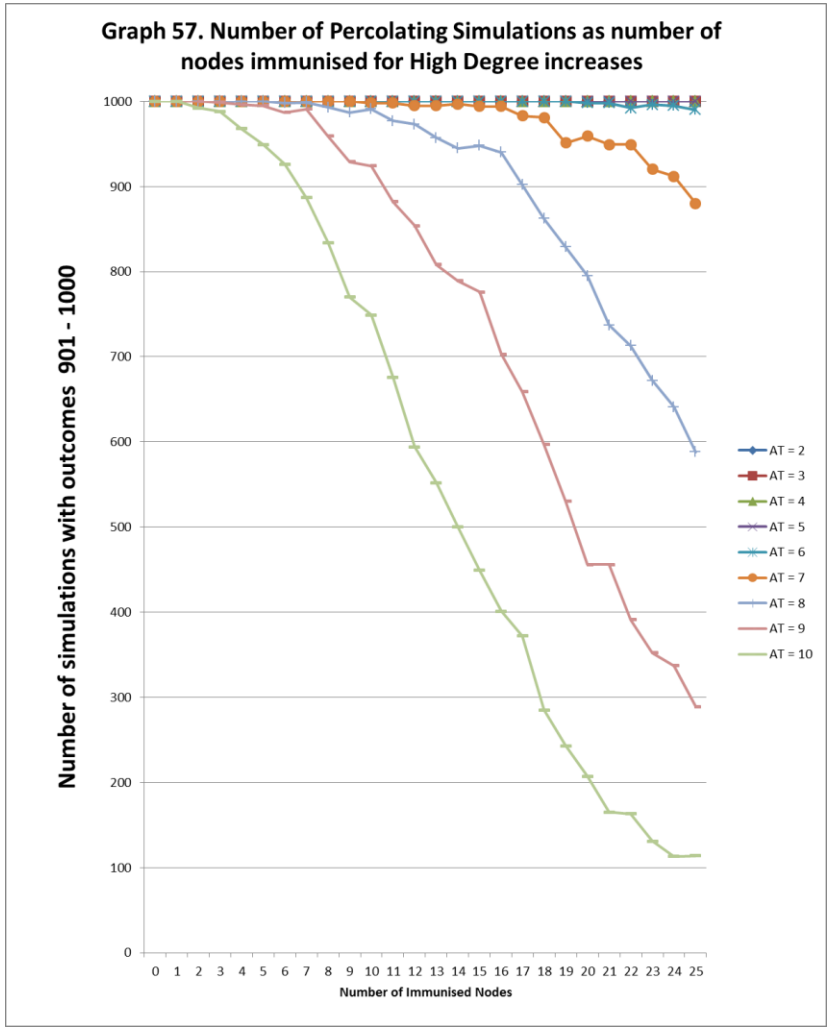
Bootstrap percolation: Random Recovery



Bootstrap Percolation :Targeted recovery



Rate of Decline in Percolating Simulations



Future Work

- Repeat these experiments on more graphs at the threshold, varying target graph properties

- In the simulations that fail to percolate:
  - investigate the link between the set of active seeds and the targeted nodes
  - investigate local neighbourhood properties

- Repeat simulations:
  - Euclidean random geometric graphs in the unit disc
  - Erdős Rényi random graphs

Thank You

R = 5.7_13 graph properties	
Density	0.098962
Average Degree	98.962
Diameter	3
WS CC	0.780167
Transitivity	0.475365
Size component	1000
Degree centralisation	0.639957
Betweenness centralisation	0.124498
Closeness centralisation	0.603207
Average shortest path	2.05492
Number of lines	49481

Top Ranked Node Degree Centrality Scores

737
709
560
538
534
517
511
510
458
451
450
422
415
411
390
388
380
367
366
361
335