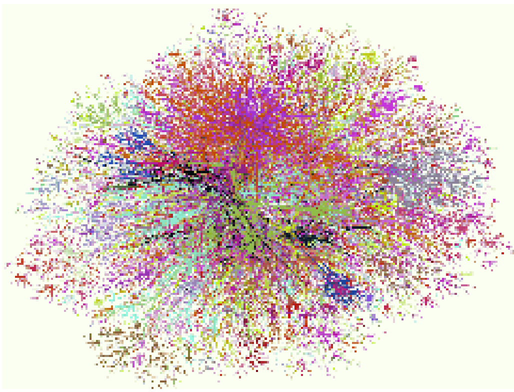
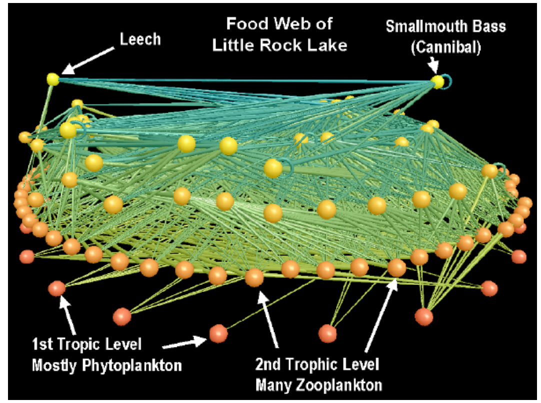
NetMine: Mining Tools for Large Graphs

Deepayan Chakrabarti
Yiping Zhan
Daniel Blandford
Christos Faloutsos
Guy Blelloch

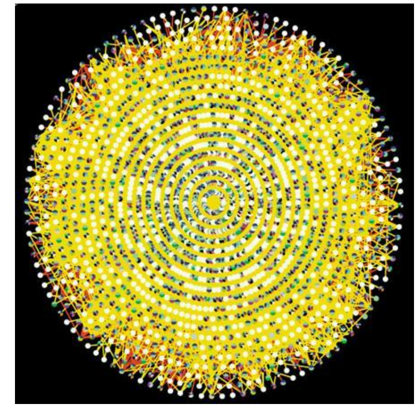
Introduction



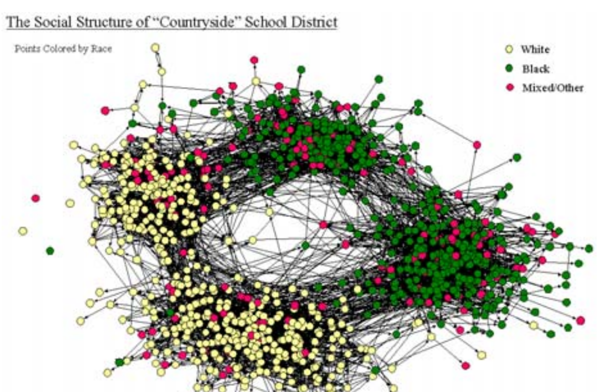
Internet Map
[lumeta.com]



Food Web
[Martinez '91]



Protein Interactions
[genomebiology.com]

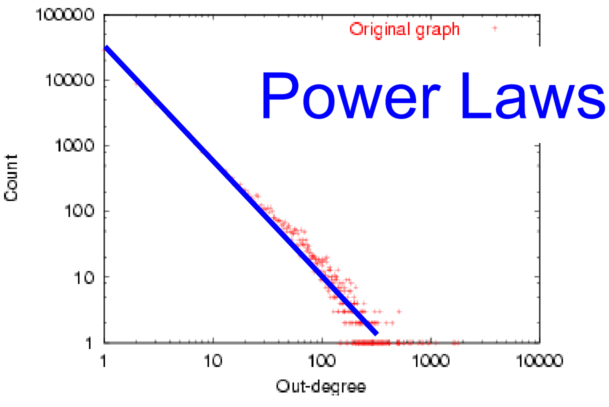


Friendship Network
[Moody '01]

► Graphs are ubiquitous

Graph "Patterns"

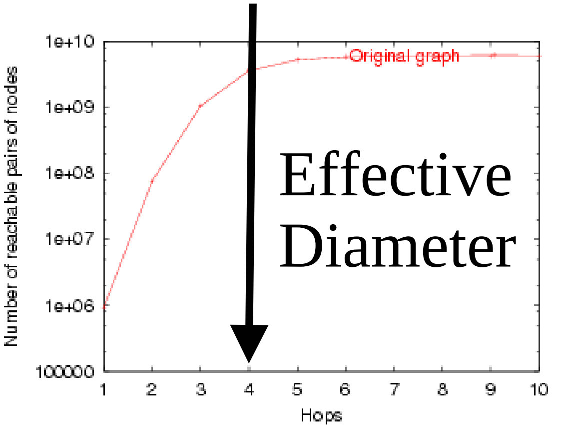
- Given a large graph dataset, what do we focus on?
- Patterns ➔ Aspects of graphs that show up frequently, in datasets from diverse domains.
  - Degree distributions



Count vs Outdegree

Graph "Patterns"

- Given a large graph dataset, what do we focus on?
- Patterns ➔ Aspects of graphs that show up frequently, in datasets from diverse domains.
  - Degree distributions
  - Hop-plots
  - "Scree" plots
  - and others…



Hop-plot

Graph "Patterns"

- Why do we like them?
  - They capture interesting properties of graphs.
  - They provide "condensed information" about the graph.
  - They are needed to build/test realistic graph generators (→ useful for simulation studies).
  - They help detect abnormalities and outliers.

Our Work

The NetMine toolkit

➔ contains all the patterns mentioned before, and adds:

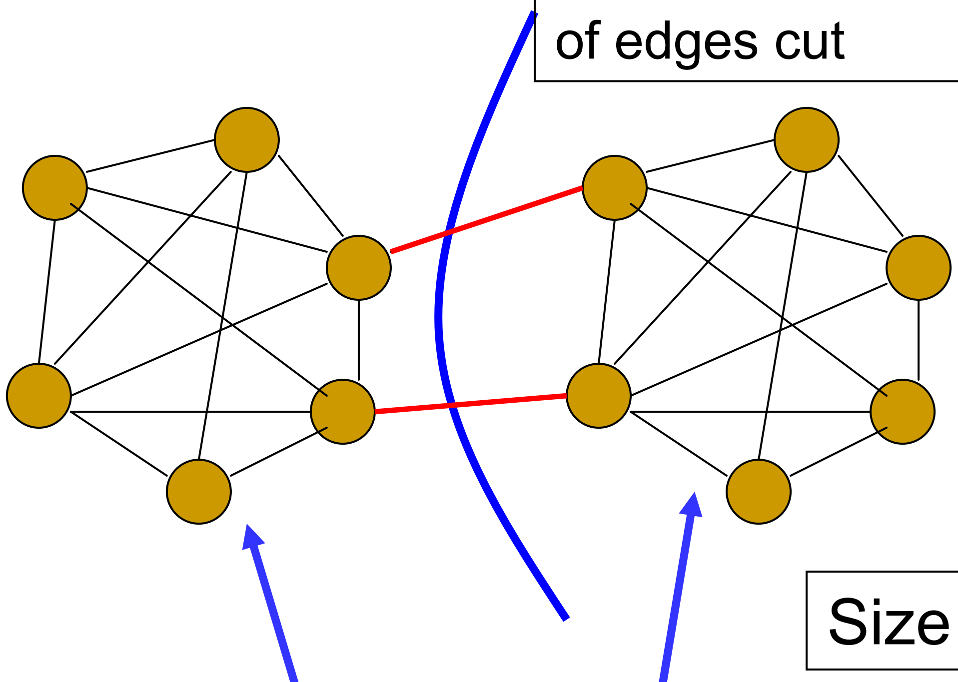
- The “min-cut” plot
  - a novel pattern which carries interesting information about the graph.
- A-plots
  - a tool to quickly find suspicious subgraphs/nodes.

Outline

- Problem definition
- “Min-cut” plots (+experiments)
- A-plots (+experiments)
- Conclusions

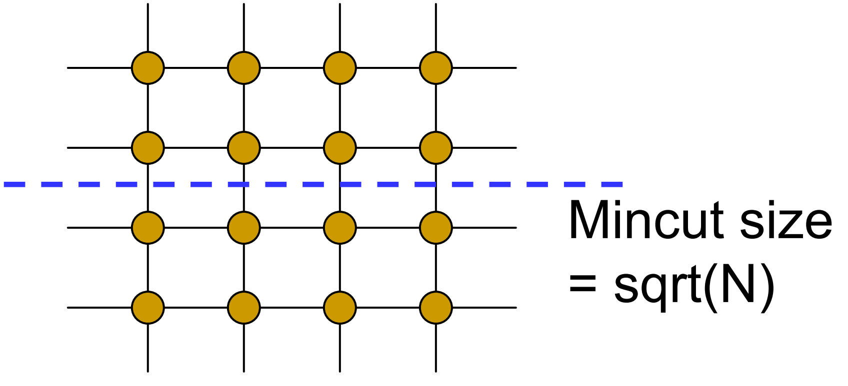
"Min-cut" plot

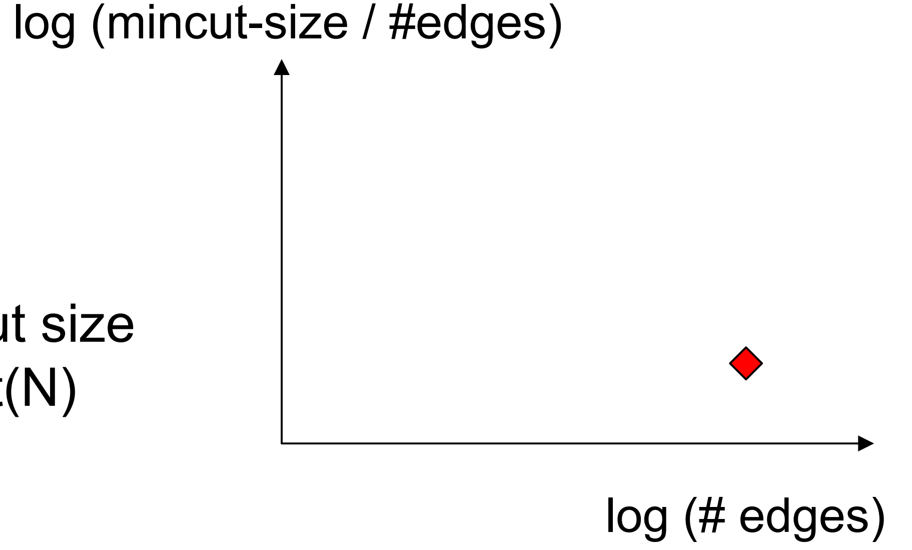
- What is a min-cut?



“Min-cut” plot

- Do min-cuts recursively.



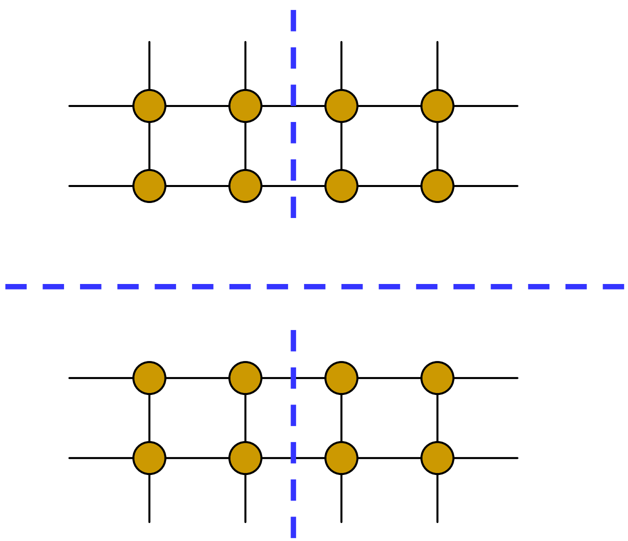


N nodes

“Min-cut” plot

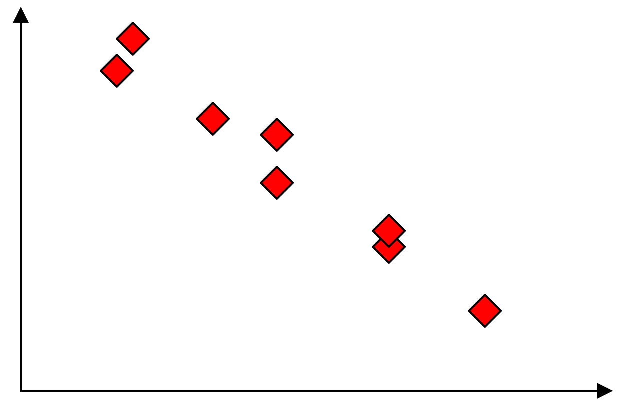
- Do min-cuts recursively.

New min-cut



N nodes

log (mincut-size / #edges)

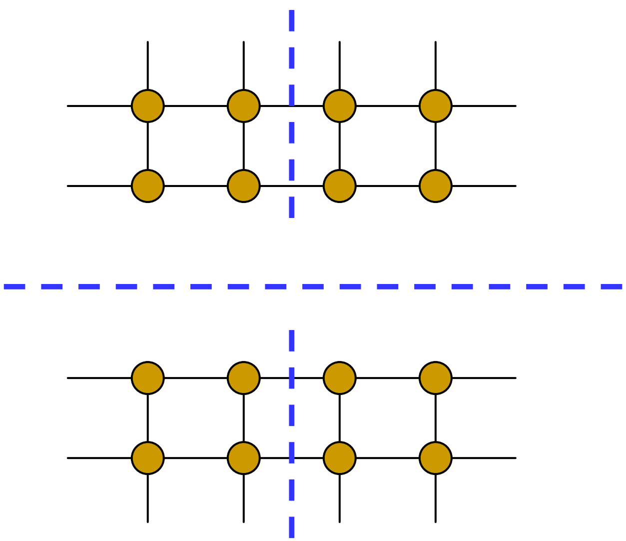


log (# edges)

"Min-cut" plot

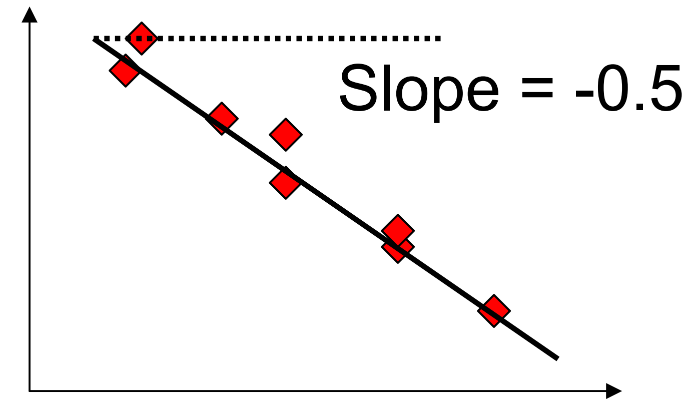
- Do min-cuts recursively.

New min-cut



N nodes

log (mincut-size / #edges)



log (# edges)

For a d-dimensional grid, the slope is -1/d

"Min-cut" plot

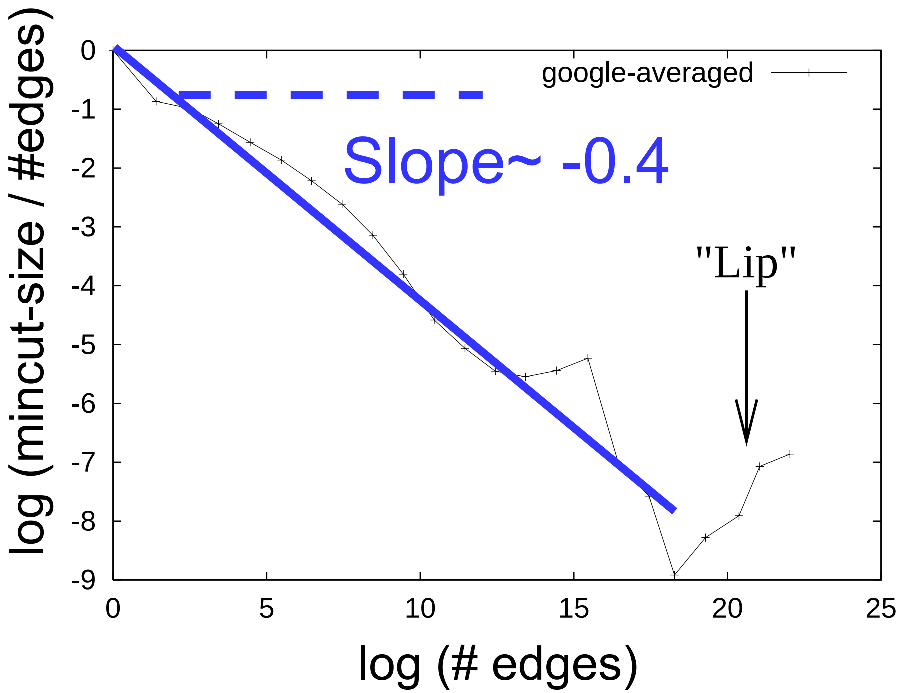
- Min-cut sizes have important effects on graph properties, such as
  - efficiency of divide-and-conquer algorithms
  - compact graph representation
  - difference of the graph from well-known graph types
    - for example, slope = 0 for a random graph

Experiments

- Datasets:
  - Google Web Graph: 916,428 nodes and 5,105,039 edges
  - Lucent Router Graph: Undirected graph of network routers from www.isi.edu/scan/mercator/maps.html; 112,969 nodes and 181,639 edges
  - User → Website Clickstream Graph: 222,704 nodes and 952,580 edges

Experiments

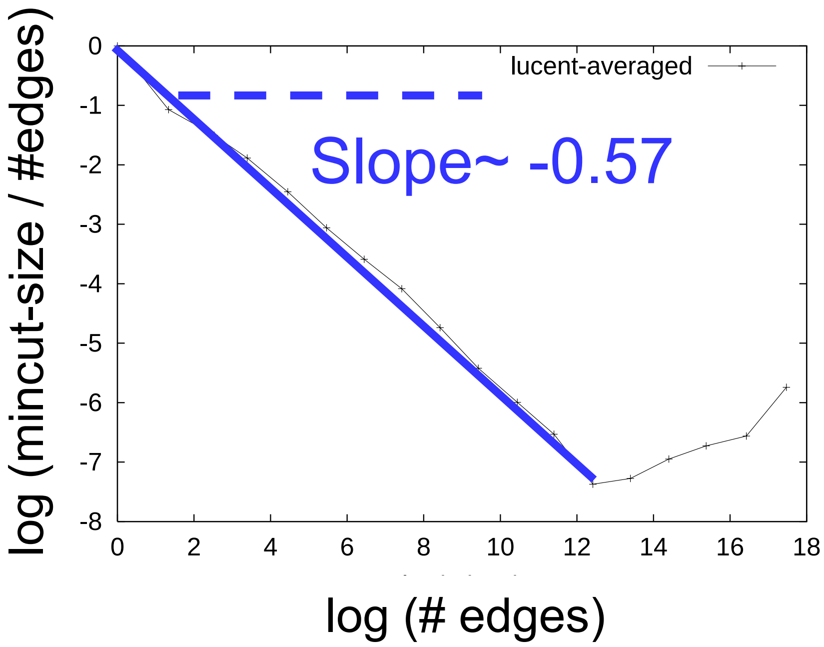
- Used the METIS algorithm [Karypis+, 1995]



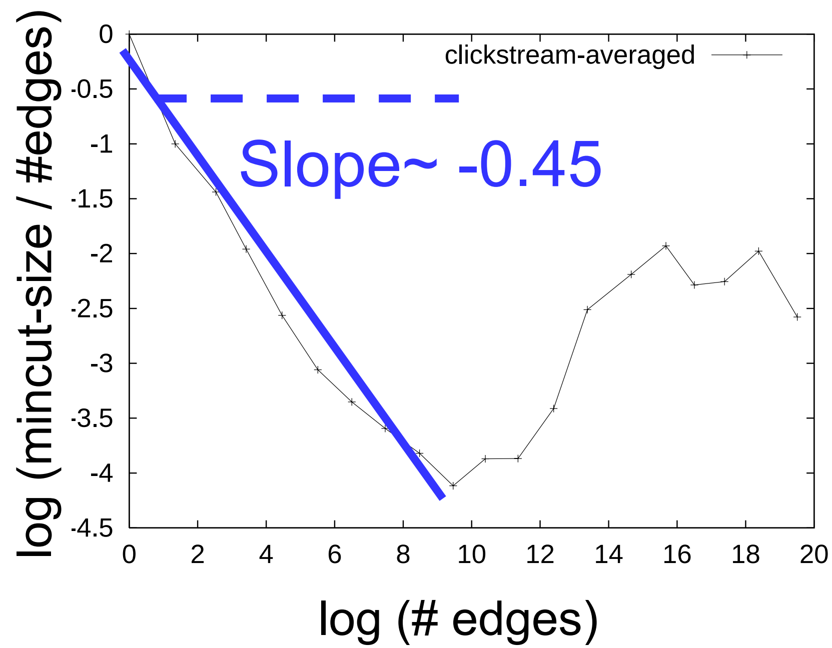
- Google Web graph
- Values along the y-axis are averaged
- We observe a “lip” for large edges
- Slope of -0.4, corresponds to a 2.5-dimensional grid!

Experiments

- Same results for other graphs too…



Lucent Router graph



Clickstream graph

Observations

- Linear slope for some range of values
- “Lip” for high #edges
- Far from random graphs (because slope ≠ 0)

Outline

- Problem definition
- "Min-cut" plots (+experiments)
- A-plots (+experiments)
- Conclusions

A-plots

- How can we find abnormal nodes or subgraphs?
  - Visualization
    - but most graph visualization techniques do not scale to large graphs!

A-plots

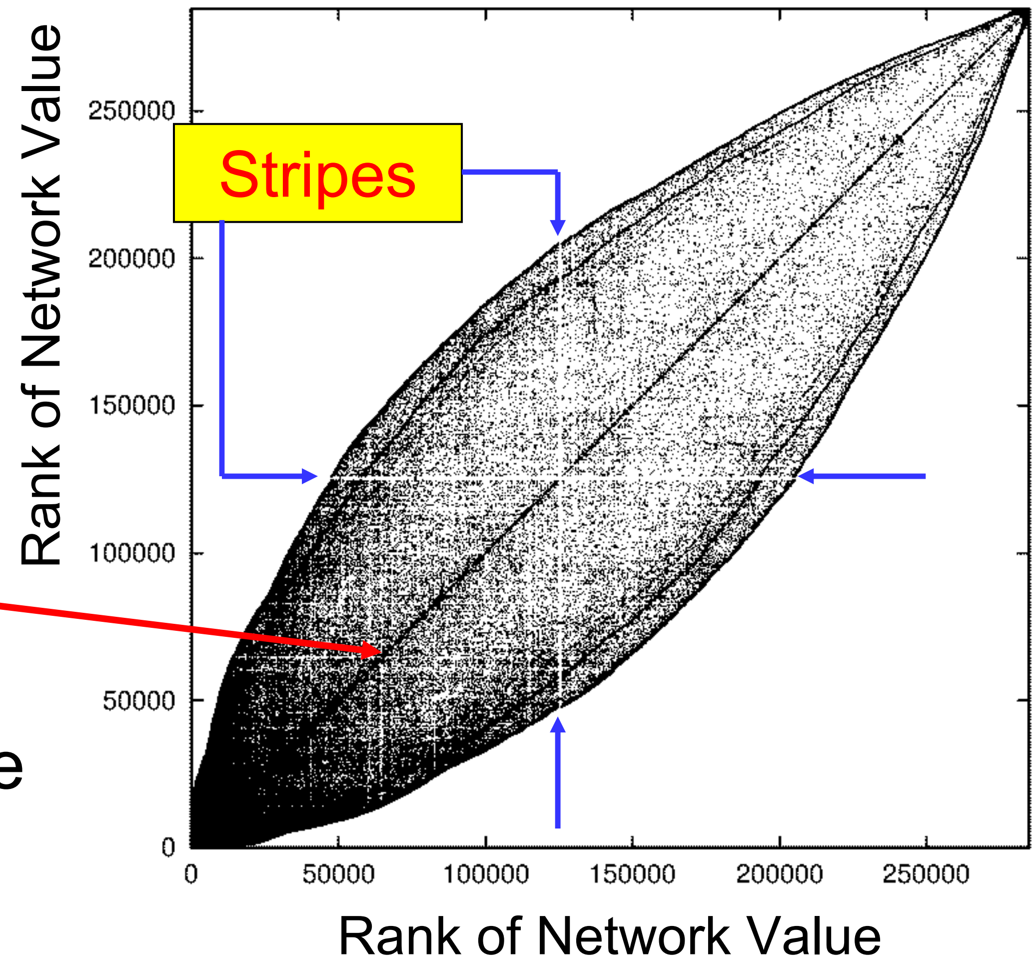
- However, humans are pretty good at "eyeballing" data ☺
- Our idea:
  - Sort the adjacency matrix in novel ways
  - and plot the matrix
  - so that patterns become visible to the user
- We will demonstrate this on the Lucent Router graph (112,969 nodes and 181,639 edges)

A-plots

- Three types of such plots for undirected graphs…
  - RV-RV (RankValue vs RankValue) ➔ Sort nodes based on their "network value" (~first eigenvector)
  - RD-RD (RankDegree vs RankDegree) ➔ Sort nodes based on their degree
  - D-RV (Degree vs RankValue) ➔ Sort nodes according to "network value", and show their corresponding degree

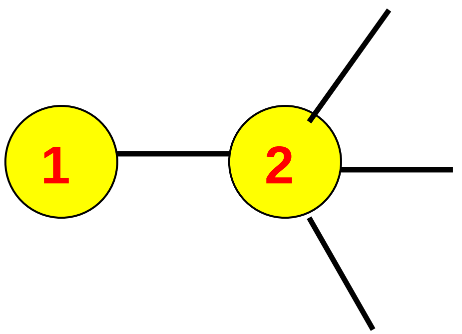
RV-RV plot (RankValue vs RankValue)

- We can see a "teardrop" shape
- and also some blank "stripes"
- and a strong diagonal
  - (even though there are no self-loops)!

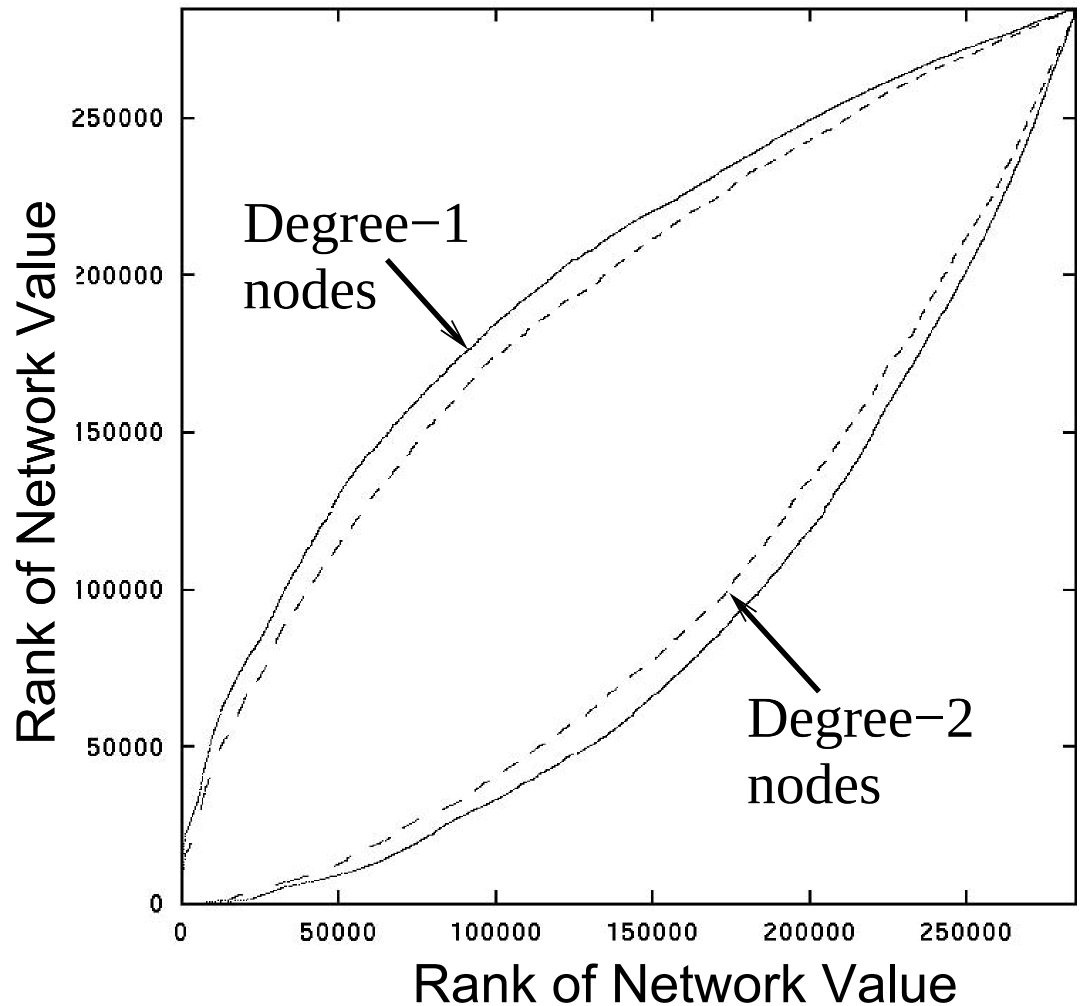


RV-RV plot (RankValue vs RankValue)

- The "teardrop" structure can be explained by degree-1 and degree-2 nodes

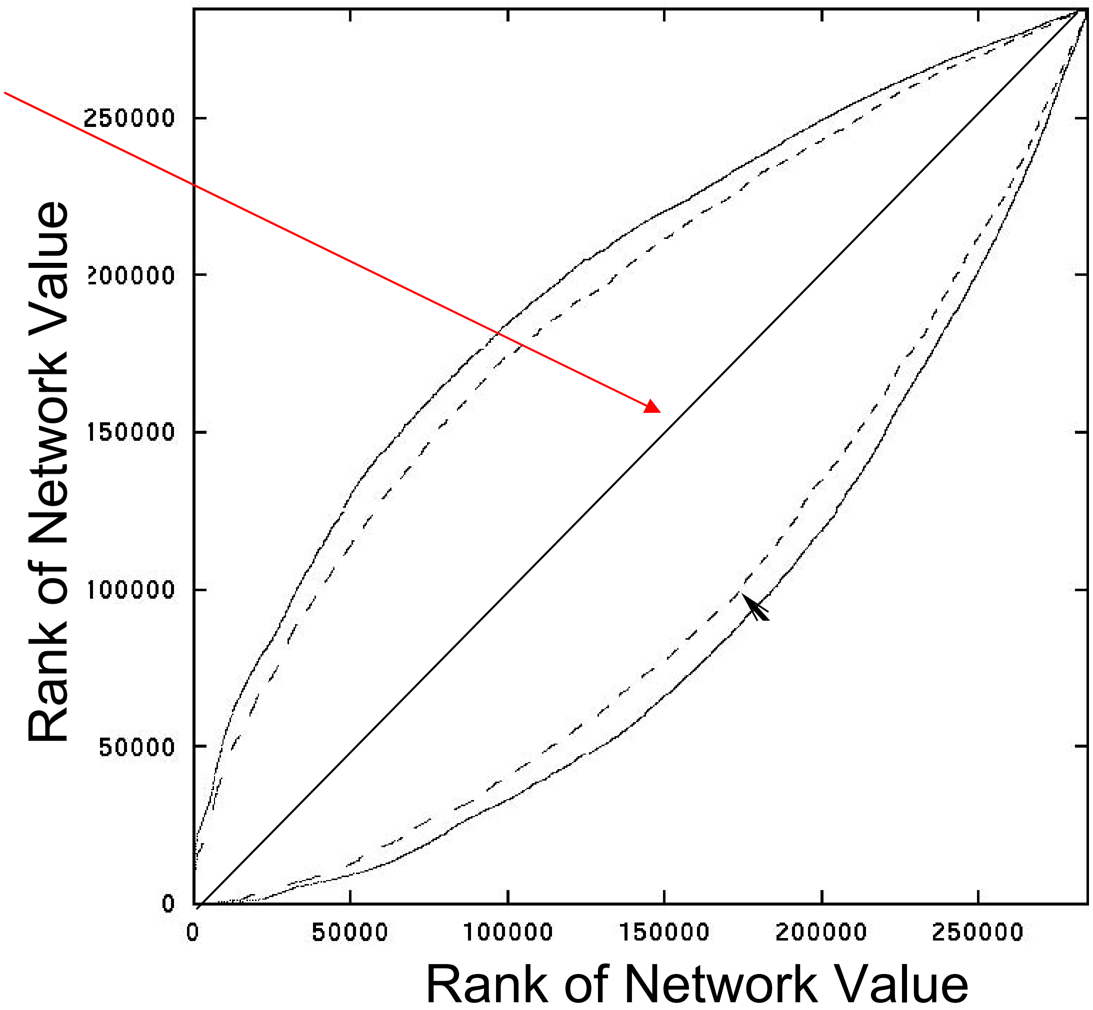


$NV_1 = 1/\lambda * NV_2$

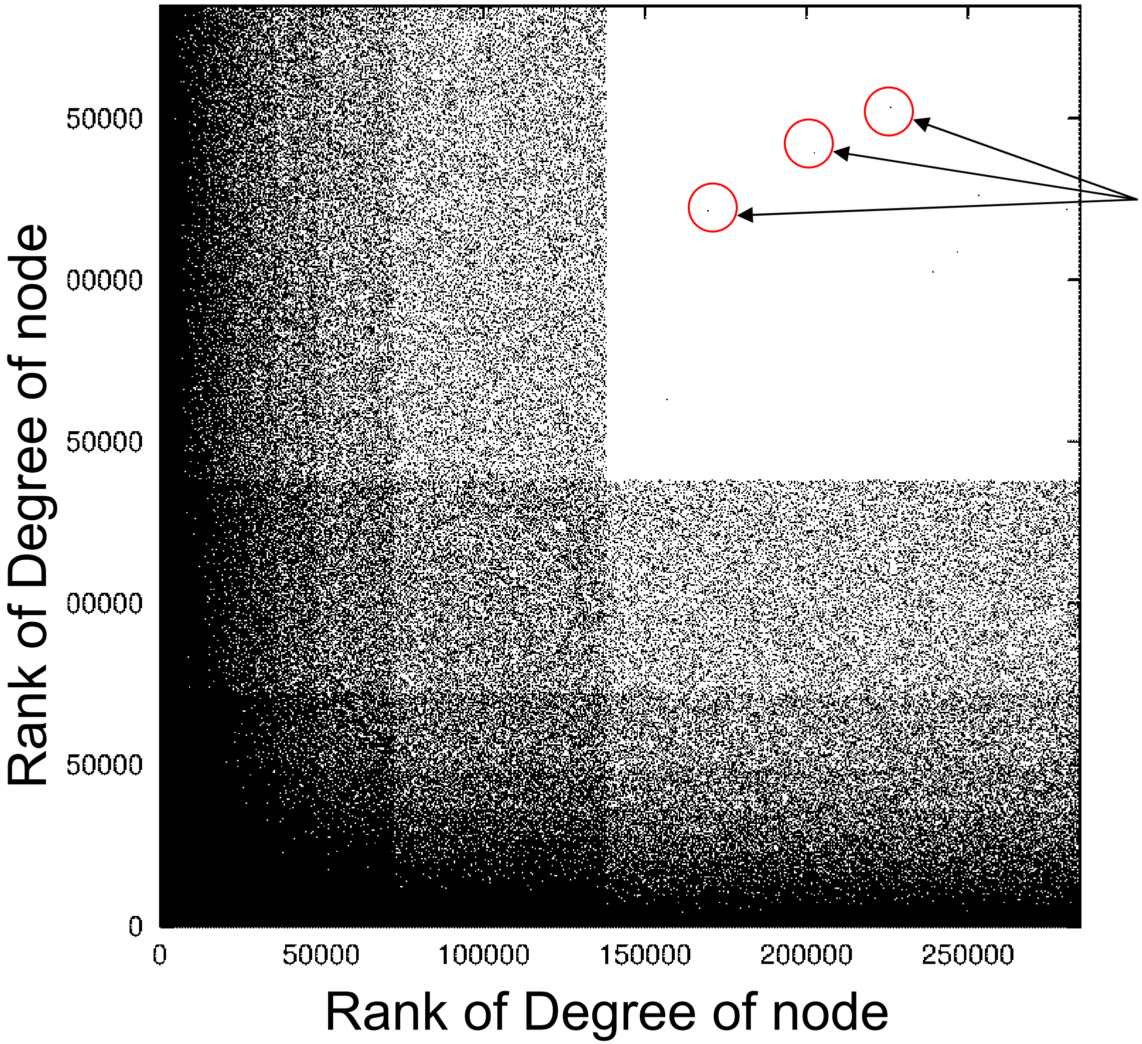


RV-RV plot (RankValue vs RankValue)

- Strong diagonal ➔ nodes are more likely to connect to "similar" nodes

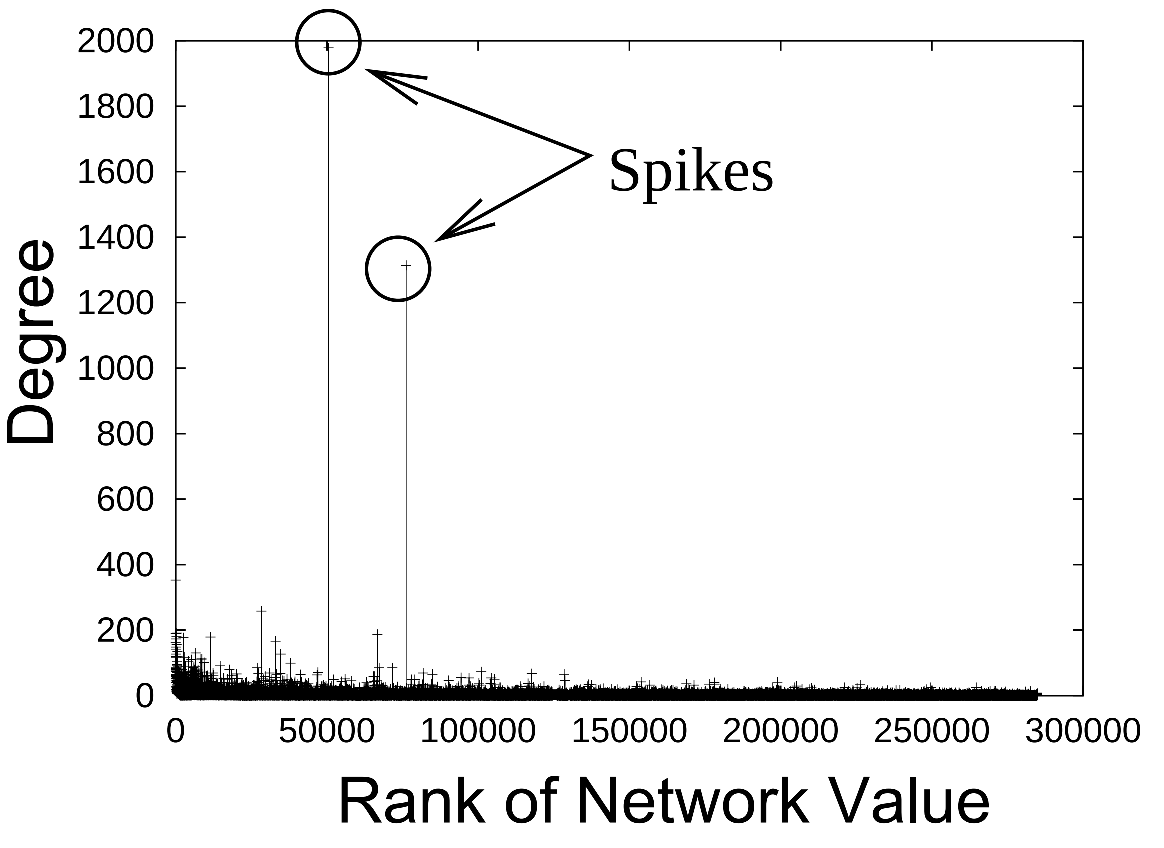


RD-RD (RankDegree vs RankDegree)



- Isolated dots ➔ due to 2-node isolated components

D-RV (Degree vs RankValue)

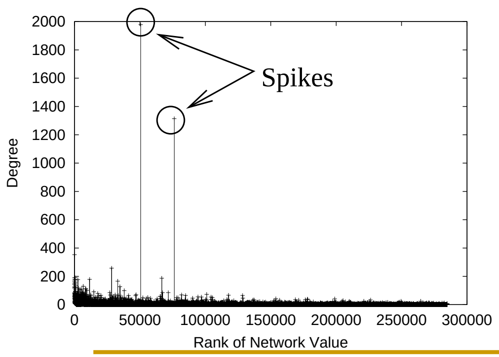


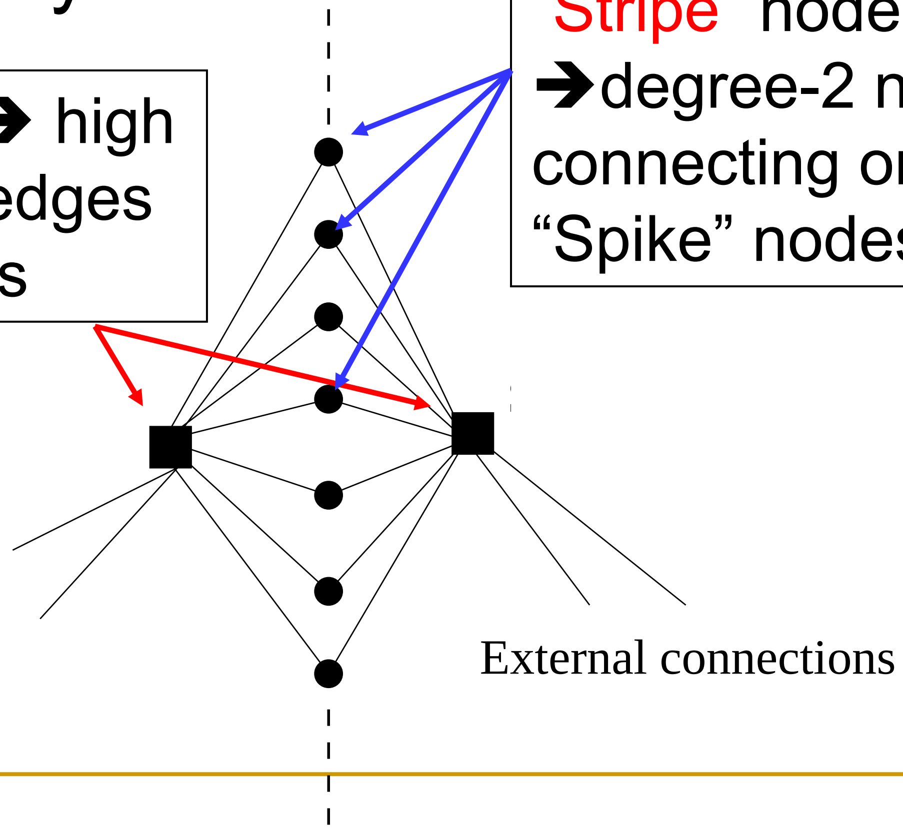
Explanation of “Spikes” and “Stripes”

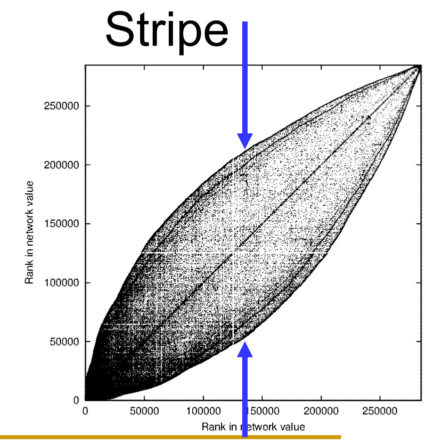
- RV-RV plot had stripes; D-RV plot shows spikes. Why?

“Spike” nodes ➔ high degree, but all edges to “Stripe” nodes

“Stripe” nodes ➔degree-2 nodes connecting only to the “Spike” nodes







A-plots

- They helped us detect a buried abnormal subgraph
- in a large real-world dataset
- which can then be taken to the domain experts.

Outline

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Conclusions

- We presented
  - "Min-cut" plot
    - A novel graph pattern
    - with relevance for many algorithms and applications
  - A-plots
    - which help us find interesting abnormalities
  - All the methods are scalable
  - Their usage was demonstrated on large real-world graph datasets

RV-RV plot (RankValue vs RankValue)

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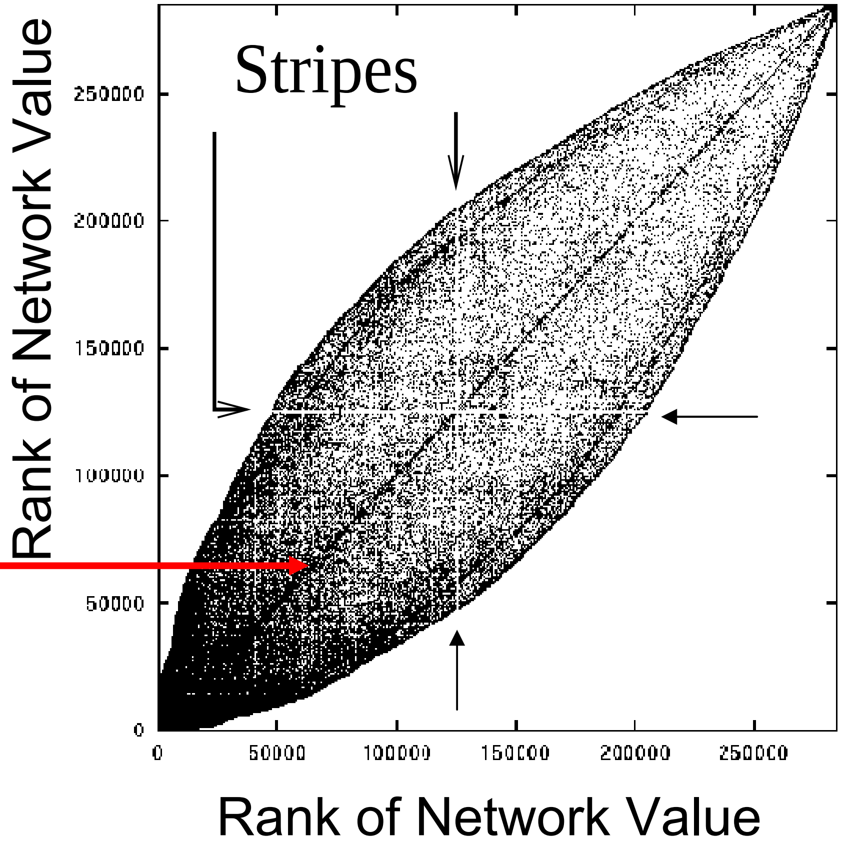
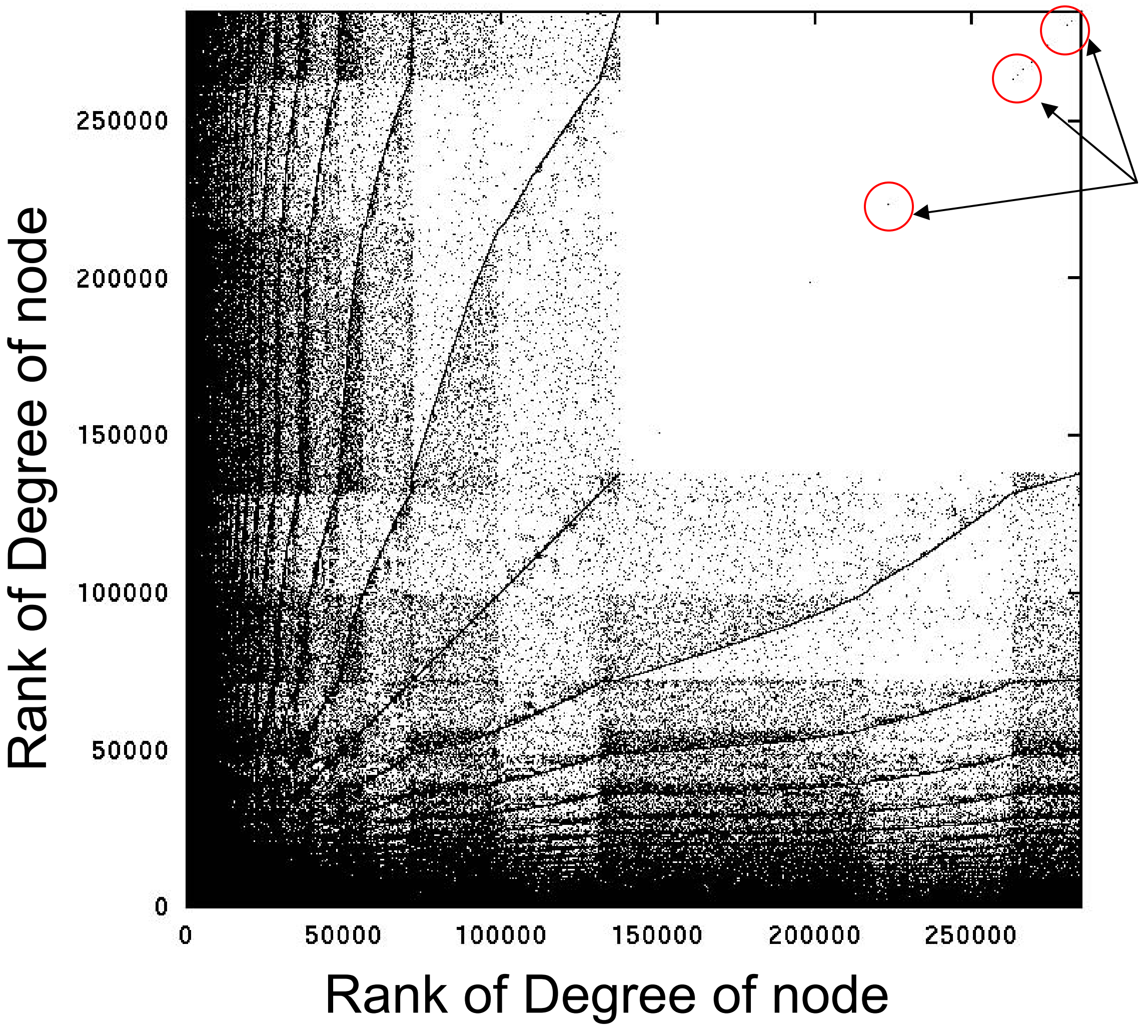


RD-RD (RankDegree vs RankDegree)



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