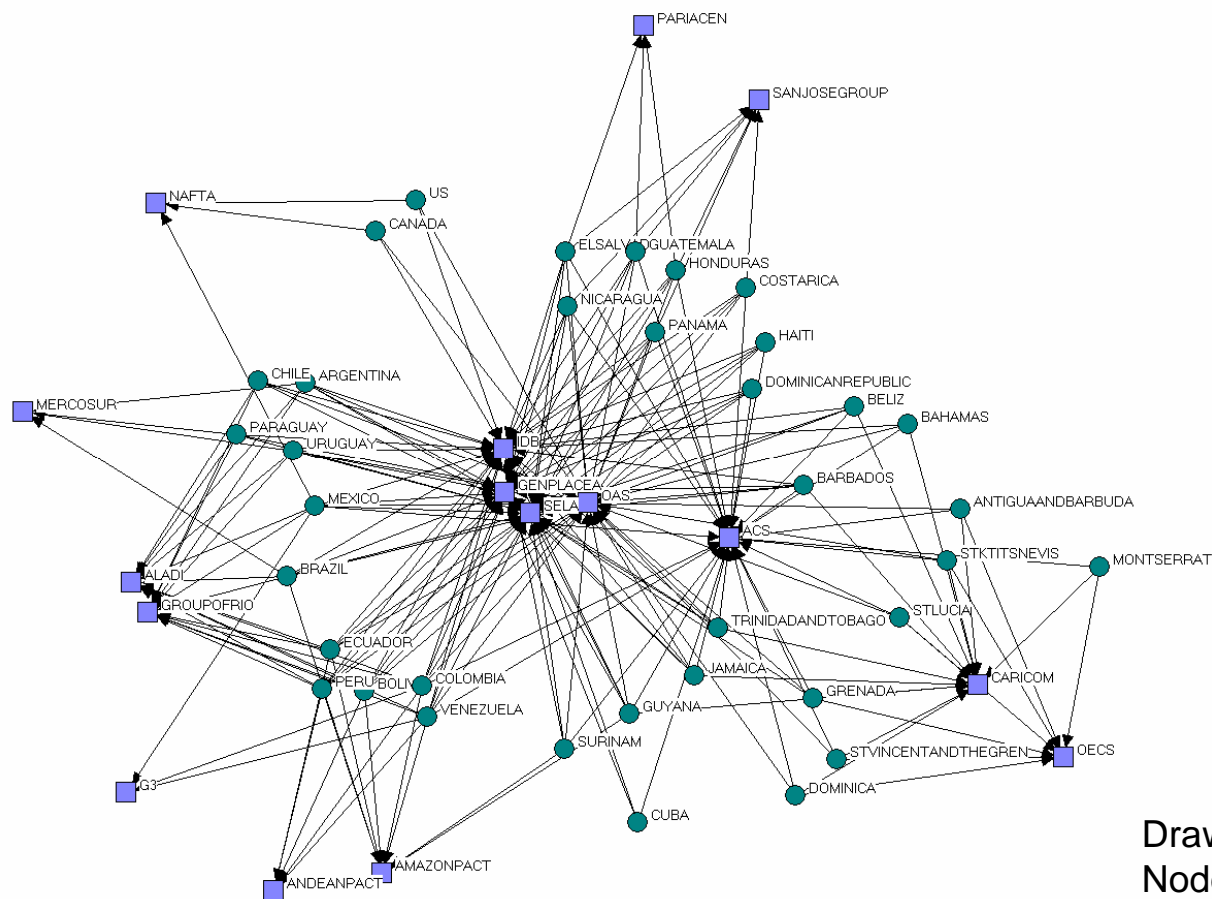
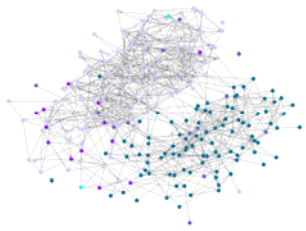


# Two mode network

Western hemisphere countries, memberships in international organizations



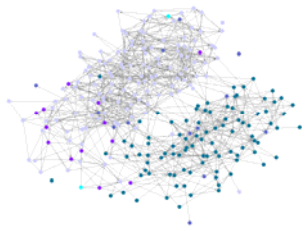
Drawn in Netdraw using  
Node repulsion  
Equal edge length



# Overview of some social network methods

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- Connectivity
- Centrality
- Cohesion
- Relational patterns and reductions
- Local network methods: dyads and triads
- Testing structural hypotheses



# Levels of network properties

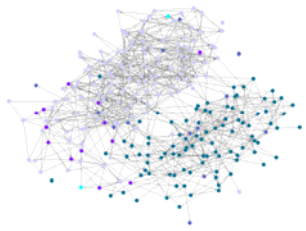
---

- Actor
- Dyad
- Triad
- ...
- Subgroup
- Network

Local/Micro



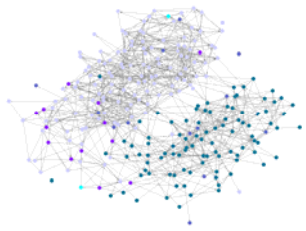
Global/Macro



# Connectivity

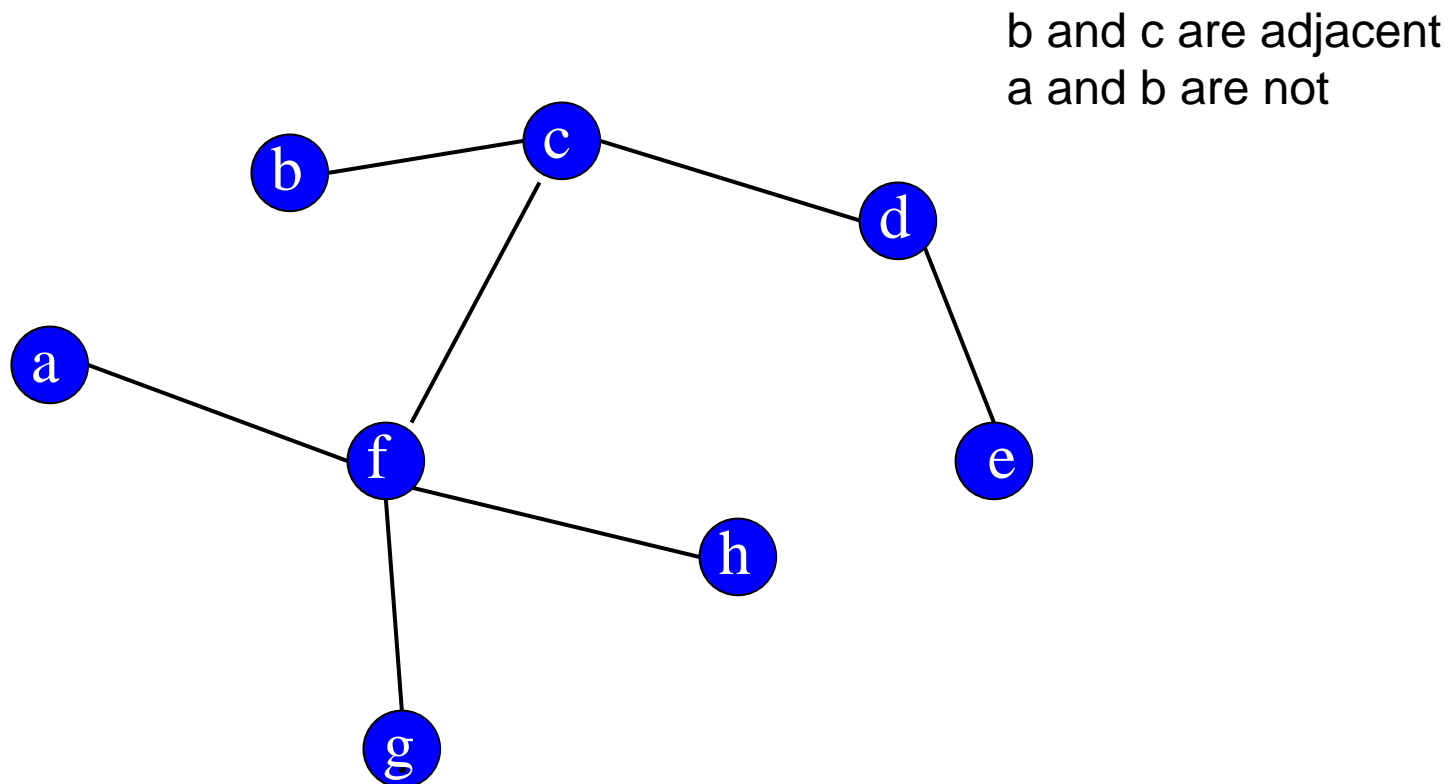
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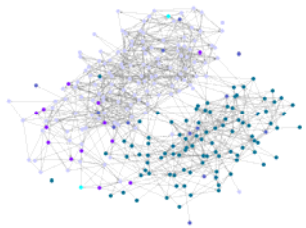
- Adjacency
- Degree
- Density
- Paths and reachability
- Cutpoints and bridges



# Adjacent

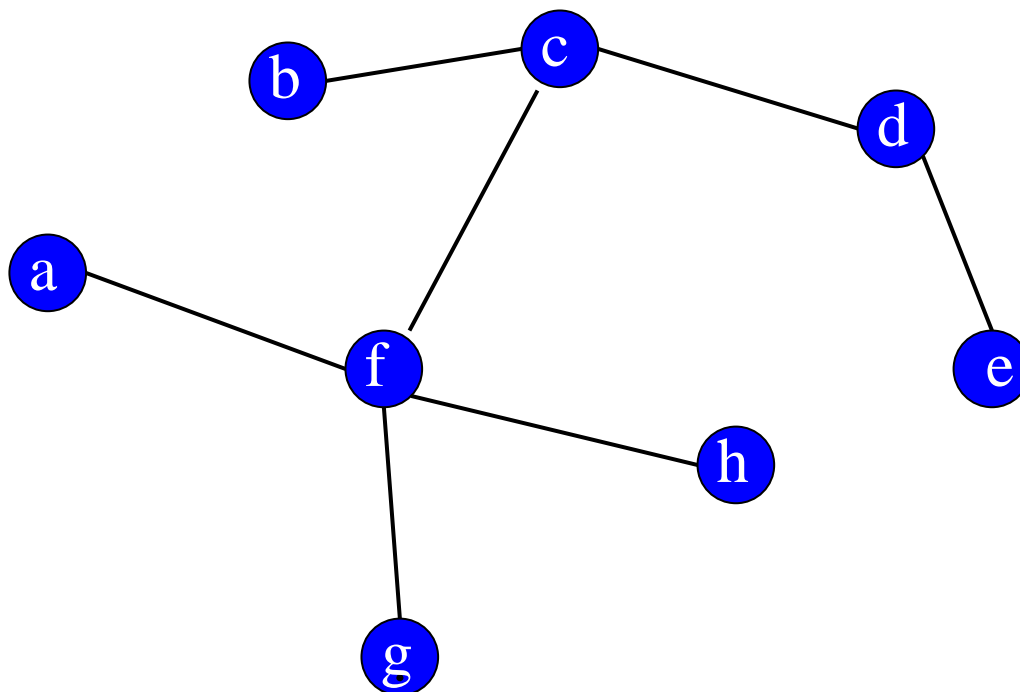
- Two nodes are adjacent if there is an edge between them



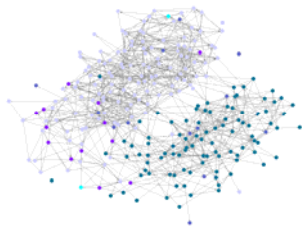


# Node degree

- The number of nodes adjacent to a given node

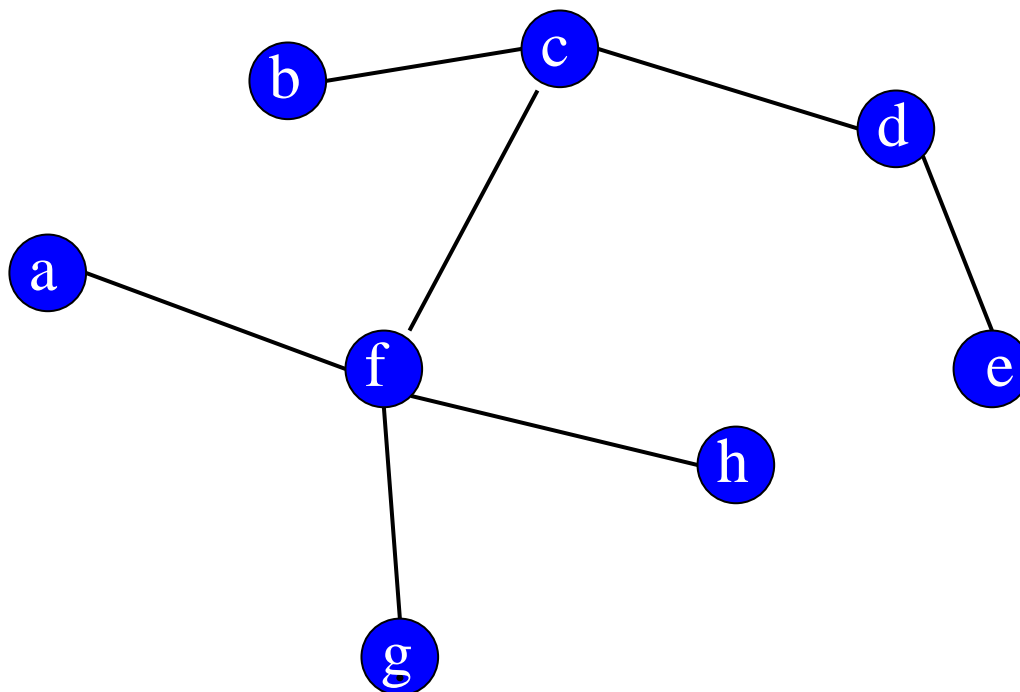


Node	Degree
a	1
b	1
c	3
d	2
e	1
f	4
g	1
h	1

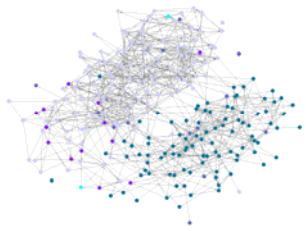


# Density

- The proportion of ties that are present



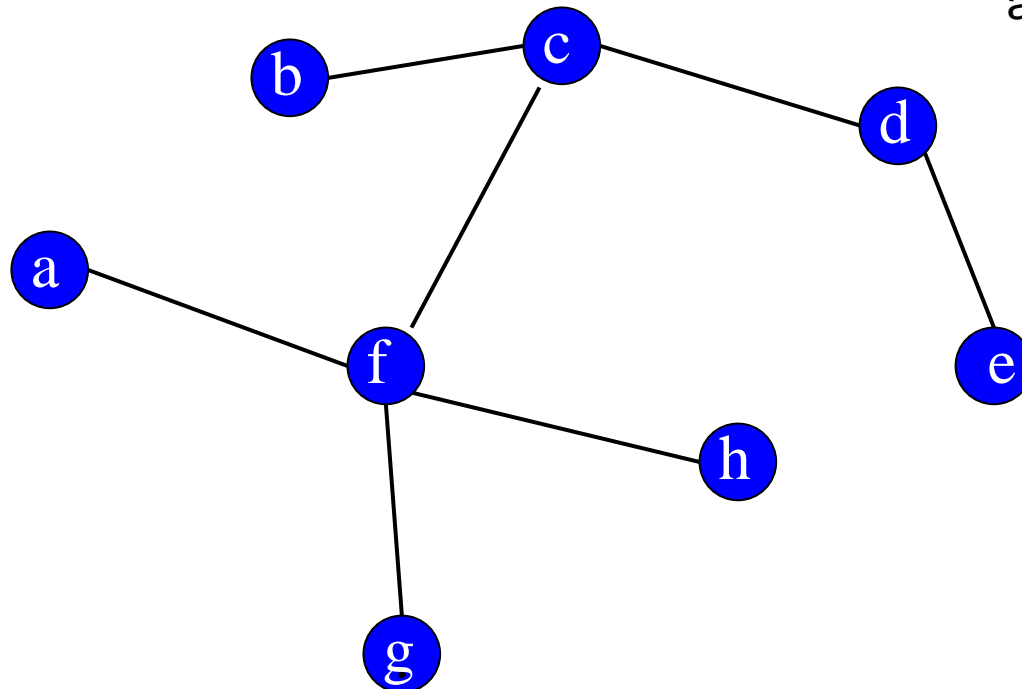
$$\frac{7}{28} = .25$$



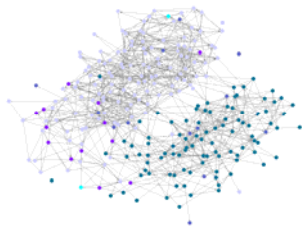
# Reachability

- Two nodes are reachable if there is a path between them

In this graph  
all pairs of nodes  
are reachable

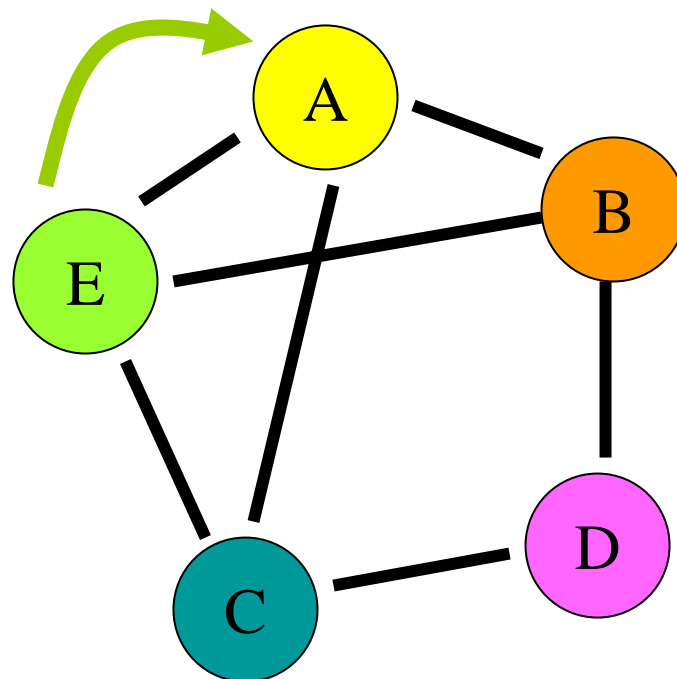




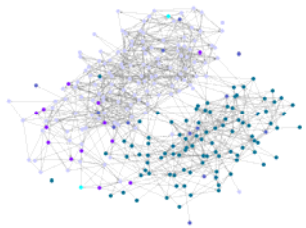


# Walk

E - A

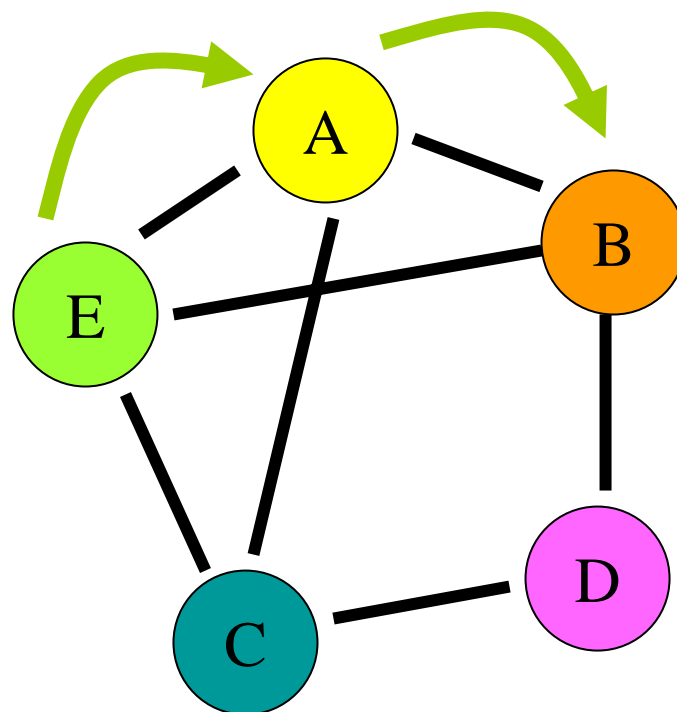


May repeat nodes and lines

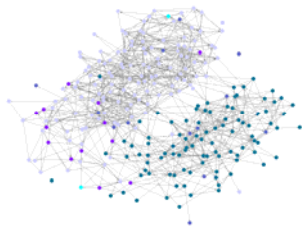


# Walk

E – A – B

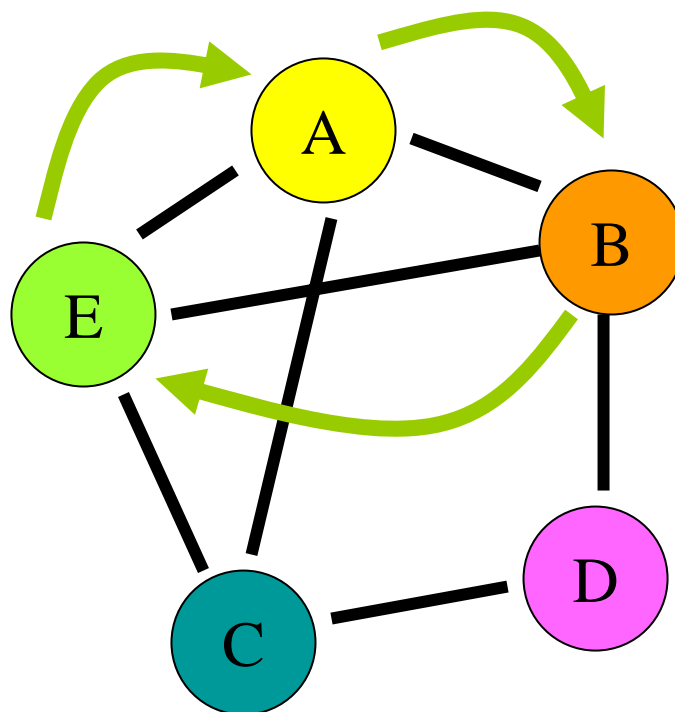


May repeat nodes and lines

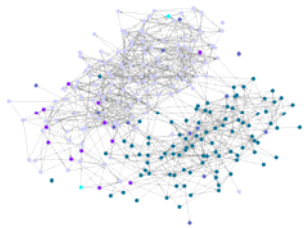


# Walk

E - A - B - E

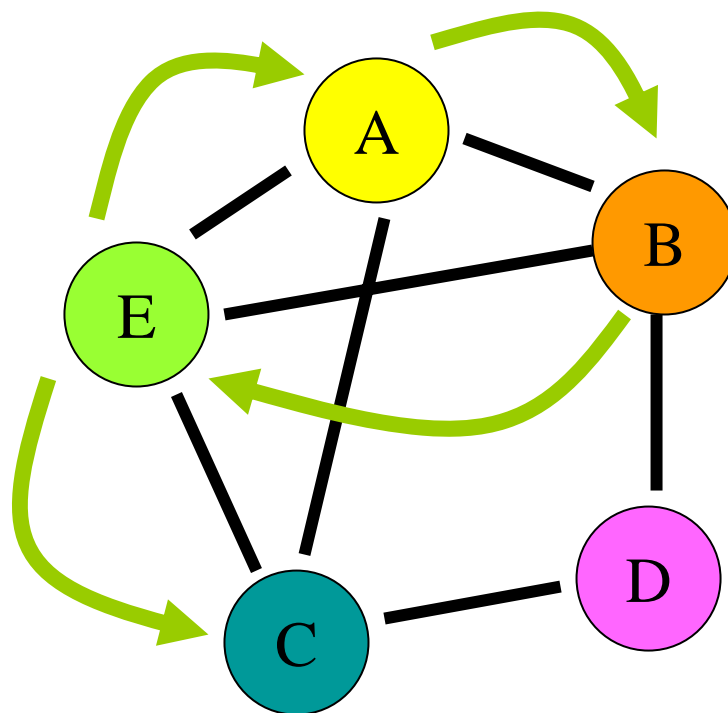


May repeat nodes and lines

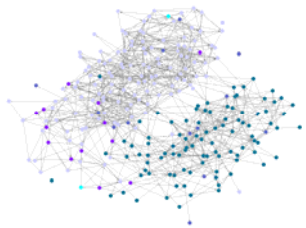


# Walk

E - A - B - E - C

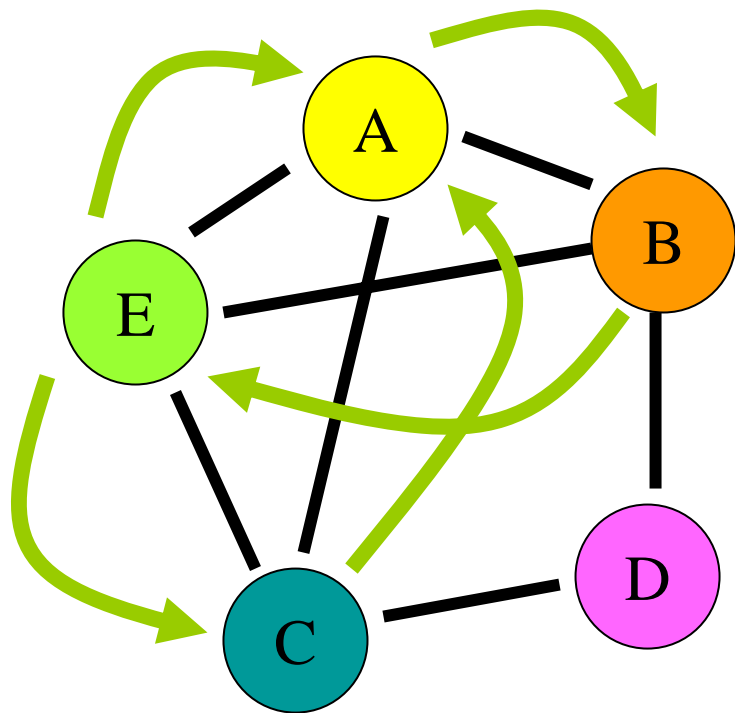


May repeat nodes and lines

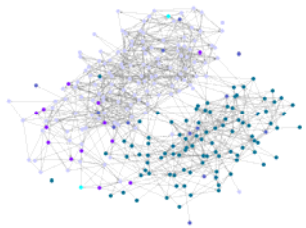


# Walk

E - A - B - E - C - A

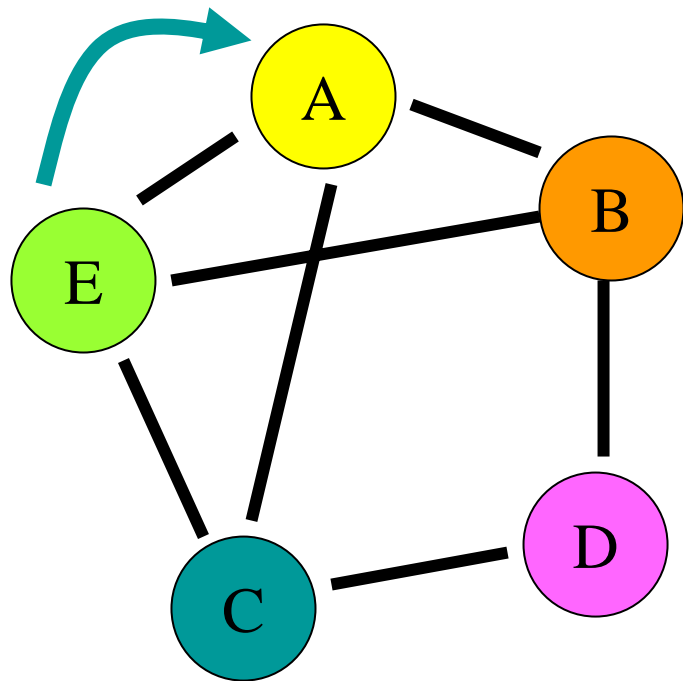


May repeat nodes and lines

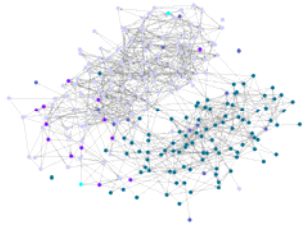


# Path

E - A

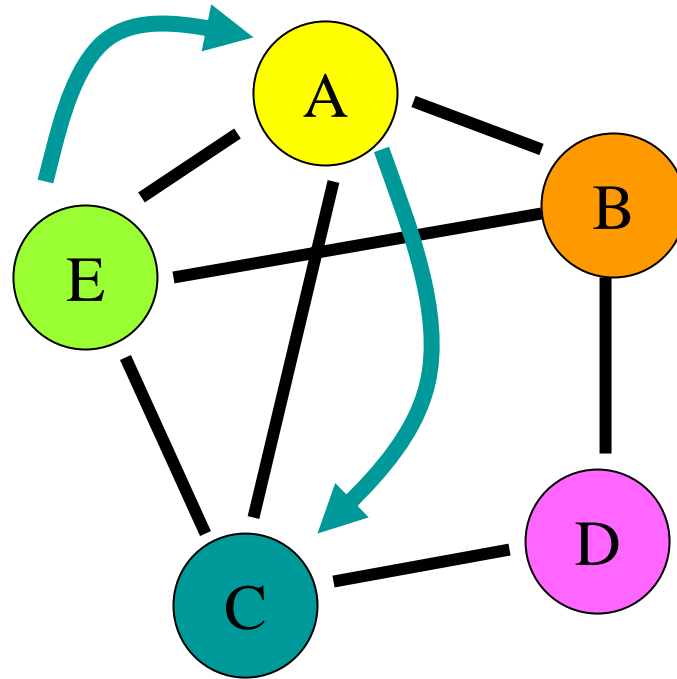


No nodes or lines are repeated

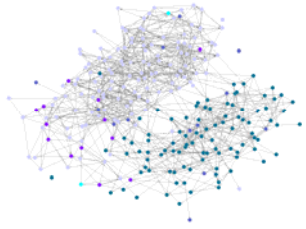


# Path

E - A - C

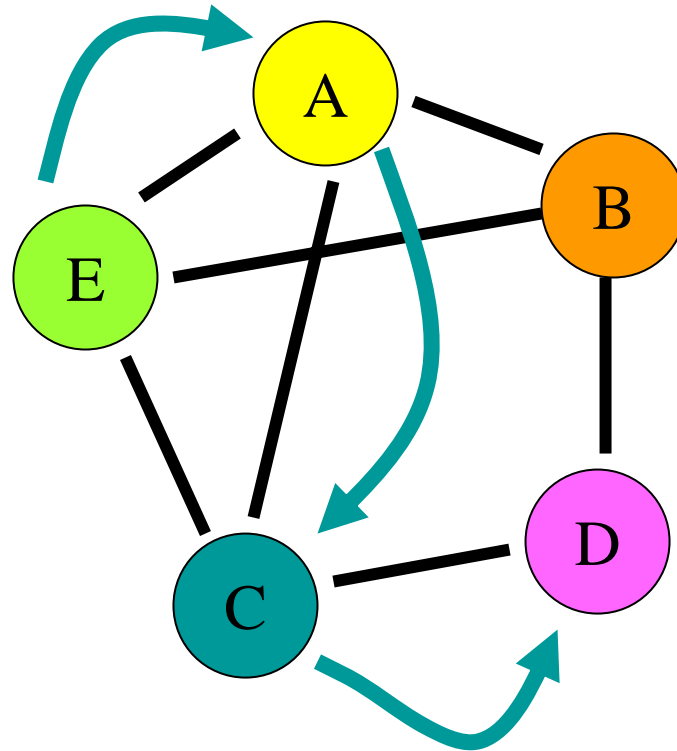


No nodes or lines are repeated



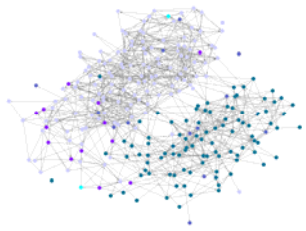
# Path

E - A - C - D - B



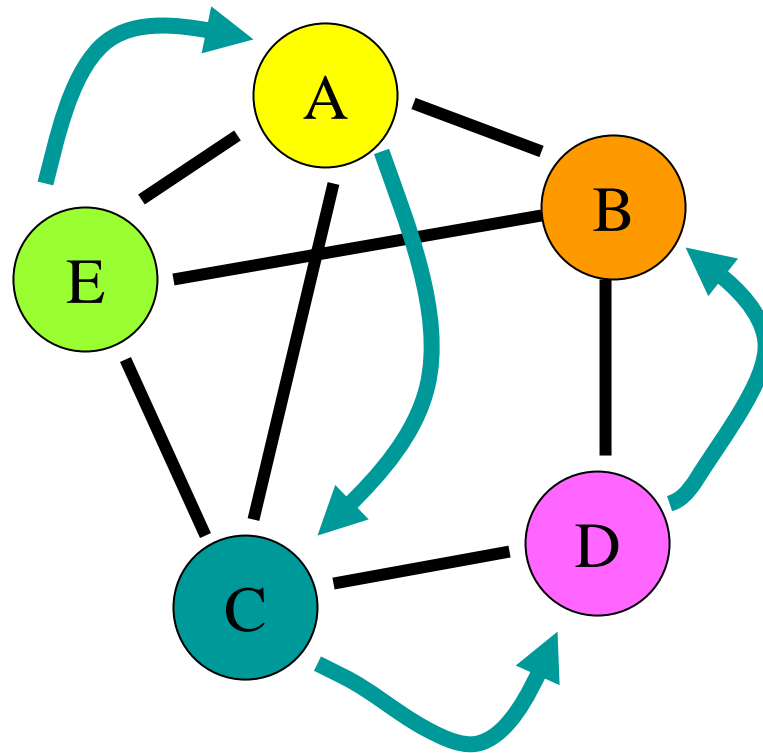
No nodes or lines are repeated



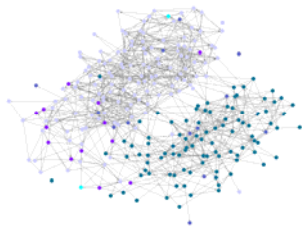


# Path

E - A - C - D - B

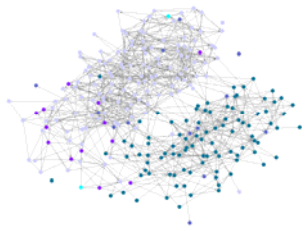


No nodes or lines are repeated



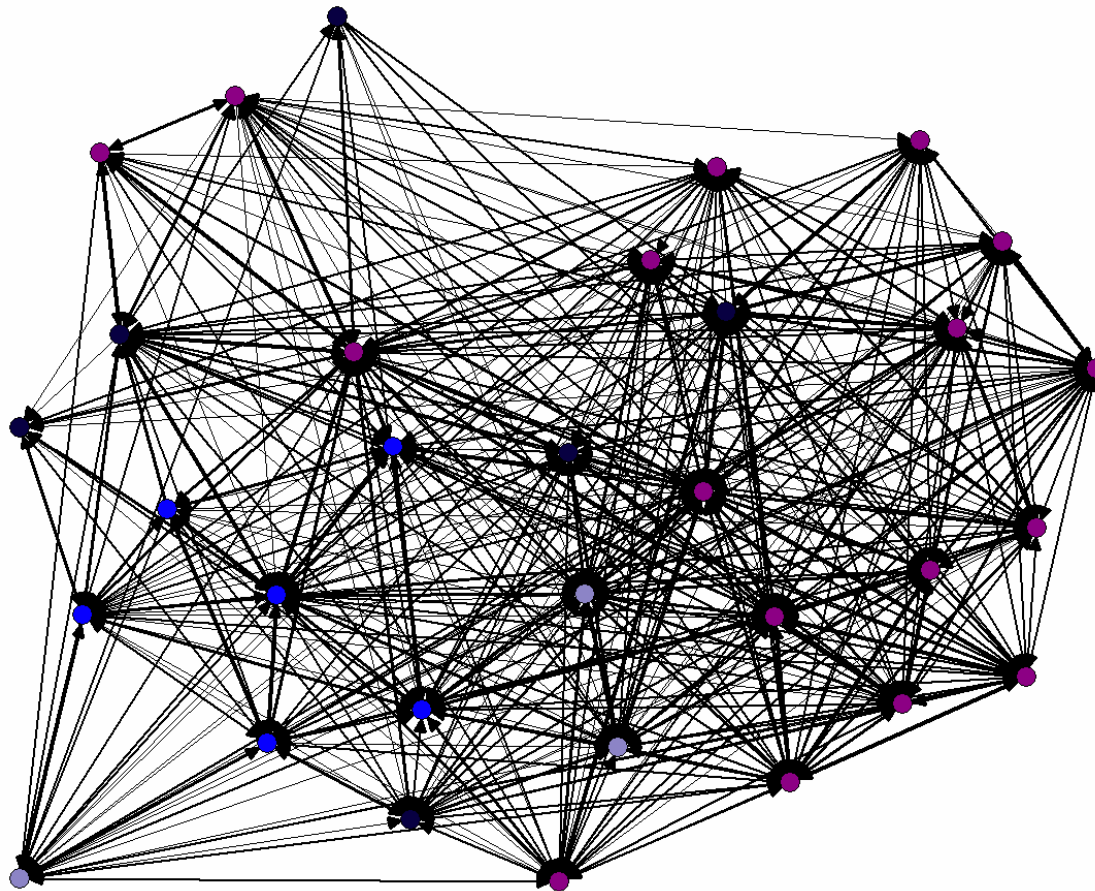
# Connectivity

- 
- A graph is connected if all pairs of nodes are reachable
  - Important for transmission on a network

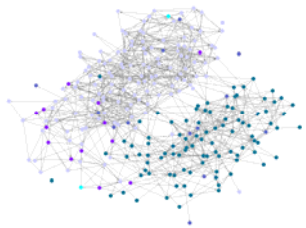


# Connected graph

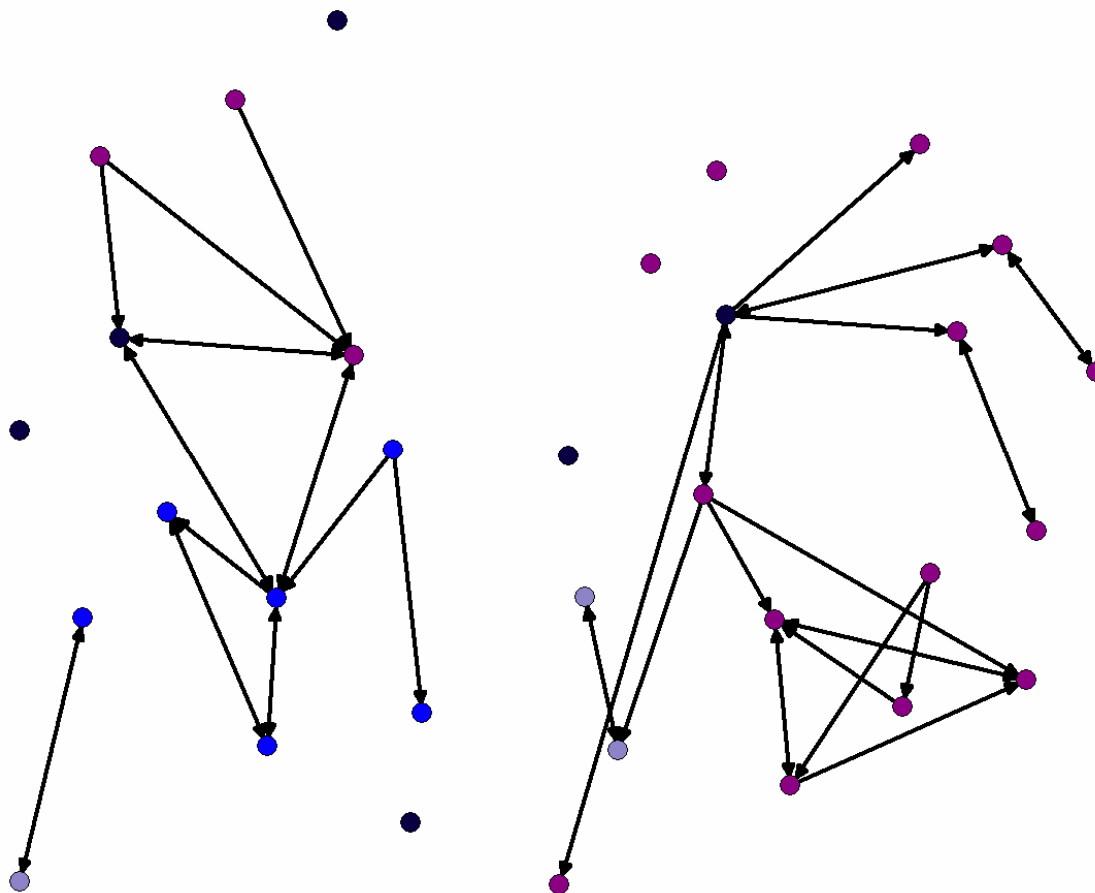
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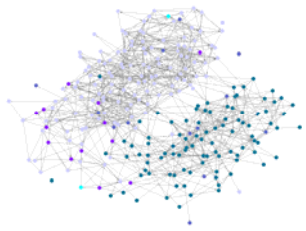
Acquaintanceship between social science researchers, Freeman



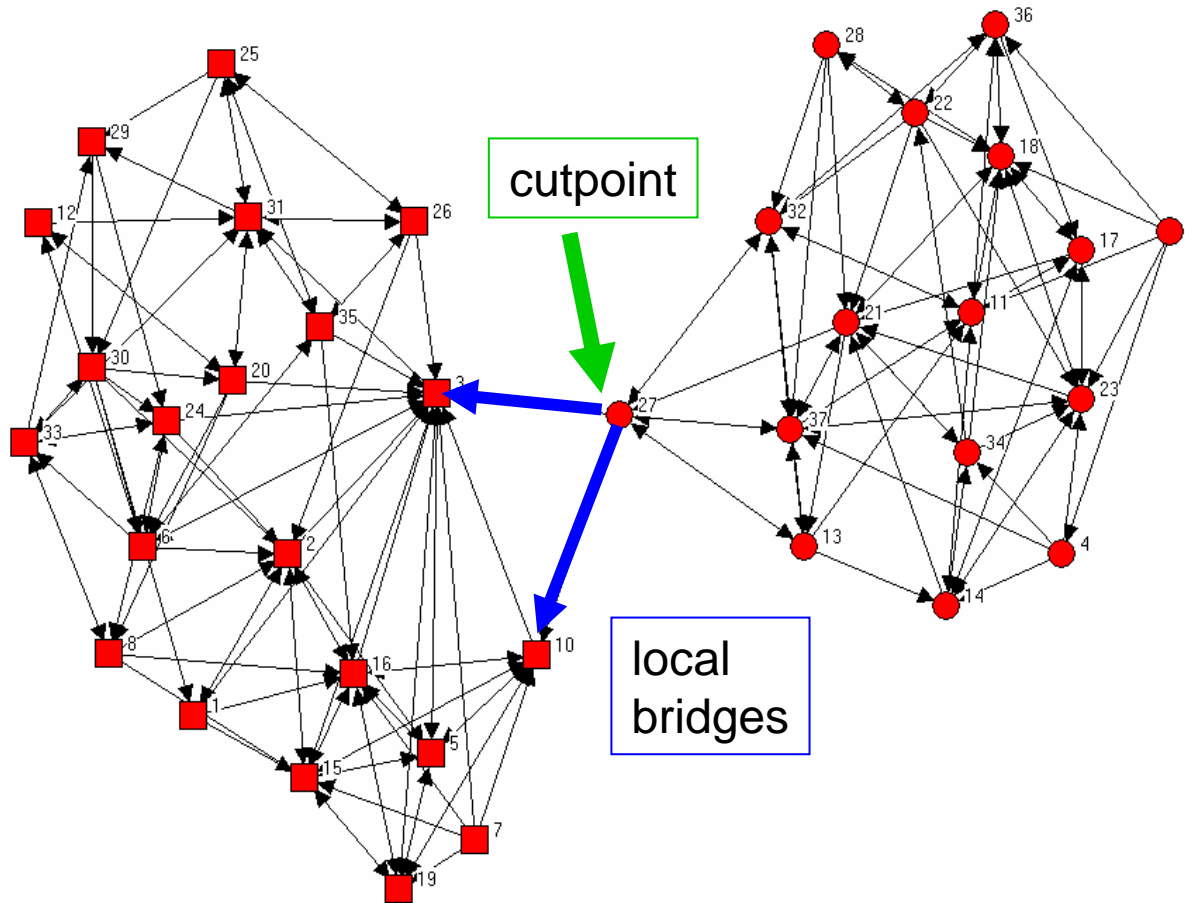
# Graph is not connected

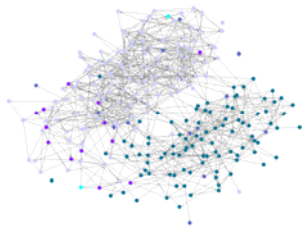


Strong friendships between social science researchers, Freeman



# Cutpoints and bridges

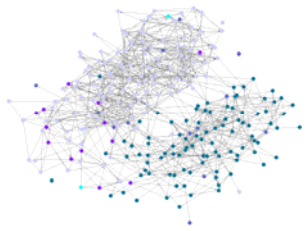




# Centrality

---

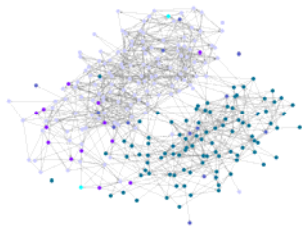
- Actor centrality
  - Identify important or prominent actors
- Network centralization
  - Characterize the structure of the network



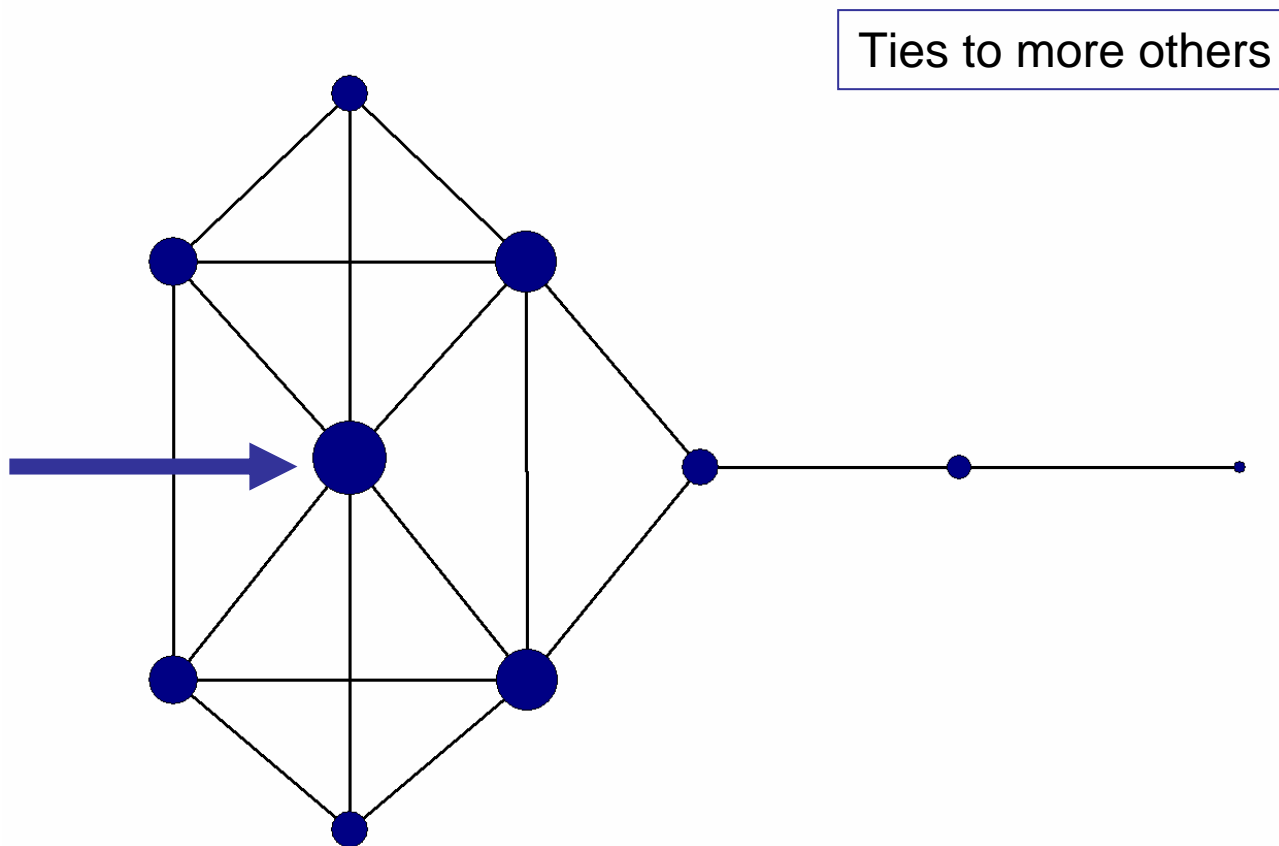
# Structural intuitions for actor centrality

---

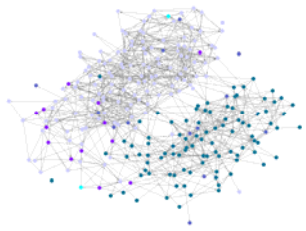
<u>Intuition</u>	<u>Measure</u>
• Activity, visibility	degree
• Brokerage, control	betweenness
• Efficiency	closeness
• Status, rank	eigenvector



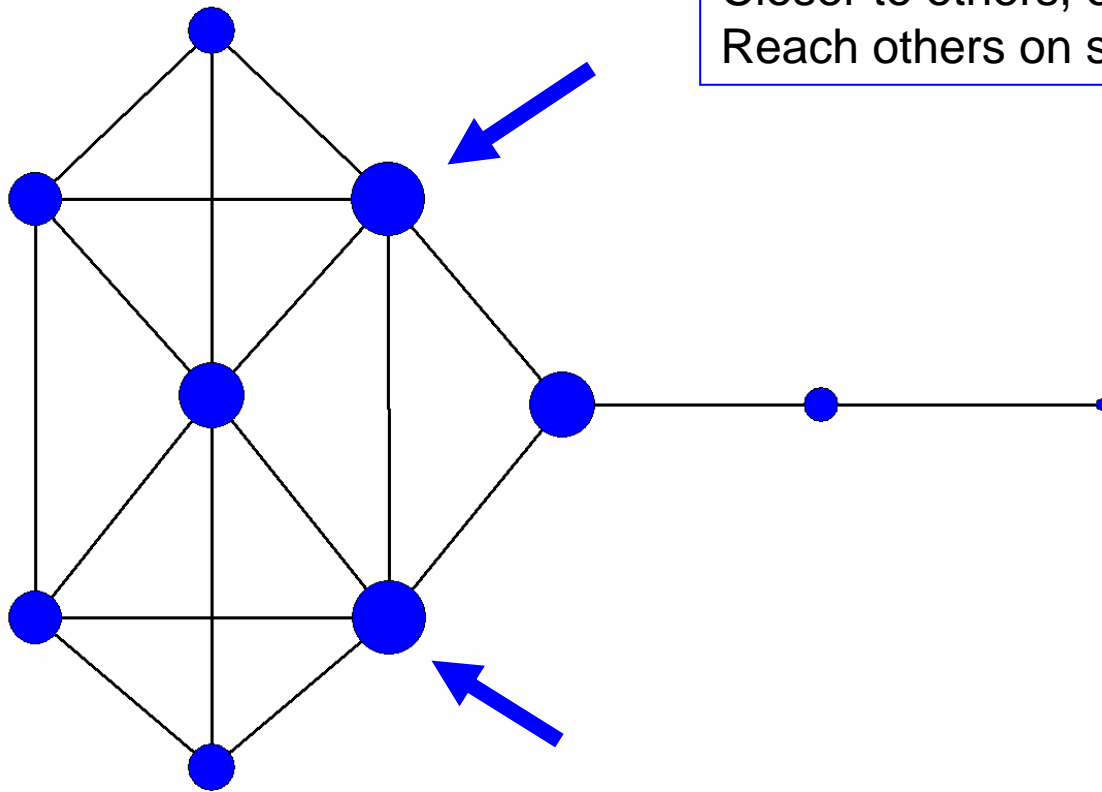
# Actor degree centrality

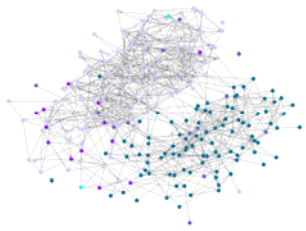




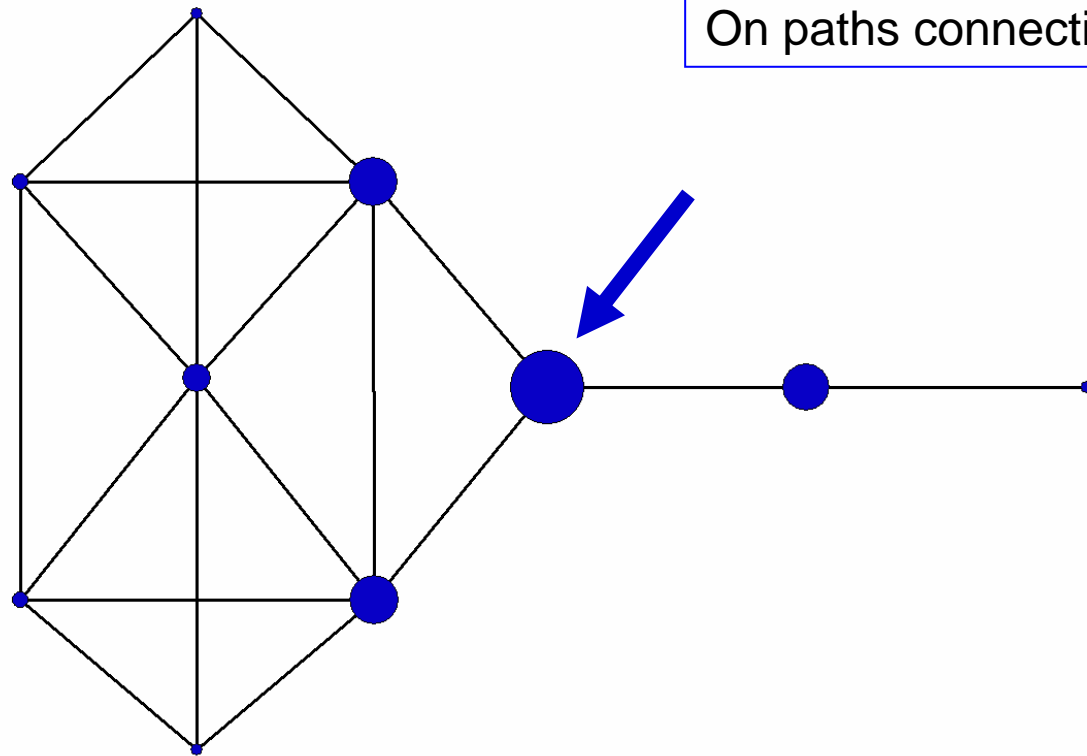


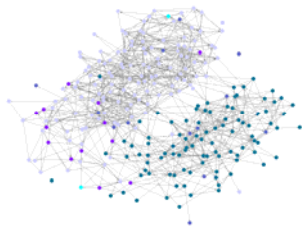
# Actor closeness centrality





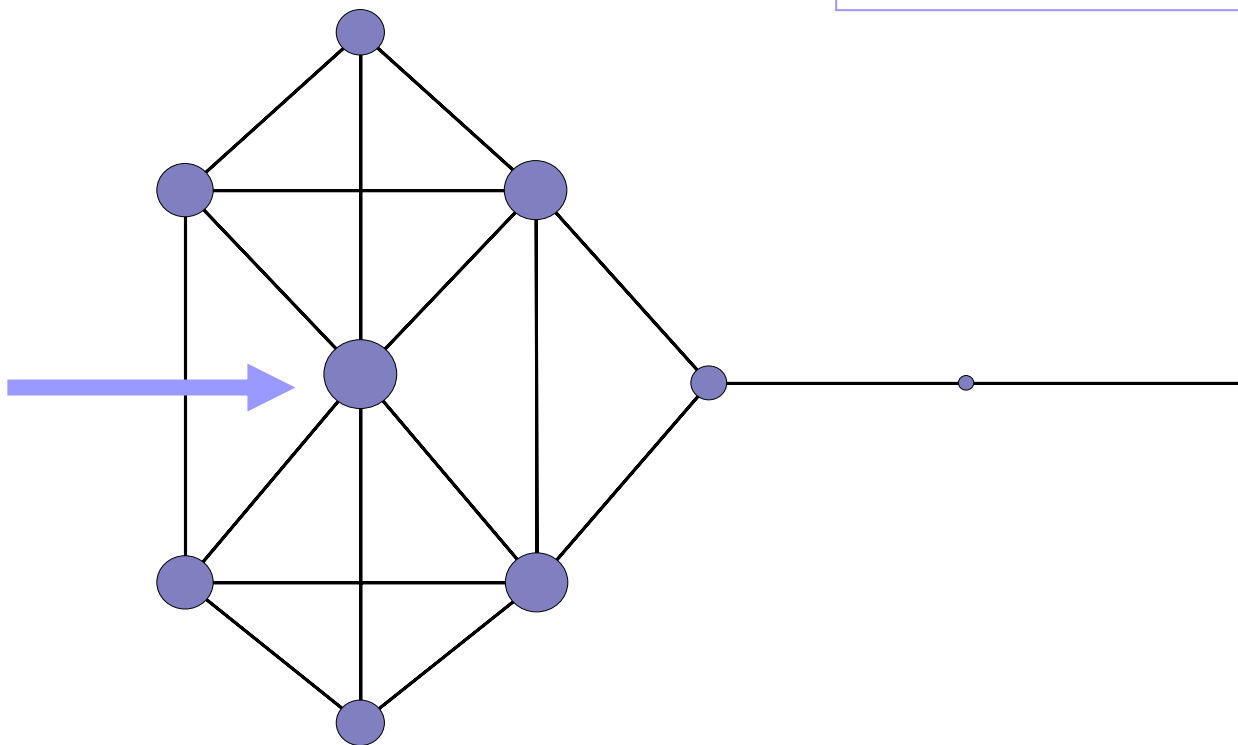
# Actor betweenness centrality

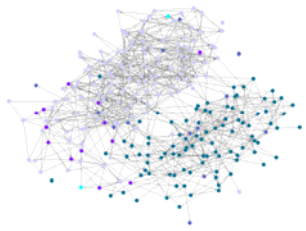




# Actor eigenvector centrality

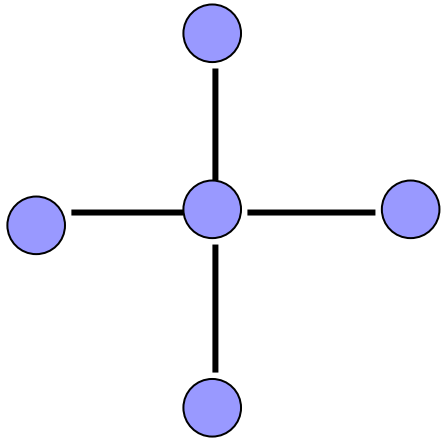
Ties to prominent others



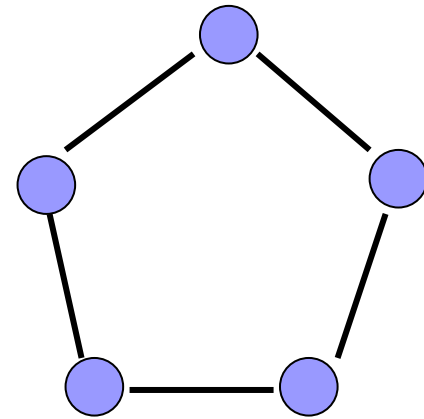


# Network centralization

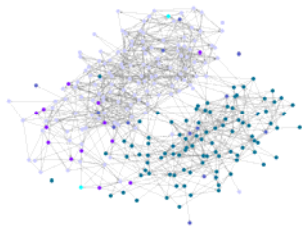
- One or a few actors are quite central, other actors are not central



Centralized



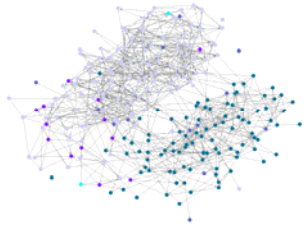
Not centralized



# Subgroup cohesion

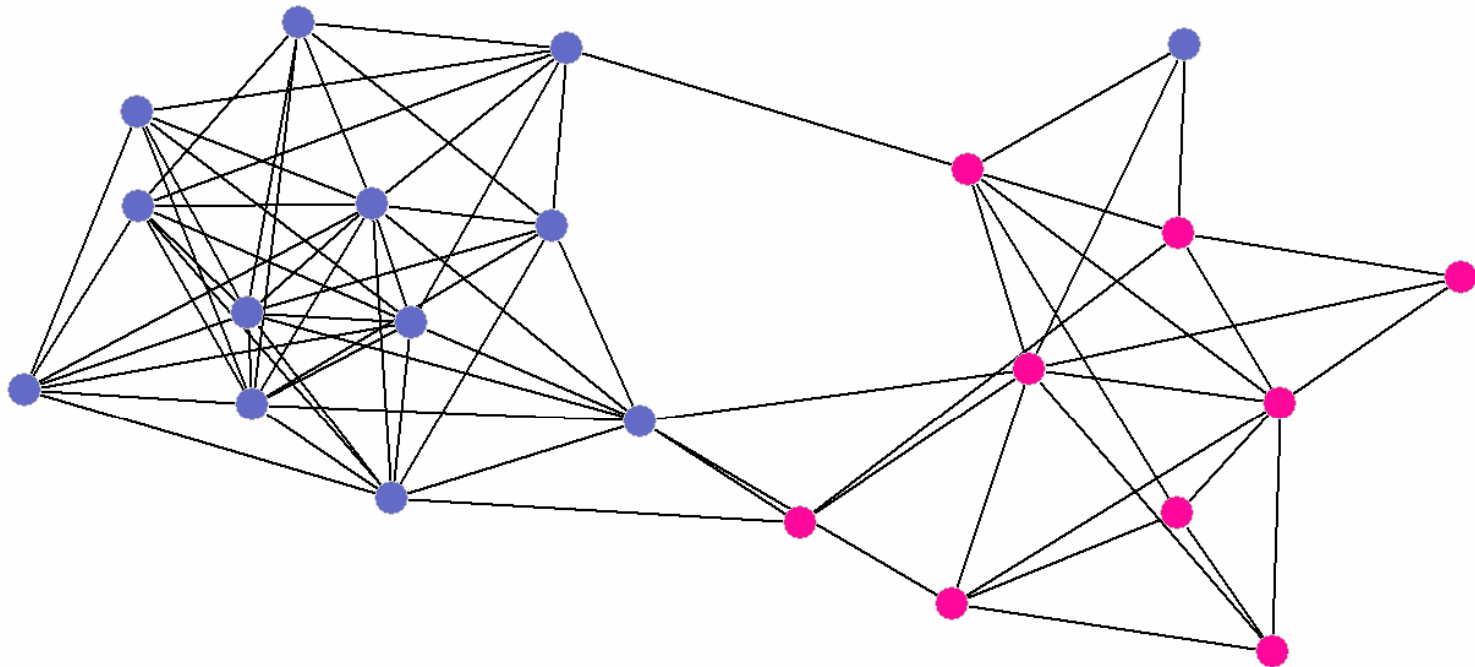
---

- Structural intuitions
  - High level of activity or strong ties
  - Ties to many other subgroup members
  - Close, compact
- Approaches
  - Cliques etc.

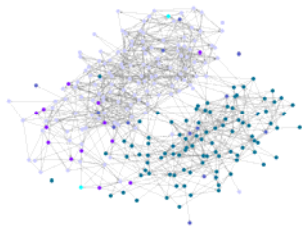


# Cohesive subgroups

Friendship in a fifth grade classroom

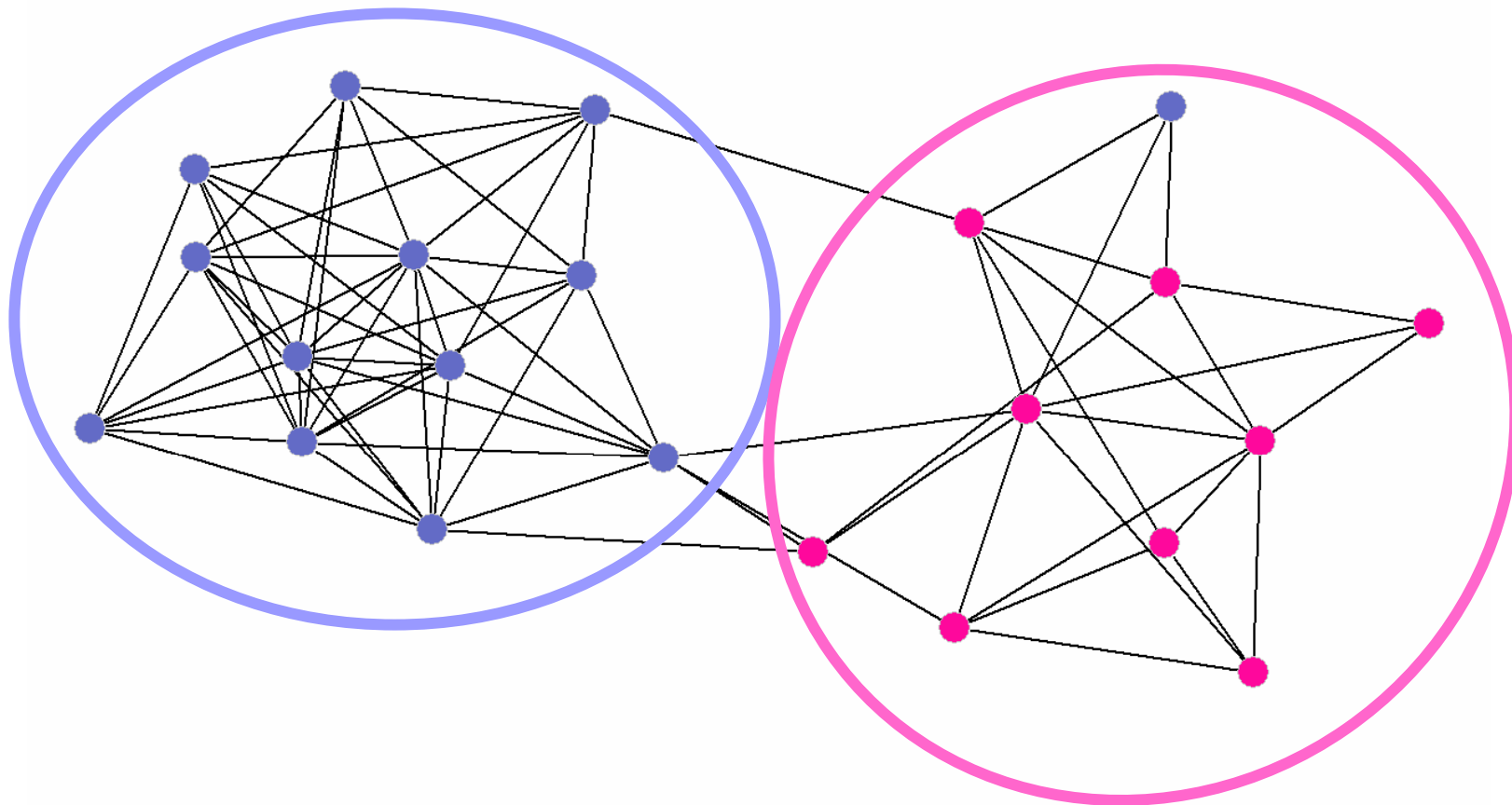


Nodes colored by sex

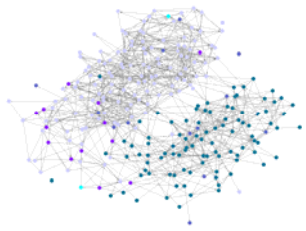


# Cohesive subgroups

Friendship in a fifth grade classroom



Subgroups identified using factions in UCINET

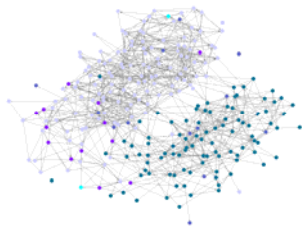


# Relational patterns and reductions

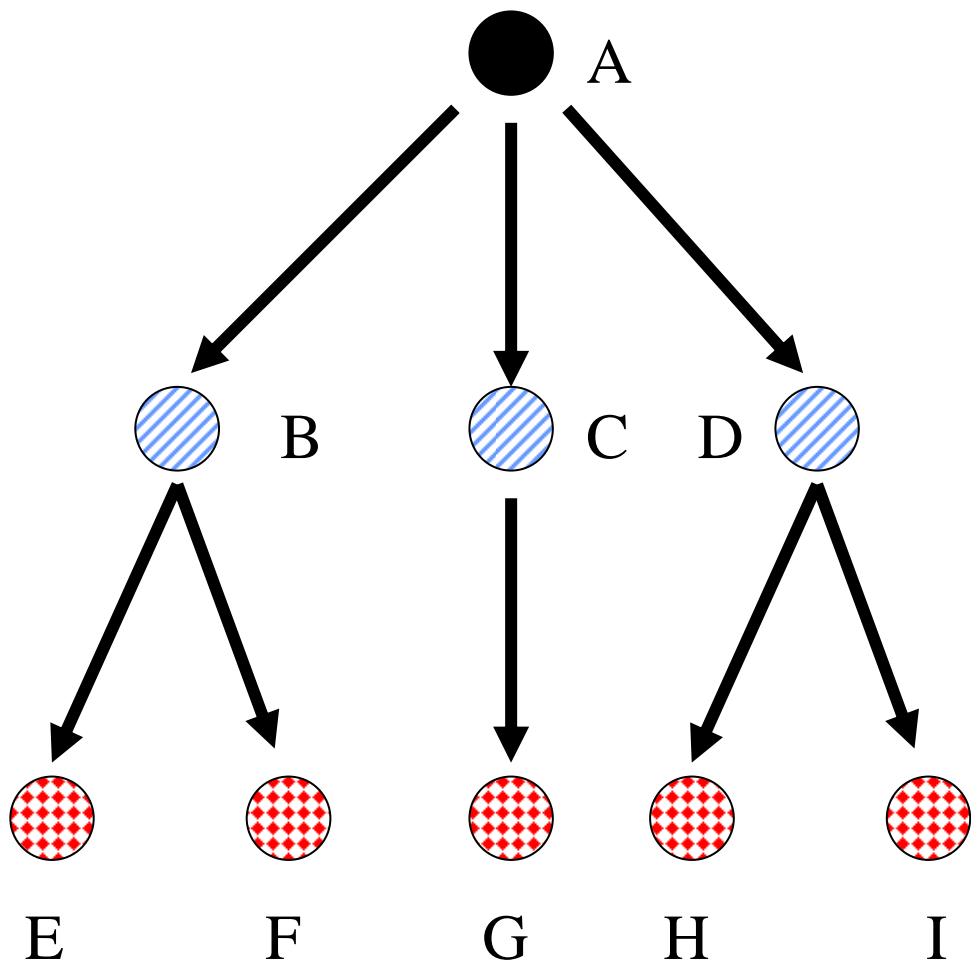
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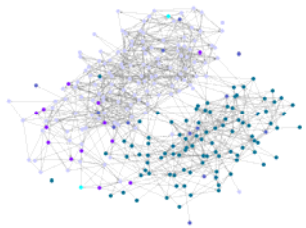
- Relational formalization of
  - Social position
  - Social role
- Reduced image of network (blockmodel)



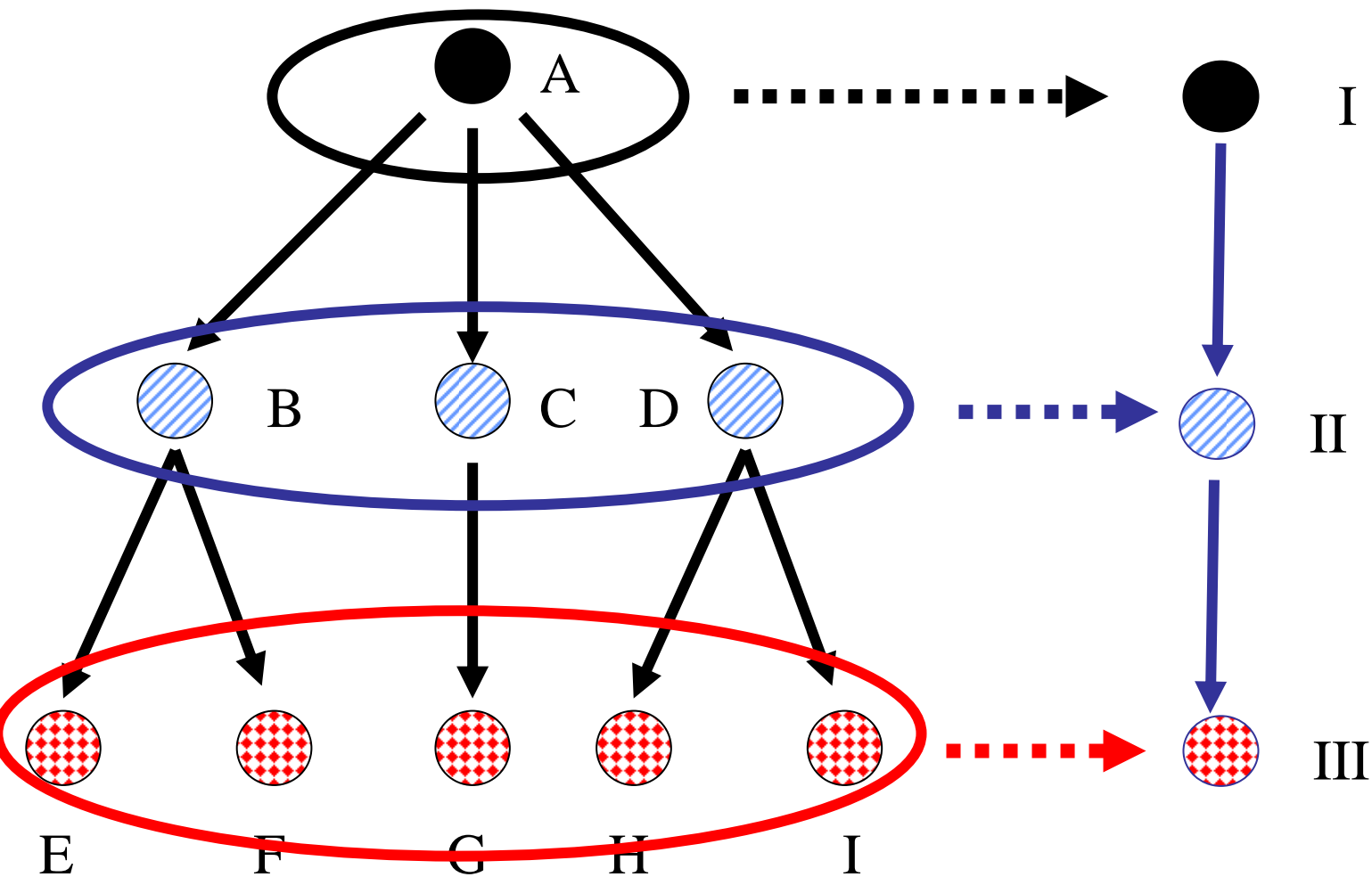


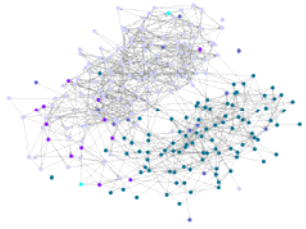
# Graph with three levels





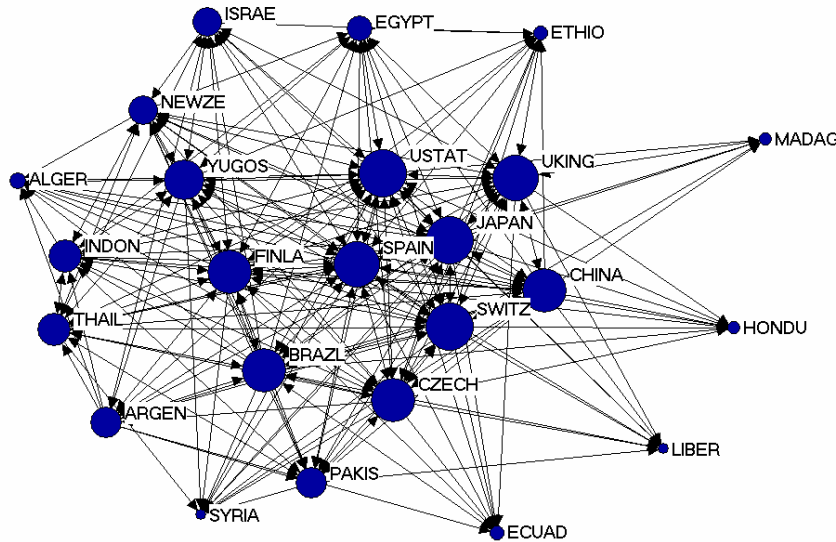
# Regular equivalence reduction



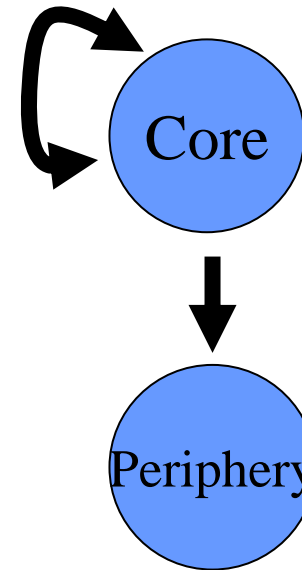


# Blockmodel image

Export Basic Manufactured Goods



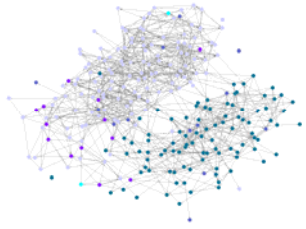
Reduced image



- BRAZL
- CHINA
- CZECH
- FINLA
- INDON
- JAPAN
- PAKIS
- SPAIN
- SWITZ
- THAIL
- UKING
- USTAT
- YUGOS

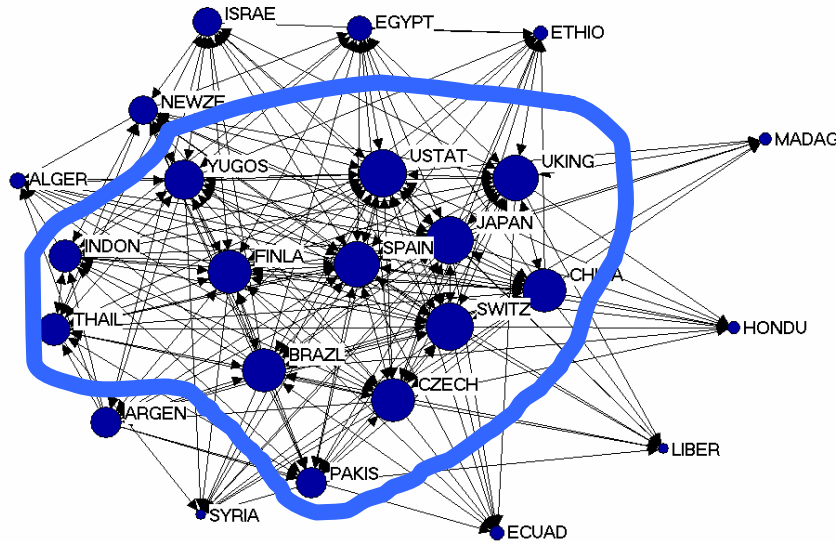
- ALGER
- ARGEN
- ECUAD
- EGYPT
- ETHIO
- HONDU
- ISRAE
- LIBER
- MADAG
- NEWZE
- SYRIA

Regular blockmodel in Pajek

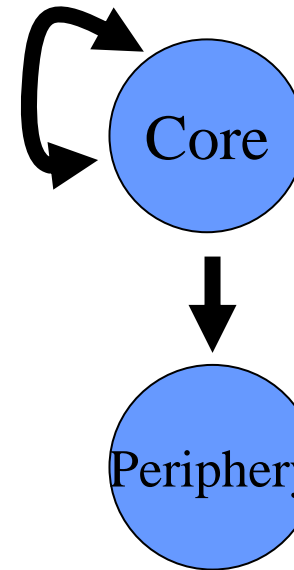


# Blockmodel image

Export Basic Manufactured Goods



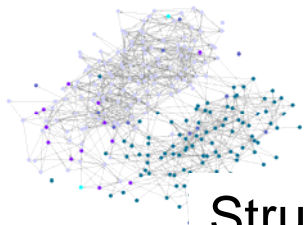
Reduced image



- BRAZL
- CHINA
- CZECH
- FINLA
- INDON
- JAPAN
- PAKIS
- SPAIN
- SWITZ
- THAIL
- UKING
- USTAT
- YUGOS

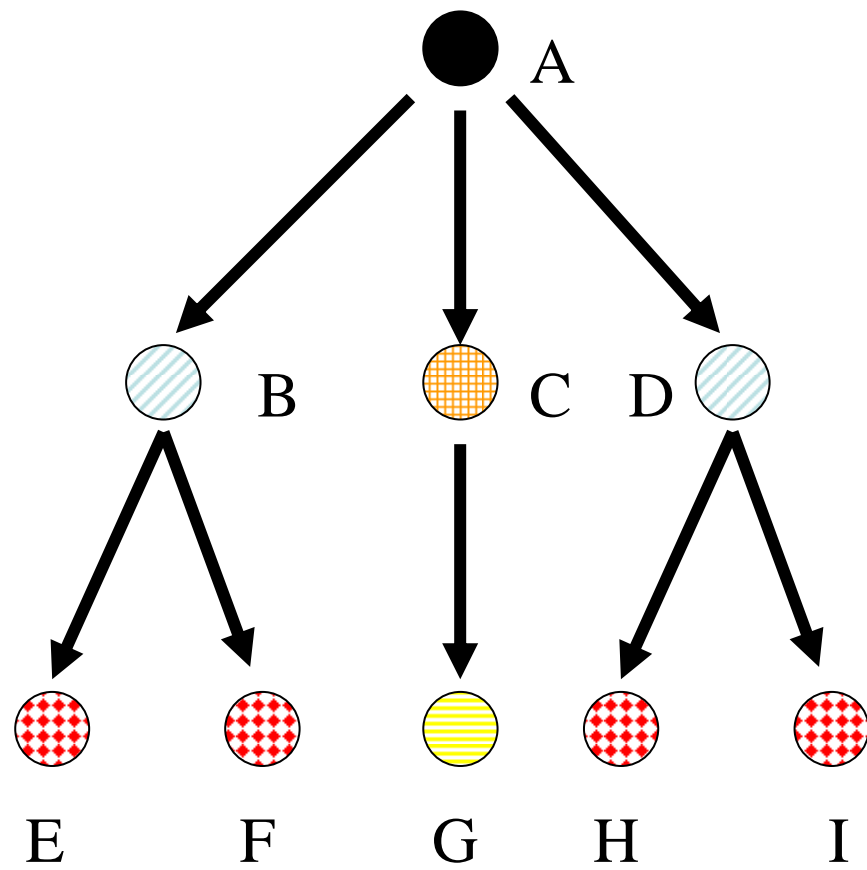
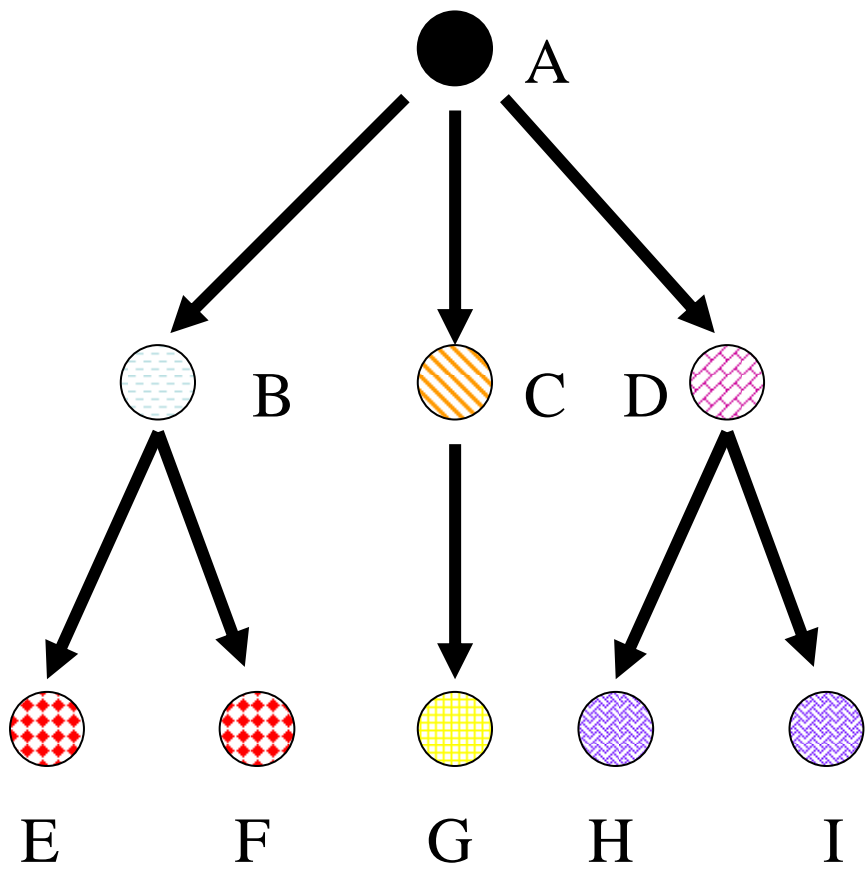
- ALGER
- ARGEN
- ECUAD
- EGYPT
- ETHIO
- HONDU
- ISRAE
- LIBER
- MADAG
- NEWZE
- SYRIA

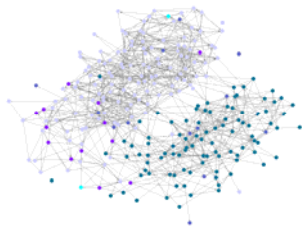
Regular blockmodel in Pajek



Structural equivalence

Automorphic equivalence

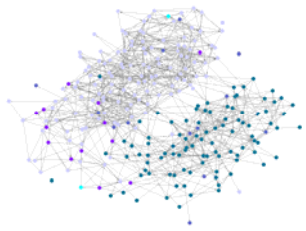




# Local network approaches

---

- Subgraphs
  - Dyads
  - Triads
  
- Local structures  $\leftrightarrow$  global structures



# Dyad

- Pair of nodes and the arc(s) between them

- Mutual

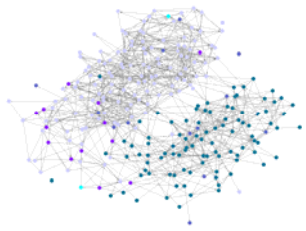


- Asymmetric



- Null

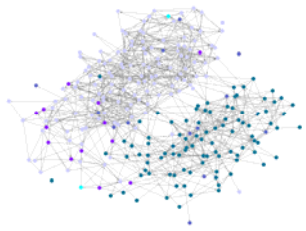




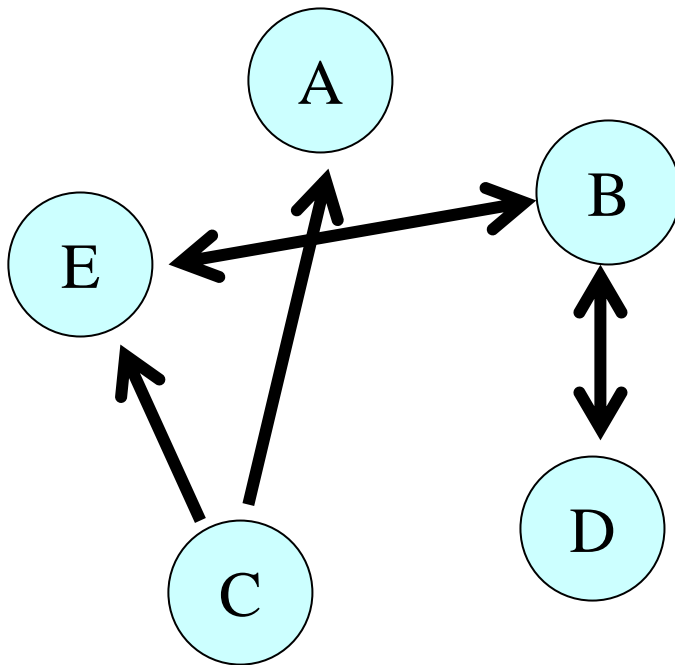
# Dyad census

- 
- Count the number of dyads that are
    - Mutual
    - Asymmetric
    - Null
  - Tendency for mutuality vs. asymmetry



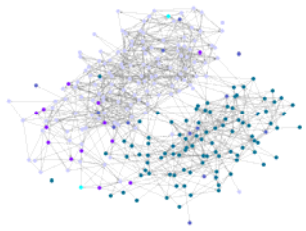


# Dyad census



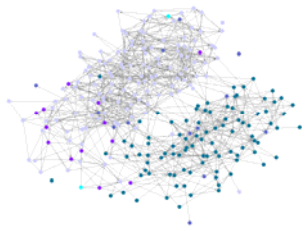
AB	Null
AC	Asym
AD	Null
AE	Null
BC	Null
BD	Mutual
BE	Mutual
CD	Null
CE	Asym
DE	Null

$M = 2$   
 $A = 2$   
 $N = 6$



# Triads

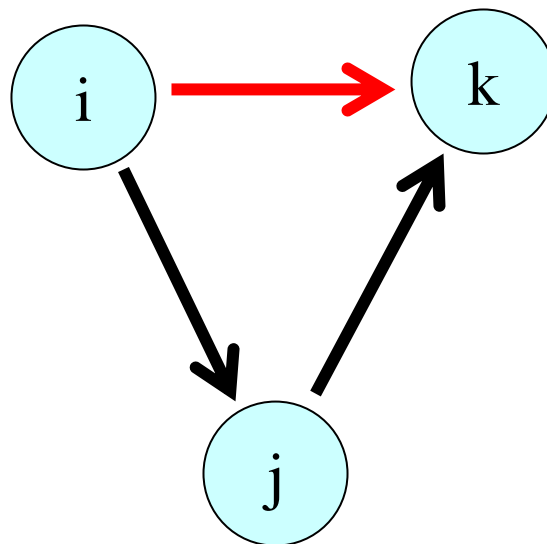
- 
- Triad: Three nodes and the arcs among them

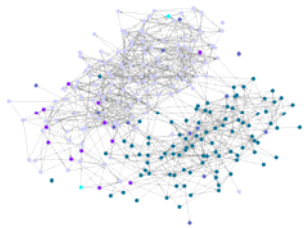


# Transitivity

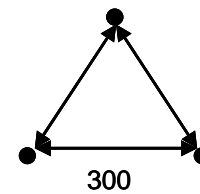
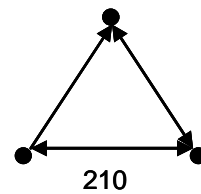
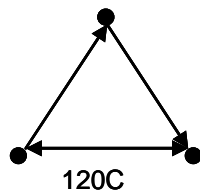
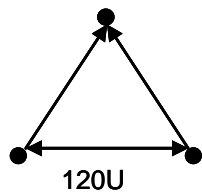
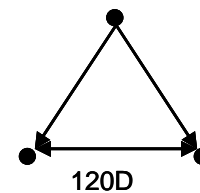
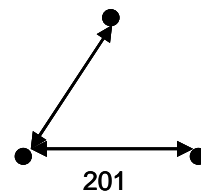
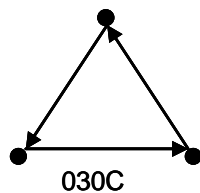
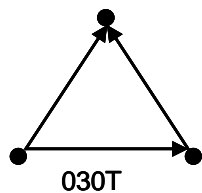
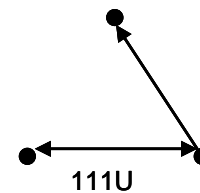
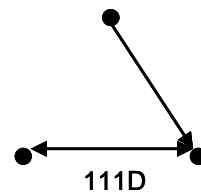
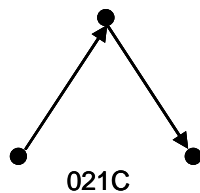
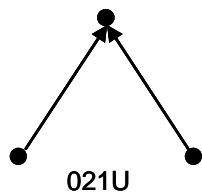
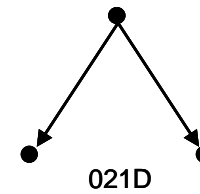
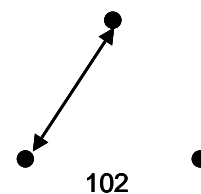
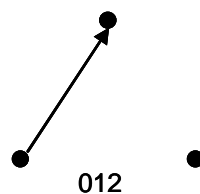
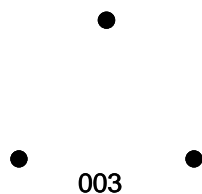
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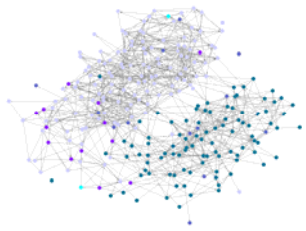
if  $i \rightarrow j$  and  $j \rightarrow k$ , then  $i \rightarrow k$





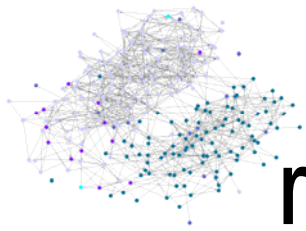
# 16 types of triads





# Triad census

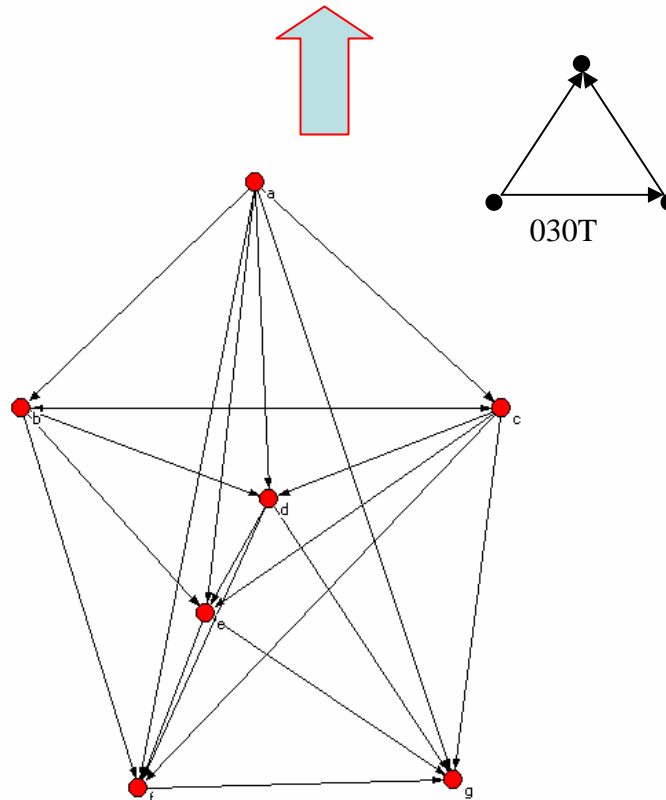
- Counts the number of each of the 16 triad types
- Test hypotheses about triadic tendencies
  - Transitivity
  - Triadic closure
  - ...
- Investigate theoretical macro structures
  - Subgrouping
  - Hierarchy

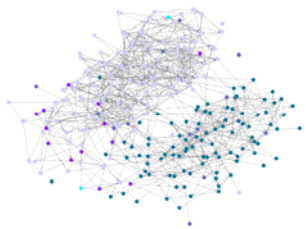


# Triad census

## rhesus monkeys win in fights

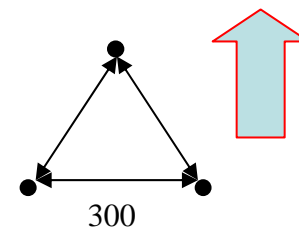
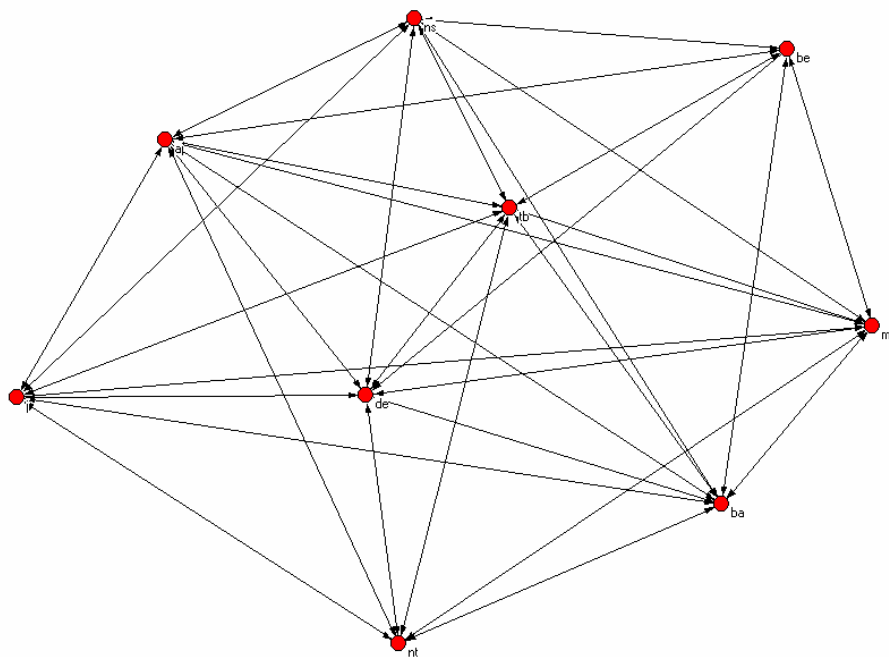
003	012	102	021D	021U	021C	111D	111U	030T	030C	201	120D	120U	120C	210	300
0	0	0	1	0	3	0	1	26	0	0	1	3	0	0	0
0%	0%	0%	3%	0%	9%	0%	3%	74%	0%	0%	3%	9%	0%	0%	0%

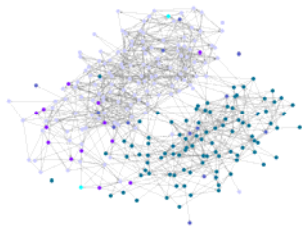




# Triad census chimpanzees grooming

003	012	102	021D	021U	021C	111D	111U	030T	030C	201	120D	120U	120C	210	300
0	0	2	0	0	0	3	0	0	0	14	0	1	0	23	41
0%	0%	2%	0%	0%	0%	4%	0%	0%	0%	17%	0%	1%	0%	27%	49%



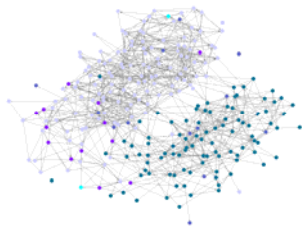


# Testing structural hypotheses

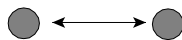
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- Statistical approaches
  - Network dependencies
  - Exponential random graph models (ERGM)
- Social influence and social selection
- Diffusion





# Some network structural effects



a. Mutual



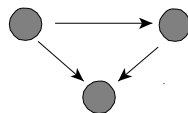
b. Out 2-star



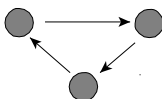
c. In 2-star



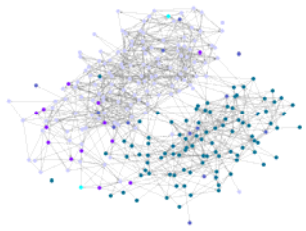
d. Mixed 2-star



e. Transitive triple



f. Cyclic triple



# Future directions for social network analysis

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- Data challenges
  - High quality data
  - Replicated in multiple settings
  - Theoretically and substantively rich
  - Sampling and missing data
- Network processes
  - Theoretically and empirically grounded
- Statistical inference