Social and Economic Networks

Introduction

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Outline

1. What are networks?
2. Why study networks?
3. Examples
   - Florentine marriages
   - Do we live in a small world?
4. Challenge

Section 1

What are networks?

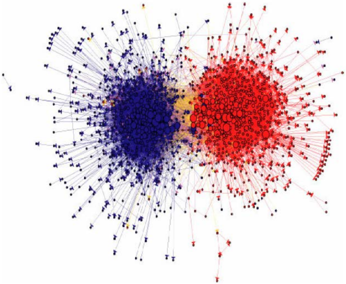
What are networks?

- Networks are a representation of interaction structure among units.

  In the case of social and economic networks, these units (nodes) are individuals or firms.
- At some broad level, the study of networks can encompass the study of all kinds of interactions.

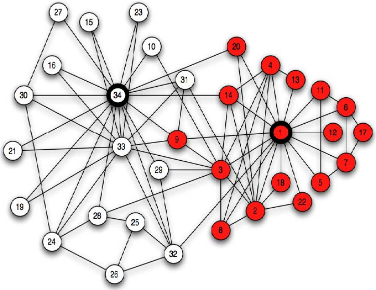
Visual example 1

The network structure of political blogs prior to the 2004 U.S. Presidential election reveals two natural and well-separated clusters (Adamic and Glance, 2005)



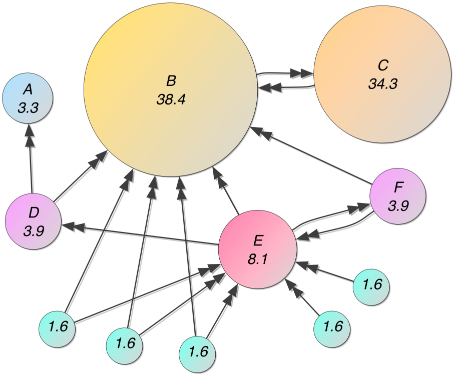
Visual example 2

The social network of friendships within a 34-person karate club provides clues to the fault lines that eventually split the club apart (Zachary, 1977)



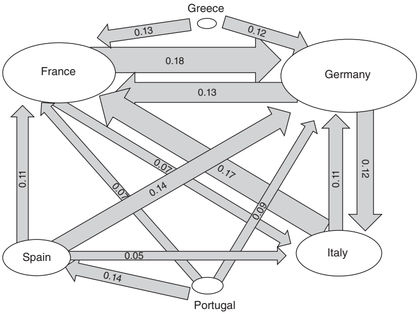
Visual example 3

PageRank is an algorithm used by Google Search to rank websites in their search engine results. PageRank was named after Larry Page, one of the founders of Google. PageRank is a way of measuring the importance of website pages.



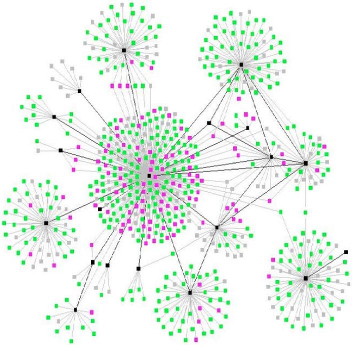
Visual example 4

European debt cross-holdings (Elliott, Golub and Jackson, 2014)



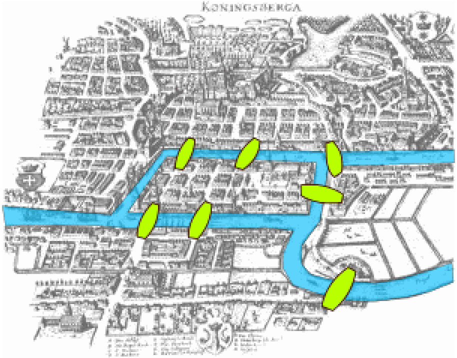
Visual example 5

The spread of an epidemic disease (such as the tuberculosis outbreak shown here) is another form of cascading behavior in a network.



Visual example 6

The Seven Bridges of Konigsberg is a historically notable problem in mathematics. Its negative resolution by Leonhard Euler in 1736 laid the foundations of graph theory and prefigured the idea of topology.



Section 2

Why study networks?

Why study networks?

Many economic, political, and social interactions are shaped by the local structure of relationships:

- trade of goods and services, most markets are not centralized…
- sharing of information, favors, risk…
- transmission of viruses, opinions…
- access to info about jobs…
- choices of behavior, education…
- political alliances, trade alliances…

Why study networks? (Cont.)

Social networks influence behavior:

- Will you lend money to your friend? Will you follow their advice? Will you imitate their behavior? Will you trade with other firms that you are potentially "connected to"?
- crime, employment, human capital, voting, smoking...
- networks exhibit heterogeneity, but also have enough underlying structure to model.

Example: Networks in labor markets

- Myers and Shultz (1951) for textile workers:
  - 62% first job from contact.
  - 23% by direct application.
  - 15% by agency, ads, etc.
- Networks and social interactions in crime:
  - Reiss (1980, 1988): 2/3 of criminals commit crimes with others.
  - Glaeser, Sacerdote and Scheinkman (1996): social interaction important in petty crime, among youths, and in areas with less intact households.

Primary questions

- What do we know about network structure?
  - What are the commonalities in different (social, economic and other) networks?
- How do networks form? Do the “right” networks form?
  - Diffusion of new technologies and spread of epidemics have certain common features when one looks at their dynamics.
  - Does this mean that they obey the same logic?
  - Should we have a single theory to explain both?
  - Should we use the same mathematical tools to analyze both?
- How do networks influence behavior? (and vice versa)

Three areas

- Theory
  - network formation, dynamics, design…
  - how networks influence behavior
  - coevolution?
- Empirical and experimental work
  - observe networks, patterns, influence
  - test theory and identify regularities
- Methodology
  - how to measure and analyze networks

Central focus

Models for analyzing and understanding networks:

- Random graph methods
- Strategic, game theoretic techniques
- Hybrids, statistical models

Goals

- Presume no prior knowledge on network
- Introduce you to a variety of approaches to modeling networks (more breadth than depth)
- Give a sense of different disciplines' techniques and perspectives

Models

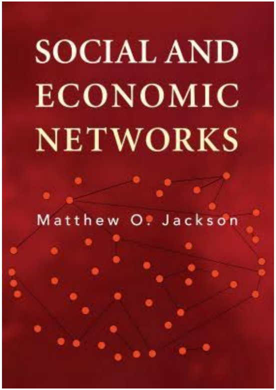
- Provide insight into why we see certain phenomena
  - Why do social networks have short average path lengths?
- Allow for comparative statics
  - How does component structure change with density? Important in contagion/diffusion/learning…
- Predict out of sample
  - What will happen with a new policy (vaccine, R&D subsidy, …)?
- Allow for statistical estimation
  - Is there significant clustering on a local level or did it appear at random?

Course outline

- Background and fundamentals
  - Definitions and characteristics of networks
  - Empirical background
- Network formation
  - Random network models
  - Strategic network models
- Networks and behavior
  - Diffusion and learning
  - Games on networks

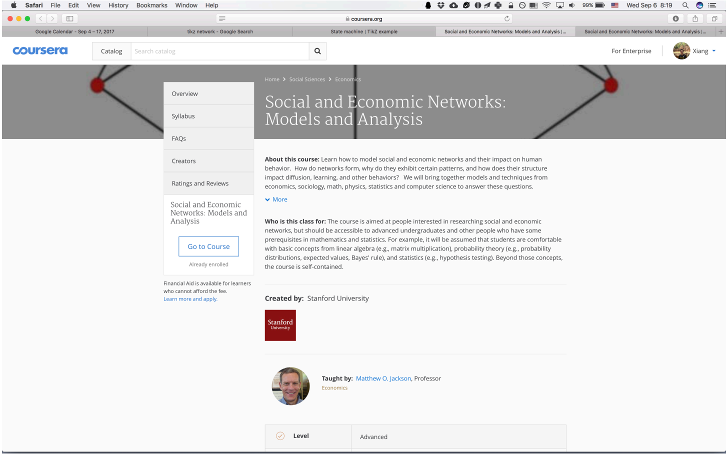
Course outline: References

Matthew Jackson, *Social and Economic Networks*, Princeton University Press, 2010.



Course outline: References

MOOC: Social and Economic Networks: Models and Analysis.



Section 3

Examples

Subsection 1

Florentine marriages

Florentine marriages: Background

- The Medicis emerged as the most influential family in 15th century Florence. Cosimo de' Medici (科西莫・德・美第奇) ultimately formed the most politically powerful and economically prosperous family in Florence, dominating Mediterranean trade.
- The Medicis, to start with, were less powerful than many other important families, both in terms of political dominance of Florentine institutions and economic wealth.
- How did they achieve their prominence?
- It could just be luck (in social science, we have to be very careful to distinguish luck from a systematic pattern, and correlation from causation).

Florentine marriages: Network?

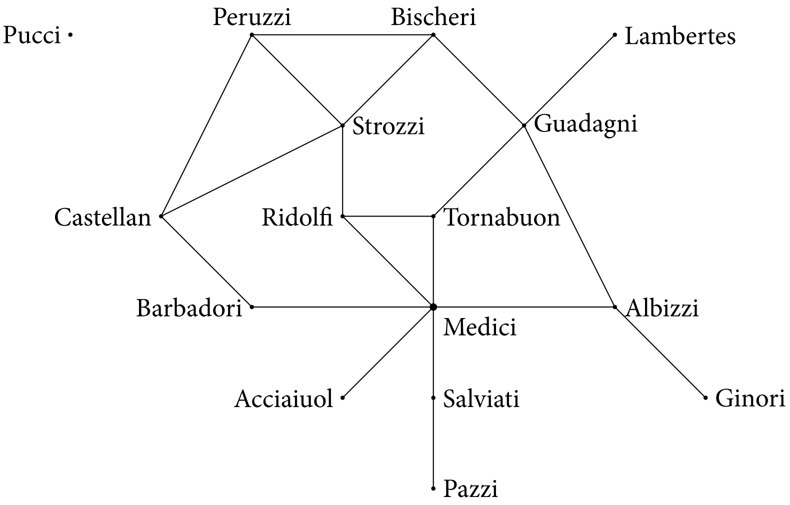
- If one examines wealth and political clout, the Medici did not stand out at this point.

  For instance, the Strozzi had both greater wealth and more seats in the local legislature, and yet the Medici rose to eclipse them.

$\Rightarrow$ One has to look at the structure of social relationships to understand why it was the Medici who rose in power.

- Padgett and Ansell (1993) provide powerful evidence for this by documenting the network of marriages between some key families in Florence in the 1430's.

Florentine marriages: Marriage network



Florentine marriages: Degree

If we do a rough calculation of importance in the network, simply by counting how many families a given family is linked to through marriages, then the Medici do come out on top.

- The Medici: 6
- The Strozzi and the Guadagni: 4
- However, the difference is not significant.

Florentine marriages: Betweenness

- Let $P(ij)$ denote the number of the shortest paths connecting family i to family j.

  Let $P_k(ij)$ denote the number of these paths that family k lies on.
- The shortest path between the Barbadori and Guadagni has three links in it.

  There are two such paths: Barbadori - Medici - Albizzi - Guadagni, and Barbadori - Medici - Tournabouni - Guadagni.

  The Medici lie on both paths.

Florentine marriages: Betweenness (Cont.)

- In order to get a fuller feel for how central a family is, we can look at an average of the betweenness calculation.
    - For each pair of other families, compute the fraction of the total number of shortest paths between the two given family lies on.
    - Then averaging across all pairs of other families gives us a sort of betweenness (or power measure) for a given family.
- For each family k, we calculate

$$\sum_{i,j:\ i\neq j, i\neq k, j\neq k} \frac{P_k(ij)/P(ij)}{\binom{n}{2}}.$$

If there are no paths connecting i and j, we set $P_k(ij)/P(ij) = 0$.

Florentine marriages: Betweenness (Cont.)

- This measure of betweenness for
  - the Medici: 0.522,
  - the Strozzi: 0.103,
  - the Guadagni: 0.255.
- Padgett and Ansell (1993): "Medician political control was produced by network disjunctures within the elite, which the Medici alone spanned."

Florentine marriages: Summary

- This analysis shows that network structure can provide important insights beyond those found in other political and economic characteristics.
- The example also illustrates that the network structure is important beyond a simple count of how many social ties each member has, and suggests that different measures of betweenness or centrality will capture different aspects of network structure.
- Several questions:
  - Was it simply by chance that the Medici came to have such a special position in the network or was it by choice and careful planning?
  - Why did other families not form more ties, or try to circumvent the central position of the Medici?
  - Was the resulting network optimal from a variety of perspectives?

Subsection 2

Do we live in a small world?

Do we live in a small world: Background

- Early 20th century Hungarian poet and writer Frigyes Karinthy first came up with the idea that we live in "small world". He suggested, in a play, that any two people among the one and a half billion inhabitants of the earth then were linked through at most five acquaintances.
- The sociologist Stanley Milgram made this famous in his study "The Small World Problem" (1967)—though this study is now largely discredited.

Do we live in a small world: Background (Cont.)

- He asked certain residents of Wichita and Omaha to contact and send a folder to a target person by sending it to an acquaintance, who would then do likewise etc., until the target person was reached. This would allow Milgram to measure how many "intermediate nodes" would be necessary to link the original sender and the target.
- 42 of the 160 letters supposedly made it to their target, with a median number of intermediates equal to 5.5.

Do we live in a small world

- Hence was born the idea of six degrees of separation.
- Can you think why Milgram's procedure could give misleading results? Or why we may not wish to take these results on faith?
- There are similar studies for other types of networks. For example, Albert, Jeong, and Barabasi (1999) "Diameter of the World Wide Web" estimated that in 1998 it took on average 11 clicks to go from one random website to another (at the time there were 800 million websites).
- What do these kind of "small world" results imply?

Interpreting small worlds

- Suppose that each node has λ neighbors (e.g., each website has links to λ other websites).
- Each of my λ neighbors will then have λ neighbors themselves.
- Suppose (unrealistically) that my neighbors don't have any neighbors in common (i.e., the λ websites that are linked to my website are not linked among themselves). Then in two steps, I can reach λ^2 other nodes.

Interpreting small worlds (Cont.)

- Repeating the same reasoning (and maintaining the same unrealistic assumption), in d steps I can reach λ^d other nodes.
- Now imagine that this network has $n = \lambda^d$ nodes.
- This implies that the "degrees of separation" (average distance) is

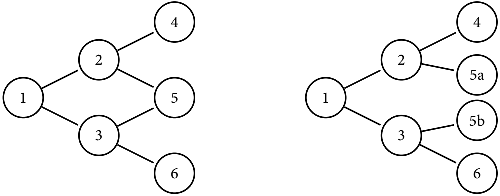
$$d = \frac{\ln n}{\ln \lambda}.$$

- The Karinthy conjecture, under the Poisson assumption, would require that each person should have had approximately 68 "independent" friends.

$$e^{\ln(1{,}500{,}000{,}000)/5} \approx 68.5.$$

Interpreting small worlds (Cont.)

- But our unrealistic assumption rules out the reasonable triadic relations and clustering phenomena, which are common both in social networks, web links, and other networks.



- Interestingly, however, in Poisson (Erdos-Renyi) random graphs, we will see that average distance can be approximated for large n by $d = \frac{\ln n}{\ln \lambda}$ (where λ is the expected degree of a node).
- This is because triadic relations shown in the figure are relatively rare in such graphs.

Interpreting small worlds (Cont.)

- This last result in fact can be interpreted as stating that Poisson (Erdos-Renyi) random graphs, though mathematically convenient, will not be good approximations to social networks.
- Instead, most people would be connected to others in remote parts through "special links" (or "connectors"), such as their political representatives, village head, or cousin in a different city etc.
- Models of small world networks try to capture this pattern (albeit not always perfectly).

Section 4

Challenge

Challenge

- How many networks on just 30 nodes?
- Person 1 could have 29 possible links, person 2 could have 28 not counting 1, …, total = 435.
- So 435 possible links, each could either be present or not, so 2^{435} networks.