Social Network Analysis

SNA Intro.

Dr. Chun-Hsiang Chan

Department of Geography,
National Taiwan Normal University

Photo credit: midjourney

Outline

– The Introduction to Complex Network
– The Social Network Perspective
– Historical and Theoretical Foundations
– The Formulation of Network
– Special Network Case
– Network Examples
– Level of Analysis
– Paper Reading
– References

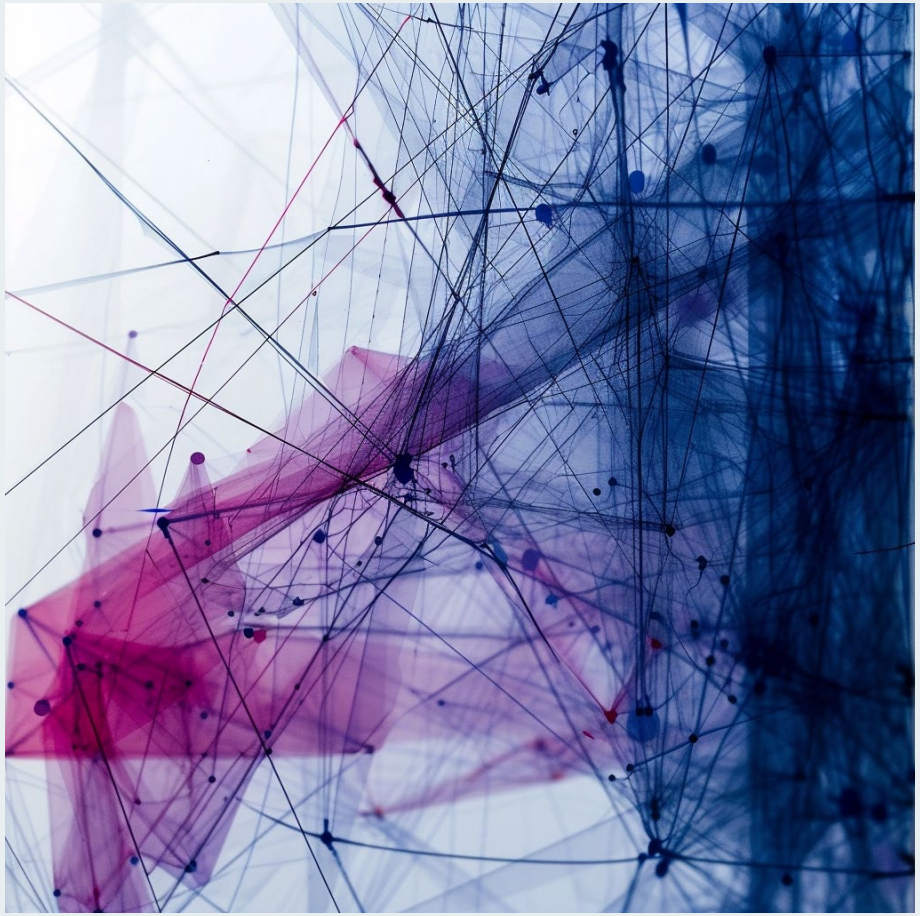


Photo credit: midjourney

The Introduction to Social Network

- The complex network originated from the social network.
- Most studies concentrated on the focus of social network analysis on relationships among social entities and also characterized the patterns and implications of this relationship.
- To quantify these relationships and patterns, researchers developed various structural variables to characterize the social network.

The Social Network Perspective

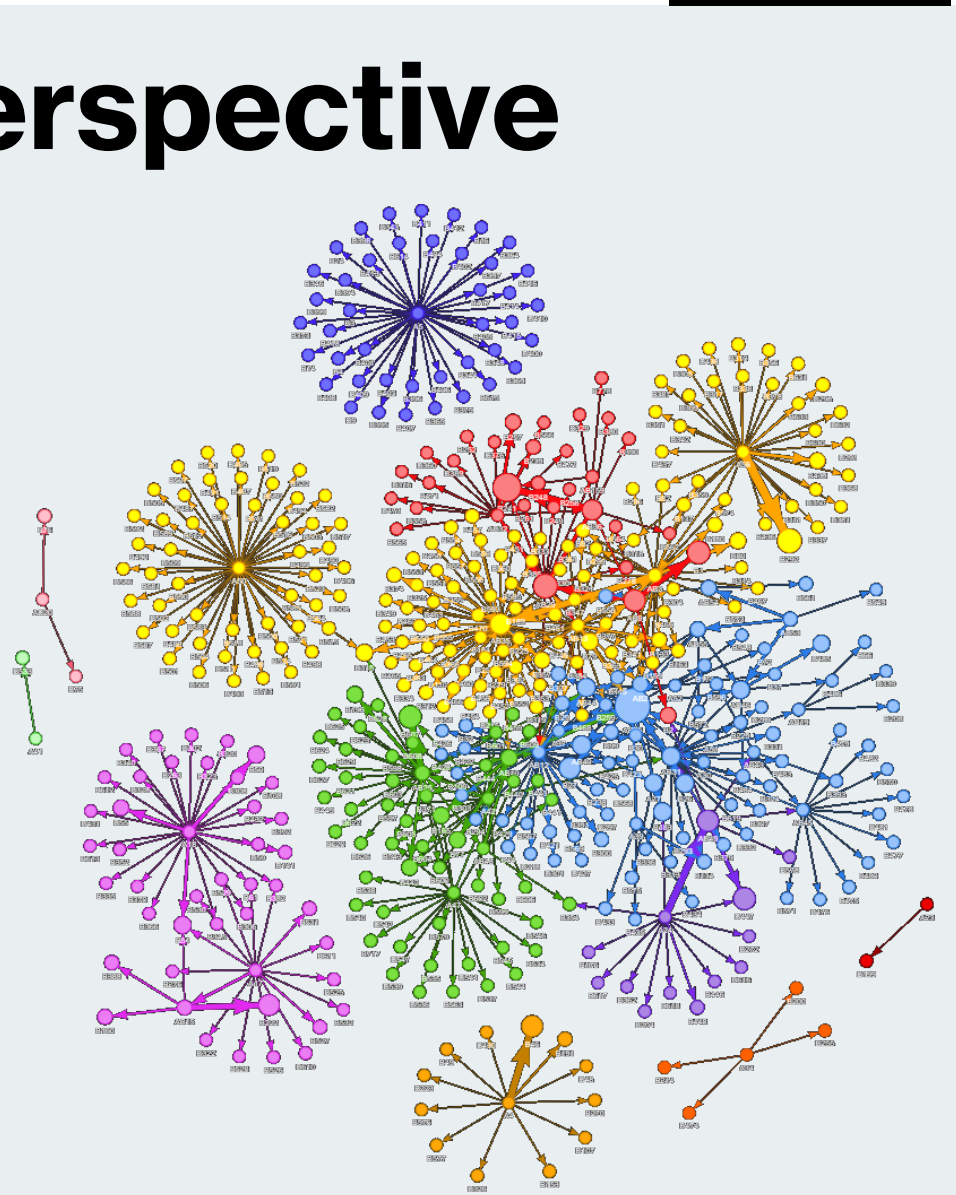
– Previous studies integrated a consensus about the central principles underlying the network properties:

1. Actors and their actions are viewed as interdependent rather than independent, autonomous units.
2. Relational ties (linkages) between actors are channels for transfer or “flow” of resources (either materials or nonmaterial)
3. Network models focusing on individuals view the network structural environment as providing opportunities for or constraints on individual action.
4. Network models conceptualize structure (social, economic, political, and so forth) as lasting patterns of relations among actors.

The Social Network Perspective

– Social network analysis is inherently an interdisciplinary endeavor.

– Freeman (1984) mentioned that “group” and “social role” are essential ideas to characterize the formulation of social networks.



Historical and Theoretical Foundations

– Empirical motivations

Moreno (1953) invented a novel concept – sociogram to visualize the relationship between people. Many social scientists agree that the sociogram invented by Moreno could measure interpersonal relations in small groups and enlighten the structure of small groups in the first two decades.

Moreno, J. L. (1953). Who shall survive? Foundations of sociometry, group psychotherapy and socio-drama.

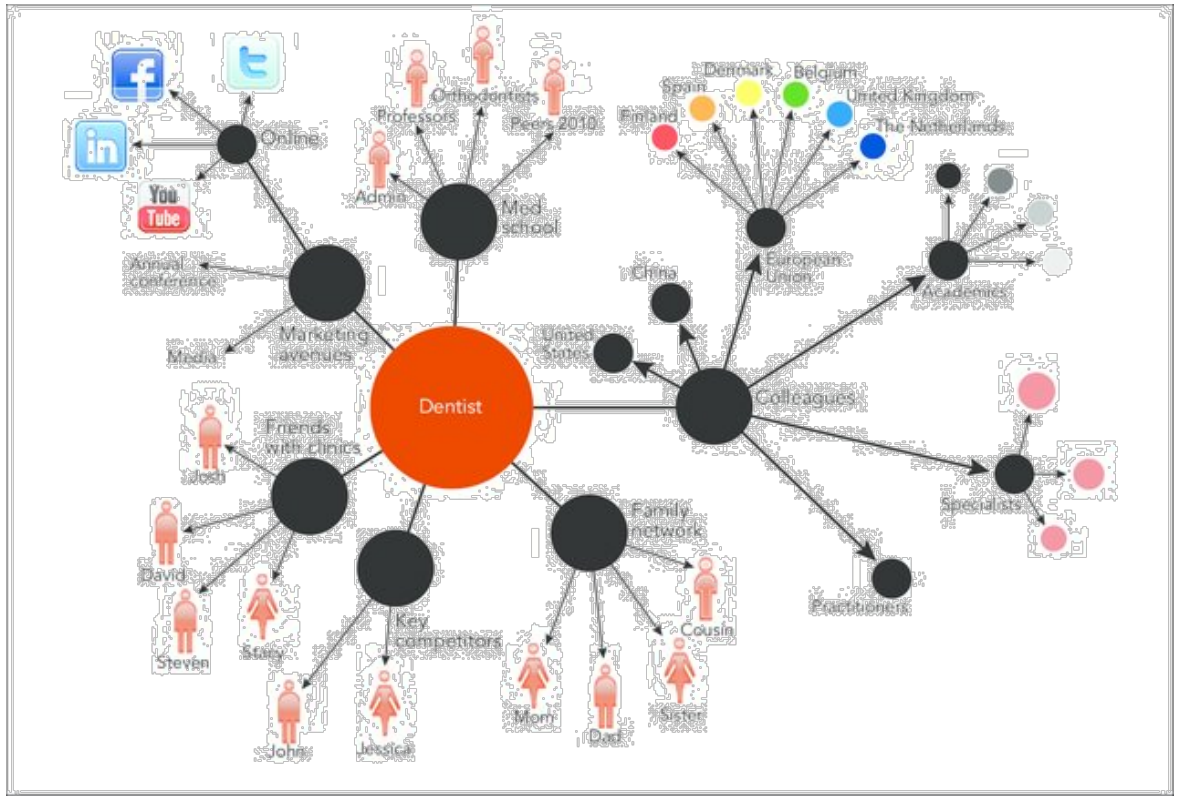
Historical and Theoretical Foundations

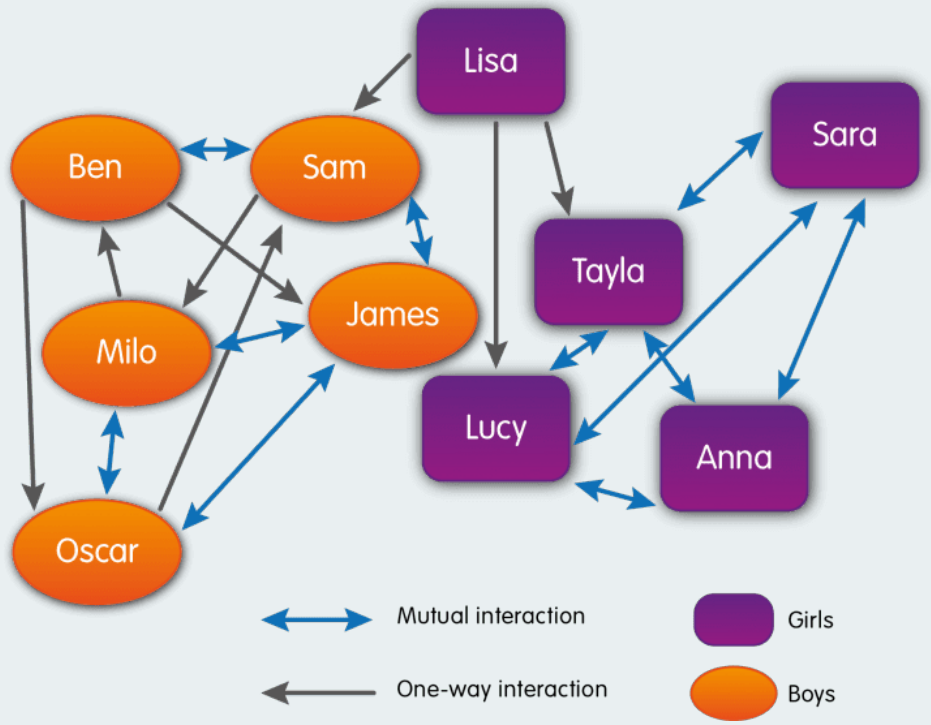
– Empirical motivations

In the 1940s and 1950s, many psychologists found experimental structures useful for understanding the group process (evolution) (Leavitt 1949, 1951; Bavelas 1948, 1950; Smith 1950).

Leavitt, H. J. (1949). Some effects of certain communication patterns on group performance. Massachusetts Institute of Technology, Boston, MA
Leavitt, H. J. (1951). Some effects of certain communication patterns on group performance. *The journal of abnormal and social psychology*, *46*(1), 38.
Bavelas, A. (1948). A mathematical model for group structures. *Human organization*, *7*(3), 16-30.
Bavelas, A. (1950). Communication patterns in task-oriented groups. *The journal of the acoustical society of America*, *22*(6), 725-730.
Smith, S. L. (1950). Communication pattern and the adaptability of task-oriented groups: an experimental study. *Group Networks Laboratory, Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge*, *1*.

Empirical motivations – Sociogram





[left] Hilla Dotan (2011) The dentist as a manager: building effective relationships and networks for personal and professional advancement. Orthodontics : the Art and Practice of Dentofacial Enhancement 12(1):78-81
[right] https://www.6seconds.org/2017/07/03/sociogram-definition/

Historical and Theoretical Foundations

– **Theoretical motivations**

1. In order to quantify the **structural characteristics of social networks**, several scientists developed various indicators, for instance,

   Social group, isolate, popularity, liaison, prestige, balance, transitivity, clique, subgroup, social cohesion, social position, social role, reciprocity, mutuality, exchange, influence, dominance, conformity.

2. In the beginning, most social scientists focused on the social group with the graph theoretic entity of a **clique**.

Historical and Theoretical Foundations

– **Theoretical motivations**

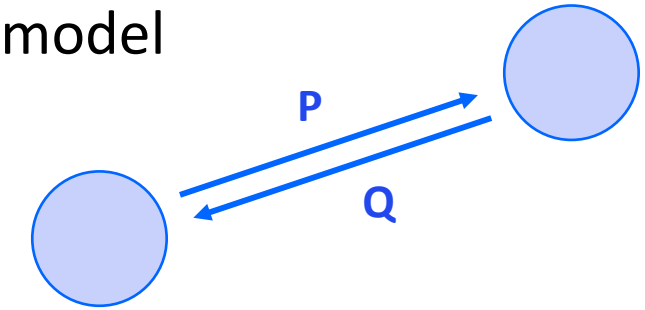
3. In the 1940s, Heider (1946) introduced another vital concept – **structural balance**. Balanced relations commonly appeared in empirical works.
4. In the 1970s, social role, social status, and social position extended the range of network studies. Lorrain and White (1971) introduced the "**structural equivalence**" with a mathematical expression.

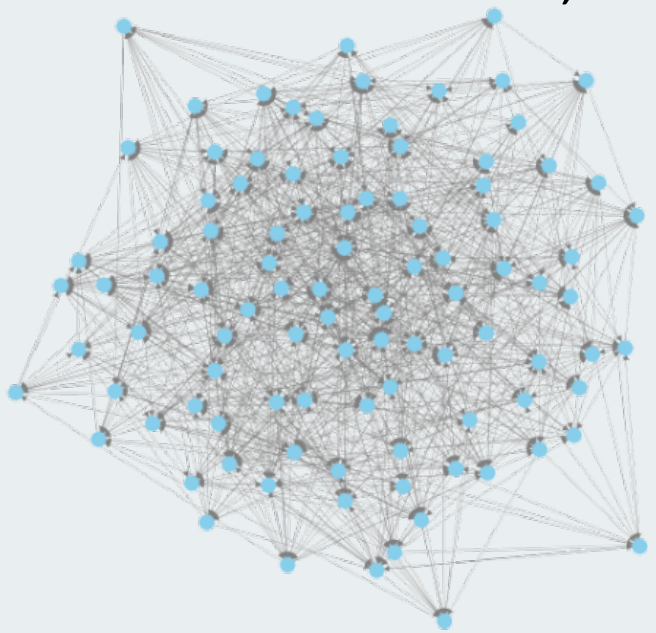
Historical and Theoretical Foundations

– **Mathematical motivations**

In the 1940s, scientists aimed to quantify the **reciprocity** in the social network. There are three major mathematical foundations of social networks, as well as complex networks:

- Graph theory
- Statistical and probability theory
- Algebraic model





Historical and Theoretical Foundations

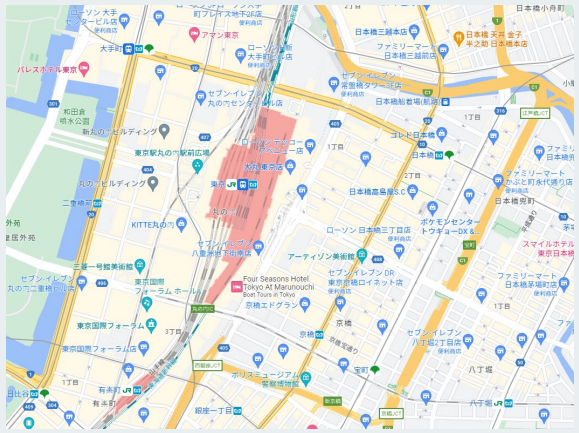
– **Mathematical motivations**

1. Early sociometricians found graph theory and distributions or random graphs.
2. Mathematicians were interested in random graphs and distributions (Erdos and Renyi, 1960).
3. Graph theory provides an appropriate representation of a social network and a set of concepts that can be used to study the formal properties of social networks.

The Formulation of Network

- The fundamental elements of a network include actor, relational tie, dyad, triad, subgroup, relation, and network.
- **Actors** are discrete individual, corporate, or collective social units. Most social network applications focus on collection actors that are all of the same type. We called it a one-mode network.
- **Relational ties are the linkages between one actor and another; however,** relational ties are not limited to social ties. The definition of relational tie is the connection between a pair of actors.

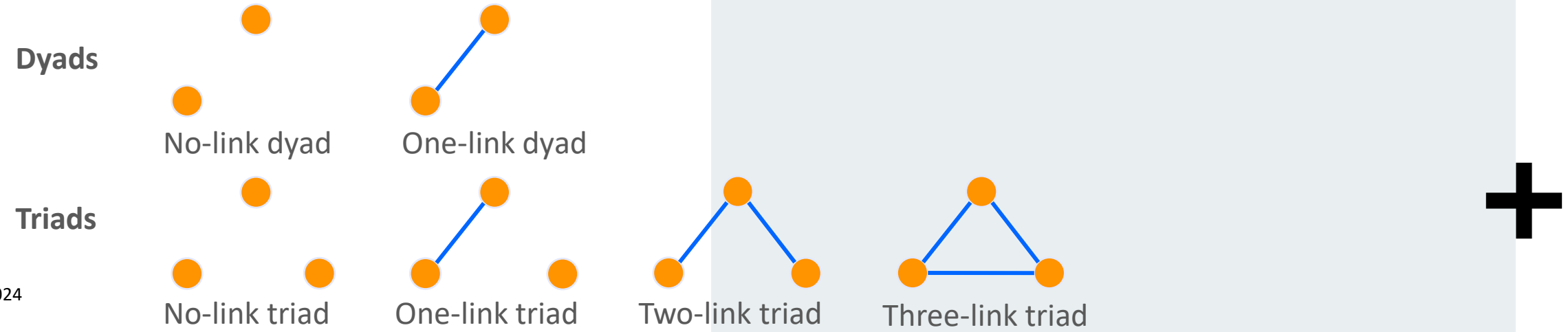
The Formulation of Network



- **Examples of Relational Tie**
  - Social media relationship (friendship)
  - Movement networks (aviation market, migration, and contagious disease)
  - Behavior interaction (communications and sending messages)
  - Physical connection (bridge between regions and road between districts)
  - Biological relationship (protein, skeletal, and vascular system)
  - Company network (structural positions)

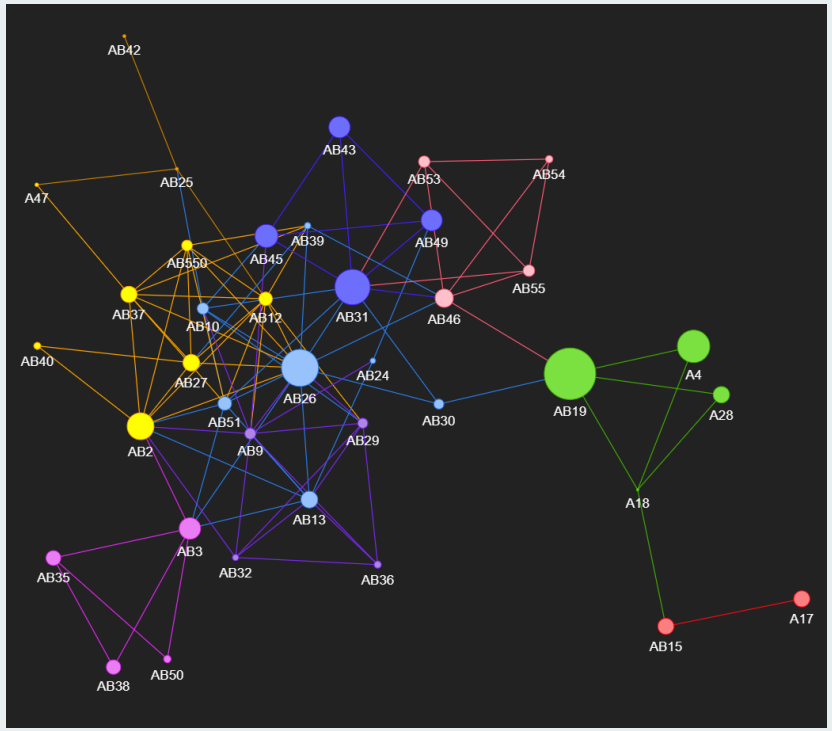
The Formulation of Network

- **Dyad:** The simple linkage or relationship connects two actors by a relational tie; additionally, we may utilize a linkage between two pairs.
- **Triad:** Many crucial networks and ties are formulated as a triad, especially in an extensive network, a subset of three actors and the possible ties among them.



The Formulation of Network

- **Subgroup:** Dyads are pairs of actors and associated ties; triads are triples of actors and associated ties. It follows that we define a subgroup of actors as any subset of actors and all ties among them.
- **Group:** The power of network analysis lies in the ability to model the relationships among a system of actors; the definition of “Group” in the network requires theoretical, empirical, conceptual, or mathematical criteria.



The Formulation of Network

– **Relation:** The collection (set) of ties of a specific kind among group members is called a relation. For instance, the friendship on the social media in the university.

– **Network** consists of a finite set or sets of actors and the relation or relations between/ among them.

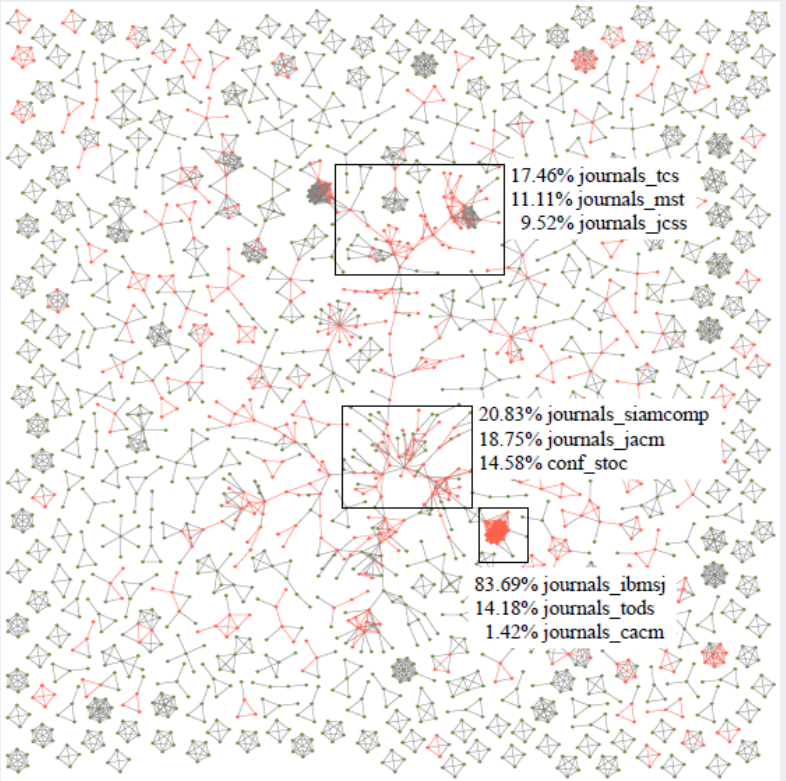


Figure 6: Expanding communities from 1980 to 1981. Edges (i, j) with red color correspond to the gradients that meet $[A'(t)]_{ij} > \delta$. Three largest expanding communities are marked with rectangles.

Yu, W., Aggarwal, C. C., & Wang, W. (2017, February). Temporally factorized network modeling for evolutionary network analysis. In *Proceedings of the Tenth ACM International conference on web search and data mining* (pp. 455-464).

Special Network Case – Small World

- **Small world network**
- A small-world network is a type of mathematical graph in which most nodes are not neighbors of one another, but the neighbors of any given node are likely to be neighbors of each other, and most nodes can be reached from every other node by a small number of hops or steps.

Special Network Case

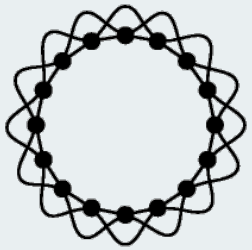
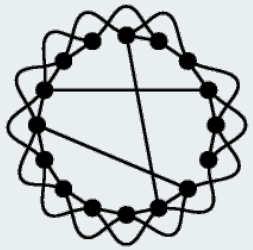
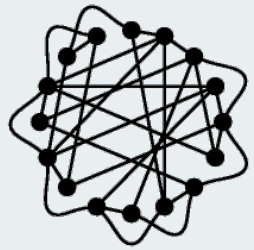
Small World

Published: 24 July 2018

Is the Urban World Small? The Evidence for Small World Structure in Urban Networks

Zachary Neal

Networks and Spatial Economics **18**, 615–631 (2018) | Cite this article

			
Network	Lattice, Ordered	Small World	Random, Disordered
Clustering Coefficient	High	High	Low
Mean Path Length	Long	Short	Short

Neal, Z. (2018). Is the urban world small? The evidence for small world structure in urban networks. *Networks and Spatial Economics*, *18*, 615-631.

Feb. 26, 2024

Special Network Case

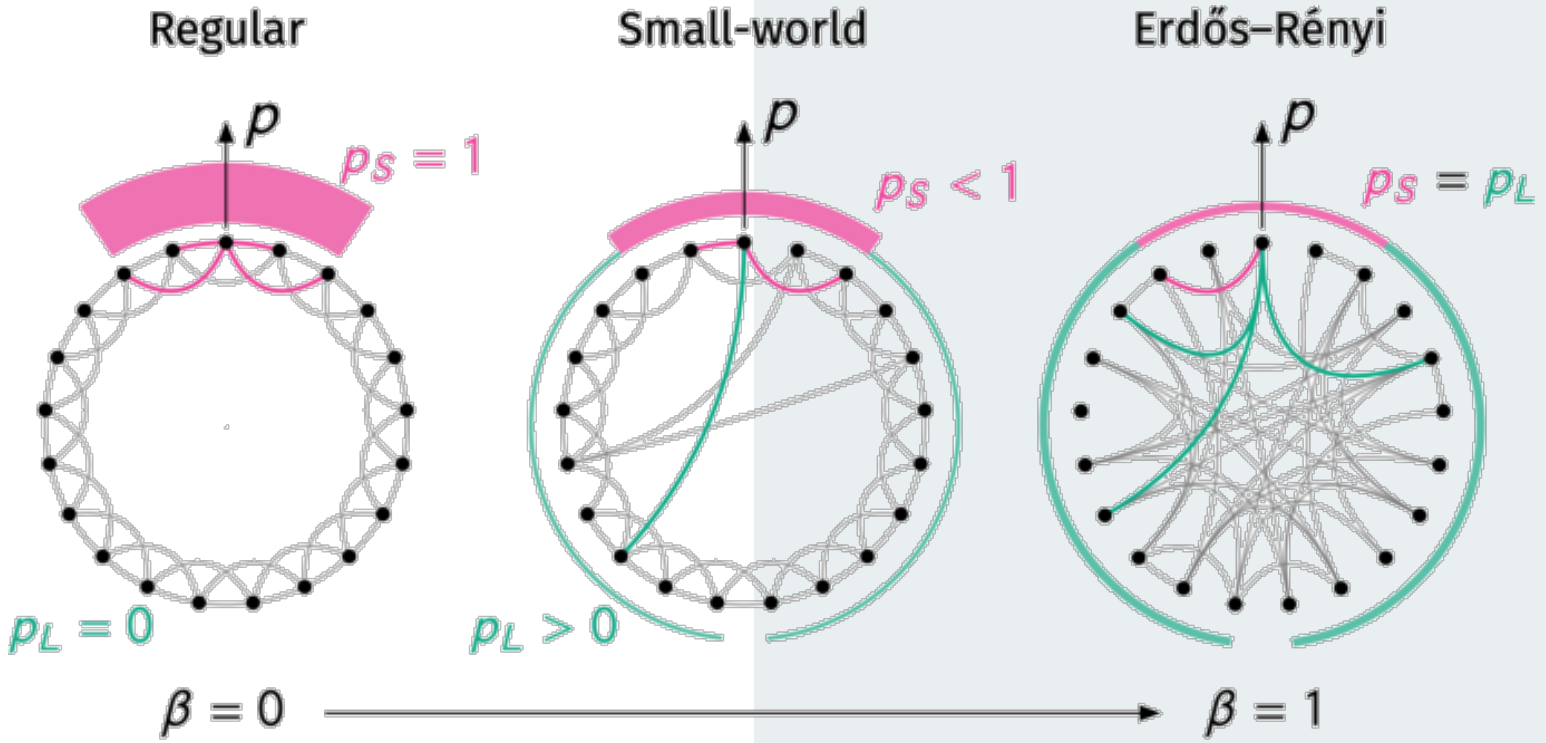
Small World to Random Network

- The conception of small worldliness developed by Watts and Strogatz (1998) describes a class of networks that exist between the extremes of a highly ordered and highly disordered network.
- A highly ordered network such as a lattice is distinguished by two key structural characteristics.
  - First, it has a relatively large clustering coefficient (*C*), which measures the extent to which two of a node's neighbors are connected to each other. For example, in the social context, this occurs when one's friends are also friends with one another.
  - Second, it has a relatively large mean path length (*L*), which measures the average number of steps required to move from one node to another node along the shortest path.

Neal, Z. (2018). Is the urban world small? The evidence for small world structure in urban networks. *Networks and Spatial Economics*, *18*, 615-631.
Watts DJ, Strogatz SH (1998) Collective dynamics of 'small-world' networks. Nature 393:440–442

Special Network Case

From Small World to Random Network



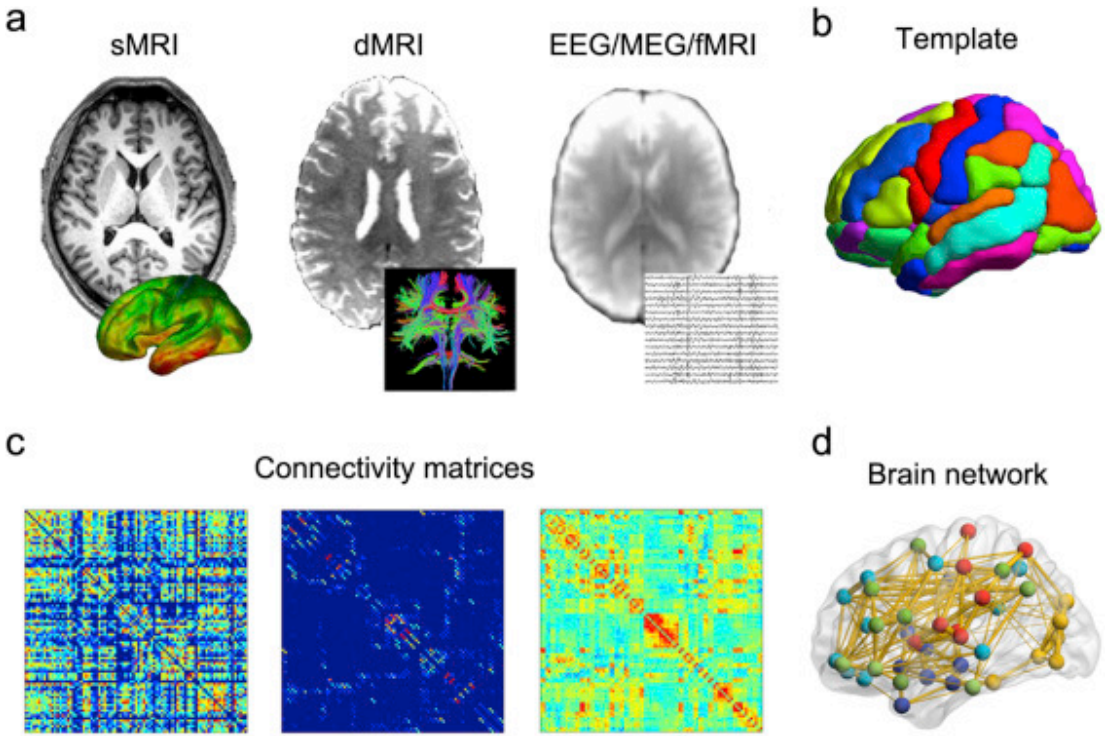
Short-range probability p_S and Long-range probability p_L

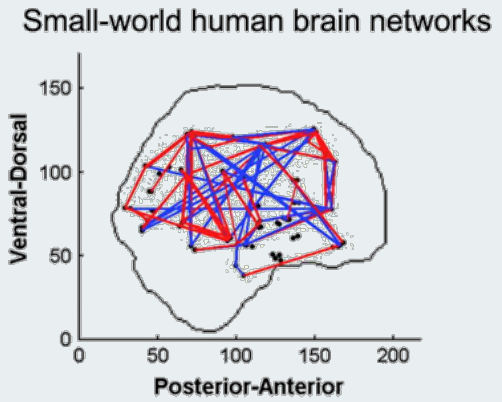
Maier, B. F. (2019). Generalization of the small-world effect on a model approaching the Erdős–Rényi random graph. *Scientific reports*, *9*(1), 1-9.

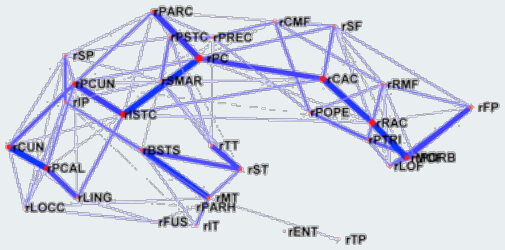
Feb. 26, 2024

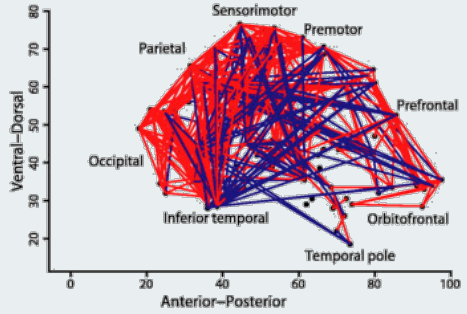
Special Network Case

Small World & Neuroscience







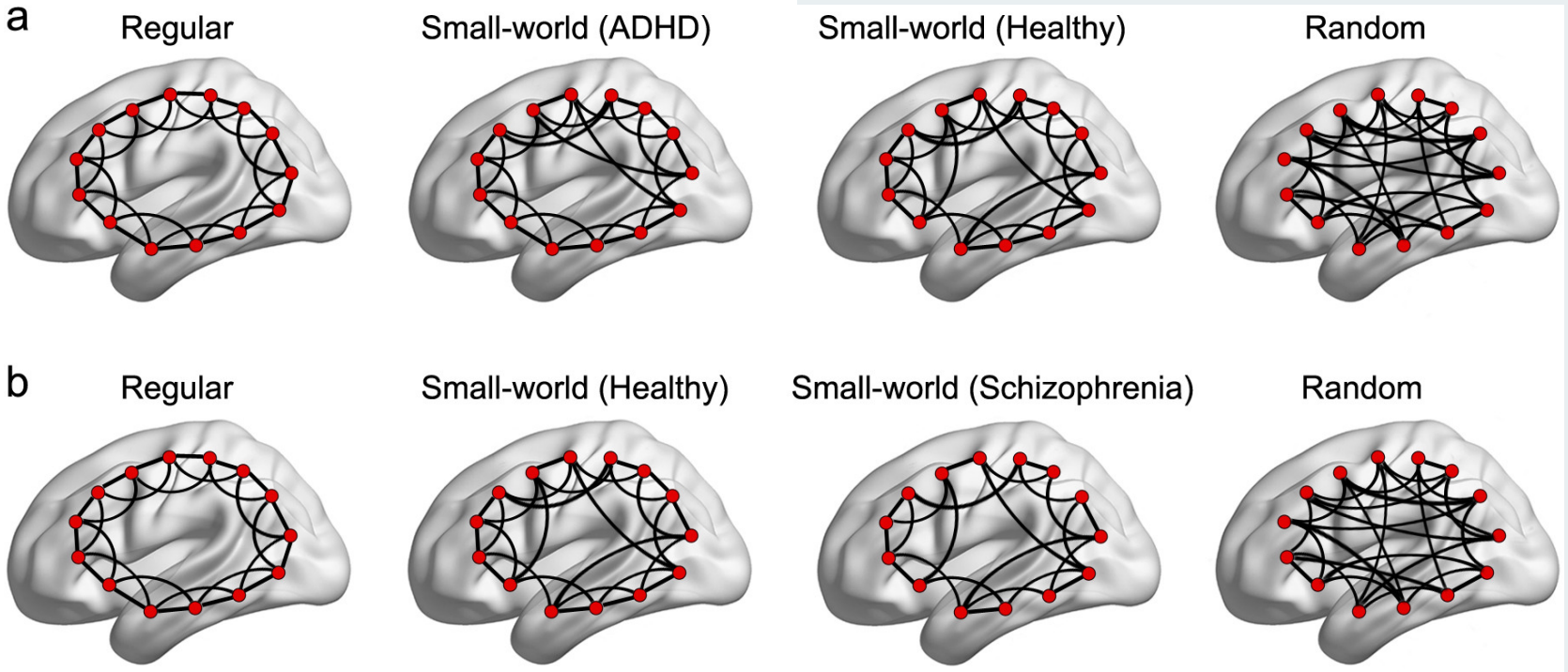


Feb. 26, 2024

Liao, X., Vasilakos, A. V., & He, Y. (2017). Small-world human brain networks: perspectives and challenges. *Neuroscience & Biobehavioral Reviews*, *77*, 286-300.

Social Network Case

Small World & Neuroscience



Liao, X., Vasilakos, A. V., & He, Y. (2017). Small-world human brain networks: perspectives and challenges. *Neuroscience & Biobehavioral Reviews*, *77*, 286-300.

Social Network Case

Scale–free Network

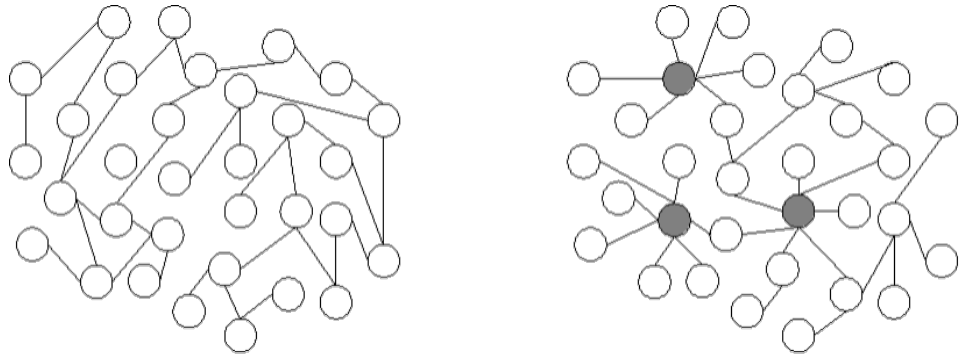
– A **scale-free network** is a network whose degree distribution follows a power law, at least asymptotically. That is, the fraction $P(k)$ of nodes in the network having k connections to other nodes goes for large values of k as

$$P(k) \sim k^{-\gamma}$$

– where γ is a parameter whose value is typically in the range $2 < \gamma < 3$ (wherein the second moment (scale parameter) of k^{γ} is infinite but the first moment is finite), although occasionally it may lie outside these bounds.

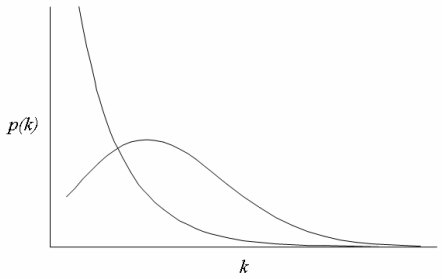
Social Network Case

Scale–free Network

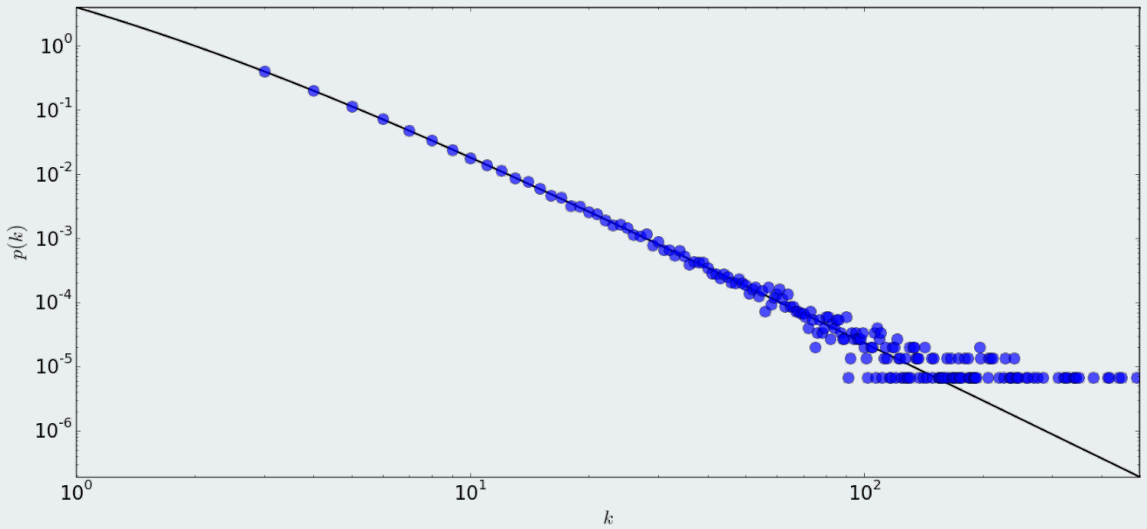


(a) Random network (b) Scale-free network

Random network (a) and scale-free network (b). In the scale-free network, the larger hubs are highlighted.



Complex network degree distribution of random and scale-free



Degree distribution for a network with 150000 vertices and mean degree = 6 created using the Barabási–Albert model (blue dots).

The distribution follows an analytical form given by the ratio of two gamma functions (black line) which approximates as a power-law.

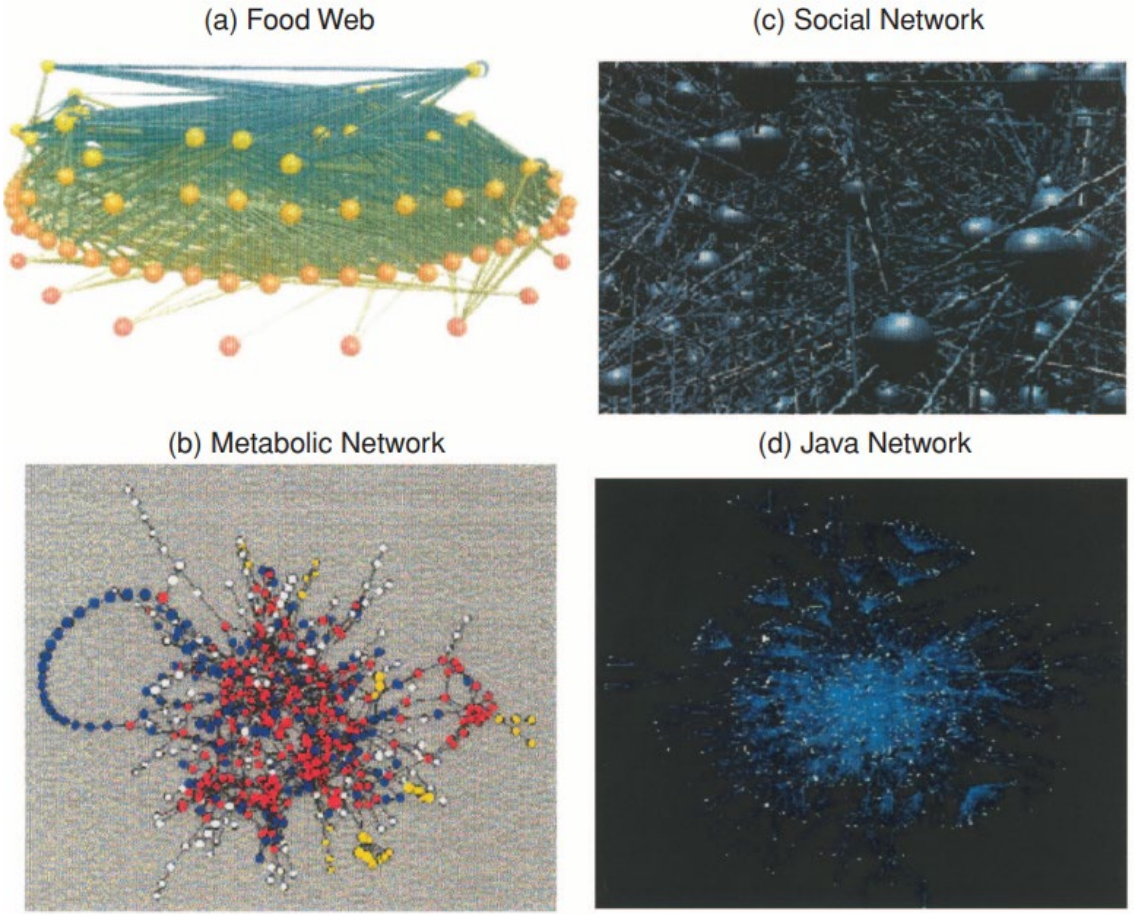
Social Network Case

Six Degrees of Separation

– Six degrees of separation is the idea that all people are six or fewer social connections away from each other. As a result, a chain of "**friend of a friend**" statements can be made to connect any two people in a maximum of six steps. It is also known as the six handshakes rule.

[1] https://en.wikipedia.org/wiki/Six_degrees_of_separation
[2] https://www.ualberta.ca/newtrail/ideas/forget-6-degrees-of-separation.html

Network Examples



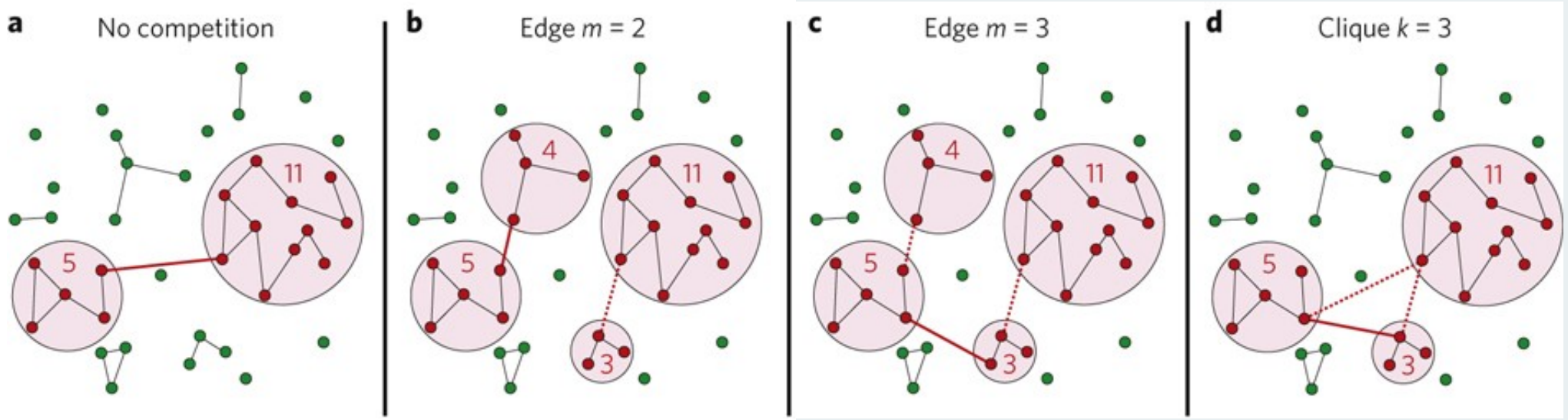
Wiring diagrams for several complex networks. (a) The food web of Little Rock Lake shows "who eats whom" in the lake. The nodes are functionally distinct "trophic species". (b) The metabolic network of the yeast cell is built up of nodes—the substrates that are connected to one another through links, which are the actual metabolic reactions. (c) A social network that visualizes the relationship among different groups of people in Canberra, Australia. (d) The software architecture for a large component of the Java Development Kit 1.2. The nodes represent different classes, and a link is set if there is some relationship (use, inheritance, or composition) between two corresponding classes.

 [1] https://www.ee.cityu.edu.hk/~gchen/pdf/CW-CASM03-overview.pdf

Level of Analysis

- Although analysis levels are not mutually exclusive, there are three general levels into which networks may fall: micro-level, meso-level, and macro-level.
- **Micro level:** At the micro level, social network research typically begins with an individual, snowballing as social relationships are traced, or may begin with a small group of individuals in a particular social context. For example, dyadic level, triad level, actor level, and subset level.

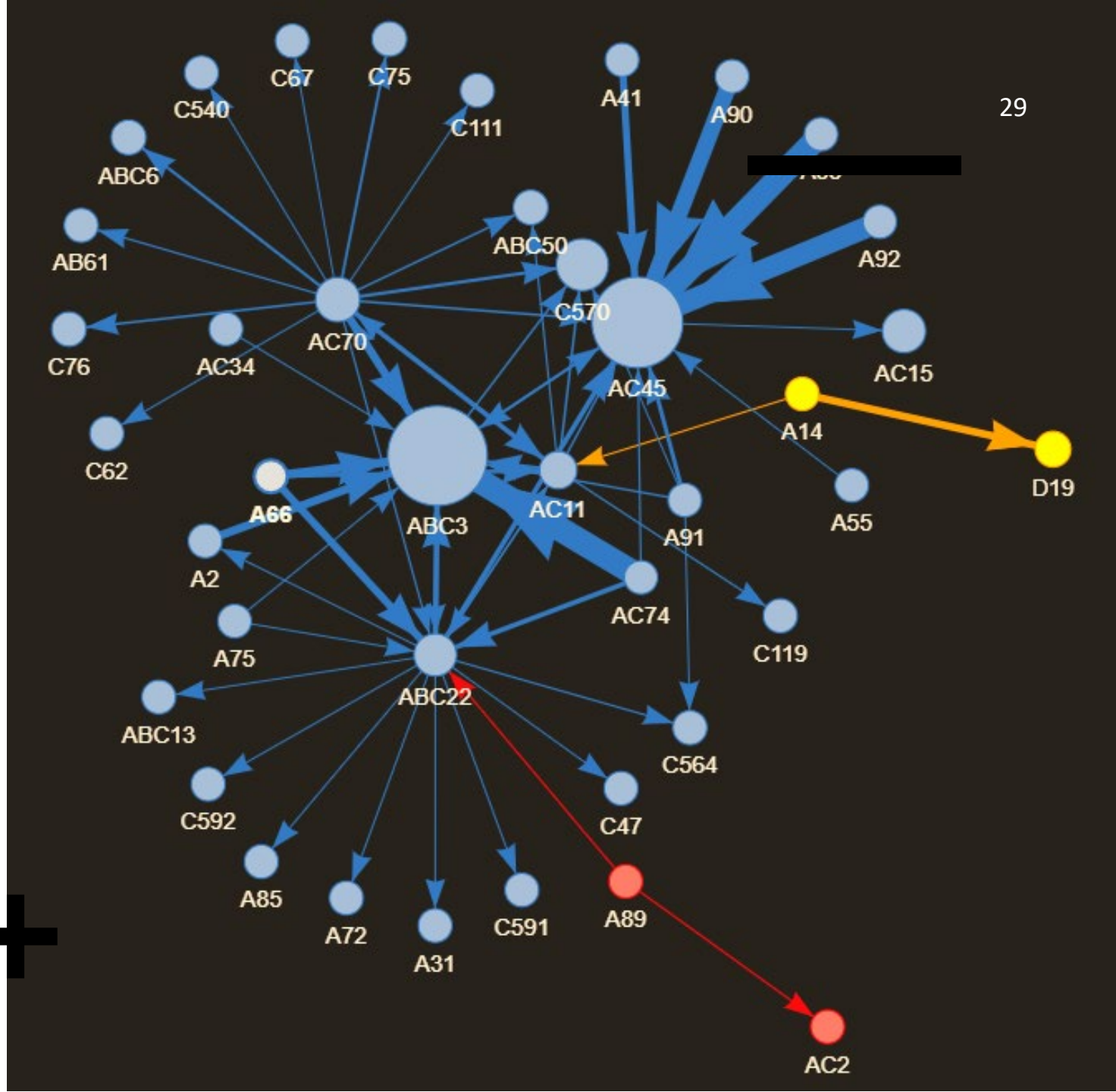
Level of Analysis

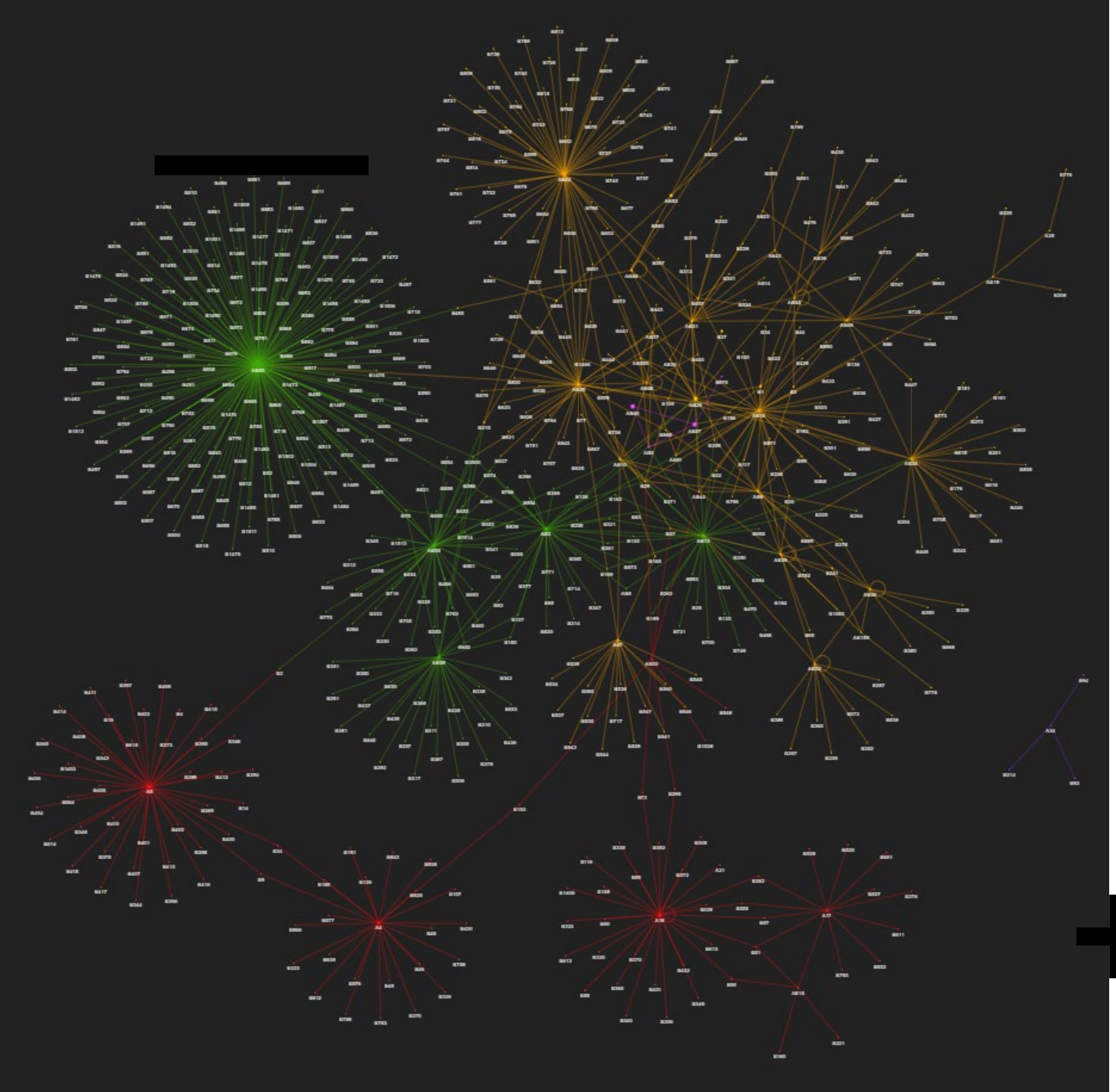


a, Non-competitive Erdös–Rényi percolation: new links are randomly chosen and just add. **b**, Edge competition: *m*=2 links compete with each other and clusters of sizes 4 and 5 win the competition and join to form a new cluster of size 9. **c**, *m*=3 links compete with one another. Clusters of sizes 3 and 5 join. **d**, Clique competition (*k*=3): three links within a clique compete. Clusters of sizes 3 and 5 join. Throughout all panels, small discs indicate nodes; solid black lines indicate existing links; large shaded discs indicate clusters entering the competition with numbers denoting their sizes; red dashed lines indicate potentially new, competing links; solid red lines indicate actual links added.

Level of Analysis

- **Meso level:** Meso-level theories begin with a population size that falls between the micro- and macro-levels. However, meso-level may also refer to analyses that are specifically designed to reveal connections between micro- and macro-levels. Meso-level networks are low-density and may exhibit causal processes distinct from interpersonal micro-level networks.
- For example, organizations, randomly distributed networks, scale-free networks



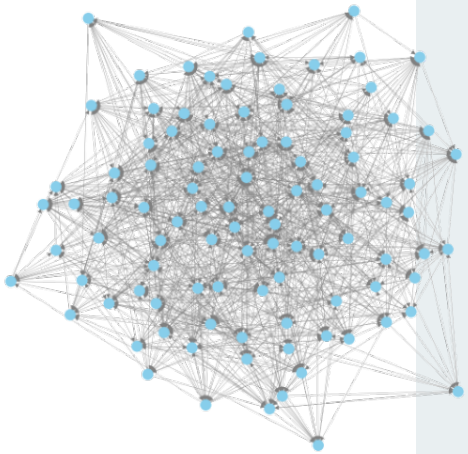


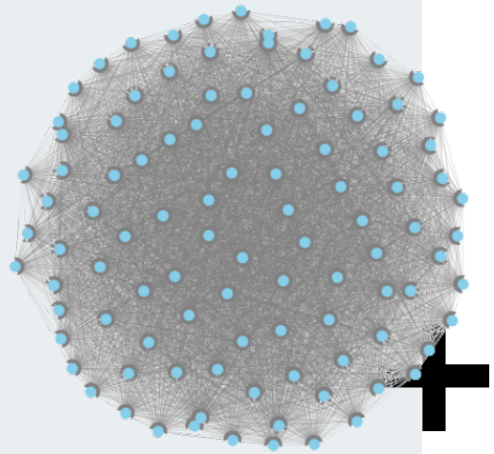
Level of Analysis

– **Macro level:** Rather than tracing interpersonal interactions, macro-level analyses generally trace the outcomes of interactions, such as economic or other resource transfer interactions over a large population, such as large-scale networks and complex networks.

Open Discussion

– After understanding the basis of network structure, please give three network examples, and elaborate the following elements:
  – **Node (actor): …**
  – **Edge (tie): …**
  – **Subgroup/ Group:**



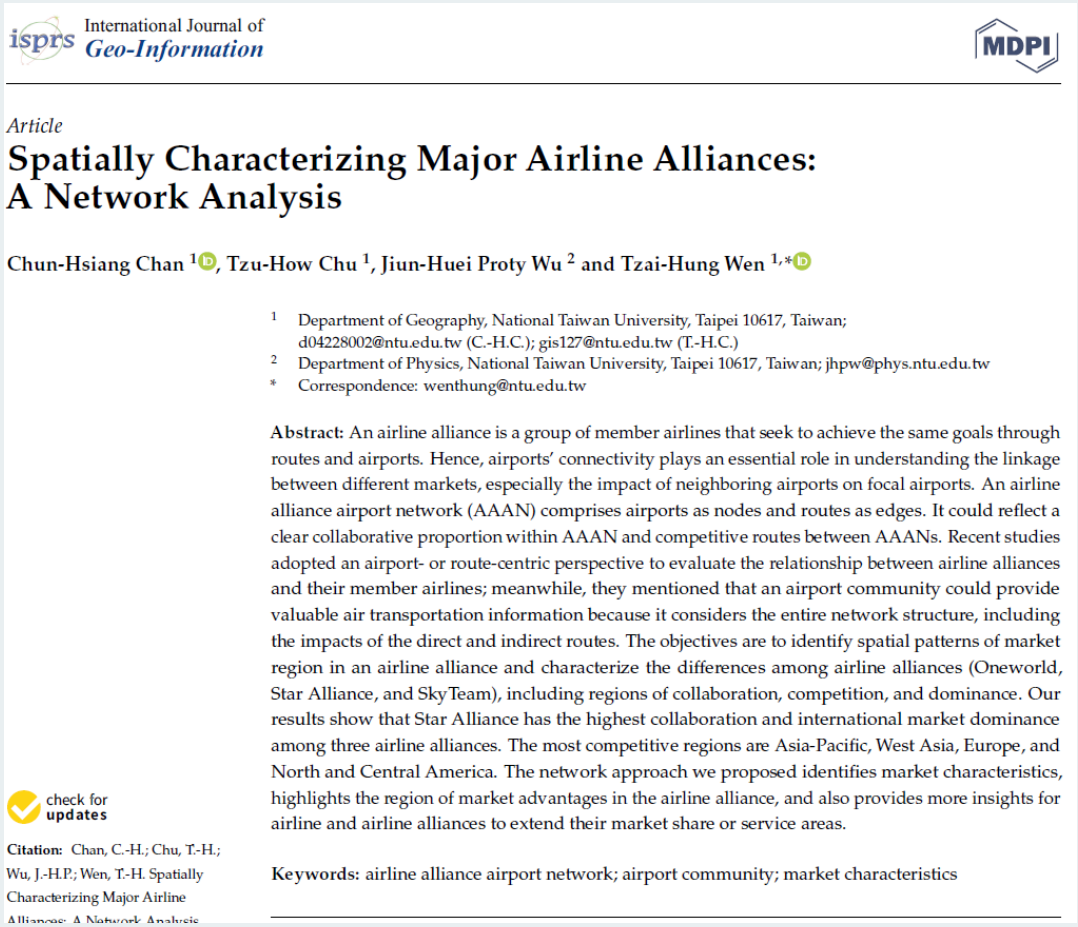


Paper Reading

Chan, C. H., Chu, T. H., Wu, J. H. P., & Wen, T. H. (2021). Spatially Characterizing Major Airline Alliances: A Network Analysis. *ISPRS International Journal of Geo-Information*, 10(1), 37.

Questions:

1. What is the objective of this paper?
2. What are the nodes (actors) and edges (ties) of the transportation network in this paper?
3. How did the authors formulate the transportation network?
4. What are the findings of this study?



isprs International Journal of *Geo-Information*

MDPI

Article

Spatially Characterizing Major Airline Alliances: A Network Analysis

Chun-Hsiang Chan [1], Tzu-How Chu [1], Jiun-Huei Proty Wu [2] and Tzai-Hung Wen [1,*]

[1] Department of Geography, National Taiwan University, Taipei 10617, Taiwan; d04228002@ntu.edu.tw (C.-H.C.); gis127@ntu.edu.tw (T.-H.C.)
[2] Department of Physics, National Taiwan University, Taipei 10617, Taiwan; jhpw@phys.ntu.edu.tw
* Correspondence: wenthung@ntu.edu.tw

Abstract: An airline alliance is a group of member airlines that seek to achieve the same goals through routes and airports. Hence, airports' connectivity plays an essential role in understanding the linkage between different markets, especially the impact of neighboring airports on focal airports. An airline alliance airport network (AAAN) comprises airports as nodes and routes as edges. It could reflect a clear collaborative proportion within AAAN and competitive routes between AAANs. Recent studies adopted an airport- or route-centric perspective to evaluate the relationship between airline alliances and their member airlines; meanwhile, they mentioned that an airport community could provide valuable air transportation information because it considers the entire network structure, including the impacts of the direct and indirect routes. The objectives are to identify spatial patterns of market region in an airline alliance and characterize the differences among airline alliances (Oneworld, Star Alliance, and SkyTeam), including regions of collaboration, competition, and dominance. Our results show that Star Alliance has the highest collaboration and international market dominance among three airline alliances. The most competitive regions are Asia-Pacific, West Asia, Europe, and North and Central America. The network approach we proposed identifies market characteristics, highlights the region of market advantages in the airline alliance, and also provides more insights for airline and airline alliances to extend their market share or service areas.

Keywords: airline alliance airport network; airport community; market characteristics

check for updates

Citation: Chan, C.-H.; Chu, T.-H.; Wu, J.-H.P.; Wen, T.-H. Spatially Characterizing Major Airline Alliances: A Network Analysis

References

- Wasserman, S., & Faust, K. (1994). Social network analysis: Methods and applications.
- Tsvetovat, M., & Kouznetsov, A. (2011). Social Network Analysis for Startups: Finding connections on the social web. "O'Reilly Media, Inc.".
- Hanneman, R. A., & Riddle, M. (2005). Introduction to social network methods.
- https://en.wikipedia.org/wiki/Social_network

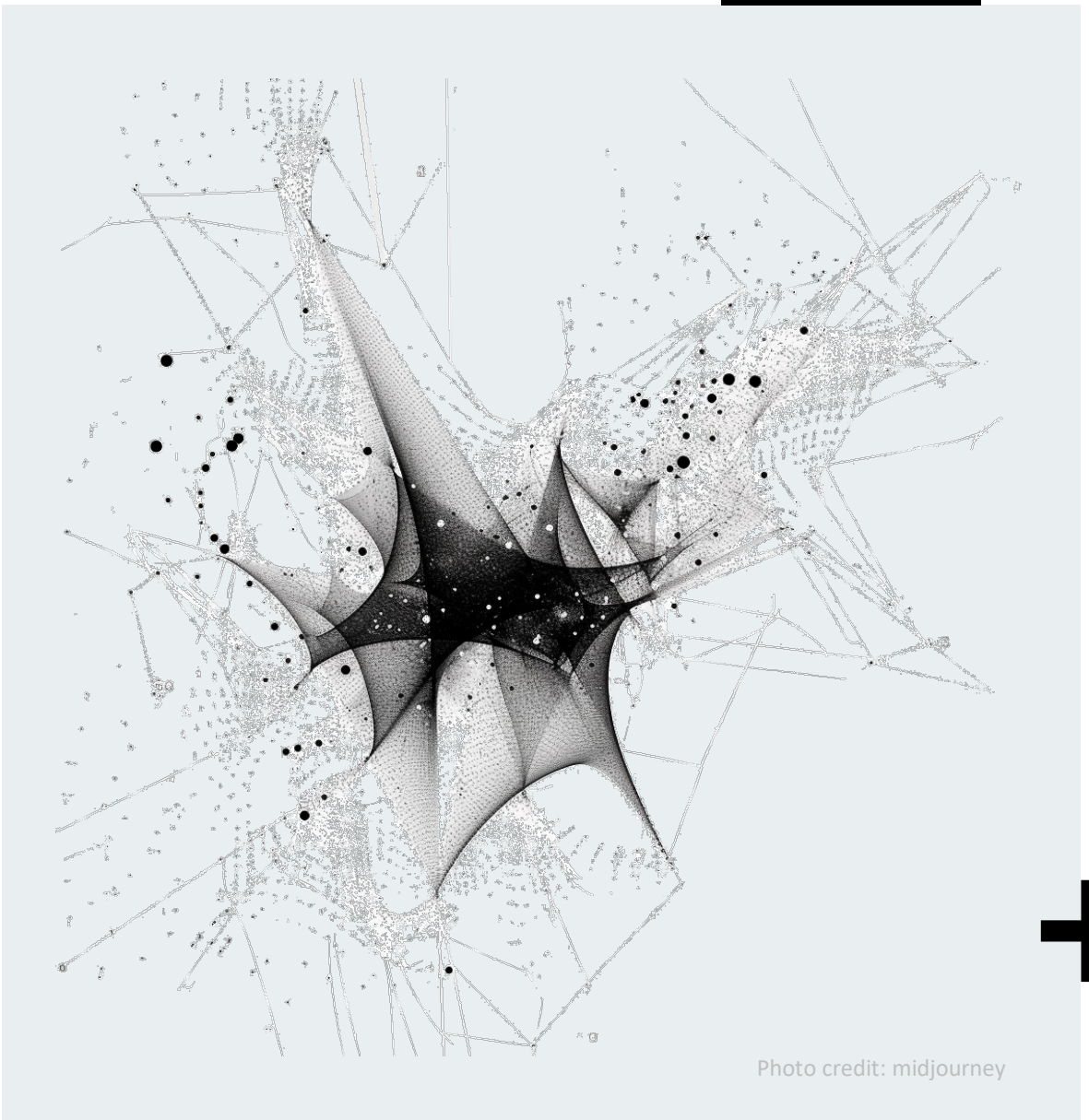


Photo credit: midjourney

The End

Thank you for your attention!

Email: chchan@ntnu.edu.tw
Website: toodou.github.io

Photo credit: midjourney