

# Advanced Data Visualization

**CS 6965**

**Spring 2018**

**Prof. Bei Wang Phillips**

**University of Utah**



**Lecture 22**

# Foundations for Network Visualization

A yellow circle with a white outline, containing the letters 'NV' in white. The circle is positioned in the bottom right corner of the slide.

NV

MOTIVATION for

Network  
Visualization  
& Analysis

NV

# Let's begin with social networks....

Some fun reading: <https://www.factslides.com/s-Facebook>

# ZUCKERBERG'S 10 RULES



<https://www.youtube.com/watch?v=HMpWXQpogqI>

# Recent research at Facebook

February 2, 2018

## StarSpace: Embed All The Things!

Conference on Artificial Intelligence (AAAI)

We present StarSpace, a general-purpose neural embedding model that can solve a wide variety of problems: labeling tasks such as text classification, ranking tasks such as information retrieval/web search, collaborative filtering-based or content-based recommendation, embedding of multi-relational graphs, and learning word, sentence or document level embeddings.

By: **Ledell Wu**, Adam Fisch, Sumit Chopra, Keith Adams, **Antoine Bordes**, **Jason Weston**

Areas:



**Facebook AI Research (FAIR)**

# Recent research at Facebook

August 28, 2017

## Social Hash Partitioner: A Scalable Distributed Hypergraph Partitioner

Very Large Data Bases Conference (VLDB)

We design and implement a distributed algorithm for balanced  $k$ -way hypergraph partitioning that minimizes fanout, a fundamental hypergraph quantity also known as the communication volume and  $(k - 1)$ -cut metric, by optimizing a novel objective called probabilistic fanout. This choice allows a simple local search heuristic to achieve comparable solution quality to the best existing hypergraph partitioners.

By: Igor Kabiljo, **Brian Karrer**, Mayank Pundir, **Sergey Pupyrev**, Alon Shalita

Areas:



**Data Science**



**Systems & Networking**

<https://research.fb.com/publications/>

# Recent research at Facebook

October 22, 2017

## Grad-CAM: Visual Explanations from Deep Networks via Gradient-based Localization

International Conference on Computer Vision (ICCV)

We propose a technique for producing ‘visual explanations’ for decisions from a large class of Convolutional Neural Network (CNN)-based models, making them more transparent and explainable.

By: Ramprasaath R. Selvaraju, Michael Cogswell, Abhishek Das, Ramakrishna Vedantam, **Devi Parikh**, **Dhruv Batra**

Areas:



Facebook AI Research (FAIR)



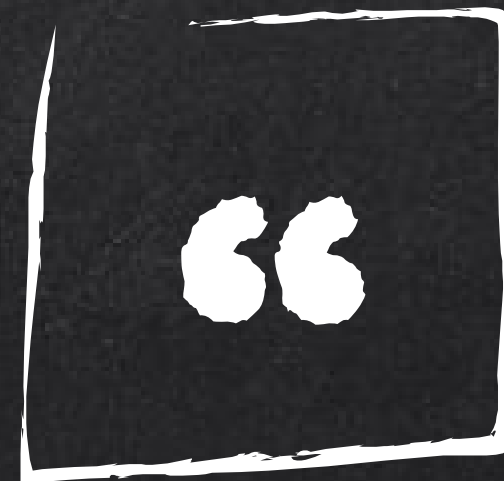
# How Facebook beat Myspace?

<http://www.digitaltrends.com/social-media/former-myspace-ceo-reveals-what-facebook-did-right-to-dominate-social-media/>

<http://www.forbes.com/sites/adamhartung/2011/01/14/why-facebook-beat-myspace/#10a134077023>

## HOW FACEBOOK BEAT MYSPACE?

- Same audience, social media revolution
- The failure of professional management (by News Corps.) v.s White Space management (letting the marketplace decide)
- What do users want? User-driven apps and functionalities



Facebook was able to overtake MySpace because Facebook “perfected” the social networking concept, whereas MySpace just introduced people to it.

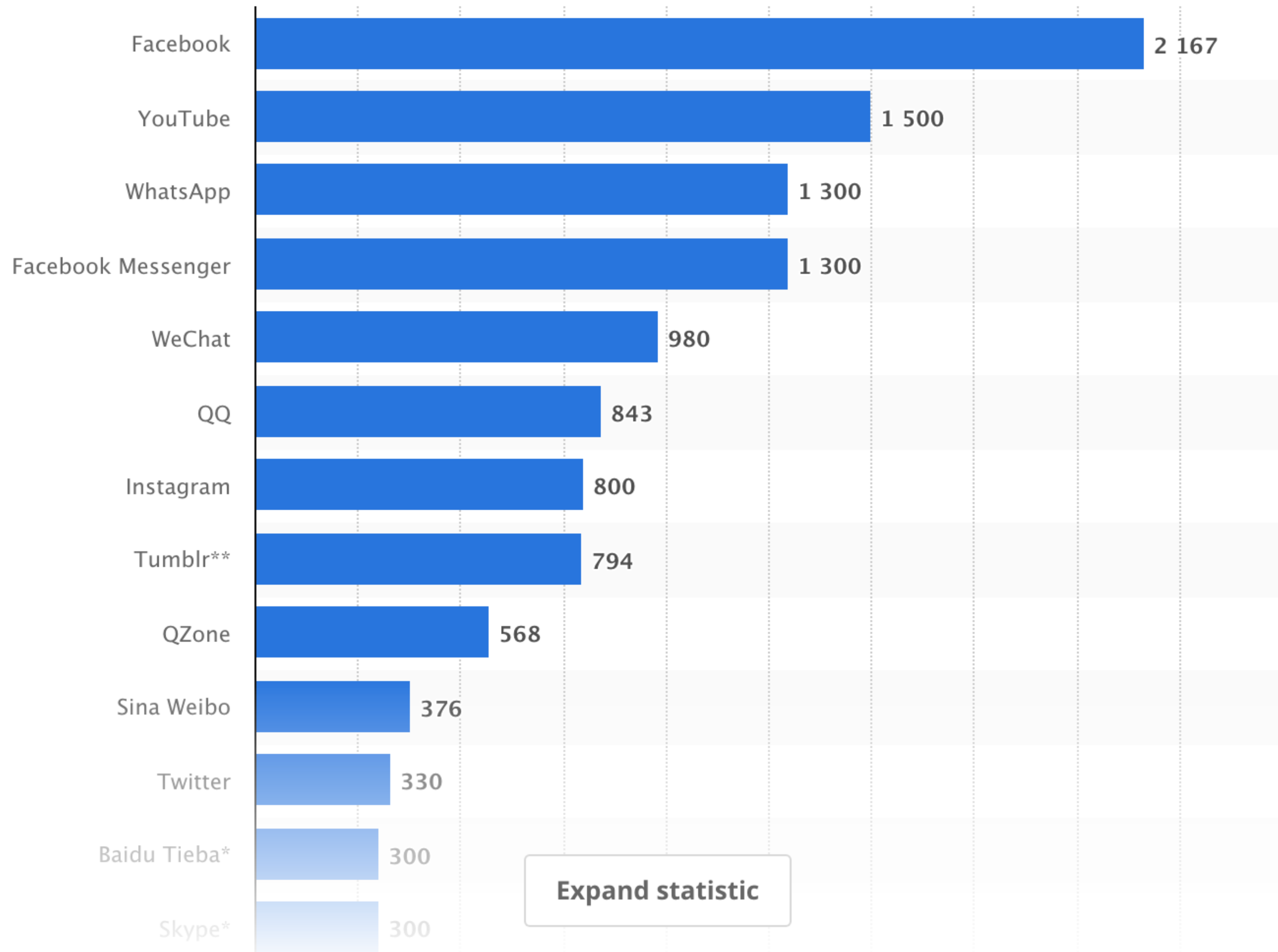
- Mike Jones, formerly the head of MySpace.

Read more: <http://www.digitaltrends.com/social-media/former-myspace-ceo-reveals-what-facebook-did-right-to-dominate-social-media/#ixzz44yAwZx91>

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## HOW FACEBOOK BEAT MYSPACE?

- ❑ MySpace put up barriers to user enjoyment by forcing members to use anonymous pseudonyms in place of their real identities.
- ❑ As of March 2015, Facebook has 1.44 billion users a month, Myspace has 50 million
- ❑ Which ones are the leading social networks worldwide?



# HAS GOOGLE+ REALLY DIED?

- The number of truly active users on Google+ is significantly less than 1% of the total 2.2 billion Google users, according to a study published on April 14, 2015
- On April 24, 2014, Alexia Tsotsis and Matthew Panzarino wrote in TechCrunch that “Google+ Is Walking Dead.”
- Google has consistently failed to get to heart of social. People prefer Facebook to Google+, fundamentally because Google’s approach to social isn’t fun.
- A head-on challenge to Facebook was inevitably unsuccessful.
- Failure to offer something genuinely new
- Further reading: <http://www.forbes.com/sites/stevedenning/2015/04/23/has-google-really-died/#34f09f5b16e9> <http://www.forbes.com/sites/stevedenning/2015/04/17/five-reasons-why-google-died/#6542a4dd33c0>

## HAS GOOGLE+ REALLY DIED?

- Nov, 2015. Major redesign of Google+
- Communities and Collections functionality: narrow the service's scope into interest-based networking

# 2017



WHY YOU SHOULD  
STOP THINKING  
GOOGLE+  
IS DEAD

<https://blumint.co/stop-thinking-google-plus-dead>



## FUTURE OF FACEBOOK?

- Virtual reality: Gear VR; Oculus Rift.
- AI
- Further reading: <http://www.businessinsider.com/mark-zuckerberg-interview-with-axel-springer-ceo-mathias-doepfner-2016-2>

Mark Zuckerberg: "Virtual Reality is the next platform"



<https://www.youtube.com/watch?v=8vQggbWtjOo>

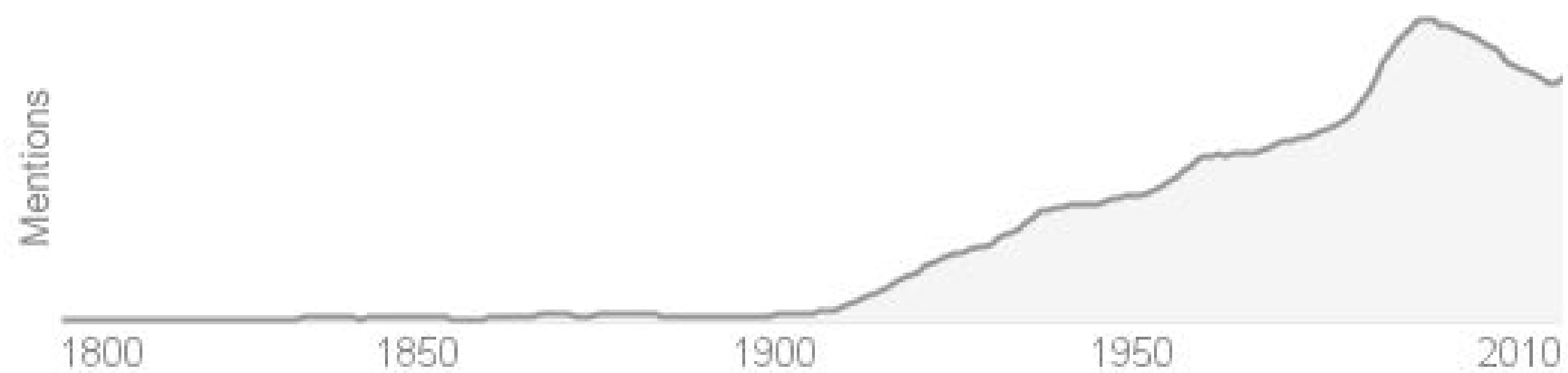


<https://www.youtube.com/watch?v=YulgyKLPt3s>

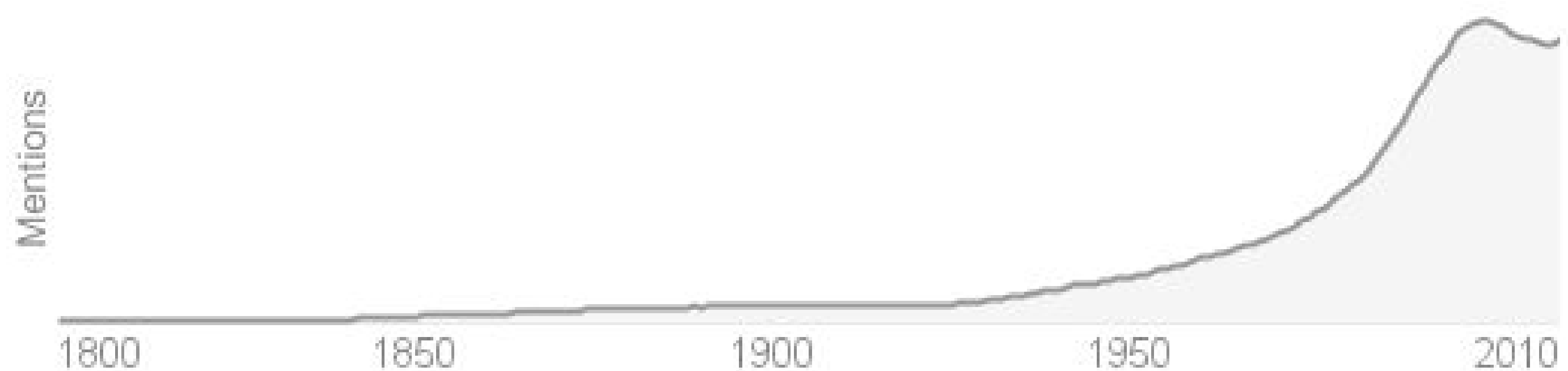
**Imaging new form of  
data available with  
advancement with social  
networks!**

# GRAPH ANALYSIS

Use over time for: graph



Use over time for: network



# GRAPHS AND NETWORKS

WHAT IS A GRAPH?



**Graph** may refer to:

**In information science:**

- **Chart**, a graphical representation of data also called a "graph"
- **Infographic**, a graph intermixing data and visual or textual information

**In mathematics:**

- **Graph (discrete mathematics)**, a set of vertices and edges
  - **Graph theory**, the study of such graphs
- **Graph of a function**

**In computer science:**

- **Graph (abstract data type)**, an abstract data type representing relationships or connections
- **Conceptual graph**, a model for knowledge representation and reasoning

WHAT IS A NETWORK?

NETWORK SCIENCE?

COMPLEX NETWORK?

**Network science** is an academic field which studies **complex networks** such as **telecommunication networks**, **computer networks**, **biological networks**, cognitive and **semantic networks**, and **social networks**, considering distinct elements or actors represented by *nodes* (or *vertices*) and the connections between the elements or actors as *links* (or *edges*). The field draws on theories and methods including **graph theory** from mathematics, **statistical mechanics** from physics, **data mining** and **information visualization** from computer science, **inferential modeling** from statistics, and **social structure** from sociology. The **United States National Research Council** defines network science as "the study of network representations of physical, biological, and social phenomena leading to predictive models of these phenomena."<sup>[1]</sup>

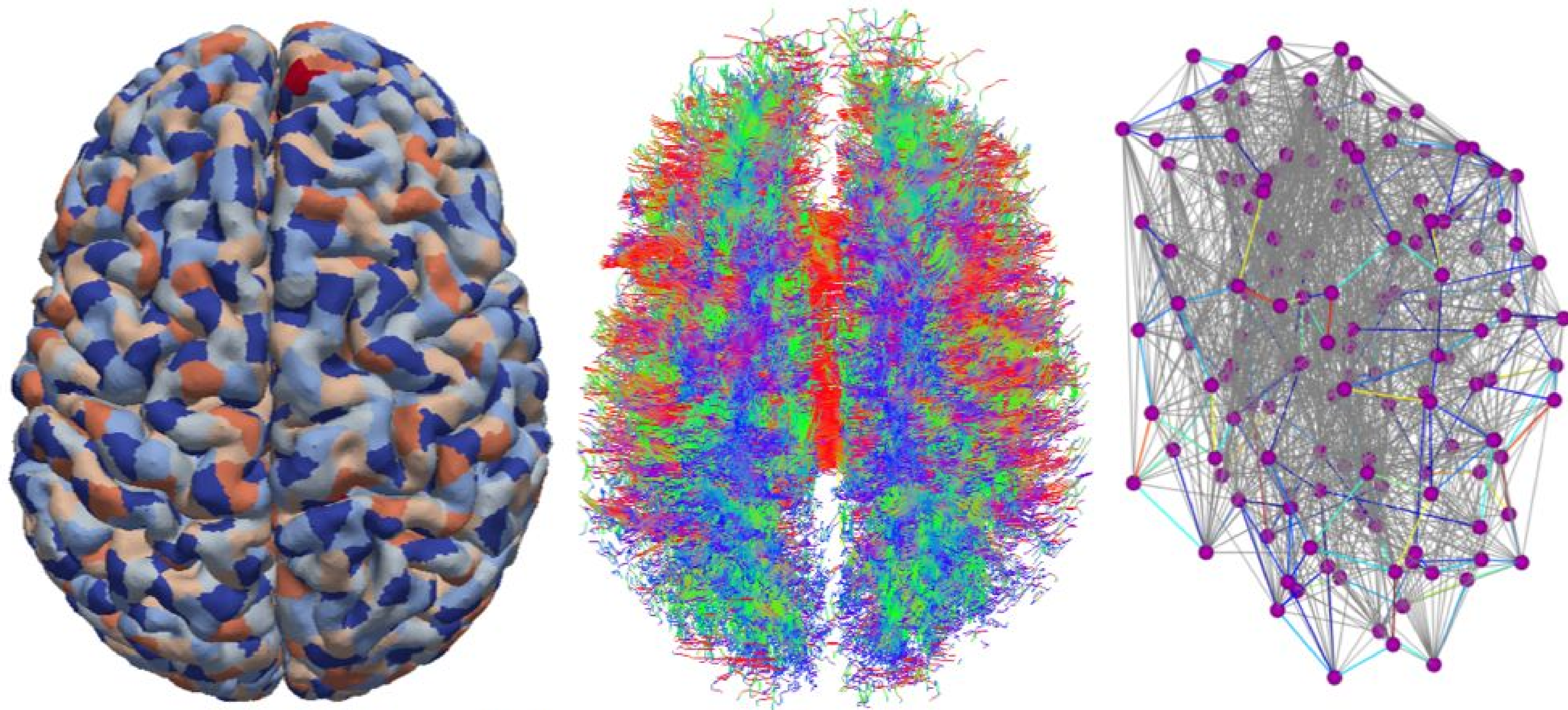
[https://en.wikipedia.org/wiki/Network\\_science](https://en.wikipedia.org/wiki/Network_science)

In the context of [network theory](#), a **complex network** is a [graph](#) (network) with non-trivial [topological](#) features—features that do not occur in simple networks such as [lattices](#) or [random graphs](#) but often occur in graphs modelling of real systems. The study of complex networks is a young and active area of scientific research (since 2000) inspired largely by the empirical study of real-world networks such as [computer networks](#), technological networks, brain networks and [social networks](#).

[https://en.wikipedia.org/wiki/Complex\\_network](https://en.wikipedia.org/wiki/Complex_network)

# BRAIN NETWORKS

- Structurally connectivity and functional connectivity
- Subject comparisons in clinical studies: medical prognosis, brain disorders, e.g., autism, Alzheimers disease, and schizophrenia.



Left: cortical surface. Middle: brain structural networks. Right: brain functional networks.

[Hammond, Gur, Johnson, 2013]

# Brain network analysis in predicting autism severity

- Correlation between brain functional networks and ADOS using kernel partial least squares regression (kPLS)
- ADOS: Autism Diagnostic Observation Schedule scores
- Regress network topology against behavioral phenotypes
- Adding topological features to raw fMRI correlations



functional network



behavior

[Wong, Palande, **Wang**, Zielinski, Anderson, Fletcher (ISBI), 2016.]

# SOCIAL NETWORKS



# SOCIAL NETWORK ANALYSIS

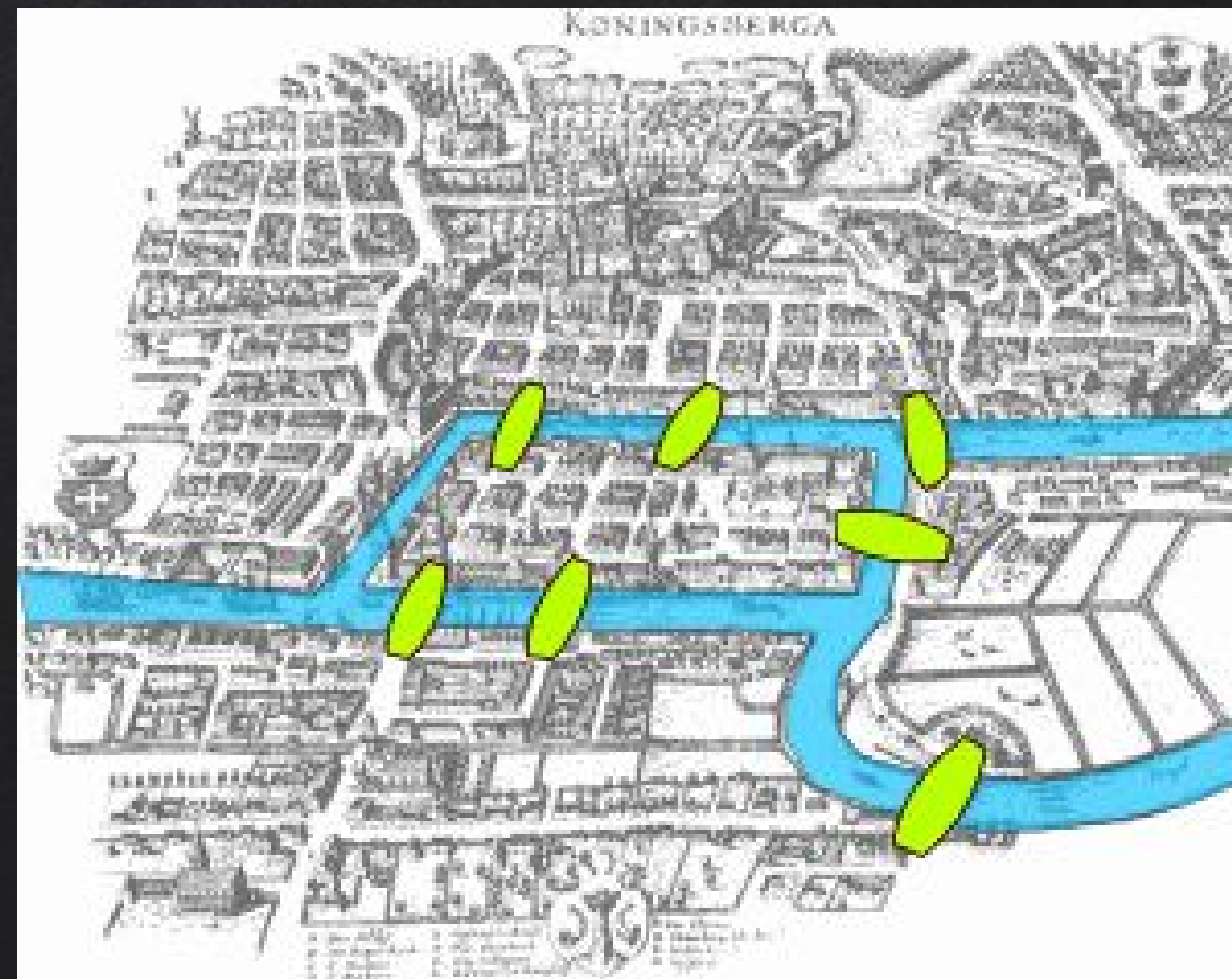
- A **social network** is a social structure made up of a set of social actors (such as individuals or organizations), sets of dyadic ties, and other social interactions between actors.
- Provides a set of methods for analyzing the structure of whole social entities as well as a variety of theories explaining the patterns observed in these structures.
- Identifies local and global patterns, locate influential entities, and examine network dynamics.
- E.g. who is the most influential person in Facebook? Hint: Obama and Huckabee in 2012 according to some statistics

BACK TO THE BASICS

# GRAPH THEORY

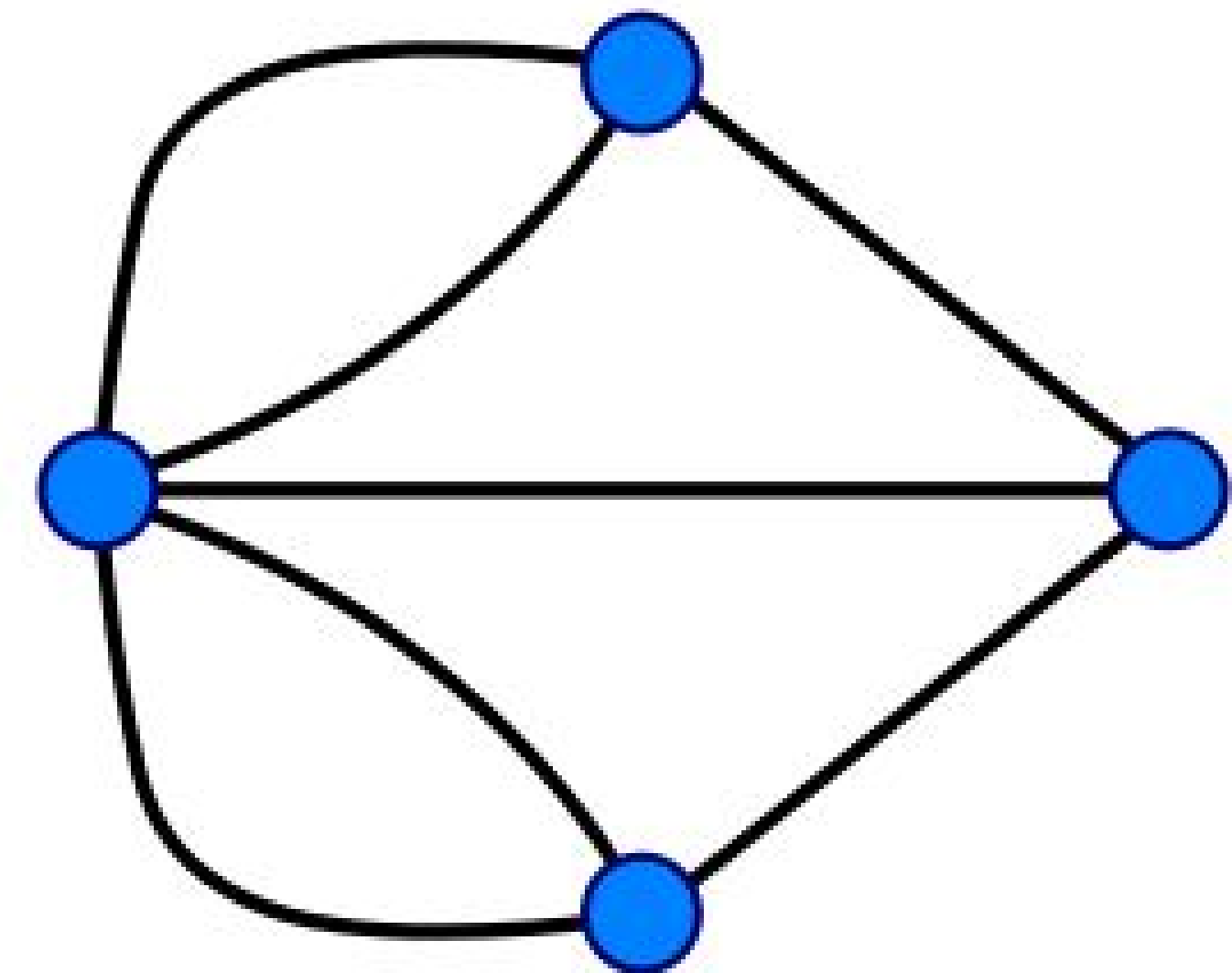
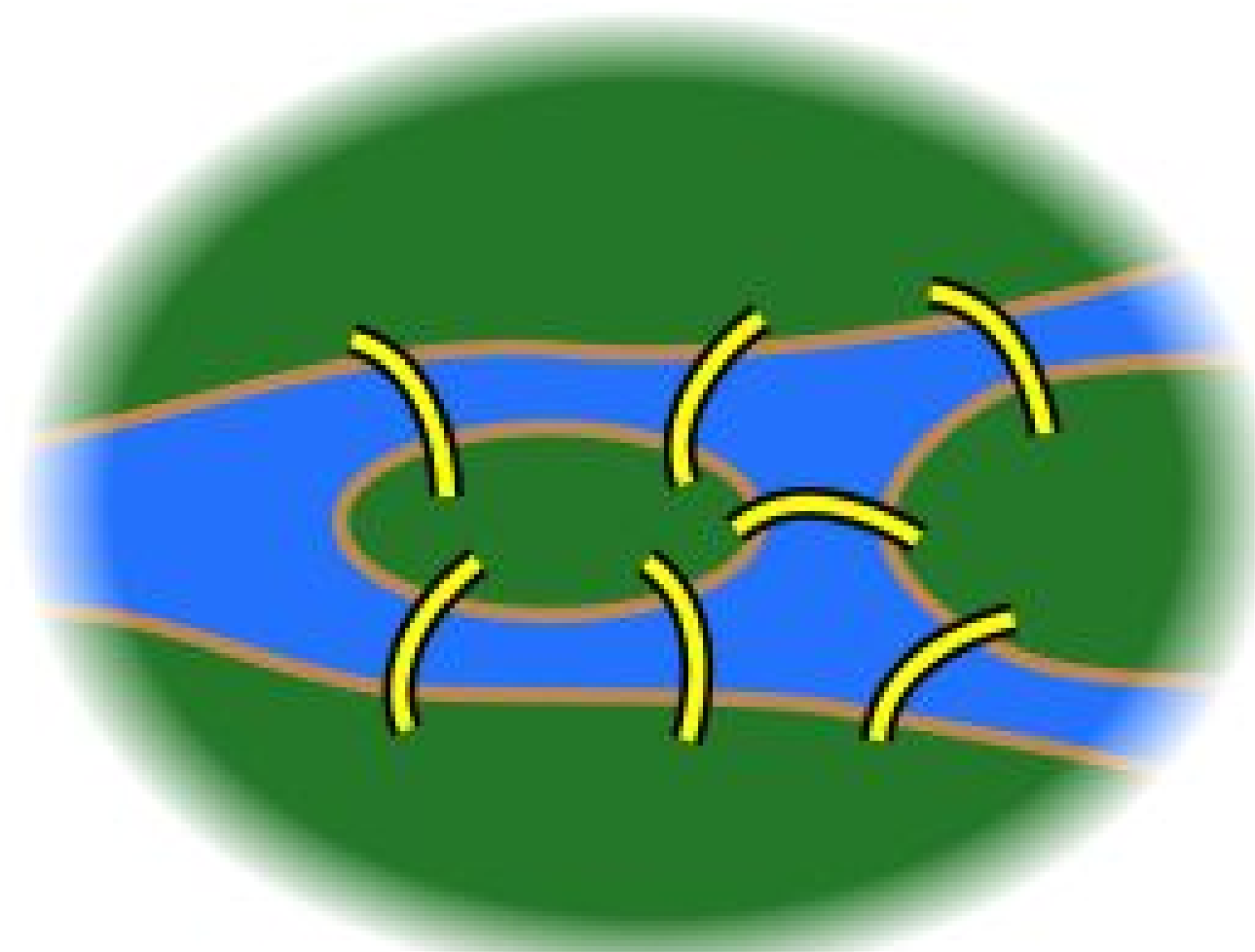
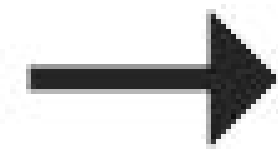
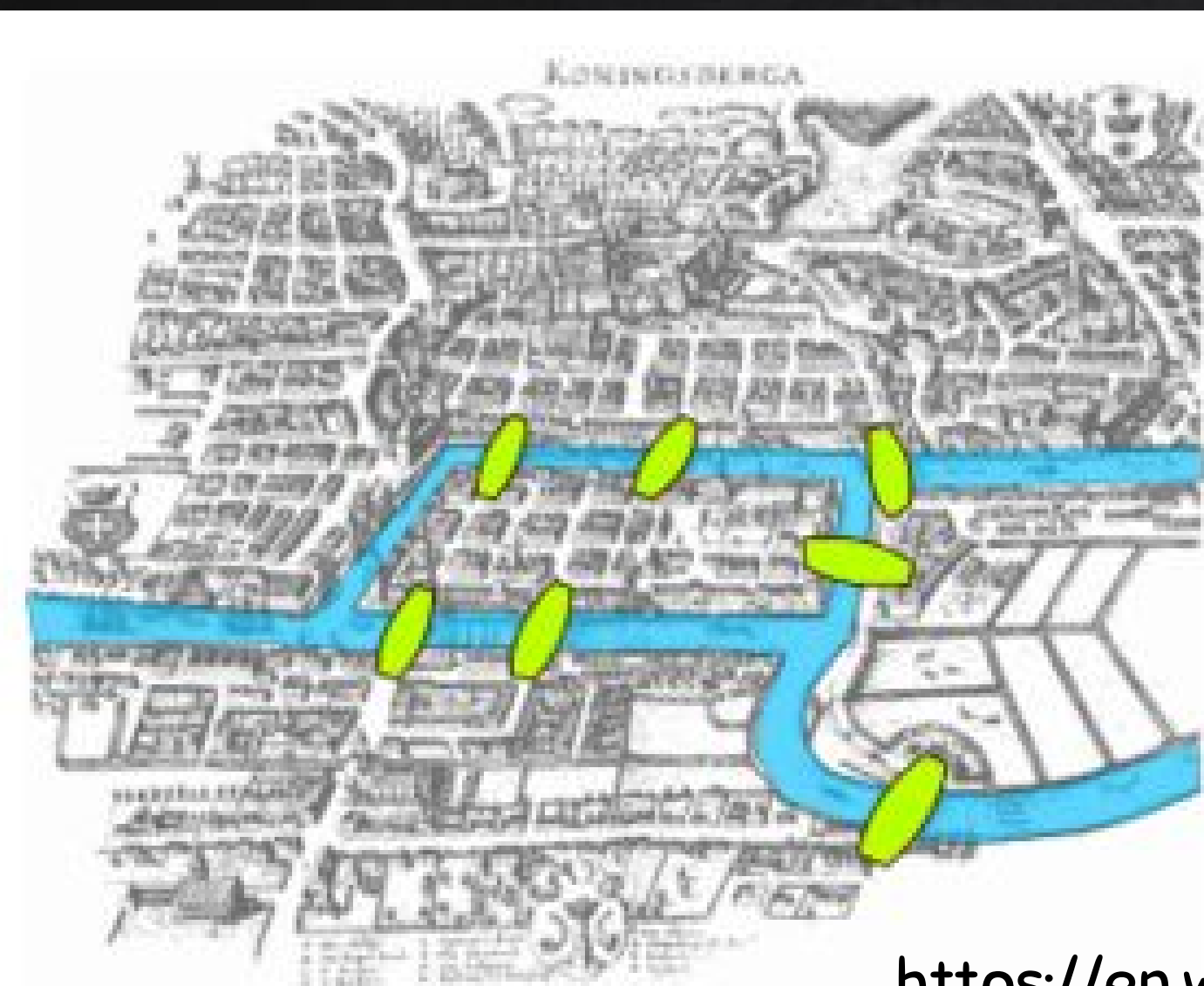
# GRAPH THEORY

- The mathematical study of properties and applications of graphs.



# Seven Bridges of Königsberg

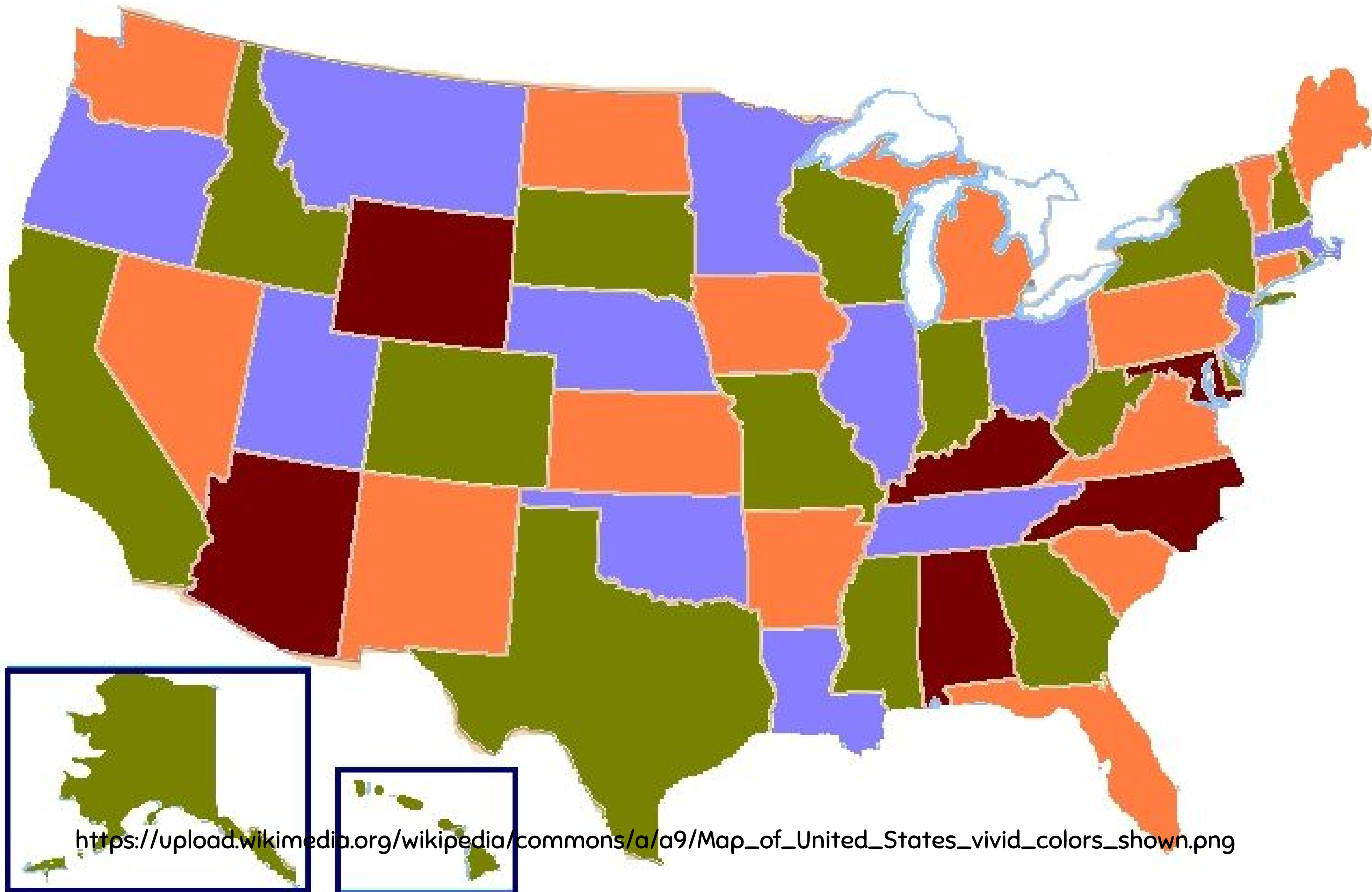
- Devise a walk through the city that would cross each bridge once and only once
- Abstraction
  - Every land mass is a **vertex**
  - Every bridge is an **edge**
  - The # of bridges touching a land mass (except starting point) must be **even**



# FOUR COLORING PROBLEM

Is it true that any map drawn in the plane may have its regions colored with four colors, in such a way that any two regions having a common border have different colors?

- Francis Guthrie, 1852
- Proven in 1976 by Appel and Haken: first major theorem to be proved using a computer
- Simpler proof using computer: 1997
- 2005, Gonthier with general purpose theorem proving software



[https://upload.wikimedia.org/wikipedia/commons/a/a9/Map\\_of\\_United\\_States\\_vivid\\_colors\\_shown.png](https://upload.wikimedia.org/wikipedia/commons/a/a9/Map_of_United_States_vivid_colors_shown.png)

# BASIC CONCEPTS IN GRAPH THEORY

EASY READING: [HTTPS://EN.WIKIPEDIA.ORG/WIKI/GRAPH\\_  
\(DISCRETE\\_MATHEMATICS\)](https://en.wikipedia.org/wiki/Graph_(discrete_mathematics))



## SOME BASIC NOTIONS

- Type of graphs:
  - directed, undirected
  - Weighted, unweighted



## The Language of Networks

0:09 / 4:21

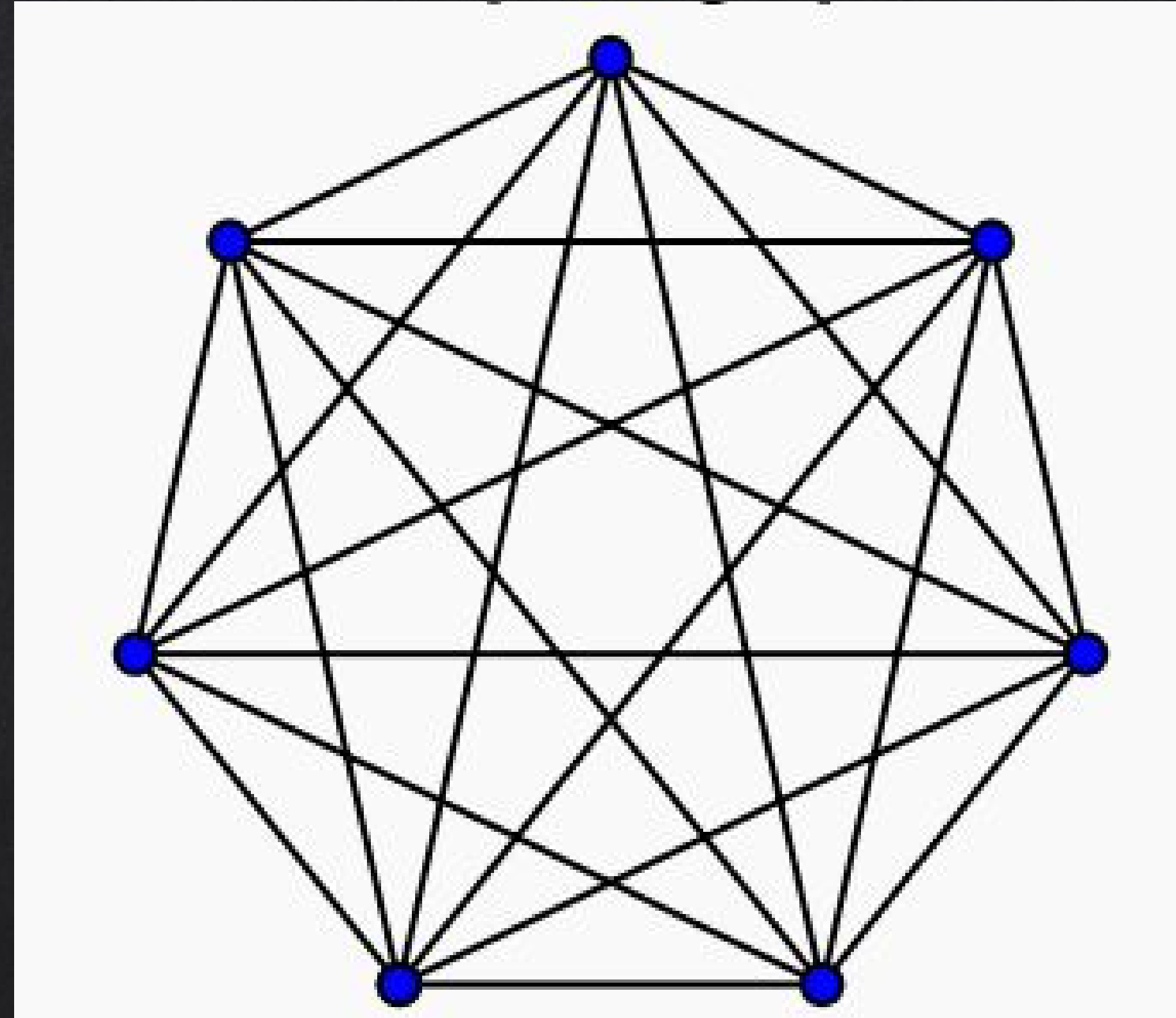
▶ ⏩ 🔊 CC ⚙️ HD 📺 🗉

<https://www.youtube.com/watch?v=82zIRaRUsaY>

# Describe graphs by structure

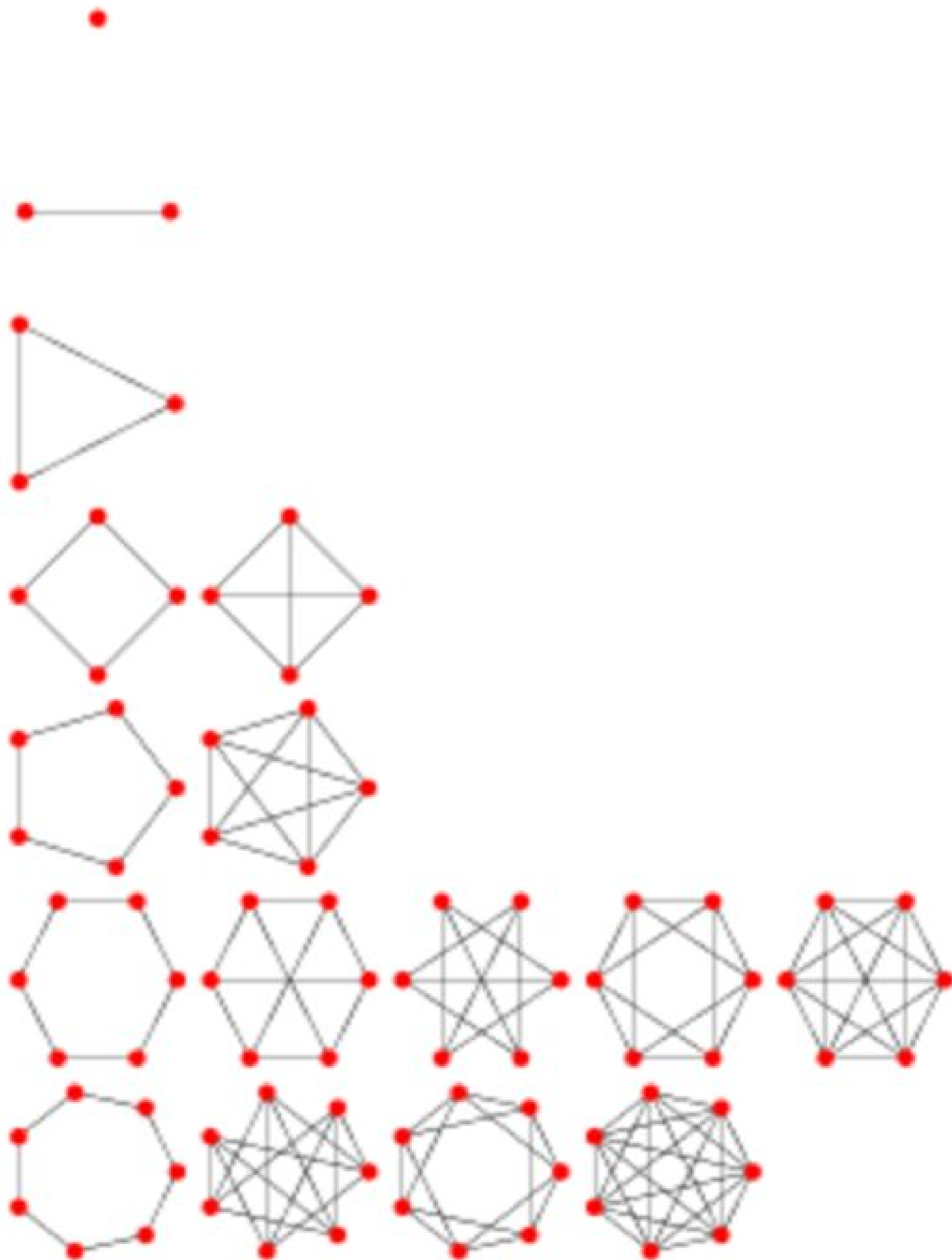
Slides inspired by: [http://www.slideshare.net/BenjaminBengfort/social-network-analysis-with-python?from\\_action=save](http://www.slideshare.net/BenjaminBengfort/social-network-analysis-with-python?from_action=save)

# Complete Graphs



Read more: [https://en.wikipedia.org/wiki/Complete\\_graph](https://en.wikipedia.org/wiki/Complete_graph)

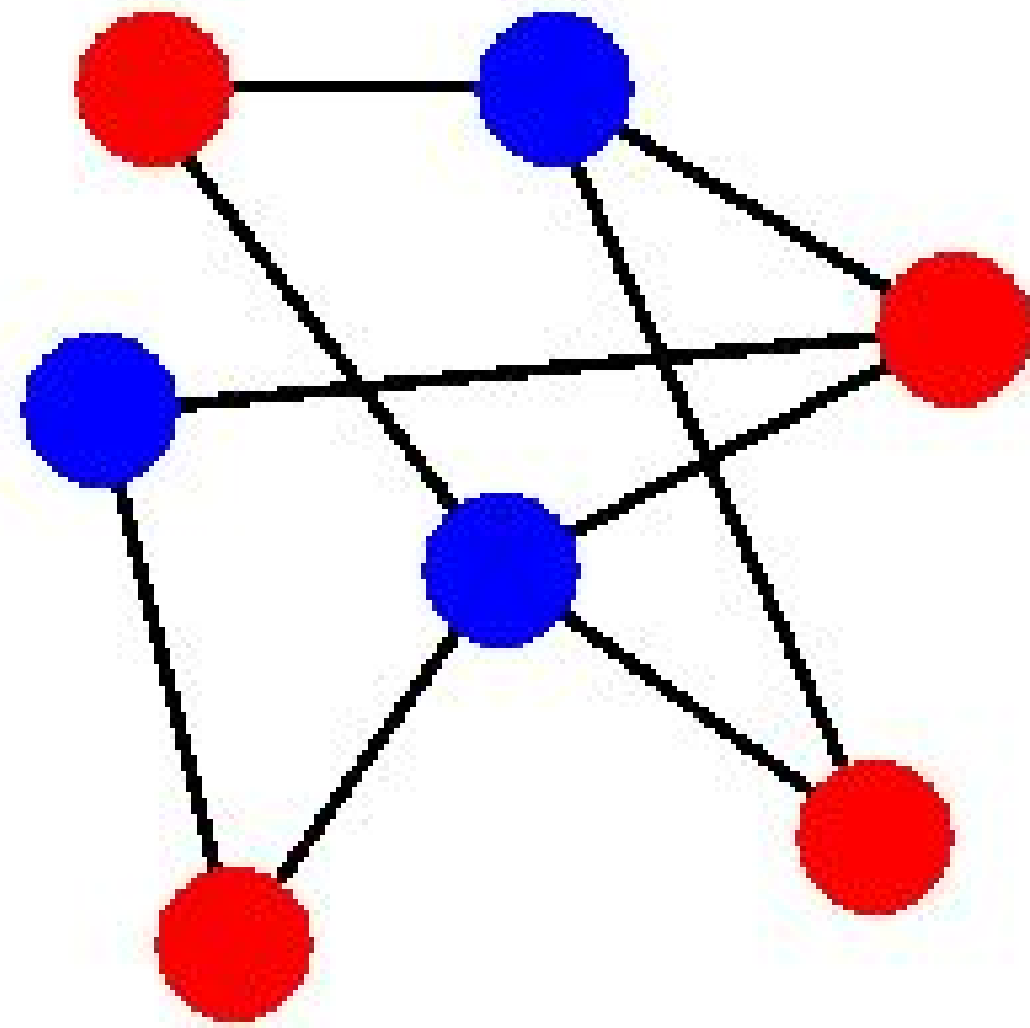
# Regular Graphs



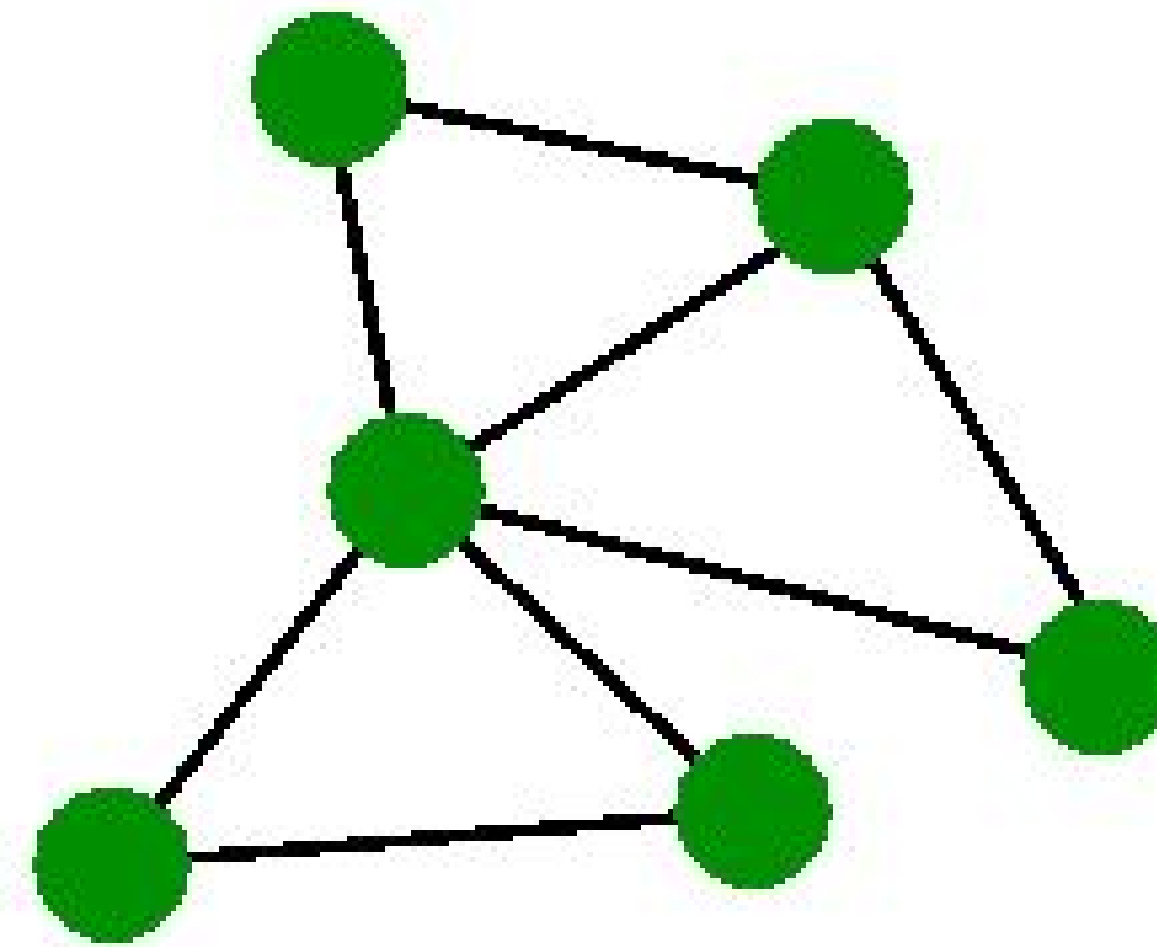
Read more: <http://mathworld.wolfram.com/RegularGraph.html>

[https://en.wikipedia.org/wiki/Regular\\_graph](https://en.wikipedia.org/wiki/Regular_graph)

# Bipartite Graphs



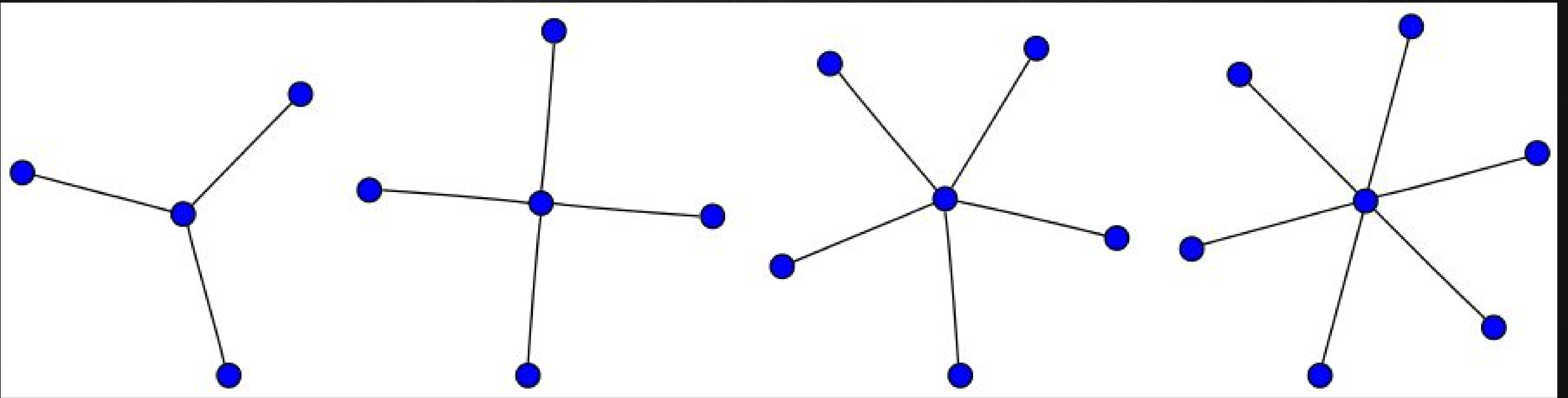
A) A Bipartite Graph



B) A non-Bipartite Graph

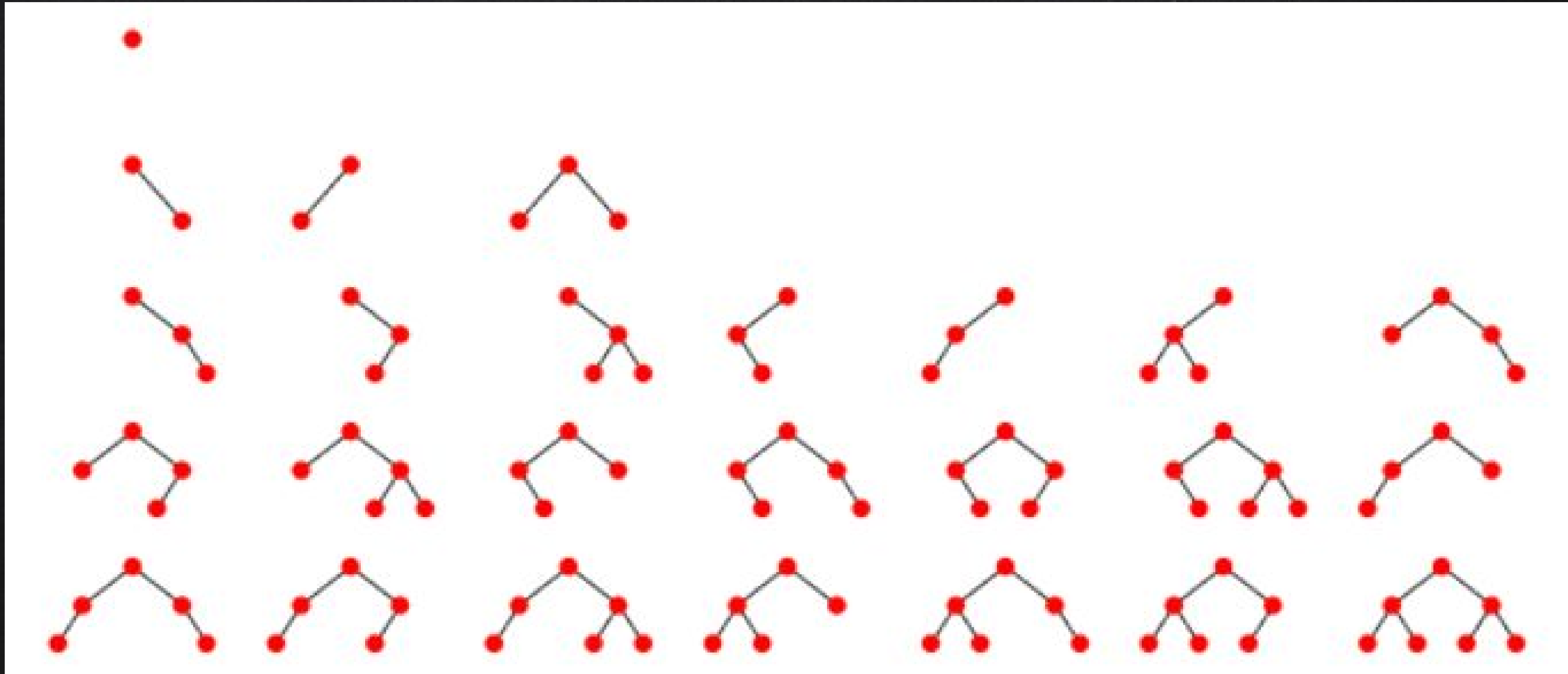
Credit: <http://users.dickinson.edu/~braught/courses/cs332s03/projects/project2.html>

# Star Graphs



Credit: [https://en.wikipedia.org/wiki/Star\\_\(graph\\_theory\)](https://en.wikipedia.org/wiki/Star_(graph_theory))

# Tree



Binary Trees

Credit:

<http://mathworld.wolfram.com/BinaryTree.html>



Some graph algorithms

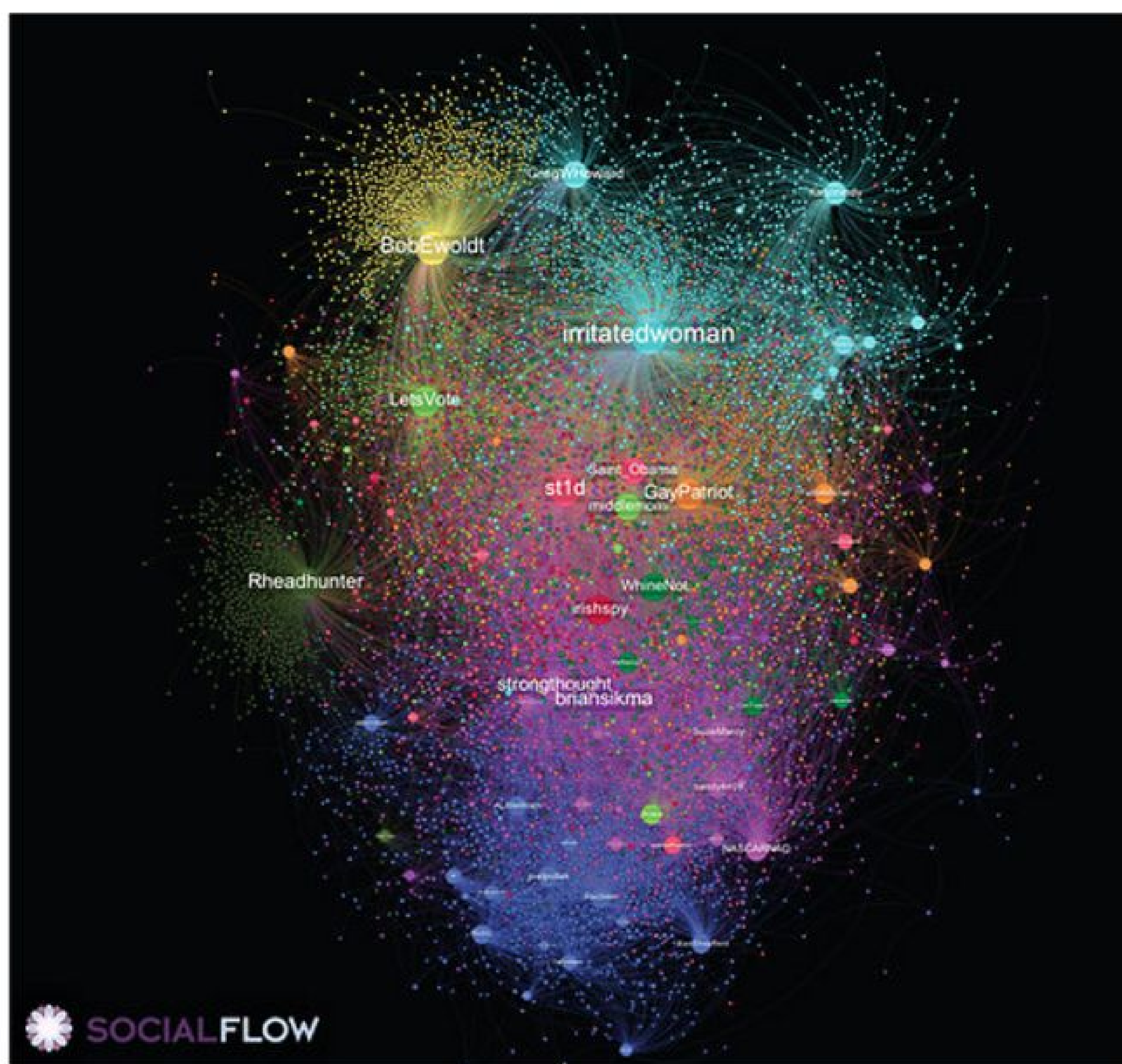
## EXAMPLES OF GRAPH ALGORITHMS

- Traversal (shortest distance, network flow)
- Search (optimal node, subgraph)
- Clustering (group sets of nodes)

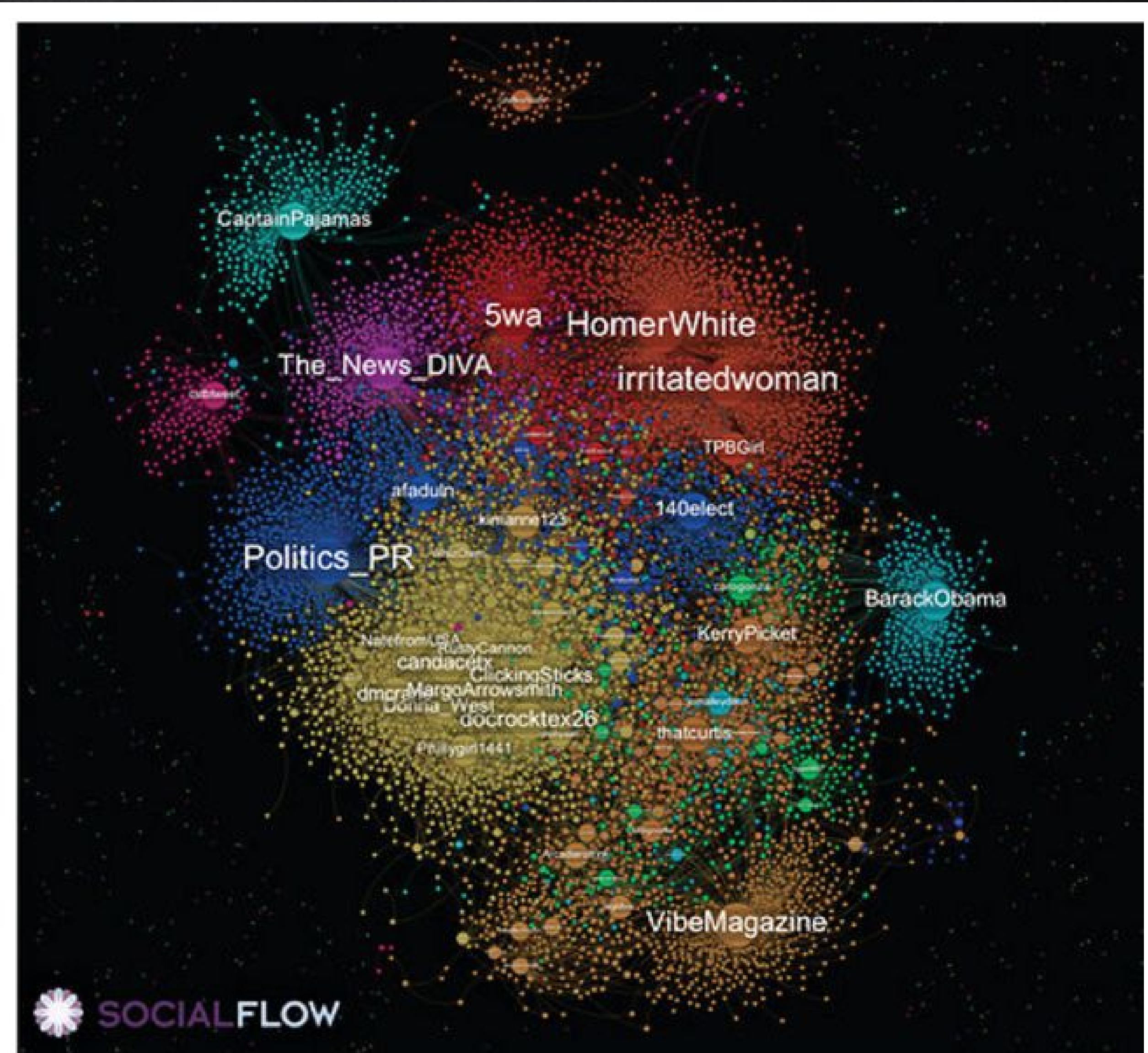
Further reading:

[https://en.wikipedia.org/wiki/Category:Graph\\_algorithms](https://en.wikipedia.org/wiki/Category:Graph_algorithms)

Why are graphs important?



Social Flow The most followed accounts among Twitter users who gave the debate to Paul Ryan.



Social Flow The most followed accounts among Twitter users who gave the debate to Vice President Biden.

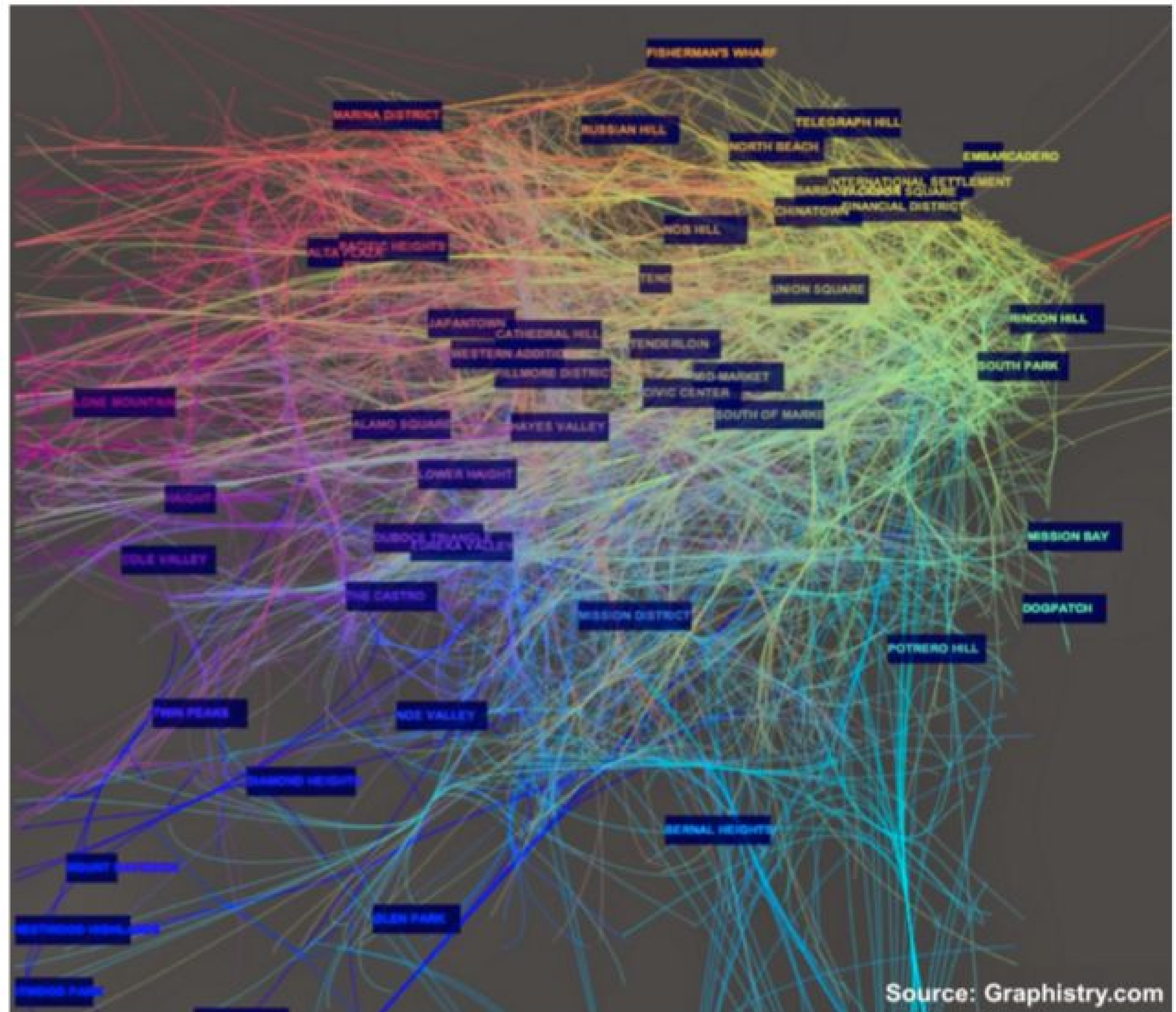
# Ryan vs Biden Debate (Twitter Reaction)

[http://thecaucus.blogs.nytimes.com/2012/10/16/who-won-presidential-debate-on-twitter/?\\_r=1](http://thecaucus.blogs.nytimes.com/2012/10/16/who-won-presidential-debate-on-twitter/?_r=1)



# Uber Trips in San Francisco

<http://radar.oreilly.com/2014/07/there-are-many-use-cases-for-graph-databases-and-analytics.html>



Source: Graphistry.com

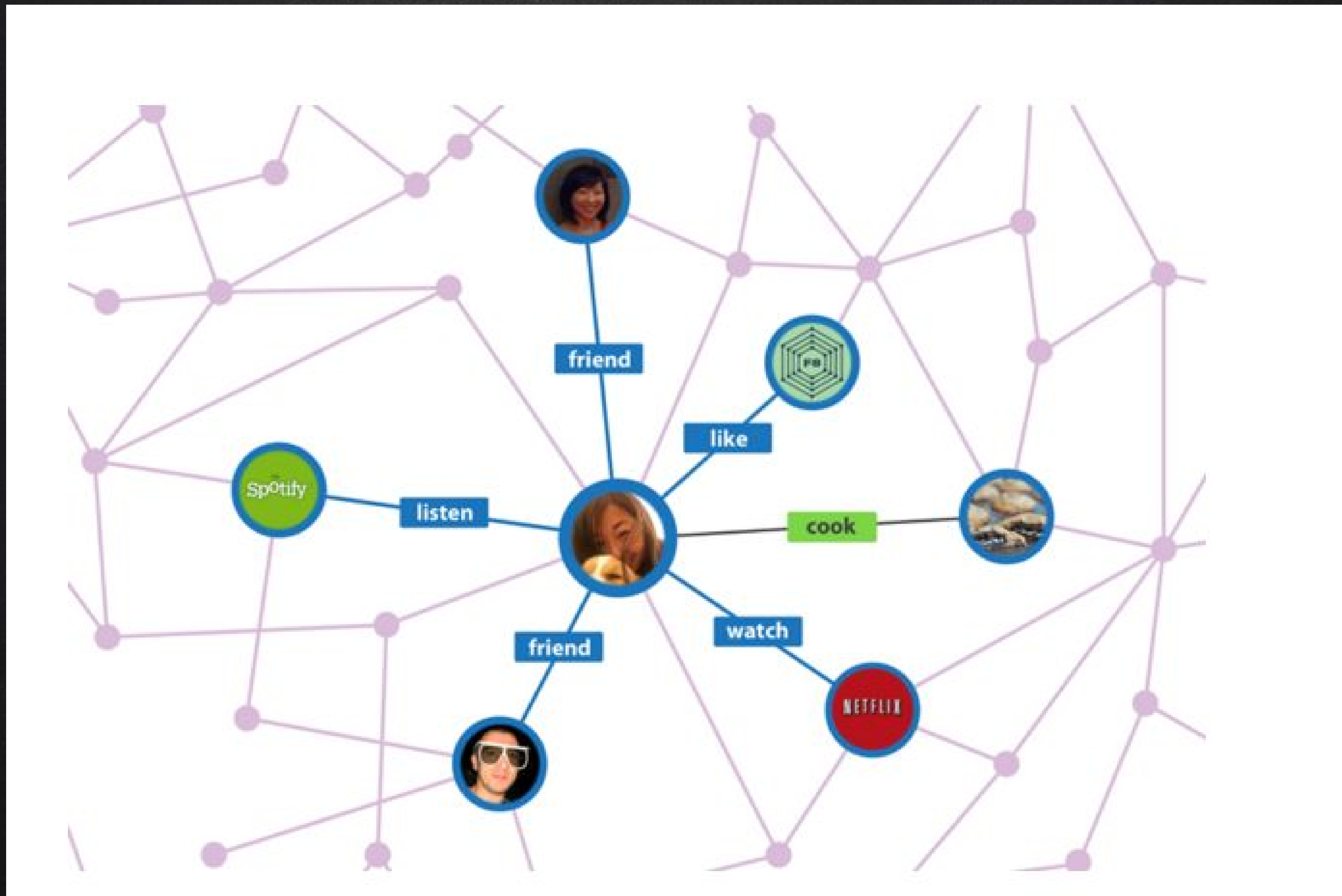
Interactive analyzer of Uber trips across San Francisco's micro-communities

Why graphs?

# Why graphs?

- Abstractions of real-world data
- Capture relationships among entities
- Enable large-scale computations
- PageRank, SocialGraph, etc.
- Everyone is doing it!!!





Reading: <http://www.businessinsider.com/explainer-what-exactly-is-the-social-graph-2012-3>

Why graphs are useful for  
analytics?

Easily understood,  
interpretable  
information

Obtain Insight

Improve performance for  
some learning algorithms

# More materials

- Complex Labs
  - <http://complexitylabs.io/product/network-theory-book/>
  - Network theory overview
    - <https://www.youtube.com/watch?v=qFcuovfgPTc>
- Graph theory overview
  - <https://www.youtube.com/watch?v=82zIRaRUsaY>

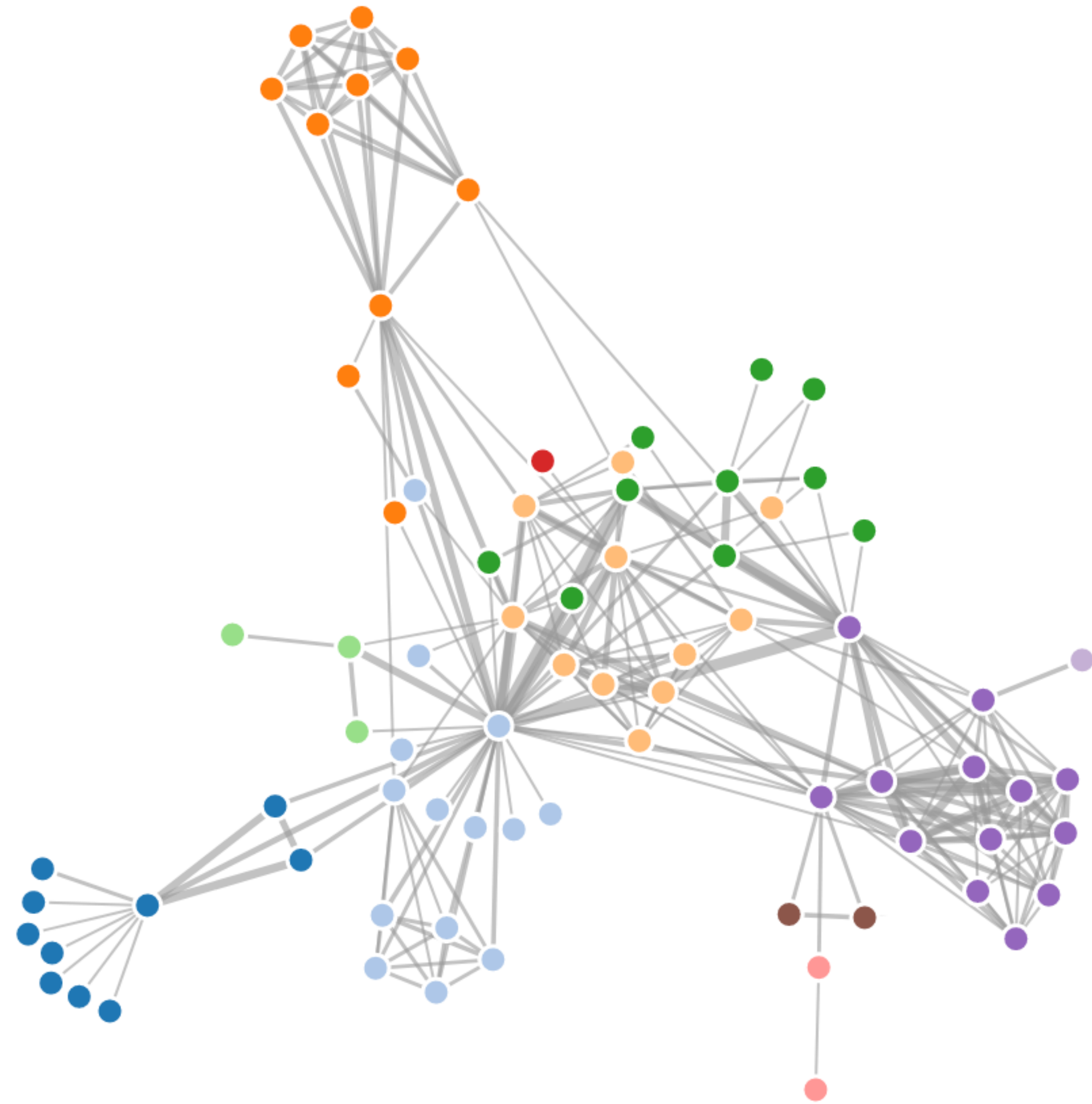
# Graph Visualization

Teaser.....





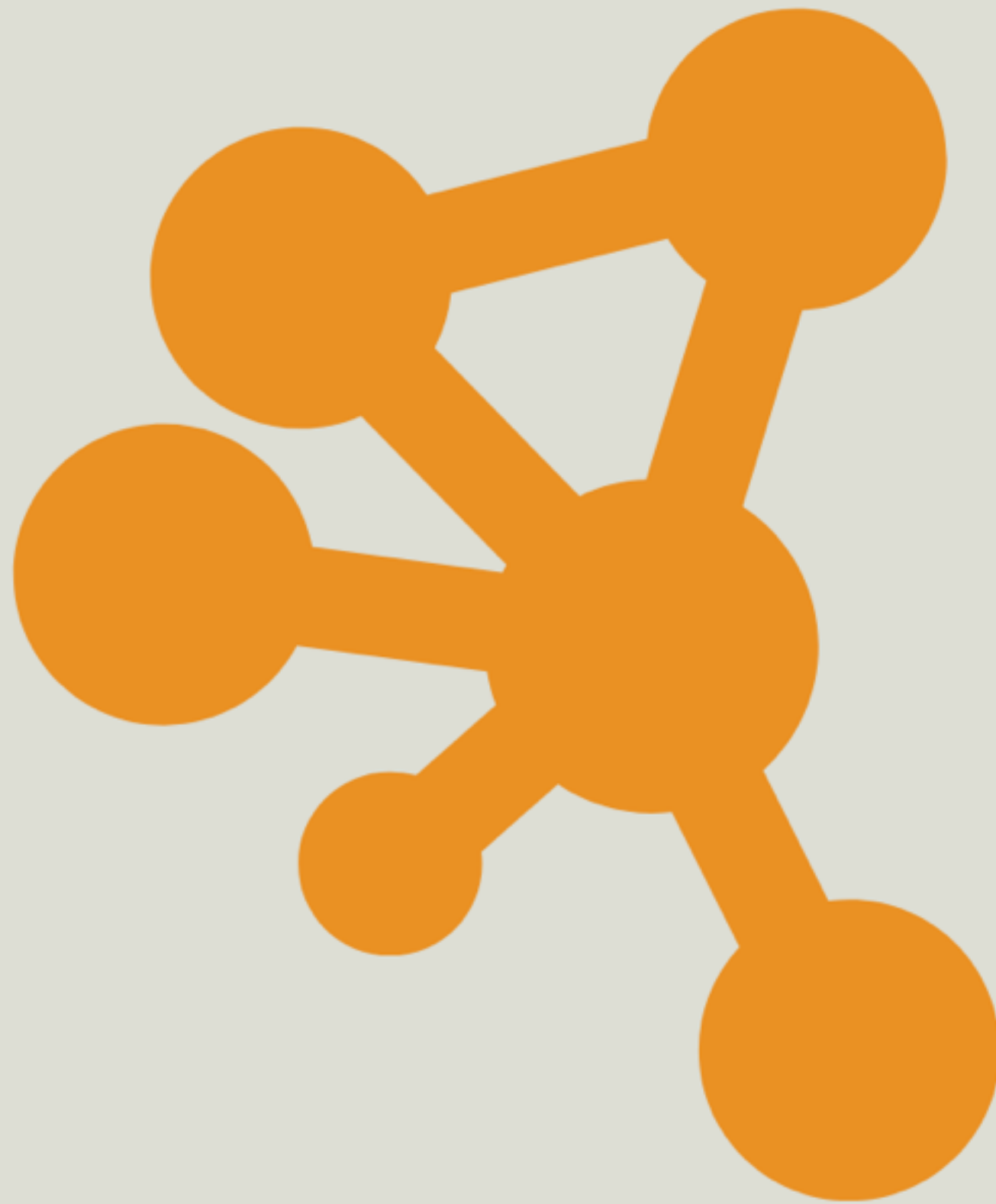
# Force- directed Layout



<https://bl.ocks.org/mbostock/4062045>

# Take home task

- <http://cytoscape.org/>



## What is Cytoscape?

**Cytoscape** is an open source software platform for **visualizing** molecular interaction networks and biological pathways and **integrating** these networks with annotations, gene expression profiles and other state data. Although Cytoscape was originally designed for biological research, now it is a general platform for complex network analysis and visualization. Cytoscape *core* distribution provides a basic set of features for data integration, analysis, and visualization. Additional features are available as **Apps** (formerly called *Plugins*). Apps are available for network and molecular profiling analyses, new layouts, additional file format support, scripting, and connection with databases. They may be developed by anyone using the Cytoscape open API based on [Java™](#) technology and App community development is encouraged. Most of the Apps are freely available from [Cytoscape App Store](#).



# Thanks!

Any questions?

You can find me at: [beiwang@sci.utah.edu](mailto:beiwang@sci.utah.edu)

# CREDITS

Special thanks to all people who made and share these awesome resources for free:

- ☐ Presentation template designed by [Slidesmash](#)
- ☐ Photographs by [unsplash.com](#) and [pexels.com](#)
- ☐ Vector Icons by [Matthew Skiles](#)

# Presentation Design

This presentation uses the following typographies and colors:

## Free Fonts used:

<http://www.1001fonts.com/oswald-font.html>

<https://www.fontsquirrel.com/fonts/open-sans>

## Colors used

