

Check list

- [] Microphone turned on
- [] Zoom room open
- [] Sound Volume on
- [] Open Discord
- [] Quiz

Advanced Topics in Network Science

Lecture 02: Small World Networks

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SSIE 641 –Advanced Topics in Network Science

Sadamori Kojaku

Lecture

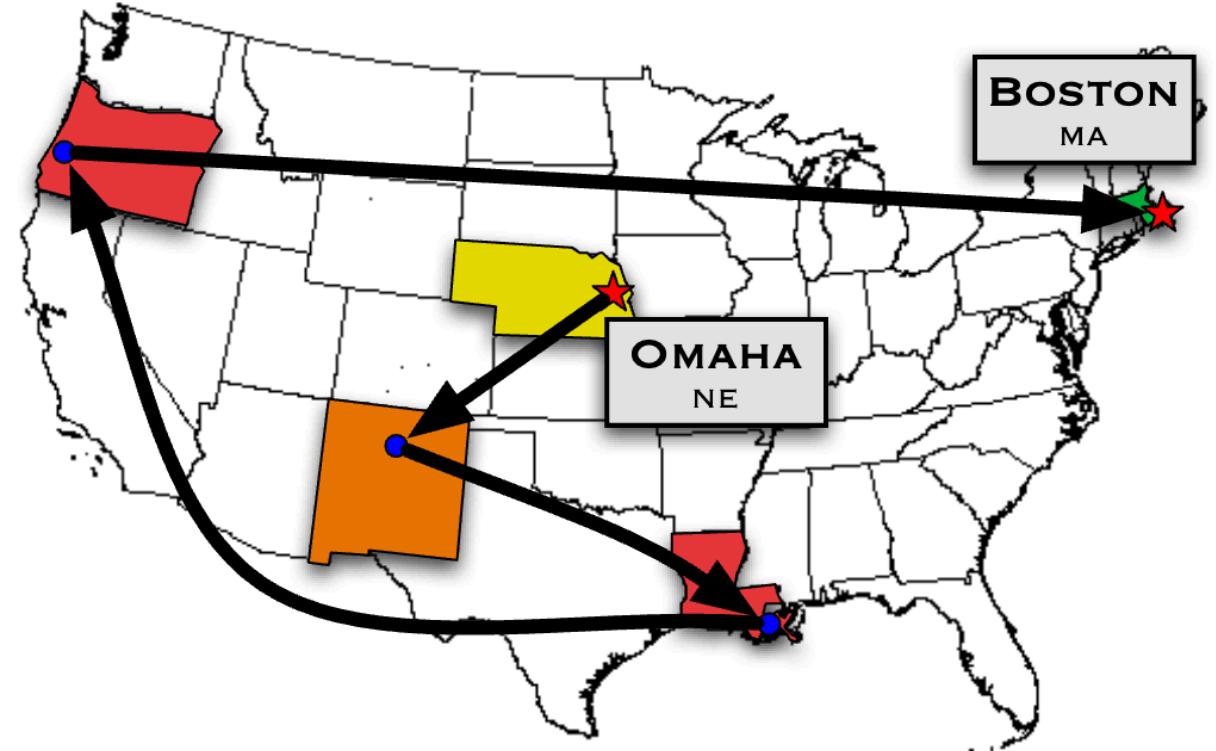
Small World Networks

What we'll learn:

-  Small-world experiments
-  Network distance concepts
-  Efficient network data handling
-  Measuring node distances

Milgram's Small World Experiment

-  Packets sent to random people in Nebraska & Kansas
-  Goal: Reach target person in Boston
-  Results: ~6 people to reach target (64/160 successful)
-  "Six degrees of separation" coined later



Modern Small World Confirmations

-  Yahoo email experiment: ~4-7 steps (2009)
-  Facebook study: 4.74 avg. path length (2012)

Wikirace Game



- 🏎️ Navigate Wikipedia from start to end page
- 🔗 Find shortest path through hyperlinks
- 👀 Experience "small world" phenomenon firsthand

<https://wiki-race.com/>



Wiki
Race

Why is the world small?

-  Explore "6 degrees of separation" concept
-  Understand small world network properties
-  Practice network analysis without computer

<https://skojaku.github.io/adv-net-sci/m02-small-world/pen-and-paper.html>

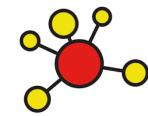
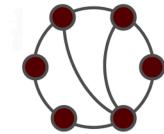
Handling Large Networks

Tools for Network Analysis

- networkx
- igraph
- graph-tool
- scipy
- pytorch-geometric
- ...



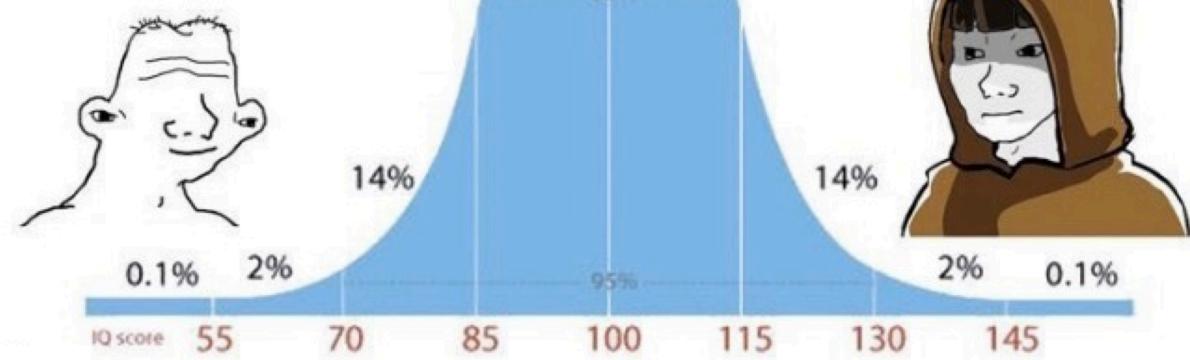
networkx, igraph,
graph-tool...



scipy

List, Tuple, Array

`>>> [[0,1,0],[1,0,1],[0,0,0]]`



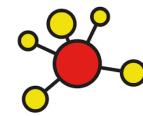
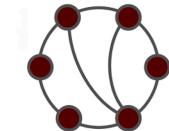
networkx vs igraph



- `networkx` : Beginner-friendly library
- `igraph` : Mature library. Originally an R package.
- `networkx` is great! But there are persistent bugs in some algorithms.
- `igraph` is a more reliable and faithful implementation of algorithms.



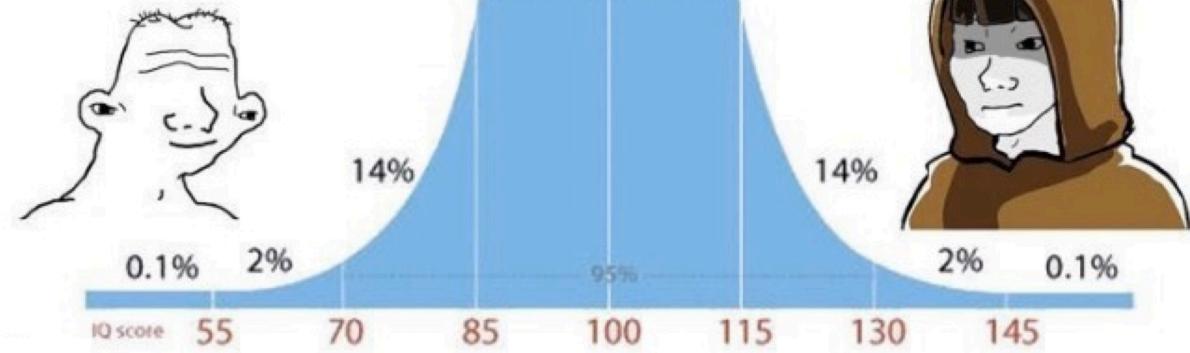
networkx, igraph,
graph-tool...



scipy

List, Tuple, Array

```
>>> [[0,1,0],[1,0,1],[0,0,0]]
```

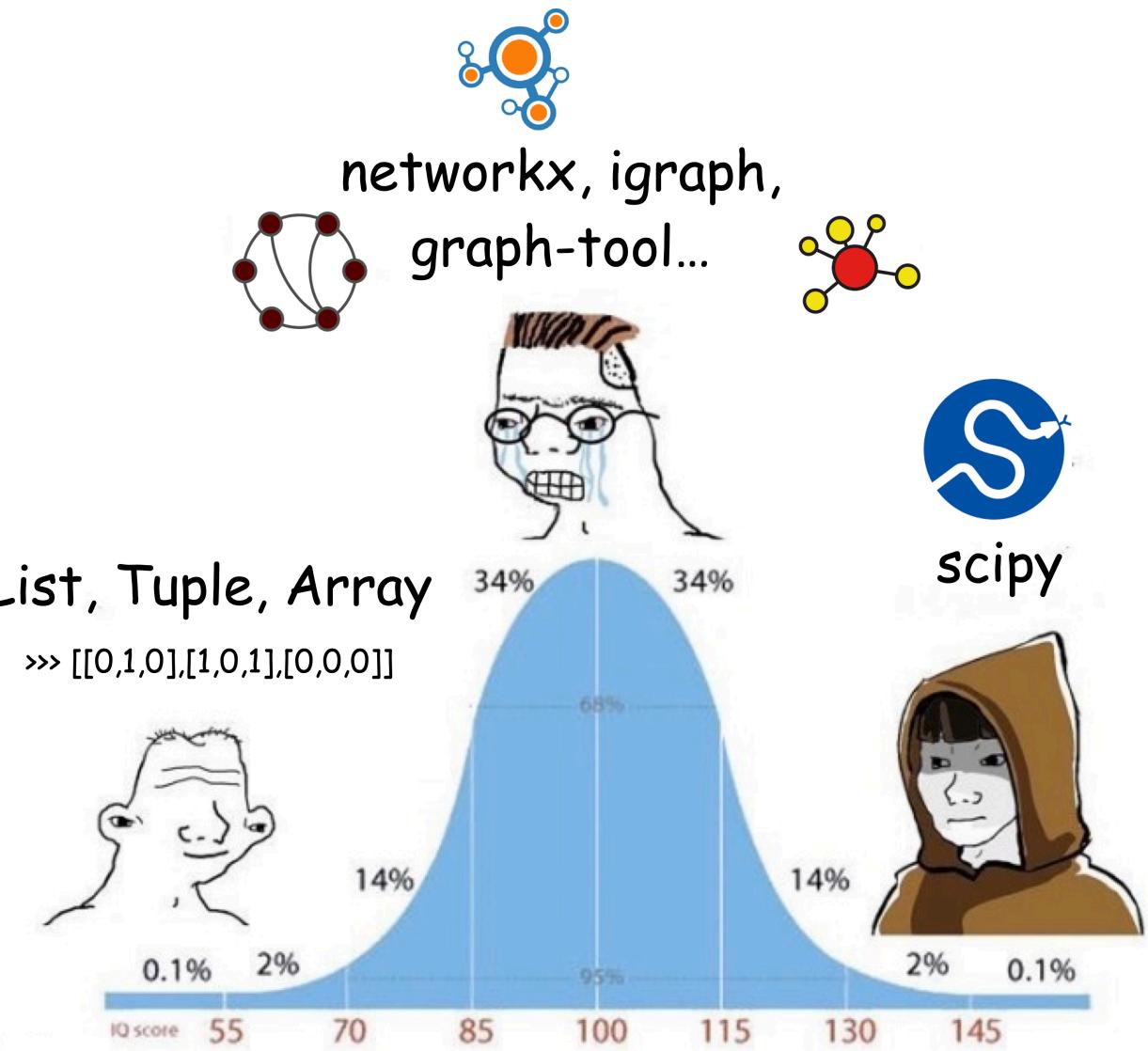


Other Python package

- `graph-tool` : A rich library for stochastic block modeling
- `pytorch-geometric` : A library for deep learning on graphs
- `scipy` : Provides efficient functions for sparse matrices

GUI tools

- Networks + Analytics: [Gephi](#), [Cytoscape](#), [Pajek](#)
- Visualization: [HeliosWeb](#)



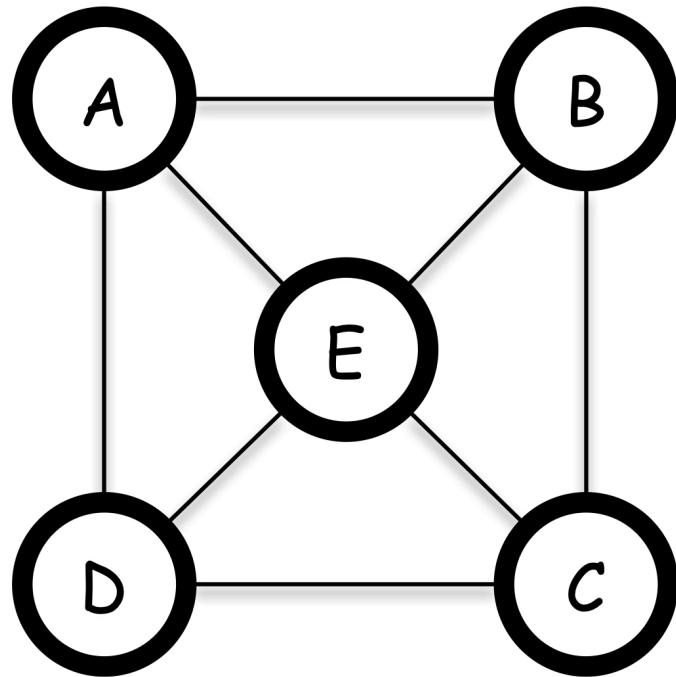
Efficient Network Representation

- Challenge: Storing large adjacency matrices
- Solution: Compressed Sparse Row (CSR) format
- Stores only non-zero entries
- Memory efficient for sparse networks

Pen and Paper Exercise



Walk, Trail, Path, Circuit, Cycle



Walk: A-B-E-C-B-E-D

All nodes are unique

Path: A-B-E-C-D

All edges are unique

Trail: A-B-E-C-B-E-D

Cycle: A-B-E-C-D-A

Path that starts
and ends with the
same node

Circuit: A-B-E-C-B-E-D-A

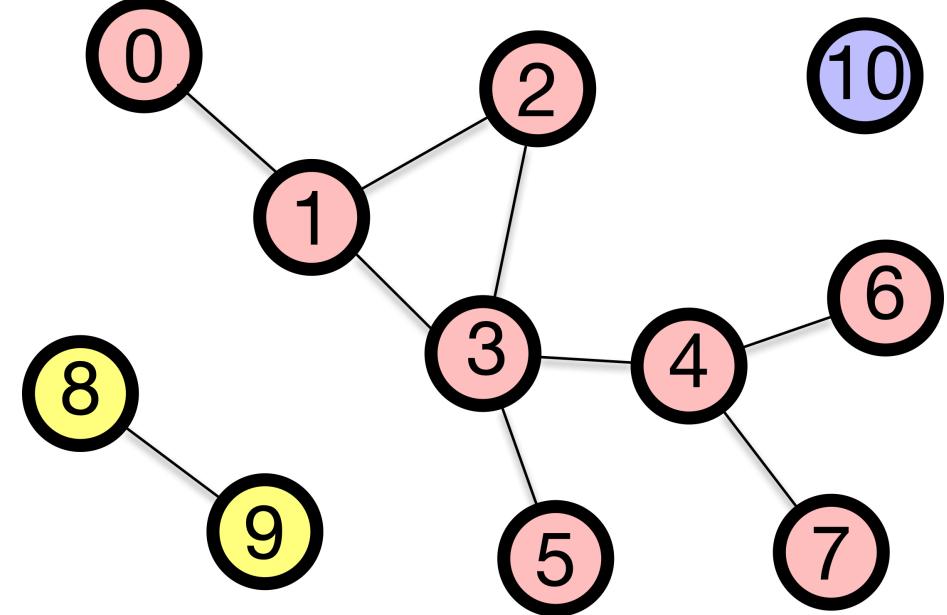
Trail that starts and ends with
the same node

Walk, Trail, Path, Circuit, Cycle

-  **Walk:** Sequence of connected nodes
-  **Trail:** Walk with no repeated edges
-  **Path:** Walk with no repeated nodes
-  **Loop, Circuit, Cycle:** Special closed walks

Connectedness in Networks

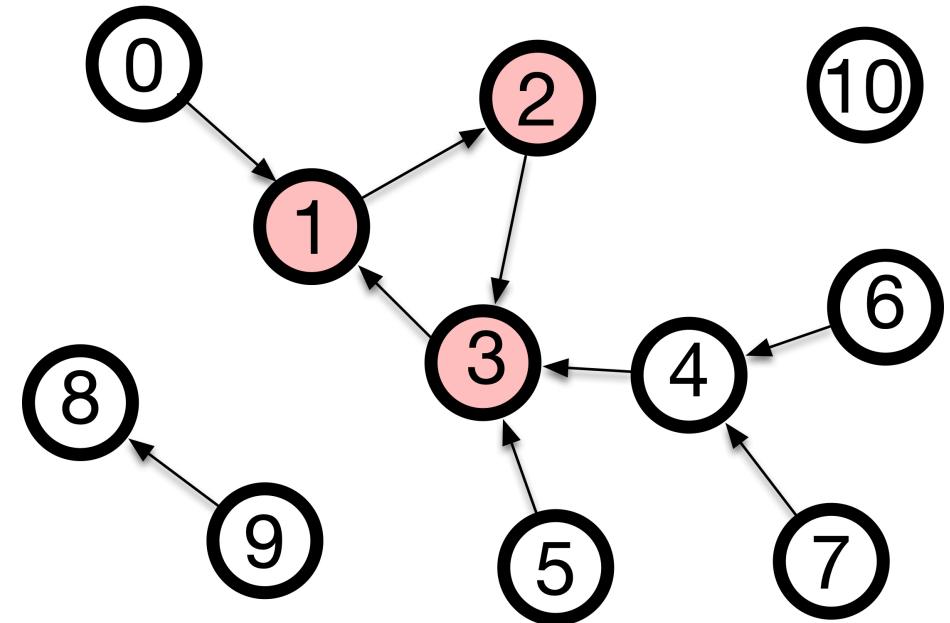
- 🔗 Connected vs Disconnected networks
- 🧩 Connected components
- 🌟 Giant component



Directed Network Connectedness

- 💪 Strongly connected: Path between all node pairs
- 🤝 Weakly connected: Path ignoring edge direction

Strongly connected component



Hands-on: Network Analysis with igraph

-  Create and visualize graphs
-  Find shortest paths
-  Identify connected components
-  Analyze directed networks

<https://skojaku.github.io/adv-net-sci/m02-small-world/connectedness-hands-on.html>

Assignment: Small World Experiment



-  Compute average path length in scientist network
-  Use efficient CSR format
-  Apply igraph for network analysis

<https://skojaku.github.io/adv-net-sci/m02-small-world/assignment.html>

Thank You! Questions? 🤔