

Introduction to Network Science, Machine Learning & Simulation

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Network Science and Graphs Analytics

Is already powering the best known AI applications



Knowledge

Graph



Social Graph



Product Graph







Knowledge Graph



Active Research Area in Finance



Risk Journal founded by Kimmo Soramäki | link



Risk Book by Kimmo Soramäki and Samantha Cook, FNA's Chief Scientist | link



Two-day Training course in London, New York and Washington DC, lead by Kimmo Soramäki | link

Multi-disciplinary



Bioinformatics

Network Science / Network Theory

Machine Learning vs Artificial Intelligence

Difference between machine learning and Al: If it is written in Python, it's probably machine learning If it is written in PowerPoint, it's probably ΑI

Al in nutshell

Network Theory is about

New Way of Looking at Data

- How is data connected with other data?
- How do these connections matter?
- How do complex systems move in time?

For the first time we are able to measure and model this!



Complex Systems

"Systems with rich interactions between the components of the system"

eg. financial markets, payment systems, road systems, friendship networks, ... almost **every** socio-economic system.





Three Main Modes of Analysis

• Top down analysis

- Bottom up analysis
- Features of Data



Top down



PHOTO: FINANCIAL NETWORK ANALYTICS

Typical use cases:

- Systemic risk analysis
- System monitoring
- System design
- System stress testing
- Clustering/Classification
- Early warning
- Anomaly detection

Bottom Up



Typical use cases:

- Criminal investigation
- Terrorist networks
- Money laundering
- KYC & KYCC
- Fundamental investment analysis
- Supply chain analysis

Network Features of Data



Typical use cases:

- AI/ML
- Fraud algorithms
- Recommendation engines
- Algorithmic investment

FNA Research: <u>Comparison of Graph</u> <u>Computing Platform Performance</u>



Types of Networks

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Network Concepts

Constituents

- Networks (graphs)
- Nodes (vertices)
- Links (ties, edges or arcs)

Links can be

- Directed (arcs) vs undirected (edges, ties)
- Weighed vs unweighted

Graph + properties = Network



Some Graph Types



Some Graph Types



Random Graphs



Random (Erdos-Renyi)



Scale-free (Barabasi-Albert)



Centrality

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Centrality measures importance of nodes (or links) in a network. Depends on process that takes place in the network!

Trajectory

- Geodesic paths (shortest paths)
- Any path (visit no node twice)
- Trails (visit no link twice)
- Walks (free movement)

- Transmission

- Transfer

DHL Package = Transfer via shortest path Money = Transfer via random walks Virus = Serial duplication via paths

etc. Borgatti (1998)

• Parallel duplication • Serial duplication

Common Centrality Metrics







Со

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Communities



Community Detection

If networks are large and complex and we want to simplify, categorize and label nodes into meaningful groups or communities.

Community detection is carried out by maximizing modularity

"Modularity is the *fraction* of the links that fall within the given groups minus the *expected fraction* if links were distributed at random"







Community Detection

Community detection is an **unsupervised machine learning** way of doing this, and there are numerous methods available.

- How do we know result is correct. What is correct?
- Which algorithm to choose?
- Some algorithms detect well large, but not small communities
- Is it a community or a cluster of several?
- What about overlapping communities?

Still more an art than a science. Try what works?

FNA Research: <u>Overview and Comparison of Community Detection</u> <u>Algorithms</u>









Layouts

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Information visualisation

Our goal is to transmit relevant information

- Humans find statistical thinking and abstraction very challenging and require significant training
- We depend on statistics that summarise properties of data
- Human visual processing system is developed to spot interesting patterns and its use is natural

Anscombe's quartet





Network visualisation basics

For any given network, there exists an infinite number of network diagrams. For example, below is a networks visualized with two different *layout algorithms*.



Force-Directed



Circle

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