Milliman **MedInsight**

Using Networks in Healthcare Analysis

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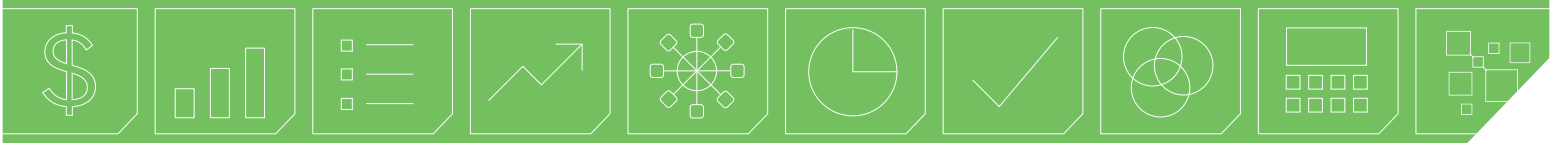


Networks, and their applications in graph theory, have become more prevalent in recent years due to their adoption by high-profile firms. Facebook is built on a social network where people are connected to others through their interactions, such as friend requests or messaging. Google has built a search engine empire based on a large network of web pages and users flowing between them. In addition to supporting their core business, both of these networks have enhanced their respective company's products by generating a rich source of data for analyzing relationships.

Relationships exist within healthcare as well, such as relationships between healthcare providers. A primary care provider creates a relationship with a specialist when referring a patient to that specialist. A specialist creates a relationship with a clinical lab when ordering a test for a patient. These providers share connections through their composite care of a patient or a population. Below we'll look at common analyses of networks and their applications in healthcare.

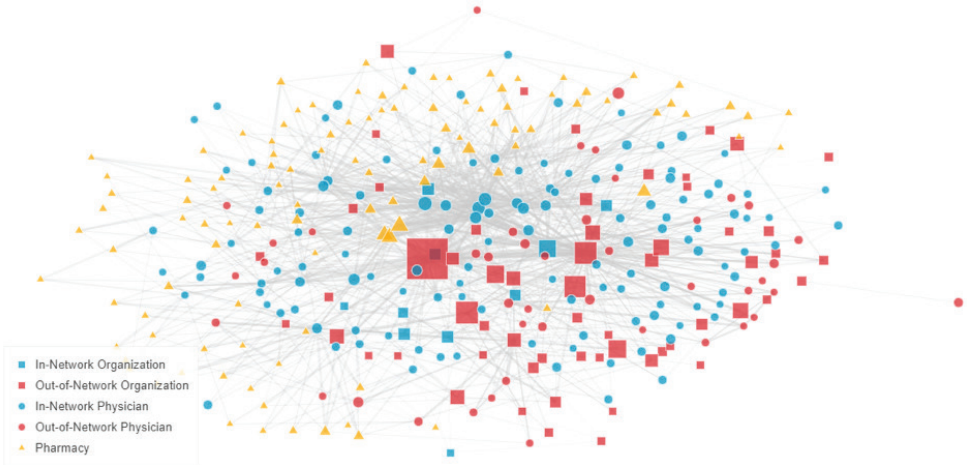
Introduction to Networks

In graph theory (the formal study of networks), a network consists of nodes and edges. Nodes are the people or things that make up a network. Edges are the connections between nodes in a network. These connections can be explicit, such as a message or a phone call, or they may be inferred by analyzing patterns in data. Additionally, edges can have a direction (e.g., Person A called Person B), or they can be undirected (e.g., Person A and Person B are friends). Edges can also have a weight that quantifies the number of interactions or the importance of interactions.

When visualizing a network, nodes are typically represented as a basic geometric shape. Edges are typically represented as lines that connect nodes.[1] Figure 1, on page 2, shows a visualization of a provider network for a managed patient population. The nodes consist of individual providers and provider organizations, while the edges consist of patient services that may have resulted from a referral between providers.

1 Borsboom, D., & Cramer, A. O. (2013). Network analysis: an integrative approach to the structure of psychopathology. *Annual review of clinical psychology*, 9, 91-121.

Figure 1: Visualizing Networks With Nodes and Edges



The network visualization in Figure 1 uses coloring to represent provider group status. The differing shapes distinguish individual providers from organizations or facilities. Additionally, the sizes of the shapes represent the importance of the provider to the network, such as the total quantity of services provided. Lastly, the visualization uses lines of varying thickness to show the quantity of services that connect providers.

Networks offer a very flexible tool with varying uses:

- **Exploratory Data Analysis:** Networks can help uncover novel insights that lead to further developments.
- **Network Algorithmic Analysis:** The availability of algorithms specific to networks enhances the value of using and creating a network from relationships within data. Common algorithm analyses include finding optimal paths, defining neighborhoods, or determining connectedness between nodes.
- **Machine Learning with Networks:** Machine learning techniques are becoming more common, and networks are no exception. Machine learning can be used to proactively detect future anomalies in networks and predict new relationships between nodes.[2]
- **Interactive Visualization:** Providing users a way to easily interact with their data through a helpful spatial arrangement of nodes can increase understanding of grouping, prominence, and bridging.[3]

Network Analysis in Healthcare

Networks can be a useful tool in healthcare analytics and have already been explored for a number of uses, including:

- Identifying patterns of Deprivation, High Morbidity, and Mortality[4]
- Detecting Fraud, Waste and Abuse in Healthcare Data[5]
- Understanding Chronic Disease progression[6]

A common usage for network analytics within healthcare is the creation of networks that focus on the movement of information and resources between providers. These networks are typically built for two distinct purposes: evaluating information exchange between providers (patient flow, referral information, how providers might work together for a patient)[7] and studying the epidemiological effects of a network (infection spread and disease management).[8]

2 Lichtenwalter, R. N., Lussier, J. T., & Chawla, N. V. (2010, July). New perspectives and methods in link prediction. In *Proceedings of the 16th ACM SIGKDD international conference on knowledge discovery and data mining* (pp. 243-252). ACM.

3 Bennett, C., Ryall, J., Spalteholz, L., & Gooch, A. (2007). The aesthetics of graph visualization. *Computational aesthetics*, 2007, 57-64.

4 Bath, P. A., Craigs, C., Maheswaran, R., Raymond, J., & Willett, P. (2005). Use of graph theory to identify patterns of deprivation and high morbidity and mortality in public health data sets. *Journal of the American Medical Informatics Association*, 12(6), 630-641.

5 Liu, J., Bier, E., Wilson, A., Guerra-Gomez, J. A., Honda, T., Sricharan, K., ... & Davies, D. (2016). Graph analysis for detecting fraud, waste, and abuse in healthcare data. *AI Magazine*, 37(2), 33-46.

6 Khan, A., Uddin, S., & Srinivasan, U. (2016, February). Adapting graph theory and social network measures on healthcare data: A new framework to understand chronic disease progression. In *Proceedings of the Australasian Computer Science Week Multiconference* (p. 66). ACM.

7 Brunson, J. C., & Laubenbacher, R. C. (2017). Applications of network analysis to routinely collected health care data: a systematic review. *Journal of the American Medical Informatics Association*.

8 Ibid.

Building Healthcare Networks

Healthcare data can be difficult to work with, as it often combines vast amounts of structured, semi-structured, and unstructured data.[9] Creating a healthcare network may require some careful inference, as many data sources lack explicit information on connections or referrals between providers. Healthcare networks are generally created in three ways:[10]

1. Concurrence on records
2. Sequential Occurrences on Chronological records
3. Source or target destinations on transmission records

In the example shown in Figure 1, the network is made up of directed edges between providers. The edges were created by observing sequential services on chronological medical records of patients to infer potential referral patterns between providers. A referral is considered directed, because while a primary care provider may send a patient to a lab, the lab will not "send" the patient back. Most connections discovered this way will not represent formal referrals that fulfill preauthorization requirements, but they are still important connections that help understand how the providers interact with each other.

A network built in this manner can be used to explore a number of use-cases for provider groups that are involved in population health management:

- Identifying patient leakage in a managed care setting
- Identifying notable pre-acute care providers
- Identifying notable post-acute care providers
- Identifying providers that are influential in a patient network
- Identifying underutilized specialties

Network-based analytics provide exciting opportunities for drawing insight from the healthcare space, and ultimately may help to improve patient outcomes and increase the efficiency of patient care.

9 Holzinger, A., & Jurisica, I. (2014). Knowledge discovery and data mining in biomedical informatics: The future is in integrative, interactive machine learning solutions. In *Interactive knowledge discovery and data mining in biomedical informatics* (pp. 1-18). Springer, Berlin, Heidelberg.

10 Brunson, J. C., & Laubenbacher, R. C. (2017). Applications of network analysis to routinely collected health care data: a systematic review. *Journal of the American Medical Informatics Association.*

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