Comparing Network Similarity Metrics for Structural Change Detection in Evolving Mineral Trade Networks

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Extended Abstract

Quantifying structural change in evolving networks is a central challenge in network science. Dynamic systems, from social and biological interactions to trade and communication, are characterized by both gradual transformations and abrupt reconfigurations, yet capturing these changes in a rigorous and interpretable way remains difficult [1]. A wide range of similarity and distance measures have been proposed, but each emphasizes different aspects of network evolution [2].

This study systematically contrasts four widely used metrics for comparing consecutive network states: (i) Graph Edit Distance (GED, L1 norm), a measure of the magnitude of change in edge weights; (ii) the L2/L1 ratio, which highlights whether changes are concentrated in a few links or distributed across the system; (iii) weighted Jaccard similarity, which emphasizes the persistence of overlapping edge weights; and (iv) cosine similarity, which captures the stability of relative flow distributions regardless of scale. Together, these measures provide complementary perspectives on network evolution.

We demonstrate the comparative diagnostic power of these metrics using international trade networks of energy transition metals (copper, nickel, cobalt, 1995–2023) as a case study. GED identifies periods of major restructuring, L2/L1 ratios distinguish localized shocks from systemic shifts, Jaccard similarity highlights enduring relationships, and cosine similarity captures persistent distributional patterns even during large volume changes. Application results further showed that cosine similarity was more sensitive than weighted Jaccard in detecting subtle structural shifts and proved especially effective at identifying singular, large-scale events. The L2/L1 ratio successfully detected polarized change without overlapping with GED (L1 norm), confirming its distinct diagnostic role. See Table 1 for a summary of the distinct properties of these metrics.

This comparative approach shows how methodological choices shape interpretations of structural resilience and vulnerability in complex systems. While demonstrated on international trade, the framework is generalizable to evolving biological, communication, and social networks.

Ethical Considerations: This work is based on publicly available, aggregated trade data (CEPII BACI) and does not involve personal or sensitive information. Ethical concerns are therefore minimal. Nonetheless, we emphasize responsible communication of findings, particularly in contexts where analyses of trade dependencies may have geopolitical or policy implications.

References

[1] Holme, Petter. "Modern temporal network theory: a colloquium." The European Physical Journal B 88.9 (2015): 234.

[2] Koutra, Danai, Joshua T. Vogelstein, and Christos Faloutsos. "Deltacon: A principled massive-graph similarity function." Proceedings of the 2013 SIAM international conference on data mining. Society for Industrial and Applied Mathematics, 2013.

Table 1. Properties of network similarity measures used to analyze evolving networks.

Metric	**Primary Focus**	**Captures Well**	**Limitations**
GED (L1 norm)	Magnitude of total change	Large cumulative shifts in edge weights	Does not show if change is localized vs. distributed
L2/L1 ratio	Concentration of change	Distinguishes systemic vs. localized shocks	Requires GED for context, harder to interpret alone
Weighted Jaccard	Overlap in weighted relationships	Persistence of strong recurring ties	Sensitive to small fluctuations, ignores proportionality
Cosine similarity	Distributional stability of flows	Pattern preservation despite scale changes	Ignores absolute magnitudes of change