

Impact of Graph Fusion Strategies on Multi-Layer Open-Source Ecosystem Networks

A Comparative Study on Union-based and Consensus-based Approaches

[Jingsen Zhang, Zeqiang Wang, Zixi Chen]

[NYU Shanghai]

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This project is developed for the 'OpenRank Cup' Open-Source Digital Ecosystem Analysis and Application Innovation Competition, and is implemented based on the EasyGraph open-source framework.

Core Message: Open-Source Software (OSS) ecosystems are inherently multi-dimensional.

Key Content:

- 1 **Heterogeneous Signals:** Collaboration (PRs/Issues), Activity (Events), and Popularity (Stars/OpenRank).
- 2 **The Problem:** Current studies often “flatten” these signals into a single graph prematurely.
- 3 **Positioning:** Graph fusion is a significant modeling choice, not a trivial preprocessing detail.

Technical Route (Based on EasyGraph)

- OpenDigger data as input
- Construct multiple node-aligned graph layers using EasyGraph
- Apply graph fusion strategies: union-based and consensus-based
- Perform structural analysis and evaluation using EasyGraph analytics

Core Message: Defining the Node-Aligned Multi-Layer Graph.

Formal Definition:

- 1 **Input:** A set of graphs $\mathcal{G} = \{G_1, G_2, \dots, G_k\}$ where all layers share a consistent node set V .
- 2 **Challenge:** Layers differ in edge semantics and weight distributions.
- 3 **Objective:** Construct a unified representation G^* that preserves meaningful relational signals.

Why Existing Practices Are Insufficient

Core Message: Moving beyond simple embedding-based similarity.

Critical Limitations:

- 1 **Embedding Gap:** High semantic similarity in embedding space does not equal actual interaction or co-occurrence in reality.
- 2 **Methodological Blind Spot:** Most studies default to one fusion strategy without comparing the systematic bias introduced.

Research Questions (RQs)

Objective: Systematically investigating the trade-offs of fusion.

The Three Questions:

- ➊ **RQ1 (Structural Impact):** How do fusion strategies alter network density and degree distributions?
- ➋ **RQ2 (Trade-offs):** What is the balance between maximizing information coverage and filtering noise?
- ➌ **RQ3 (Stability):** To what extent do core nodes and community structures remain invariant?

Context: A reproducible setting using OpenDigger (GitHub event-derived data).

- 1 **Layer Details:** Stars, Forks, OpenRank, and Developer Collaboration.
- 2 **Implementation:** Shared identifiers in structured JSON files enable straightforward cross-layer node alignment.

Methodology: Comparison of Fusion Strategies

Strategy 1: Union-based Fusion

Formula: $E_{union} = \cup E_i$

Aim: Maximize information coverage and include weak signals.

Strategy 2: Consensus-based Fusion

Formula: $E_{cons} = \cap E_i$

Aim: Multi-view support as a proxy for reliability; reduce noise.

Metric Layers:

- ① **Macro:** Degree distribution and clustering coefficients.
- ② **Meso:** Stability of community detection results (e.g., Louvain/Infomap).
- ③ **Micro:** Ranking stability of top nodes (e.g., influential repositories).
- ④ **Qualitative:** Visual inspection of core subgraphs.

Expected Outcomes & Significance

Deliverables: A reproducible fusion pipeline and comparative report.

Significance: Provides a transparent roadmap for researchers to select fusion strategies based on specific analysis goals (e.g., identifying stable cores vs. emerging projects).

Key Literature (Must Include):

- Kivelä et al. (2014). Multilayer Networks. *Journal of Complex Networks*.
- De Domenico et al. (2014). Multilayer Networks: Structure and Function. *Physics Reports*.
- Hamilton (2020). Graph Representation Learning.
- Yang et al. (2025). A Survey on Multi-View Knowledge Graphs. *IJCAI*.

Thank You!

GitHub Repository: <https://github.com/your-repo/graph4socialscience>

Q & A