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Adaptive Semantic Interoperability and Living Graphs: New Post-Static Paradigm Dynamics in Scientific Communication

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Abstract

This research addresses the emergence of Living Graphs as a new paradigm for supporting scientific communication and Knowledge Organization. The objective was to present a reflection on the transition from the documentary paradigm to that of interconnected data, highlighting how Living Graphs, based on the architecture of FAIR Digital Objects (FDOs), can improve Knowledge Organization. The methodology consisted of a qualitative and exploratory literature review. The results demonstrate that Living Graphs overcome the static paradigm by capturing the temporality and adaptive interoperability of modern scientific knowledge.

1.0 Introduction

The history of Knowledge Organization (KO) is marked by a constant search for stability and systematization. Traditionally, classification and taxonomy operated under the premise that information retrieval depended on the fixation of knowledge into perennial categories. However, the dawn of the 21st century, characterized by an explosion of data and the unstoppable fluidity of interdisciplinarity, exposed the deep fissures in this structure (Auer 2018). Currently, scientific production faces what we call “conceptual friction”: research is an organic flow, but its primary record, the PDF article, remains a static artifact, a “digital mummy” that fossilizes knowledge, reducing its multidimensionality to a constraining linearity.

Within this context of inertia, this work introduces the concept of the Living Graph as a response to the crisis of the static paradigm in scientific communication. A Living Graph is a dynamic architecture for representing knowledge that organizes information into nodes (entities) and edges (semantic relations), operating at the level of atomic assertions (Groth et al. 2023). In this context, the research problem is: How can Living Graphs, in line with Knowledge Organization, foster Scientific Communication in a more dynamic way?

To address this question, the general objective of the article is to present how the concept of Living Graphs, combined with FAIR principles and Knowledge Organization, can contribute to more dynamic Scientific Communication. The specific objectives are: To characterize what Living Graphs are; To demonstrate the contribution of Living Graphs together with the FAIR Principles to scientific communication; and To identify how Living Graphs, articulated with the foundations of Knowledge Organization, can foster more dynamic scientific communication.

Unlike static knowledge graphs, the Living Graph functions as an evolving ecosystem where information is continuously updated rather than simply stored. It represents knowledge with fine granularity, enabling real-time updates of relationships between data and scientific claims while accurately reflecting the dynamic progression of knowledge.

2.0 From Taxonomy to Knowledge Graphs and Semantic Interoperability

The knowledge organization has been a dynamic field, evolving from purely hierarchical systems to complex networks of meaning. To understand this transition and the need for a dynamic representation, it is essential to analyze the following points.

Traditional taxonomies, as hierarchical classification systems, have served as the foundation for the knowledge organization for centuries. However, their rigid and one-dimensional nature often imposes limitations on the representation of the complexity and fluidity of contemporary knowledge. In this context, these classificatory structures can generate “ontological friction”— that is, a misalignment between the speed at which knowledge is produced and the slowness of traditional formats for organizing and disseminating information, in which this knowledge is recorded and communicated (Auer and Mann 2019).

Faced with this scenario, the Living Graphs proposal does not eliminate the role of taxonomies, but rather reintegrates them into a new informational framework. In this model, taxonomy functions as a layer of controlled vocabulary that provides semantics to the graph’s edges, allowing knowledge navigation to maintain a certain degree of structure while operating within a more dynamic, fluid, and adaptive environment.

This perspective is directly linked to the use of graphs as mathematical structures capable of representing knowledge in a relational manner. Graphs are composed of nodes—which represent entities, concepts, or resources—and edges—which express the semantic relationships between these elements. According to Auer and Mann (2019, 37), “knowledge graphs allow us to represent information in terms of concepts, classes, properties,

relationships, and entities. [...] They allow knowledge to be understood holistically from multiple sources or domains." Knowledge graphs can transform scientific communication by converting passive textual knowledge into interconnected data structures (Linked Data), enabling the identification of granular research elements—such as problems, methods, and definitions—that often remain hidden in traditional documents like PDFs.

Structuring information with the RDF model enables knowledge graphs to connect textual content with diverse scientific artifacts—such as software, videos, and datasets—allowing researchers to perform more complex searches and quickly identify relationships and patterns beyond keyword-based limitations. Knowledge graphs improve the efficiency and transparency of the scientific ecosystem by reducing terminological ambiguity and duplicated research.

In this context, semantic interoperability becomes a central element. The capacity of different systems, applications, and communities to share information with a common meaning constitutes one of the foundations of contemporary science and is directly related to the FAIR principles. Knowledge graphs enable interoperability by using standards that connect data from multiple sources in a machine-readable way without requiring rigid prior standardization. They allow different vocabularies and conceptual schemas to be dynamically mapped and integrated, fostering adaptive interoperability (Shi et al. 2025).

The shift to Living Graphs reduces "ontological friction" by narrowing the gap between knowledge creation and its representation. Their dynamic and interconnected structures allow scientific records to more accurately reflect the evolution of human knowledge. This perspective becomes particularly relevant in light of the challenges facing traditional scientific communication, which still faces structural problems such as the "fossilization of knowledge" and the "loss of temporality" (Auer and Mann 2019). In this sense, Living Graphs emerge as an alternative capable of updating the mechanisms of organization and circulation of scientific knowledge, making them more compatible with the speed, complexity, and collaborative nature of contemporary scientific production.

3.0 Methodology

This study is a qualitative and exploratory literature review aimed at examining the limitations of static organization paradigms and the potential of new representation architectures, particularly Living Graphs and FAIR principles. Searches were conducted in Google Scholar using only the term "living graphs" and were limited to the first two pages of results, given the preliminary and exploratory nature of the research.

The inclusion criterion was relevance to graphs and knowledge organization.

4.0 Results and discussion

The study and literature review support discussing Living Graphs as an effective solution to the crisis in scientific communication and as a step toward more dynamic and adaptive

Knowledge Organization. The main contribution is proposing a shift from static document-based communication (e.g., PDFs) to a model centered on dynamic data and knowledge.

4.1 FAIR Principles, Graphs, and Interoperability

The connection between the FAIR principles - Findable, Accessible, Interoperable, Reusable – (Wilkinson et al. 2016), and knowledge graphs is fundamental to knowledge organization in the digital age. For data to be truly interoperable and reusable, it must be embedded in a semantic network that provides context and meaning. Knowledge graphs, especially Living Graphs, are the ideal framework for implementing the FAIR principles:

a) Findability and Accessibility: Graphs use unique and persistent URIs (Uniform Resource Identifiers) for each node and edge, ensuring that every entity, concept, or relationship is permanently locatable and accessible by both machines and humans. The graph structure facilitates the discovery of data and metadata, making them more visible and retrievable in distributed environments (Auer 2018).

b) Interoperability (Interoperable): This is where knowledge graphs outperform isolated taxonomies and static descriptive metadata systems. By connecting different taxonomies, ontologies, and controlled vocabularies through relationship edges, graphs create a bridge of meaning between heterogeneous systems. Adaptive semantic interoperability, enabled by Living Graphs, addresses “concept drift” and terminological heterogeneity (Shi et al. 2025), overcoming the rigidity of fixed taxonomies. By using Large Language Models (LLMs) as ontological alignment agents, the system resolves ambiguities with greater precision than manual thesauri (Qiang et al. 2024). The integration of FAIR Digital Objects (FDOs) is the epistemological imperative for ensuring this adaptability. FDOs ensure that every unit of knowledge—whether a document, a dataset, or an assertion—is a “machine-actionable” entity, carrying its own metadata and license (Alarcón-Moreno and Wilkinson 2024), thereby guaranteeing the intrinsic autonomy of the data and enabling distinct systems to interoperate flexibly.

c) Reusability: The fine granularity of graphs, which breaks down knowledge into atomic assertions (subject-predicate-object triples), allows specific parts of a query to be reused without the need to process the entire document. This promotes the intelligent composition of new knowledge and intrinsic computability, where AI algorithms can discover hidden patterns and validate assertions efficiently (Groth et al. 2023).

4.2 The Architecture of Living Graphs

Unlike traditional databases and static knowledge graphs, Living Graphs incorporate the temporal dimension as a structural element. As noted by Xu et al. (2020), Temporal Knowledge Graphs (TKGs) record not only a fact itself, but also when it was validated, when

it was refuted, and how its relationships evolved over time. In a Living Graph, new evidence continuously adjusts the weights of trust edges between nodes. The system reflects the current scientific consensus—a process of knowledge "healing"—without erasing the historical-epistemological trail. This allows for a rich understanding of the trajectory of knowledge, unlike the static model where refutations are slow and disconnected, generating a growing informational liability (Auer 2018).

In practice, a clear example of this transition toward dynamic infrastructures is the Scholarly Communication Metadata Knowledge Graph (SCM-KG) developed by Sadeghi et al. (2017). To overcome the "conceptual friction" and structural limits of static formats, Sadeghi et al. integrated isolated databases like DBLP and the Microsoft Academic Graph using a rule-based mapping and the Silk framework. Crucially, the authors addressed the temporal dimension of scientific communication by using a reification pattern to model changing properties over time, such as an author's shifting institutional affiliations. By evaluating semantic similarity at a molecular level, this practical application empirically demonstrated how an integrated RDF mesh resolves conceptual ambiguities and improves query completeness without sacrificing processing time.

4.3 Taxonomy in the Flow of Knowledge

Taxonomy functions as the structural foundation of knowledge graphs by providing controlled vocabulary and semantic rules that give meaning to their elements. In Living Graphs, taxonomies become adaptive and evolve with emerging scientific concepts, integrating as dynamically aligned ontologies that facilitate knowledge organization, discovery, and innovation. This approach allows KO to keep pace with the “conceptual drift” inherent in scientific dynamics, maintaining coherence and semantic precision (Auer 2018).

5.0 Conclusion

Traditional scientific communication relied on static texts and closed systems, which no longer meet the demands of rapid and complex discoveries. Living Graphs, grounded in FAIR Digital Objects, help overcome ontological barriers and knowledge stagnation by breaking information into semantic units, enabling adaptive interoperability, and reflecting the evolving nature of discoveries—thus making scientific communication more dynamic, connected, and responsive.

Declaration of non-use of artificial intelligence

We hereby declare, for all intents and purposes, that this work was prepared by the authors and that we bear full responsibility for the research, analysis, writing, and conclusions presented. We further declare that we did not use Generative Artificial Intelligence (GAI) tools.

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