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Semantic enrichment and interoperability: updates to the Thesa software

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Abstract

This study presents Thesa 2.0, a platform designed for the construction and management of thesauri, supporting rich semantic representation and interoperability in digital environments. It aims to analyze the system's evolution and its contributions to Knowledge Organization Systems (KOS), particularly regarding semantic enrichment and the integration of different controlled vocabularies. Methodologically, the study is grounded in the specialized literature, the international standards ISO 25964 and ANSI/NISO Z39.19, and the application of Semantic Web technologies, including SKOS, RDF, and REST APIs. The results demonstrate the expansion of associative semantic relationships, the ability to define customized properties, and the integration with external systems through multiple export formats and interoperability mechanisms. It is concluded that Thesa 2.0 strengthens knowledge representation and organization by enhancing the integration of thesauri with Information Retrieval Systems (IRS) within interconnected data ecosystems.

1.0 Introduction

Thesauri are essential tools for bibliographic indexing and can be classified according to two main criteria: language coverage and level of specificity. With respect to language coverage, thesauri are categorized as monolingual, bilingual, or multilingual, the latter also serving as supporting tools for translation activities (Dodebei 2002). Regarding specificity, microthesauri employ descriptors restricted to particular subject domains, whereas macrothesauri encompass broader concepts within the same knowledge domain (Arnaut 2012).

Traditionally, the development of thesauri has followed the guidelines established by the ANSI/NISO Z39.19 (2010) and ISO 25964-1 (2011) and ISO 25964-2 (2013) standards, which provide principles for the construction and interoperability of controlled vocabularies. In practice, however, their use often remains disconnected from Information Retrieval Systems (IRS), thereby limiting their potential to enhance information retrieval. Furthermore, the development of these instruments continues to rely largely on classical

models that adopt simplified structures of semantic relationships among terms, resulting in lower semantic richness and weaker conceptual connectivity. Developed in 2017 by researchers at the Federal University of Rio Grande do Sul (UFRGS), the Thesa software addresses this gap by providing an open-source platform for the construction and management of thesauri. It has been used primarily as a pedagogical tool in Library and Information Science programs. At the time of this study, the system hosted 1,128 thesauri, 62,471 concepts, and 79,040 terms, and had been adopted by 41 national and international higher education institutions.

Accordingly, this paper presents partial results of an ongoing research project funded by the Brazilian National Council for Scientific and Technological Development (CNPq) under the Universal Call (Grant No. 421849/2023-1), which focuses on the mapping and analysis of the semantic relationships implemented in the Thesa system. The study makes a primarily instrumental contribution, aimed at the development and enhancement of Thesa 2.0 as a Knowledge Organization System (KOS) by operationalizing and extending established standards, such as ISO 25964 and SKOS, within a computational environment. It seeks to examine the impact of expanding and refining semantic relationships in the software, while also providing a rationale for updating its underlying relational model. In this context, the study is aligned with recent research presented at the VIII Brazilian Congress on Knowledge Organization (Moura et al. 2025), particularly investigations addressing semantic relationships in Knowledge Organization Systems.

Methodologically, the study is based on the mapping of semantic relationships identified in the specialized literature and on observations of the system's use in different thesaurus development contexts. The analysis of requirements emerging during the modeling of thematic domains, particularly in the literary domain, made it possible to identify gaps and limitations in the semantic relationships traditionally implemented in the software architecture. Considering the emerging needs identified through the system's practical use, thesaurus construction and management practices revealed a demand for greater precision and diversity in semantic relationships. Accordingly, the refinement and expansion of these relationships, driven by user experience, enable the continuous improvement of Thesa while enhancing the conceptual representation of the thesauri developed within the platform.

In view of the growing adoption of Thesa by a wide range of institutions, this paper aims to present the updates introduced in Thesa 2.0. The new version reinforces the system's instrumental contribution by providing a functional and interoperable computational environment that supports compliance with current thesaurus development standards, particularly ISO 25964 and the SKOS model.

2.0 Thesa: Origins and Functionalities

The Applied Semantic Thesaurus (Thesa) was developed in 2017 at the Federal University of Rio Grande do Sul (UFRGS) to support Library and Information Science students in thesaurus construction while also serving as a research platform. The system is based on

the guidelines established by ISO 25964 (Parts 1 and 2) and the ANSI/NISO Z39.19 standard, incorporating SKOS resources to ensure interoperability among different thesauri and compatibility with Linked Data ecosystems. Its functionalities are designed to meet the semantic requirements emerging from contemporary Knowledge Organization Systems (KOS).

Freely available as a web-based application hosted by UFRGS and distributed under a Creative Commons Attribution (CC BY) license through the GitHub platform (https://github.com/ReneFGJr/Thesa), Thesa can also be deployed on servers maintained by other institutions. The system supports the development of microthesauri, macrothesauri, monolingual, bilingual, and multilingual thesauri, as well as other types of Knowledge Organization Systems, such as glossaries. One of its distinguishing features is its support for collaborative development: multiple microthesauri covering different knowledge domains can be created and edited independently before being integrated into a single thesaurus (Gabriel Junior and Laipelt 2017).

Version 2.0 introduces support for assigning multiple preferred terms (prefLabel) to the same concept, provided that each term is expressed in a different language (Figure 1), in accordance with the SKOS model. The system architecture is based on persistent Uniform Resource Identifiers (URIs), allowing the preferred term associated with a concept to be modified without affecting the identity or integrity of the concept itself. Consequently, concepts are treated as persistent entities, whereas their representations—whether expressed as terms, images, audio, or links—may evolve according to historical, linguistic, or social contexts.



Figure 1. Representation of the concept “Artichoke” in Thesa 2.0

To further enhance integration with Information Retrieval Systems (IRS), application programming interfaces (APIs) are currently being developed to support the automatic identification of candidate terms from full-text documents stored in databases. Future developments also include the analysis of user behavior through search log data, enabling the continuous improvement of system interaction and the direct reindexing of documents within the database. These functionalities are intended not only to support the work of

professional indexers but also to assist end users during the information retrieval process through interactive search and retrieval mechanisms.

Thesa has considerable potential for application in undergraduate teaching, graduate research, libraries, and other professional information environments. By reducing the operational effort involved in thesaurus construction, the platform enables users to devote greater attention to the cognitive and conceptual aspects of domain modeling and the establishment of paradigmatic and syntagmatic relationships among concepts.

3.0 Interoperability and Semantic Relationships: Evolutionary Perspectives in Thesa

The Simple Knowledge Organization System (SKOS) (W3C 2010) enables concepts to be created, published, linked to data, and integrated into other conceptual schemes on the Web. This capability enhances the representation of paradigmatic and syntagmatic relationships within Thesa, promoting semantic enrichment while supporting effective compliance with the ISO 25964 standard, which recommends the explicit representation of relationships among terms.

Within the context of Knowledge Organization Systems (KOS), the explicit representation of semantic relationships is not merely a technical requirement; it constitutes the foundation that enables both computational systems and human users to infer meanings, expand search queries, and discover conceptual connections that extend beyond the boundaries of a single thesaurus (Gabriel Junior and Laipelt 2019). As emphasized by Hjørland (2007) and Green (2001), semantic relationships play a structural role in information retrieval by improving both precision and recall while making explicit the diverse perspectives and paradigms that characterize a knowledge domain.

In this context, SKOS represents a core technology within the Linked Data (LD) ecosystem. By providing a machine-readable model for representing the structure and content of conceptual schemes, it enables Knowledge Organization Systems—including thesauri, taxonomies, and classification systems—to participate actively in the Semantic Web, transforming controlled vocabularies into interoperable and interconnected data sources (Silveira and Martínez-Ávila 2025; Pastor-Sánchez et al. 2012).

To promote semantic enrichment and interoperability in Thesa, the semantic relationship model based on skos:related has been substantially extended. Thesa 2.0 introduces a richer relational framework through the definition of a reference model that expands the traditional set of associative relationships. To achieve this, new semantic properties were incorporated into the system, as presented in Table 1, with the objective of providing more expressive descriptions of conceptual relationships while preserving the original skos:related property. Furthermore, users may select the relationship properties that best suit the representational requirements of their specific knowledge domains.

Table 1. Semantic metacategories for expanding associative semantic relationships in Thesa 2.0 (the complete list of Thesa semantic relationships is available in the Zenodo repository at zenodo.19039781

GROUP	PROPERTY	DESCRIPTION	FORMULA	EXAMPLE
Basic-Classic	thesa:hasCauseEffect *reverse of* thesa:hasEffectCause	Cause/Effect *reverse of* Effect/Cause	Term A has the effect of Term B *reverse of* Term B is caused by Term A	Consistency in "Indexing" (cause) leads to accuracy in "Information Retrieval" (effect). *reverse of* Accuracy in "Information Retrieval" (effect) is a consequence of consistency in "Indexing" (cause).
Among Entities	thesa:hasFatherSon *reverse of* thesa:hasSonFather	Father/Son *reverse of* Son/Father	Term A is the father of Term B *reverse of* Term B is the son of Term A	"José" is the father of "Thiago". *reverse of* "Thiago" is the son of "José"
Methodology	thesa:hasFieldOfStudyPhenomenon *reverse of* thesa:hasPhenomenonFieldOfStudy	Field of study/Phenomena studied *reverse of* Phenomena studied/Field of study	Term A studies the Term B *reverse of* Term B is subject of study of Term A	"Information Science" studies "Scientific Communication". *reverse of* "Scientific Communication" is a subject of study for "Information Science".

The selection of associative relationships was based on a review and adaptation of the paradigmatic and syntagmatic relationship framework proposed in the IFLA (2012) conceptual model for the Functional Requirements for Subject Authority Data (FRSAD). This framework was complemented by three additional relationship categories proposed by Gabriel Junior and Laipelt (2019), which are absent from the original standard: kinship/affinity, product characteristics, and process/agent. The model was further informed by empirical observations of the software's use in educational activities within the Classification Systems III course at the Federal University of Rio Grande do Sul (UFRGS) (Gabriel Junior and Laipelt 2019).

For Version 2.0, this process was further expanded through a documentary review of ISO 25964-1, ISO 25964-2, and both layers of the SKOS specification (SKOS Reference and SKOS Primer). This review demonstrated that the core skos:related property was insufficient to represent richer semantic relationships, motivating its extension. The enhancement was implemented through the creation of new properties within the Thesa vocabulary, each corresponding to a specific category of associative relationship while also enabling users to define custom properties according to the representational requirements of the modeled knowledge domain (Gabriel Junior and Laipelt 2023).

This extension is justified because associative relationships constitute the most complex and ambiguous category of relationships in thesauri. They establish diverse semantic connections among concepts, and their definition requires in-depth domain knowledge, clearly defined thesaurus objectives, and an understanding of the epistemological characteristics shared by related concepts. ISO 25964-1 (2011, 67) refers to these as customized relationships, acknowledging their importance for enhancing the semantic expressiveness of Knowledge Organization Systems (KOS). From the perspective of SKOS, this enhancement operates at two complementary levels: the intra-vocabulary level, which concerns semantic relationships among concepts within the same thesaurus, and the inter-vocabulary level, which addresses mappings between different controlled vocabularies (Barbosa and Viera 2022). According to Silveira and Martínez-Ávila (2025), the latter represents a key indicator of interoperability, as semantic links established between concepts belonging to different KOS expand the expressive and semantic coverage of each vocabulary.

The scope of associative relationships is inherently constrained by the conceptual domain represented within a particular thesaurus. To enable interoperability among different thesauri, however, SKOS provides mapping properties that establish semantic correspondences across vocabularies. From a practical perspective, there is a need to explicitly represent exact, close, and related conceptual correspondences using properties such as skos:exactMatch, skos:closeMatch, skos:mappingRelation, and skos:relatedMatch. It should be emphasized that interoperability among thesauri depends on the adoption of the SKOS ontology. Because Thesa 2.0 implements the SKOS Primer model, it can establish semantic links with concepts originating from other thesauri implemented according to either the SKOS Reference or SKOS Primer specifications (W3C 2008).

This capability for inter-thesaurus connectivity is fundamental to knowledge representation in complex information environments. By linking thesauri developed from different perspectives on the same knowledge domain, the system enables the emergence of collaborative conceptual networks and the creation of boundary objects, as proposed by Campos (2018). The resulting interoperability not only broadens the semantic coverage of individual vocabularies but also strengthens conceptual consistency across Knowledge Organization Systems. As empirically demonstrated in Thesa 2.0, the explicit expansion of associative relationships suggests that thesauri can achieve a level of semantic expressiveness comparable to that of ontologies (Gabriel Junior and Laipelt 2023).

For such interoperability to be fully realized within the Linked Data (LD) environment, however, concepts represented in SKOS must be assigned Uniform Resource Identifiers (URIs)—unique and persistent identifiers that locate resources on the Web and enable semantic links among conceptual schemes. Silveira and Martínez-Ávila (2025, 31) emphasize that Linked Data best practices require the identification of resources through URIs, the use of the HTTP protocol, and data representation using standards such as RDF and OWL. Thesa 2.0 satisfies these requirements by assigning persistent URIs to every concept, thereby ensuring that preferred labels can be modified without compromising the conceptual integrity of the system.

Figure 2 illustrates the application of the SKOS Primer model to connect different thesauri. Such inter-thesaurus links enrich all participating vocabularies by enabling the collaborative expansion of conceptual knowledge. Through these semantic connections, users gain access to additional terms and relationships originating from alternative perspectives that may not have been considered during the independent development of each thesaurus. In the example presented, Thesaurus A was developed from the perspective of the apple as a product, Thesaurus B emphasizes the origin and scientific classification of apple varieties, and Thesaurus C focuses on culinary preparations and texture-related characteristics.

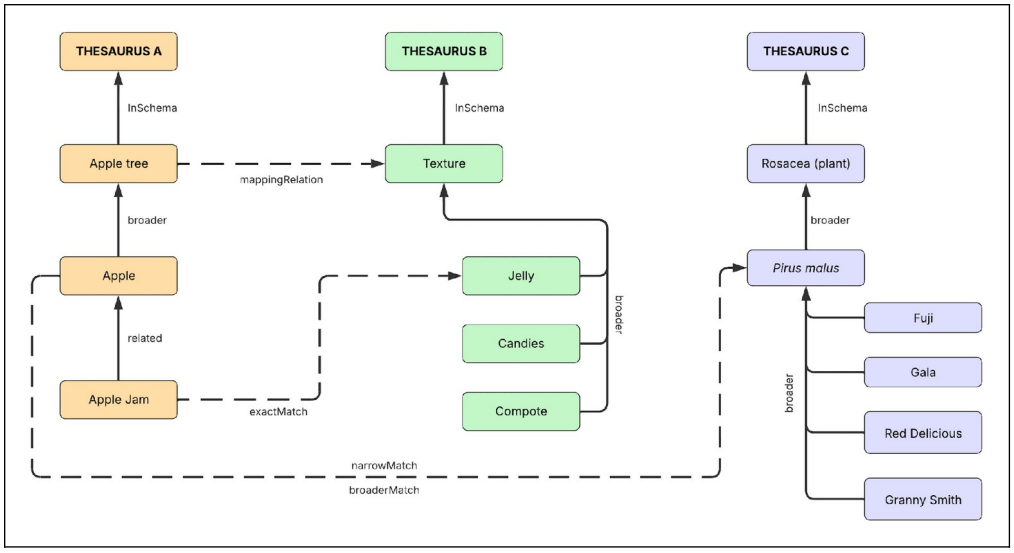

Figure 2. Inter-thesaurus relationships represented in SKOS.

Using the skos:exactMatch property, the common term apple in Thesaurus A is linked to the scientific term Malus domestica (or the corresponding scientific concept) in Thesaurus B. By accessing the scientific concept in Thesaurus B, users can also discover that additional apple varieties are represented within its conceptual structure. Likewise, by using the skos:broadMatch property to connect the concept Apple Jelly in Thesaurus A with the broader concept Jelly in Thesaurus C, users can infer from the conceptual structure of Thesaurus C that apples may also be used in other culinary preparations, such as preserves and confectioneries. Similarly, the skos:mappingRelation property links the concept Apple Tree in Thesaurus A to the concept Rosaceae (Plant) in Thesaurus B, revealing that the apple tree belongs to a broader family of flowering plants. Consequently, the information contained in the three thesauri becomes mutually complementary and semantically enriched by integrating multiple perspectives on the same domain.

This example illustrates how the explicit representation of semantic relationships generates a network of meanings that no individual thesaurus could provide in isolation. It therefore constitutes a concrete demonstration of the evolution and instrumental contribution of Thesa 2.0 to knowledge representation. By operationalizing the SKOS Primer

model within an interoperable computational environment, the system enables complementary conceptual perspectives on the same domain to be connected and mutually enriched, thereby expanding opportunities for information retrieval and knowledge discovery (Hjørland 2007; Gabriel Junior and Laipelt 2019).

This inter-vocabulary mapping strategy is supported by the empirical study of Silveira and Martínez-Ávila (2025), who demonstrated how the skos:closeMatch and skos:exactMatch properties enable the alignment of equivalent or closely related concepts originating from distinct vocabularies. Their findings indicate that concepts represented in SKOS exhibit characteristics compatible with the Linked Data (LD) paradigm, including interoperability through standardized semantic languages, the use of persistent Uniform Resource Identifiers (URIs) for concept identification, and data representation using interoperable technological standards. By adopting the SKOS Primer model together with persistent URIs, Thesa 2.0 seeks to consolidate these same principles.

Accordingly, SKOS-based interoperability can be achieved in two complementary ways: through the exchange of controlled vocabularies with other applications implementing the same protocol and through integration with Information Retrieval Systems (IRS). Integration with IRS is primarily enabled through SPARQL (SPARQL Protocol and RDF Query Language), the standard language for querying and manipulating Resource Description Framework (RDF) data. Representing thesauri in RDF allows Thesa to interoperate with other thesauri hosted internally, with external Thesa servers, and with third-party systems such as TemaTres, SKOSMOS, and Linked Data providers including Wikidata and DBpedia (Miles and Pérez-Agüera 2007).

This integration with Information Retrieval Systems represents a significant advancement over the traditional indexing model, in which thesaurus management tools primarily supported indexers without interacting directly with users during the search process. With Thesa 2.0 integrated into IRS through RESTful APIs and SPARQL, it becomes possible to provide functionalities such as standardized term autocompletion, semantically related descriptor recommendations, and dynamic document reindexing. As argued by Gabriel Junior and Laipelt (2019), such mechanisms can contribute both to the improvement of Knowledge Organization Systems and to information retrieval and the discovery of new information sources.

Within the broader context of Library Linked Data (LLD), Silveira and Martínez-Ávila (2025, 31–32) argue that Linked Data initiatives in libraries require data to be openly published, identified through persistent URIs, represented in RDF, and connected to external URI-based resources. Thesa 2.0 already operationalizes these practices through its integration with providers such as Wikidata and DBpedia, as well as with information systems including Brapci and LattesData. This convergence positions Thesa 2.0 not merely as thesaurus management software but as a semantic infrastructure fully aligned with the principles of Library Linked Data, a particularly relevant contribution in the Brazilian context, where the authors note that the subject remains underexplored from theoretical, methodological, and practical perspectives (Silveira and Martínez-Ávila 2025).

Within this framework, Thesa 2.0 is also being extended with functionalities for importing data from external systems and applications that support XML or RDF export standards. Its export capabilities include XML, RDF, Turtle, CSV, and JSON, facilitating interoperability with a broad range of external applications. Another major enhancement is the implementation of a RESTful Application Programming Interface (API), providing scalability, platform independence, and programming-language neutrality. The RESTful API enables seamless integration with distributed applications and web-based services, making Thesa suitable for deployment in heterogeneous information environments.

These functionalities are fully operational in Thesa 2.0 and have already been successfully tested through integration with library catalogs, particularly within the Brapci and LattesData systems. Together, they embody the system's primarily instrumental contribution: by operationalizing and extending established standards such as ISO 25964 and SKOS within a functional and interoperable computational environment, Thesa 2.0 serves as a semantic infrastructure for the construction, management, and sharing of semantically enriched thesauri. The combination of expanded associative relationships and technical interoperability enabled by RDF, SPARQL, and the RESTful API significantly enhances the semantic expressiveness of thesauri developed within the platform, bringing them closer to the representational capabilities of ontologies while preserving accessibility and compliance with internationally recognized standards (Gabriel Junior and Laipelt 2023).

Nevertheless, the full integration of Thesa 2.0 into the Linked Data ecosystem depends on challenges that extend beyond the software itself. Silveira and Martínez-Ávila (2025, 43–44) identify three challenges that are directly applicable to the Thesa context: the need for advanced technical expertise in markup languages and semantic web technologies among thesaurus developers; the requirement for sustained interdisciplinary collaboration between information professionals and computer scientists; and the limited theoretical, methodological, and practical exploration of Linked Data within Brazilian Information Science. Addressing these challenges, together with the broader adoption of Thesa 2.0's enhanced semantic relationships, will be essential for realizing the system's full potential as a Linked Data infrastructure for Brazilian Knowledge Organization Systems.

4.0 Conclusion

The analysis of the development of Thesa 2.0 demonstrates significant advances in the field of Knowledge Organization Systems (KOS), particularly with respect to semantic enrichment and the expansion of interoperability among thesauri. The incorporation of features based on the SKOS model, together with the extension of associative relationships and the ability to define custom semantic properties, contributes to a richer and more context-sensitive conceptual representation of knowledge domains. Furthermore, the system architecture, which clearly distinguishes concepts from their various forms of representation, enhances the flexibility of the model and supports its adaptation to diverse information environments and institutional requirements.

In addition, the functionalities implemented in Thesa 2.0—including data export in multiple formats, integration with standards such as RDF and XML, and the use of RESTful APIs for communication with external systems—substantially increase its potential for integration with Information Retrieval Systems (IRS) and Linked Data ecosystems. Consequently, the platform is emerging as a valuable resource for both academic and professional applications by supporting the collaborative development of controlled vocabularies and facilitating interoperability among different thesauri. In this way, Thesa 2.0 strengthens knowledge organization and representation practices in increasingly interconnected digital environments, providing a robust semantic infrastructure that promotes the creation, sharing, and reuse of interoperable knowledge structures.

Statement on the use of Artificial Intelligence (AI): Artificial intelligence (AI) tools were not used in the preparation of this work.

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