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Weaving the Threads of Bibliographic Ontologies

Application of a Reference Ontology to Advance Semantic Interoperability

Helena Simões Patrício, Pedro Nogueira Ramos, and Maria Inês Cordeiro

ABSTRACT

Bibliographic ontologies are crucial to make the most of networked library metadata, but they show interoperability limitations in the Semantic Web. Following a research study on the subject, this paper presents a possible solution to such limitations by means of a reference ontology (RO) intended to allow integration of different ontologies without imposing a common central one and to overcome limitations of mapping techniques, such as crosswalks and application profiles, most used in interconnecting bibliographic ontologies. Interoperability issues of Resource Description and Access (RDA) and Bibliographic Framework Initiative—BIBFRAME (BF) ontologies are addressed using real-world examples from the Library of Congress (LoC) and Biblioteca Nacional de España (BNE) datasets. For a proof of concept of the RO, this paper is focused on two specific interoperability problems that are not solvable with the usual data transformative techniques: misalignments concerning the definition and representation of Work and Expression classes; and the absence of formalization of properties essential to whole-part relationships, namely transitivity, nonreflexivity and asymmetry. The potential of the RO for solving such problem examples is demonstrated by making in-depth use of Resource Description Framework Schema/Web Ontology Language (RDFS/OWL) semantic reasoning and inference mechanisms, combined with Shapes Constraint Language (SHACL), when restrictions are needed to impose data constraints and validation. The RO innovation consists in the formulation of an independent high-level ontology, through which the elements of different source-ontologies are interlinked without being modified or replaced, but rather preserved, and in using semantic mechanisms to generate additional elements needed to consistently describe the relationship between them.

INTRODUCTION

The principles of the Semantic Web and the new data structures created by RDFS/OWL have driven the need for bibliographic standards and libraries to transform their data into data that is machine-actionable and shareable by different platforms, databases, and coding formats.[1] However, despite the consensus in the literature about bibliographic standards like the Library Reference Model (LRM), RDA, and BF being convergent with the Semantic Web, and the fact that they have been formalized as OWL ontologies by the respective maintenance agencies, there are several criticisms regarding their interoperability.[2]

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Interoperability remains "an open issue" that goes beyond the mere conversion of bibliographic datasets to the Semantic Web, requiring mechanisms for the alignment between different ontologies.[3] Bibliographic ontologies underlying LRM, RDA, and BF show conceptual misalignments, different levels of granularity, underuse of semantic mechanisms, and poor ontology interlinking.[4] Therefore, solutions are needed to overcome such interoperability issues in order to make LRM, RDA, and BF interlinkable as open vocabularies (LOV—Linked Open Vocabularies), i.e., high-quality vocabularies that can be reused for describing linked data.[5]

This paper draws on a larger research study by Patrício, investigating the possibility of overcoming some of those interoperability limitations through the creation of a reference ontology (RO) which applies mediation techniques using RDFS and OWL semantic abstraction mechanisms that allow for inference and reasoning.[6] Additionally, because of the inability of RDFS/OWL to impose and validate data restrictions, the imposition of data constraints is provided in the RO by defining restrictions with Shapes Constraint Language (SHACL).[7] This approach is distinct from transformative methods, such as crosswalks and application profiles, commonly used by bibliographic ontologies in their interconnection.

The objective of this paper is to demonstrate the RO's semantic mediation solutions and SHACL validation applied to real-world examples that denote the interoperability problems of bibliographic ontologies reported in literature. For this purpose, examples were selected from two source-ontologies, BF and RDA, belonging to datasets from the Library of Congress (LoC) and the Biblioteca Nacional de España (BNE).

The paper is structured in four parts. First, a brief literature review on issues of bibliographic ontologies interoperability and interoperability techniques provides the context of the topic. Second, the RO objectives and development methodology lays out the fundamentals of the research. Third, the exercise conveying the RO application to selected examples is presented, as proof of concept of the solution, constituting the main object of the paper. The paper closes with a summary of results and concluding remarks.

BRIEF LITERATURE REVIEW

Bibliographic Ontologies Interoperability Issues

In the literature, the main data structure insufficiencies reported as affecting interoperability are the reduced application of semantic mechanisms such as classification, equivalence, hierarchy, or transitivity, which prevents bibliographic ontologies from taking full advantage of the potential of linked data. The use of ad hoc relationships, instead of RDFS/OWL semantic primitives, leads to the isolation of ontology elements and inhibits inference and reasoning mechanisms, as noted by Poveda Villalón.[8]

Another aspect is the poor interlinking of bibliographic ontologies: the low level of external vocabularies reutilization, combined with the proliferation of bibliographic ontologies, makes it difficult to search, integrate, and reuse bibliographic data.[9] The literature also points out the problems of "cherry-picking" and "ontology hijacking" in interlinking ontologies, for example, when external elements are used directly without a link to their source or combined in an inconsistent manner with local elements.[10]

On the other hand, RDFS/OWL limitations in validating data structures can lead to consistency problems. RDFS/OWL compliance with the Open World Assumption (OWA) allows for data inference through semantic mechanisms but it also prevents the imposition of restrictions and, consequently, data validation.[11] In fact, under the OWA rationale, RDFS/OWL restrictions can only be used for inferring new information, but do not prevent inconsistent ontologies or application profiles that may exist and be applied in an open environment. Without disrespecting OWA, it should be possible to "close" parts of this open world to ensure the consistent use of bibliographic ontologies.[12] For this reason, a solution had to be found to impose data restrictions using SHACL, a high-level vocabulary for the expression of data constraints that is simultaneously a language for ontologies.[13]

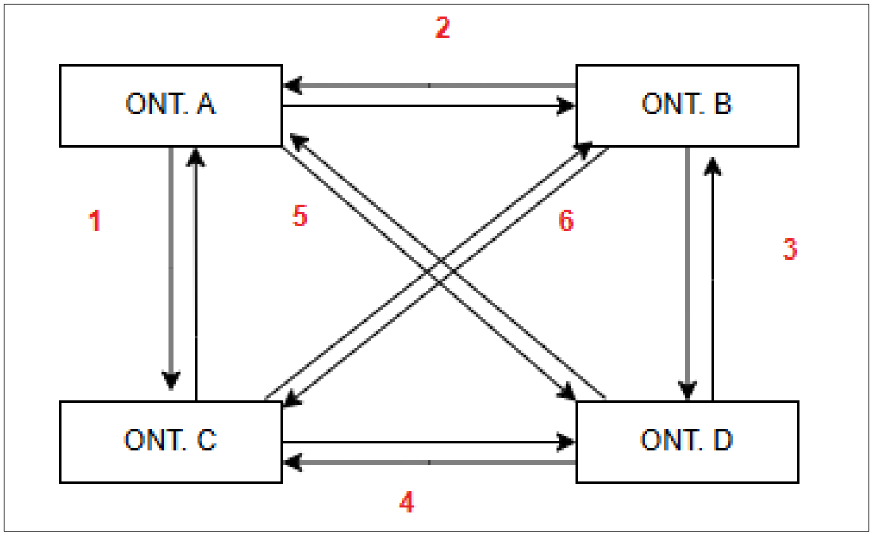
Finally, mappings between bibliographic ontologies are usually implemented as crosswalks or point-to-point mappings, following transformative methods specific to XML that do not solve issues of semantic compatibility and have scalability problems.[14]

Semantic Interoperability Methods

Overcoming semantic misalignment is usually done through elements mapping, using two different methods: (1) transformative techniques (adoption of a common single model; application profiles; crosswalks); and (2) mediation techniques (alignment; fusion).[15]

Transformative techniques are the most common methods amidst bibliographic ontologies, but they are pointed out in the literature as not being suitable to the Semantic Web. On the one hand, single models are not adequate for open and heterogeneous environments like the Web, and, on the other hand, while interoperability is achieved in industry by standardizing physical components, in the information domain, interoperability should correspond to mediating heterogeneity rather than simply standardizing.[16] The use of application profiles is also discouraged because of the difficulty in ensuring nonformalized semantic consensus in the open web environment and because it is usually not permitted to define new elements in an application profile.[17] Crosswalks are the most widely used technique in interlinking bibliographic ontologies; however, they are not considered suitable for the Semantic Web, because they do not use the Web infrastructure, nor follow any formal specifications.[18] They also present the disadvantages of point-to-point mappings that are the source of many of the interoperability problems of bibliographic ontologies.[19] In addition to these drawbacks, the decision not to use the crosswalk method is based on crosswalk scalability problems. In fact, pairwise ontology methods imply direct alignments between every two ontologies, so any new ontology that is added to the crosswalk needs to be linked to each of the other ontologies of the map.[20] The example in figure 1 shows that six pairs of alignments are necessary to map four ontologies. Any further ontology added must link to each of the four ontologies, adding four extra pairs of alignment to the six pairs already existing. The crosswalk will scale from 6 to 10 pairs of links with the fifth ontology. As the number extends and the complexity of ontologies grows, crosswalking becomes increasingly difficult.

Figure 1. Pairwise mapping of multiple ontologies.[21]

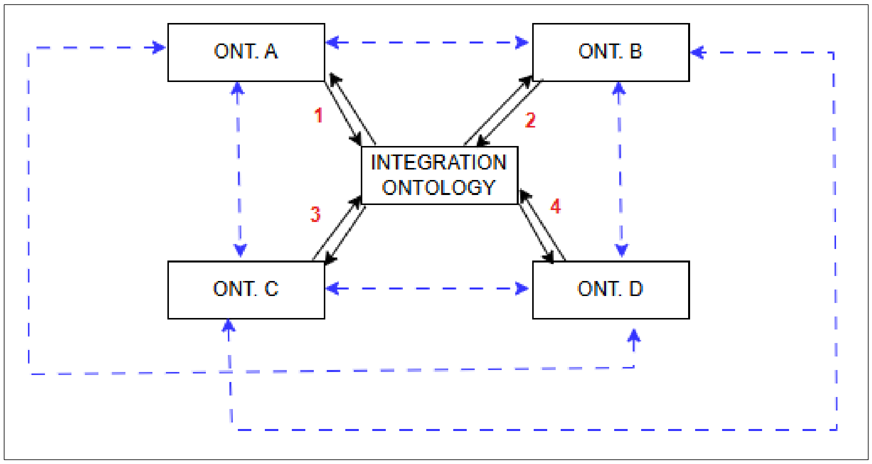


Mediation techniques offer solutions to the problem of reduced scalability of transformation methods, namely by "switching across," a technique in which there is a schema (new or existing) that is used as a switch mechanism, acting as a channel between different schemas.[22] In this type of solution, also called "inter-lingua ontology" or "ontology integration," the integration ontology functions as a "lingua franca," with the following advantages:[23]

- Each ontology that is added adds only two links to the total map (the relation to the integration ontology and its inverse).
- The relationships between the source-ontologies do not need to be expressly declared, they can be inferred from the relationships with the integration ontology.

The ontology integration method offers an indirect mapping that solves the crosswalks scalability problems exemplified in figure 1, since all source-ontologies only need to align with the reference ontology so that the relationship between each pair of ontologies is derived from the reference ontology, as exemplified in figure 2 (inferred or indirect mappings in dashed lines).[24]

Figure 2. Indirect mapping through an integration ontology.[25]



Given the above, the solution to overcome semantic limitations lies on integration techniques not limited to the simple transformation between ontologies of the same level, but rather consisting of a mediation or bridge ontology capable of representing the semantic connections between source-ontologies at a higher level of abstraction, which is the role of a reference ontology.

THE REFERENCE ONTOLOGY (RO): OBJECTIVES AND METHODOLOGY

A reference ontology is not designed for any specific application but is intended for reuse in multiple contexts.[26] It must describe the domain adequately, reflecting the community consensus so it can be applied to conceptually compare multiple ontologies, managing their differences and playing an efficient role in linking heterogeneous ontologies, serving as a core ontology for ontology management.[27]

The research carried out by Patrício explored the hypothesis of solving interoperability limitations of bibliographic ontologies by means of an RO as a mediation or bridge ontology that can represent the semantic connections between three source-ontologies—LRM, RDA, and BF—reconciling their differences and misalignments.[28] The methodology followed comprehended the work phases described below.

Phase I: Preliminary Conceptual Study

An empirical analysis of the LRM, RDA, and BF normative specifications was undertaken, including the study of their formalization as OWL ontologies and supporting bibliography. This was followed by a comparative analysis of LRM, RDA, and BF to verify the interoperability problems referred to in the literature review and to identify new discrepancies and overlaps.

In addition, the following mappings carried out by the agencies responsible for the creation and maintenance of the source-ontologies were also considered:

- Mappings from the RDA Registry, namely the alignments between RDA/LRM entities and elements, as well as the mappings between RDA/LRM classes and properties;[29]
- Library of Congress mapping between WEMI LRM/RDA classes and BF core classes.[30]

Phase II: Development of the RO

The methodology applied in this phase is of an empirical character, corresponding to the creation of the ontology to be used for testing and validation.

The misalignments between LRM, RDA, and BF are settled through the RO, using

- RDFS/OWL abstraction mechanisms (classification, hierarchy equivalence, transitivity, etc.), for solving semantic interoperability problems;
- interoperability through mediation, a method that uses alignment, intersection and composition techniques that are distinct from transformative techniques, such as crosswalk mapping and application profiles; and
- SHACL restriction and validation mechanisms that allow for defining and imposing restrictions on bibliographic ontologies, thus overcoming RDFS/OWL syntactic limitations.

The techniques used specific to ontology mediation methods, were as follows:

- Alignment—the source-ontologies are preserved, and a new ontology is produced with additional elements that map the concepts of the base ontologies. The use of a reference ontology for ontology alignment is an effective and alternative method to point-to-point mappings or pairwise alignment. In pairwise mapping, there is a direct alignment between every two ontologies; otherwise, the RO provides an indirect alignment between the source-ontologies that only need to be mapped to the RO, because the pairwise mapping is derived from the mapping to the reference ontology.[31]

- Intersection—concepts from base ontologies can be renamed.
- Composition—creation of elements and relationships that overlap the concepts and structure of the base ontologies, thus overcoming the mere mapping between them.

LRM, RDA, and BF ontologies were imported to Protégé software and merged into the RO target ontology, using the Refactor/Merge commands.[32] These commands ensure mediation of the RO as a bridge ontology, corresponding to an incomplete fusion of the source-ontologies since they are not replaced by the RO, but, instead, their concepts and relationships are duplicated in the target ontology, where the respective alignment is made through bridge axioms.[33] This solution ensures, on the one hand, that the source-ontologies are not replaced or modified and that, on the other hand, they can be reused consistently.[34]

In addition to formalizing the RO in OWL, it was necessary to resort to the SHACL formalism to model the constraints and restrictions applicable to RO classes and relations because, unlike SHACL, OWL does not allow validation of constraints, but only inference, and because there are restrictions that cannot be formalized in OWL.[35]

The ontology editor TopBraid Composer was used to edit SHACL constraints.[36]

Phase III: RO Validation

The last work phase consisted of validating the RO to check whether it solves the interoperability problems between bibliographic standards. The validation methodology consisted of RDFS/OWL reasoning to infer implicit relationships between resources and new information beyond what is expressly declared.[37] Descriptive logic queries were also carried out in the RO using the Protégé DL Query tool. HermIT Reasoner was used for both reasoning and querying.[38]

To validate the SHACL restrictions, the SHACL validator from the Top-Braid Composer software was used.

More information about the RO is accessible online at https://libraryreferenceontology.org, including the respective files and identification of the versions of the source-ontologies integrated. The RO is formalized in OWL and referred to as OROWL, using the namespace “orowl”. In parallel, constraints were formalized in SHACL, in a separate ontology called ORSHACL, with the namespace “orshacl”. OROWL and ORSHACL files are fully available in RDF/XML.

RO PROOF OF CONCEPT: APPLICATION TO REAL-WORLD EXAMPLES

This section brings to life the RO with a demonstration process to test and provide evidence of its capabilities with real-world examples.

The datasets selected for this demonstration use two of the RO source-ontologies, BF and RDA, which is related to LRM:

- The Library of Congress (LoC) dataset ID.LOC.GOV—Linked Data Service, which implements BF.[39]
- The Biblioteca Nacional de España (BNE) dataset DATOS.BNE,, which implements the BNE Ontology (BNEO), whose elements are mapped to RDA.[40]

For practical reasons of feasibility in the space of this paper, the demonstration is focused on a selection of interoperability problems identified in LRM, BF, and RDA ontologies:

- Polysemy of bf:Work—multiple correspondence between bf:Work and the LRM and RDA concepts of Work and Expression.
- Whole-Part relationship—the formalization of this type of relationship in BF, LRM, and RDA does not ensure the semantics of whole-part relationships.

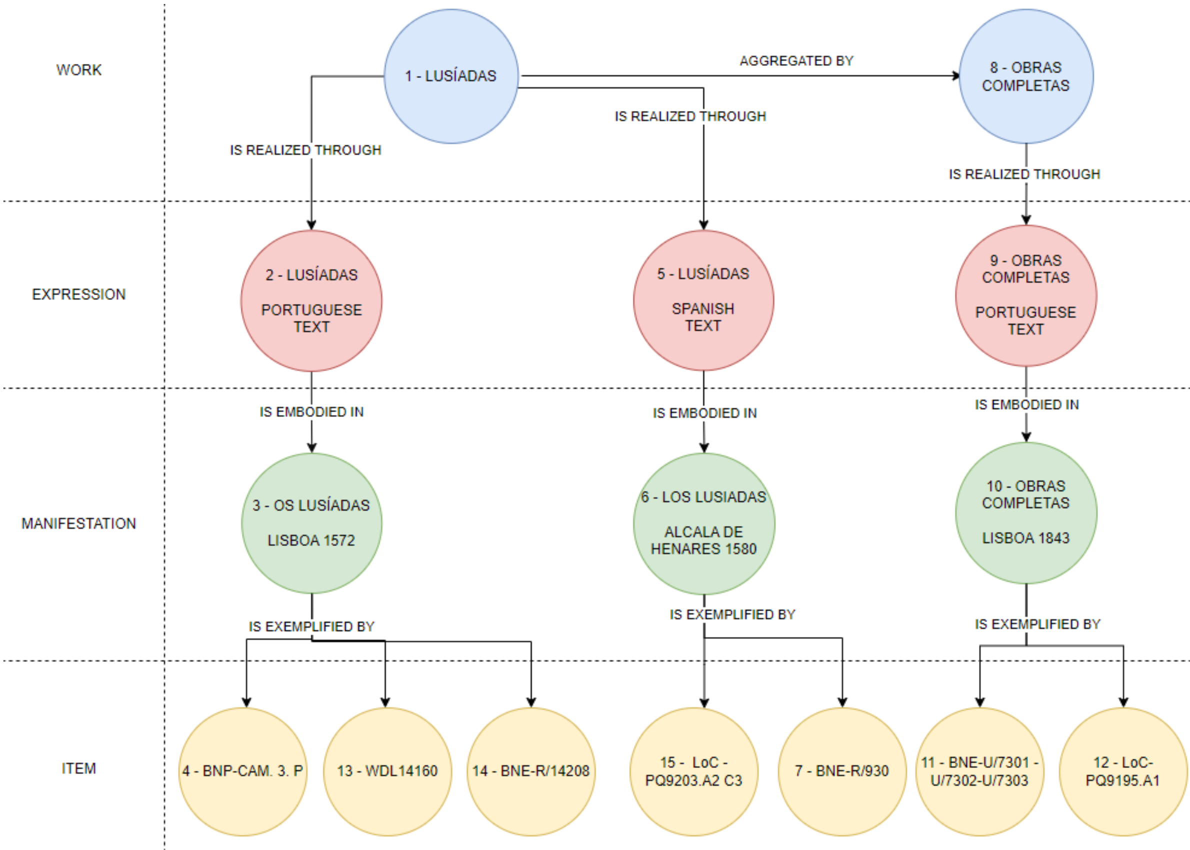
In the remainder of this section, these problems are explained and analyzed using individuals representative of the LRM WEMI entities (Work, Expression, Manifestation, and Item) present in the LoC and BNE datasets. These individuals are real-world instantiations of "The Lusiads" example, presented below.

"The Lusiads" Example

The great Portuguese epic poem "The Lusiads" ("Os Lusíadas") by Luís Vaz de Camões, the best-known Portuguese poet of the Renaissance, is used to exemplify the interoperability problems to be dealt with. In this example the following Works, Expressions, Manifestations, and Items are considered:

- Work ID1-LUS – Intellectual content of "Os Lusíadas."
- Expression ID2-LUS-PT – Realization of the Work ID1-LUS through words written in Portuguese.
    - Manifestation ID3 – Embodiment of the Expression ID2-LUS-PT in the text printed in Lisbon, by the printer António Gonçalves, in 1572.
    - Item ID4 – Exemplification of the Manifestation ID3 as the item or physical object from the National Library of Portugal collection, with the shelf mark CAM. 3 P.
- Expression ID5-LUS-SPA – Realization of the Work ID1-LUS through words written in Spanish.
    - Manifestation ID6 – Embodiment of the Expression ID5-LUS-SPA in the text printed in Alcalá de Henares, by the printer Juan Gracián, in 1580.
    - Item ID7 – Item or physical object from the Biblioteca Nacional de España collection, with the shelf mark R/930, that exemplifies the Manifestation ID6.
    - Item ID15 – Item or physical object from the LoC collection (shelf mark PQ9203.A2 C3), that exemplifies the Manifestation ID6.
- Work ID8-CWLC – Intellectual content of *Obras Completas de Luís de Camões* (*The Complete Works of Luís de Camões*).
- Expression ID9-CWLC-PT – Realization of the Work ID8-CWLC through words written in Portuguese.
    - Manifestation ID10-CWLC-1843 – Embodiment of the Expression ID9-CWLC-PT in the printed text, published in Lisbon in 1843.
    - Item ID11 – Copies or physical objects from the Biblioteca Nacional de España collection, with shelf marks from U/7301 to U/7303, that exemplify the Manifestation ID10-CWLC-1843.
    - Item ID12 – Physical object of the LoC collection, with shelf mark PQ9195.A1, that exemplifies the Manifestation ID10.

Figure 3. "The Lusiads" example.



Real-world individuals from the LoC and BNE datasets that instantiate the "The Lusiads" examples of Work, Expression, Manifestation and Item are detailed in the appendix.

In the following parts of this section, the two interoperability problems selected—the polysemy of bf:Work and the whole-part relationship properties omission—are addressed. For each problem, the abstract solution created in the RO will be explained, followed by the exemplification of the problem and the demonstration of the solution, using the BNE and LoC individuals.

Polysemy of bf:Work

Before explaining the multiple correspondence problems between bf:Work and LRM/RDA Work and Expression classes, it is important to recall these ontologies' definitions of the nuclear bibliographic entities Work, Expression, Manifestation, and Item (WEMI). In the LRM ontology WEMI entities can be grouped in two levels of analysis:[41]

- Purely conceptual entities: Work (lrm:E2) and Expression (lrm:E3), entities that reflect the intellectual and artistic content of a resource. The LRM defines Work as an abstract entity, which results from the coincidence of content common to the different Expressions of the Work. The LRM Expression corresponds to the intellectual or artistic realization of a Work through words, phrases, musical notes, etc., not including the physical format.
- Material entities that involve a production process: the entities Manifestation (lrm-E4) and Item (lrm-E5), which concern the physical form of this resource, always involving a production process. The Manifestation entity is defined as the physical materialization of an Expression of a Work. Manifestation represents all physical objects (Items) that have the

same characteristics in terms of intellectual content and physical format. The Item is the individual unit of a Manifestation, being defined by the LRM as a concrete entity, an individual physical object.

There is total conceptual similarity between RDA and LRM in the definition of WEMI entities:

- Work (rda:C10001): corresponds to a distinct intellectual or artistic creation. It is the intellectual and artistic content, the work as an abstract entity.
- Expression (rda:C10006): corresponds to the artistic or intellectual realization of a work, in the form of alphanumeric, musical, choreographic notation, sound, image, object, movement, etc., or any combination of these forms.
- Manifestation (rda:C10007): is the physical materialization of an Expression of a Work.
- Item (rda:C10003): is the individual copy or instance of a Manifestation. Defined in RDA as a “concrete entity.”

The classes of the BIBFRAME ontology that represent nuclear bibliographic entities are as follows:[42]

- bf:Work: resource that reflects the conceptual essence of the cataloged item; it is an abstract entity that reflects the content of the bf:Instances associated with a bf:Work. It has subclasses such as bf:Text; bf:Audio; bf:Cartography; bf:MovingImage, etc.
- bf:Instance: resource that reflects an individual materialization of a bf:Work. Its subclasses are bf:Manuscript; bf:Printed, etc.
- bf:Item: single example of a bf:Instance. Physical or digital copy of a bf:Instance.

LRM and RDA have more granularity than BF in representing nuclear entities, as they define four nuclear classes (Work, Expression, Manifestation, and Item), while BF defines only three main bibliographic classes (Work, Instance, and Item). The lower granularity of BF manifests itself in the lack of the Expression entity as a stand-alone class of bf:Work.

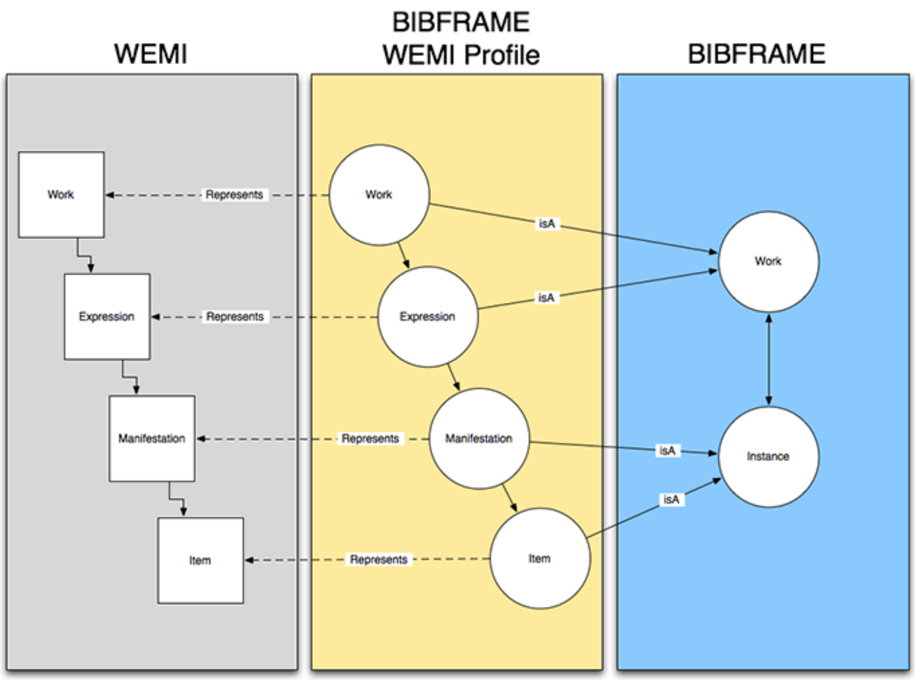
Figure 4. WEMI Entities in LRM, RDA, and BF.

WEMI entities	LRM	RDA	BIBFRAME
Work	E2 Work	C10001 Work	bf:Work
Expression	E3 Expression	C10006 Expression	
Manifestation	E4 Manifestation	C10007 Manifestation	bf:Instance
Item	E5 Item	C10003 Item	bf:Item

As Zapounidou and Taniguchi point out, bf:Work represents both the content (Work) and the signs (Expression).[43] In fact, considering that the bf:Work class corresponds to the conceptual essence of the described resource and that both LRM and RDA Work and Expression classes refer to objects of a conceptual nature, it is correct to consider that these two concepts of LRM and RDA (Work and Expression) correspond to the term bf:Work, thus presenting a case of polysemy of the bf:Work class.

The same understanding results from the mapping between the WEMI classes of LRM/RDA and BF, carried out by the Library of Congress and updated by Sally McCallum, that establishes a correspondence between the concepts of Work and Expression of the LRM model and the bf:Work class.[44]

Figure 5. BIBFRAME WEMI Profile.[45]



The WEMI LoC mapping leads to multiple correspondence, since bf:Work can be mapped to more than one LRM and RDA class (Work or Expression).[46] This illustrates that, as previously mentioned in the literature review, transformative methods like profiles or crosswalks do not solve multiple correspondence problems such as element overlap and information loss:[47]

- Element overlap occurs when mapping from a simpler ontology (BF) to a more complex one (LRM or RDA).
- Information loss arises when the mapping occurs from a richer ontology (LRM or RDA) to a simpler one (BF).

These polysemy or multiple correspondence drawbacks can be further analysed in three specific interoperability problems between BF and LRM/RDA ontologies:

- Conceptual confusion;
- Absence of a parent Work common to multiple Expressions;
- Absence of domain restriction for bf:language.

Next, these problems are illustrated with instances from the LoC and BNE datasets and their resolution in the RO is demonstrated, using the RDFS/OWL semantic mechanisms and SHACL restrictions.

Conceptual Confusion

The polysemy of bf:Work—a class that encompasses two distinct conceptual meanings (Work and Expression)—generates conceptual confusion since bf:Work instances can correspond either to the concept of Work, or to Expression, or to both concepts simultaneously.

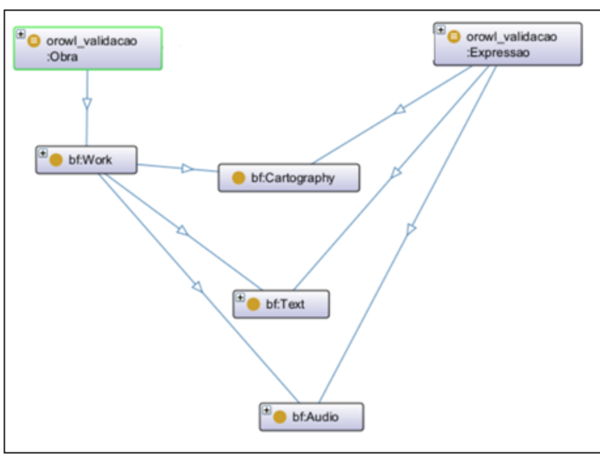
To better understand how bf:Work conceptual confusion is resolved through the RO, it is useful to introduce first the WEMI conceptualization in the RO. The core bibliographic entities are represented in the RO by the following classes that translate the consensual aspects in WEMI conceptualizations of the LRM, RDA and BF ontologies:

- orowl:Obra: class that represents an intellectual creation. It is a class without materiality, representing only ideas, i.e., its instances are purely conceptual objects, without any physical characteristics. Example: Poem
- orowl:Expressao: class that represents individuals who correspond to the Work realization, through words, sounds, etc., but which does not include its physical characteristics. It corresponds to the signs or form (written, audio, etc.) in which the Work is carried out. Example: Text in Latin
- orowl:Manifestacao: class that represents the physical materialization (content and physical format) or embodiment of an Expression. Class relating not only to intellectual content, but also to some attributes relating to physical form. It corresponds to the materialization of content with the same intellectual and physical characteristics. Example: 2nd edition, handwritten copy
- orowl:Item: class that represents concrete information resources and, therefore, only has attributes related to physical form. Example: physical copy or digital copy

To resolve the conceptual confusion caused by bf:Work polysemy, a distinct class must be assigned to each concept in the RO, relating them by class hierarchy mechanisms, as follows:

- Correspondence between the concept of Work and the superclass bf:Work, by means of a class hierarchy between orowl:Obra and bf:Work;
- Correspondence between the concept of Expression and the subclasses of bf:Work, by means of a class hierarchy between orowl:Expressao and the subclasses of bf:Work (for example, bf:Audio, bf:Cartography and bf:Text), as they represent the realization of a Work through different signs (words, sounds, images, etc.).

Figure 6. Resolution of bf:Work polysemy in the RO.




```
<owl:Class
rdf:about="http://id.loc.gov/ontologies/BIBFRAME/Text">
    <rdfs:subClassOf
rdf:resource="http://id.loc.gov/ontologies/BIBFRAME/Work"/>
    <rdfs:subClassOf
rdf:resource="http://www.xpto.com/orowl-
validacao.owl#Expressao"/>
    <terms:modified>2016-04-21
(New)</terms:modified>
    <rdfs:label>Text</rdfs:label>
</owl:Class>
```

The RO assures that the class bf:Work has uniquely the meaning of Work, due to the generalization between orowl:Obra and bf:Work, and that the subclasses of bf:Work have uniquely the meaning of Expressions, due to the generalization between orowl:Expressao and the subclasses of bf:Work (bf:Text, bf:Audio, etc.).

In the RO, the creation of WEMI classes and their relationship through class hierarchy constructs (rdfs:subClassOf) with the WEMI subclasses of source-ontologies (BF, LRM, and RDA) is a semantic mediation method alternative to transformative methods, since the RO does not replace nor modifies the source-ontologies, and also because there is no direct relationship between the classes of the source-ontologies.

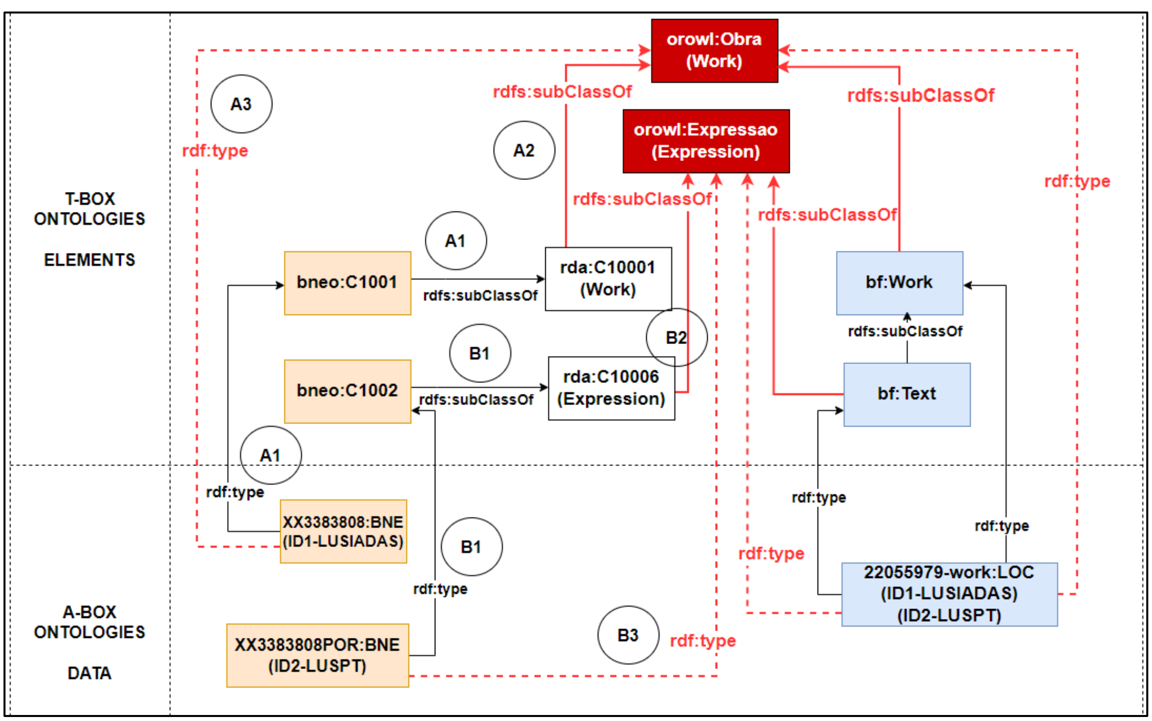
Solution with RO Abstraction and Inference Mechanisms

The examples of individuals from the BNE and LoC datasets are presented below to demonstrate that, by means of class hierarchy, these instances can be clearly classified by the RO as Works or Expressions.

The following real-world individuals (depicted in fig.7) will be used in the demonstration of the RO solution:

- Individuals from the BNE dataset (highlighted in orange):
  - XX3383808:bne (Work ID1-LUS): individual of bneo:C1001 and inferred instance of rda:C10001 (Work), because rda:C10001 is a superclass of bneo:C1001;
  - XX3383808por:bne (Expression ID2-LUS-PT): individual of bneo:C1002 and inferred instance of rda:C10006 (Expression), because rda:C10006 is a superclass of bneo:C1002.
- Individual from the LoC dataset (highlighted in blue):
  - 22055979-work:loc (simultaneously Work ID1-LUS and Expression ID2–LUS-PT) direct instance of bf:Work and bf:Text.

Figure 7. Semantic mechanisms of the RO to solve bf:Work polysemy.



In figure 7, the classes and properties explicitly stated by the RO are highlighted in red, and dashed lines represent the relationships inferred from the hierarchy relationships between the RO classes and the RDA and BF classes.

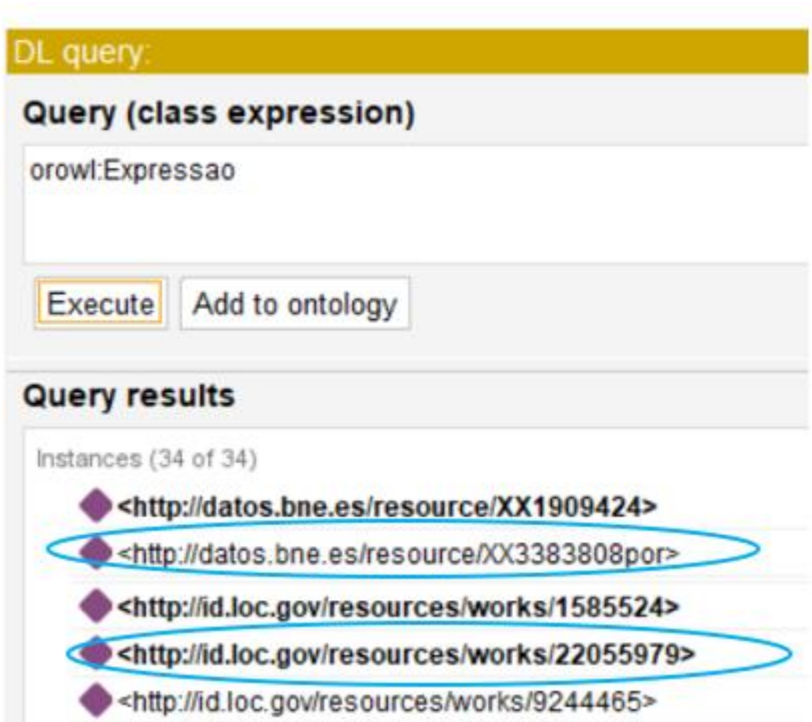
Due to the class hierarchy mechanism established in the RO between orowl:Obra and rda:C10001 (see A2 in fig. 7) and between orowl:Expressao and rda:C10006 (see B2 in fig. 7), from the BNE dataset we can infer that:

- XX3383808:bne (ID1-LUS) is a Work, since it is a direct instance of bneo:C1001 and an inferred individual of rda:C10001, which in turn is a subclass of orowl:Obra (see relationships marked A in fig. 7);
- XX3383808por:bne (ID2-LUS-PT) is an Expression, since it is a direct instance of bneo:C1002 and an inferred individual of from rda:C10006, which in turn is a subclass of orowl:Expressao (see relationships marked B in fig.7).

The example above shows that the RO uses abstractions only at the level of data elements of the source-ontologies, i.e., of their classes and properties, (see relationships A2 and B2 in fig. 7), without explicitly stating any information at the instances level. Integration occurs operating directly at the elements (classes and properties) level only (see A2 and B2 in fig. 7), and individuals or data integrated are inferred without being explicitly stated by the RO. It is from the application of semantic mechanisms to the data elements that the classification of instances in the RO WEMI classes (see inferred relationships A3 and B3 in fig. 7) is inferred, without explicitly stating types at the data level. At the data level, the relationships are explicitly stated only in the datasets (see relationships A1 and B1 in fig. 7), not at the RO level.

Additionally, the class hierarchy allows the representation of aspects common to all source-ontologies subclasses (for example, rda:C10001, rda:C10006, bf :Work and bf:Text) in the RO superclasses (in the example, orowl:Obra and orowl:Expressao), inferring the classification of instances from source-ontologies in the RO superclasses. This inference works only between the source-ontologies and the RO, not occurring horizontally between elements of the source-ontologies, therefore their original semantics is preserved, not being “hijacked” by the RO. For example, instance XX3383808por:bne (ID2-LUS-PT) of subclass rda:C10006 is inferred as an instance of superclass orowl:Expressao, but it cannot be inferred as an instance of bf:Text. Inferring ID2-LUS-PT BNE and LoC individuals (XX3383808por:bne and 22055979-work:loc) as instances of orowl:Expressao is demonstrated by the query shown in figure 8.

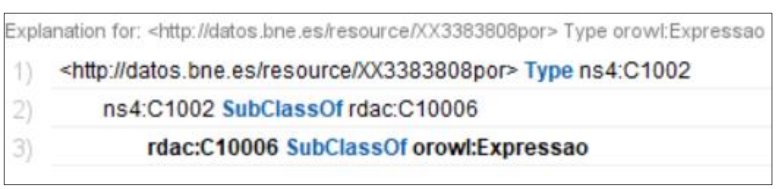
Figure 8. Query to search for Expressions in the RO.



Thus, both individuals are clearly identified as Expressions by the class hierarchy mechanism, as demonstrated in HermIt's explanation for inferring instances of bf:Text (22055979-work:loc) and rda:C10006 (XX3383808por:bne) as instances of orowl:Expressao (see figs. 9 and 10).

Figure 9. Reasoner explanation for BF instances inference.

Figure 10. Reasoner explanation for BNE instances inference.



The lower granularity of BF regarding the representation of Expressions is resolved, since both 22055979-work:loc and XX3383808por:bne are instances of orowl:Expressao, as shown in figure 8.

Absence of a Parent Work, Common to Multiple Expressions

Given that in BF there is no class representative of the bibliographic entity Expression, this ontology has lower granularity than LRM and RDA, where such class exists. The lack of granularity of BF led to the representation of Expression instances as bf:Work in the LoC mapping, so this class represents both the content (Work) and the signs (Expression).[48]

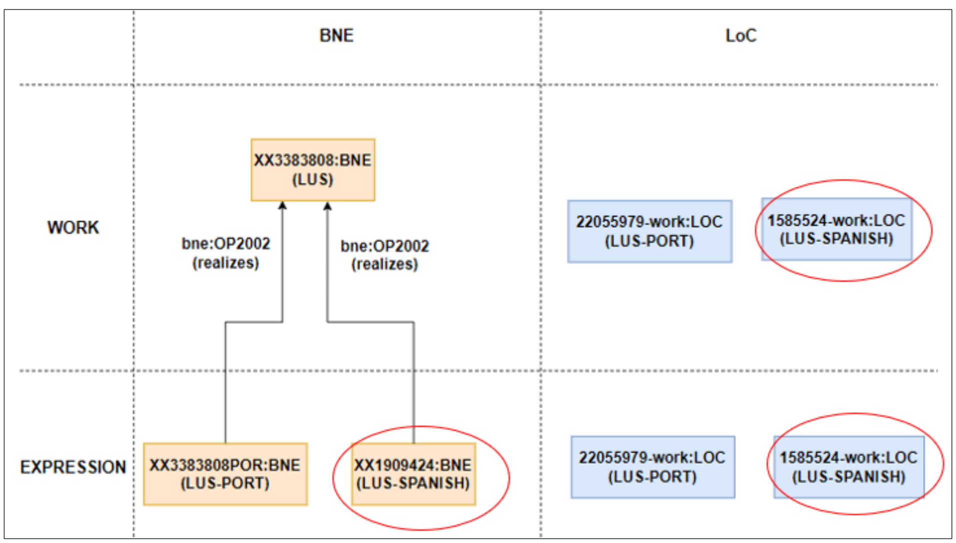
In BF, the bf:language property applies to bf:Work, so an Expression can be represented as an instance of bf:Work with an associated language. This means that, in BF, for each realization of a Work in a given language, there will be a distinct instance of bf:Work. Consequently, if there is more than one Expression for a given Work, we lose the information about multiple instances of bf:Work that represent different Expressions having the same Work as "parent."[49] For this problem, the LoC proposes a solution that represents each LRM linking relationship between a Work and an Expression ("is realized through") as an instance of bf:Work.[50] The bf:Work instances resulting from this mapping must be related to each other by bf:hasExpression. As shown below, this is not a solution, as the lack of representation of a parent Work common to multiple Expressions remains.

Solution Demonstration with RO Abstraction and Inference Mechanisms

To illustrate the absence of a parent Work common to multiple Expressions, we consider the following instances of the ID5-LUS-SPAN Expression, marked in figure 11 with a red circle:

- XX19909424:bne: instance of bne:C1002 (Expression);
- 1585524-work:loc: instance of bf:Work and of bf:Text.

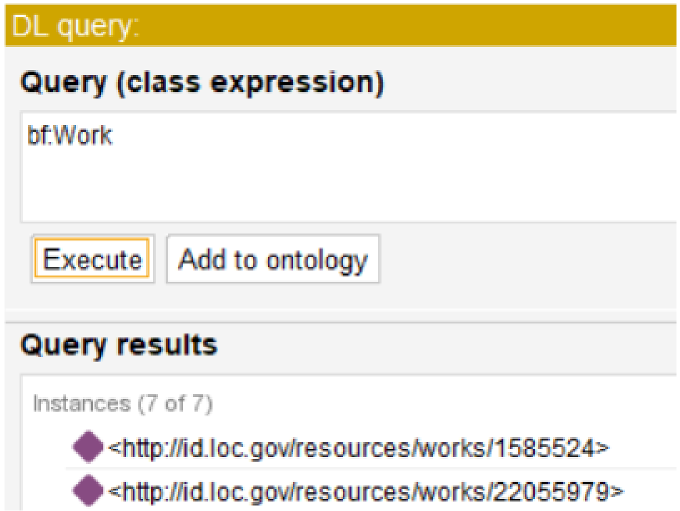
Figure 11. Example of absence of a common parent Work.



The individual 22055979-work:loc represents both the Work ID1-LUS and its Expression in Portuguese language ID2-LUS-PT. Likewise, the individual 1585524-work:loc simultaneously represents the Work ID1-LUS and its realization in Spanish, ID5-LUS-SPA. Given that each individual represents simultaneously the concept of Work and Expression, in the LoC dataset we lose the representation of Work ID1-LUS as the common parent of both Expressions (ID2-LUS-PT and ID5-LUS-SPA) and the perception that both the text in Portuguese and the text in Spanish are realizations of the same idea or intellectual content.

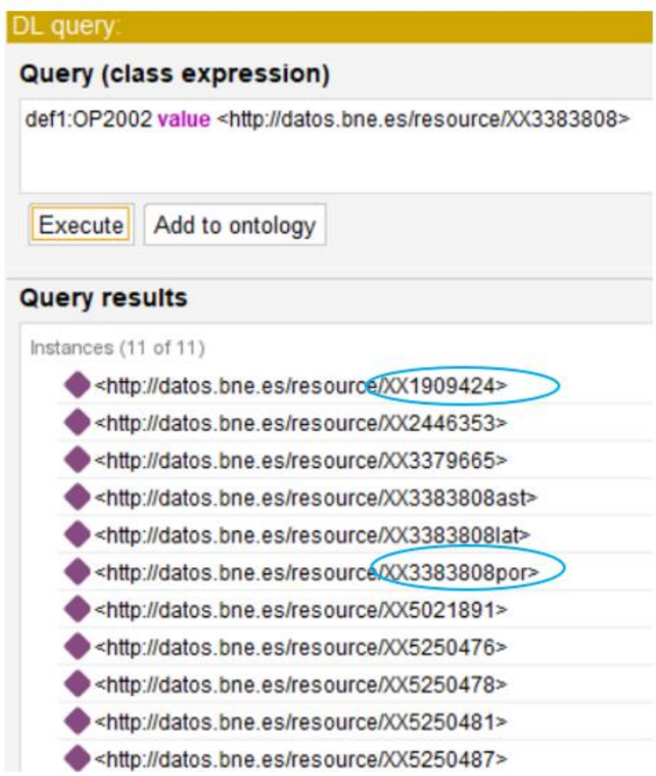
The query below (fig. 12) demonstrates that the Expressions are retrieved as two instances of bf:Work, without a Work common to both. In other words, in BF we are unable to identify the relationship between Work ID1-LUS and its Expressions. In addition, in the LoC dataset two instances of the Work "Os Lusíadas" are directly stated as distinct Works, which is not semantically correct since the Work is the same, it is the Expressions in Portuguese and Spanish that are different.

Figure 12. Query to search BF Works in the LoC dataset.



Differently from the LoC dataset, in the BNE dataset the Work (see XX3383808:bne in fig. 11) and the instances of Expression (see XX3383808por:bne and XX1909424:bne in fig. 11) are represented distinctively. Being so, in the BNE dataset the Work ID1-LUS is represented as the common parent of the Expressions ID2-LUS-PT and ID5-LUS-SPA. In the BNE dataset, Expressions are independent of the Work that they realize, and the same Work can be represented as common parent of different Expressions.

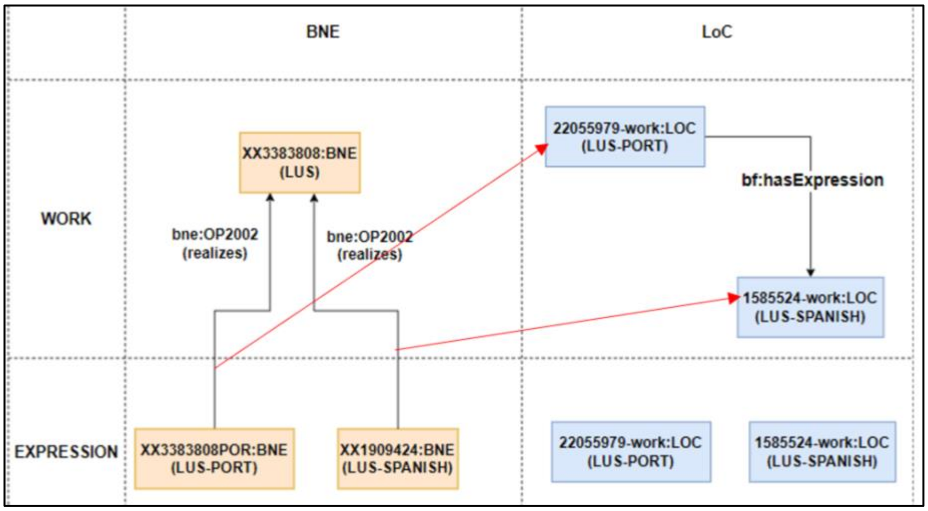
Figure 13. Query: "Individuals that are realizations of Work ID1" (property bneo:OP2002).



As shown in figure 13, to the query "Which instances realize the Work ID1 (property bneo:OP2002)", the reasoner returns as results the Expressions of "Os Lusíadas" written in Portuguese (XX3383808por:bne) and written in Spanish (XX1909424:bne).

To solve the absence of parent work in BF, LoC proposes that each LRM linking relationship between Work and Expression should be mapped to an instance of bf:Work and that the different bf:Work instances should be related to each other by bf:hasExpression, as shown in figure 14.[51]

Figure 14. Solution for the absence of a parent Work in the LoC mapping.[44]

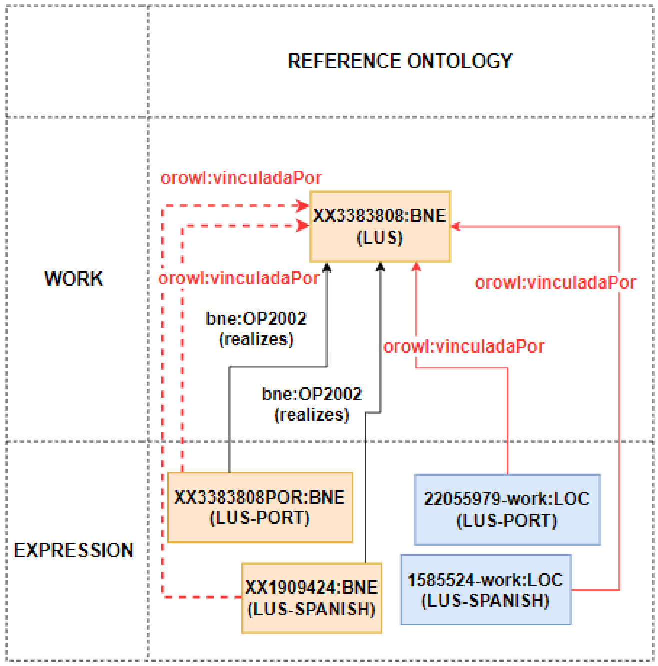


This solution not only does not represent a common parent Work, but is also semantically incorrect, because 1585524-Work:loc (ID5-LUS-SPA) is not an Expression of 22055979-work:loc (ID2- LUS-PT), rather they are both Expressions of a Work that has no language property. In fact, the language property should characterize the Expression (realization by signs), not the Work.

In contrast, the RO allows us to instantiate separately individuals of Work (ID1-LUS) and their Expressions (ID2-LUS-PT; ID5-LUS-SPA), and thus relate the common parent Work with all its Expressions. Without violating the BF ontology, it would be enough to relate the Expressions from the LoC dataset 22055979-work:loc (ID2-LUS-PT) and 1585524-work:loc (ID5-LUS-SPA) with a representative instance of Work ID1-LUS, whether created directly in the RO as an individual of orowl:Obra, or as the individual representing Work ID1-LUS in the BNE dataset (XX3383808:bne).

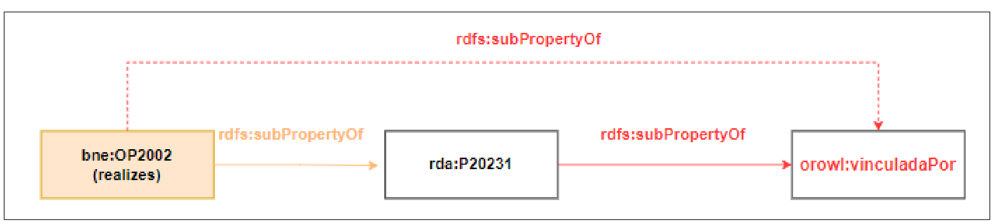
To illustrate the resolution of this problem, the Expressions in the LoC dataset were considered as realizations of the Work XX3383808:bne, using the property orowl:vinculadaPor (boundBy), as can be seen in figure 15.

Figure 15. Solving the absence of a common parent Work by the RO.



In this way, instances 22055979-work:loc and 1585524-work:loc are linked as realizations of a common parent, the Work XX3383808:bne. Additionally, the BNE Expressions (XX1909424:bne and XX3383808por) are recovered as realizations of XX3383808:bne, since the linking property between Expression and Work of BNE (bne:OP2002) is declared by the BNEO as a subproperty of the RDA property rdaeo:P20231, which the RO declares as a subproperty of orowl:vinculadaPor (boundBy) (see fig. 16).

Figure 16. Superproperty orowl:vinculadaPor.



This inference is demonstrated through the result obtained from the query “Which instances realize Work ID1-LUS (XX3383808:bne)?”, as shown with red arrows in figure 17, and respective reasoner explanation in figure 18.

Figure 17. Query: “Which instances realize Work ID1-LUS?” (XX3383808:bne).

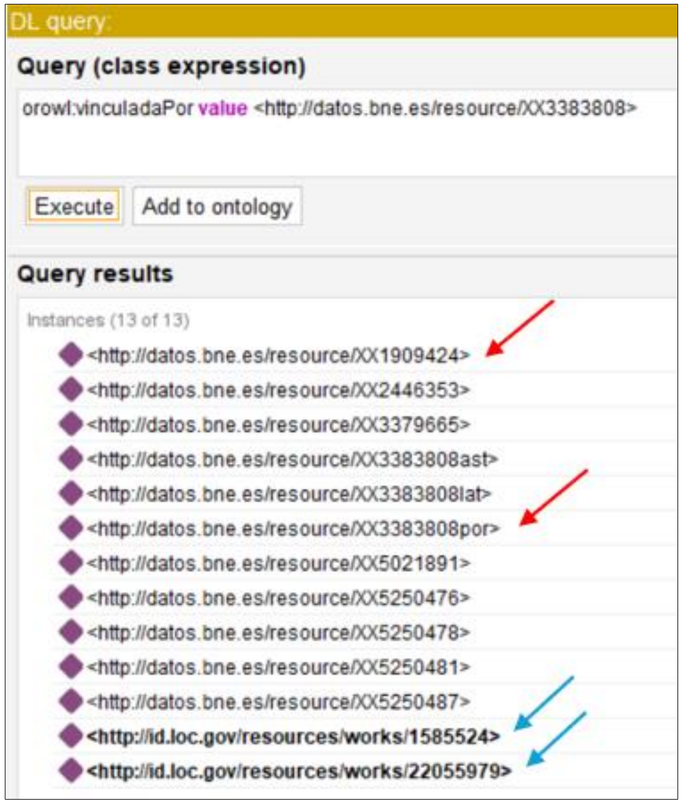


Figure 18. Reasoner explanation for inferring BNE instance.

Absence of Domain Restriction for bf:language

The polysemy of the bf:Work class raises yet another kind of problem since its properties should not be applied to all the concepts comprised in the class. Such is the case of Language which is a property specific to Expressions but that in BF may be applied to both Expressions and Works, as in this ontology there is no class corresponding uniquely to the concept of Expression. In effect, and differently from LRM and RDA, in BF the Language property of a Work does not refer to its “most representative Expression.” In BF, this property does not have domain restrictions that constrain it to the subclasses of bf:Work (which we consider equivalent to Expression) and, therefore, it can refer to both Work and Expression.

On the other hand, in BF there is a generalization relationship between Work, represented by the bf:Work class, and Expressions, represented by the subclasses of bf:Work. For this reason, the Language property should not be used to characterize instances of bf:Work, as their values could be inconsistent with the property values of individuals pertaining to bf:Text subclasses (Expressions). The only way to avoid this situation is the creation of a distinct instance of bf:Work for each language, as observed in the LoC dataset examples, causing the impossibility of representing a common parent Work to different language Expressions. In fact, when bf:language characterizes a Work, there must always be as many Works as there are realizations in different languages. That is the reason why the resolution of the polysemy of bf:Work is complete only when applying the Poveda Villalón solution, which determines the application of domain/range restrictions to the properties "relocated" to classes created for each meaning of the polysemic concept.[52]

It follows that for solving the polysemy of bf:Work it is not enough to apply class hierarchy mechanisms and properties. There is also a need for a domain restriction on bf:language to constrain its application to subclasses of bf:Work only. In this way, ID2-LUS-PT and ID5-LUS-SPA instances would have to be represented in the LoC dataset as individuals of bf:Text only, so that reasoners would not validate them as instances of bf:Work.

Only SHACL restrictions can overcome the simultaneous LoC modeling of ID2-LUS-PT and ID5-LUS-SPA as instances of both bf:Text and bf:Work, forcing their representation as linguistic realizations, as instances of bf:Text, avoiding its direct classification as bf:Work.

Solution with SHACL Constraints and Validation

In the RO a domain restriction must be applied to the bf:language property, so that it cannot be applied but to subclasses (Expressions) of bf:Work (Work). This will ensure that no instance of bf:Work has language properties that cause the impossibility of representing a parent Work, common to multiple Expressions in different languages.

Declaring the domain restriction in OWL is not enough because this language does not impose restrictions, only allows inferences based on them. Therefore, one has to resort to SHACL, since only with this language can we ensure that the bf:language property cannot be applied to instances of bf:Work and, consequently, instances 22055979-work:loc (ID2-LUS-PT) and 1585524-work:loc (ID5-LUS-SPA) may be characterized by property bf:language as instances of bf:Text only.

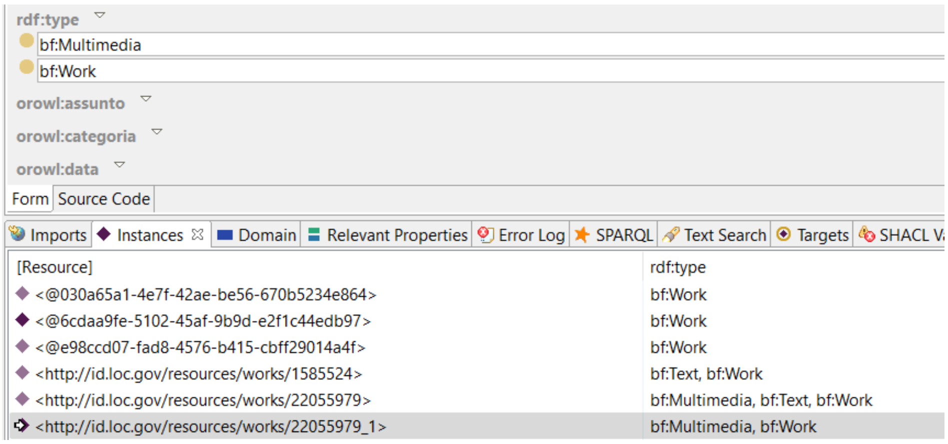
The formalization of this domain restriction in SHACL was implemented through a NodeShape (identified as Shape-H002) which determines that all bf:language subjects must be instances of the bf:Text, bf:Audio or bf:Cartography classes, using the sh:targetSubjectOf restriction, as shown in figure 19. Instances that use the bf:language property and do not belong to the domain classes are invalid.

Figure 19. SHACL SHAPE H002 in Turtle.

```
orshacl:H002
  rdf:type sh:NodeShape ;
  rdfs:label "H002" ;
  sh:class [
    rdf:type owl:Class ;
    owl:unionOf (
      bf:Text
      bf:Audio
      bf:Cartography
     ) ;
   ] ;
  sh:targetSubjectsOf bf:language ;
```

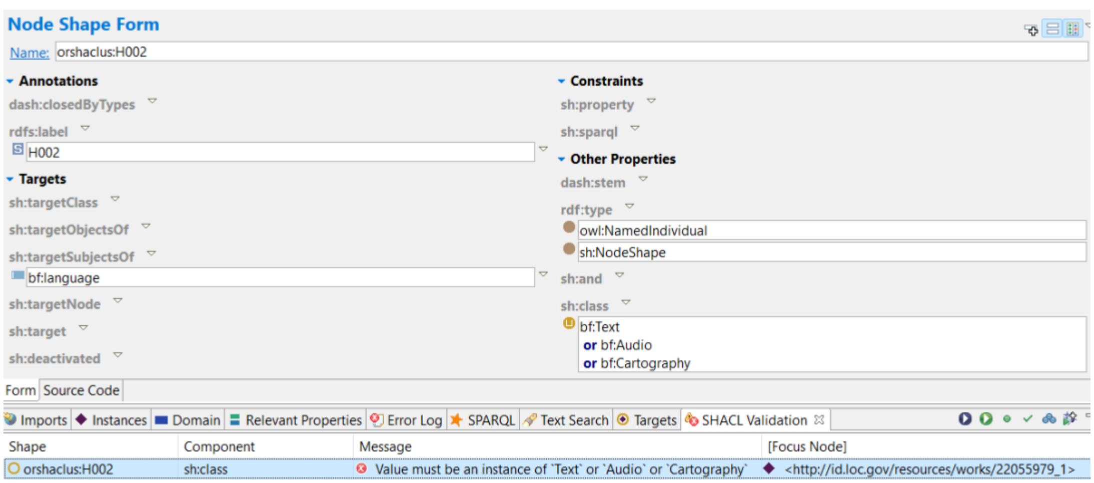
To validate the application of this NodeShape, an individual clone of 22055979-work:loc was created (individual 22055979_1), which is not an instance of bf:Text, but rather of bf:Multimedia and bf:Work, as shown in figure 20.

Figure 20. Error for testing SHAPE H002.



The imposition of Shape H02 determines that the use of bf:language with the instance 22055979_1 (clone error) as subject is invalid, which is confirmed in the SHACL Validation tab in figure 21.

Figure 21. SHAPE H002 validation.



Whole-Part Relationship Properties Omission

LRM, BF, and RDA ontologies represent whole-part bibliographic relationships as nontransitive associations, which do not formally ensure the following essential properties of a whole-part relationship: transitivity (each subpart must be able to be inferred as part of the whole); nonreflexivity (a part cannot be part of itself) and asymmetry (the whole and a part cannot be part of a part of itself).[53]

Although the transitivity of the part-whole relationship is not unanimously recognized in the literature, in the bibliographic domain any subpart of a part should also be inferred as part of the whole. For example, from the whole-part relationship between a given multivolume work and its volume 1, it should be possible to infer that chapter 1 of that volume 1 is also part of the multivolume work and not just of volume 1.

The LRM, RDA and BF semantic omissions in representing transitivity, nonreflexibility and asymmetry in whole-part bibliographic relationships illustrate the problems referred in the literature regarding both the underuse of semantic mechanisms by bibliographic ontologies and the need to impose semantic restrictions, requiring the use of SHACL.

Formalization of the transitivity of whole-part relationships was carried out in the RO through the creation of the property orowl:parteDe (part-of), as a transitive property (see fig. 22).

Figure 22. Property transitivity statement.

```
<owl:ObjectProperty rdf:about="http://www.xpto.com/orowl-validacao.owl#parteDe">
  <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#TransitiveProperty"/>
  <rdfs:domain rdf:resource="http://www.xpto.com/orowl-validacao.owl#Obra"/>
  <rdfs:range rdf:resource="http://www.xpto.com/orowl-validacao.owl#Obra"/>
</owl:ObjectProperty>
```

This orowl:parteDe property can be applied directly or declared as a superproperty of similar properties of the source-ontologies, as demonstrated in the next section.

It was not possible to represent the asymmetry and nonreflexivity restrictions in the RO using OWL, as this language cannot guarantee the application of restrictions for the purpose of validation, nor does it allow specifying asymmetry and nonreflexivity for transitive properties.[54] This objective can only be ensured by SHACL, therefore shapes representative of these restrictions were implemented.

Due to space limitations, in this paper we address only the general whole-part relationships which occur between Manifestations or Items (for example, the Manifestation *Obras Completas de Luís de Camões*, published in 3 volumes, in 1843), and not the relationships of bibliographic aggregation between Works (for example, the relationship between the Works ID1-LUS and ID8-CWLC: the Work “Os Lusíadas” – ID1-LUS, materialized in the first volume of the Work *Obras Completas de Luís de Camões* – ID8-CWLC), whose representation in the RO can be found in Patrício.[55]

Lack of Transitivity

To illustrate the problem of the lack of transitivity of whole-part relationships in BF, the following examples are considered:

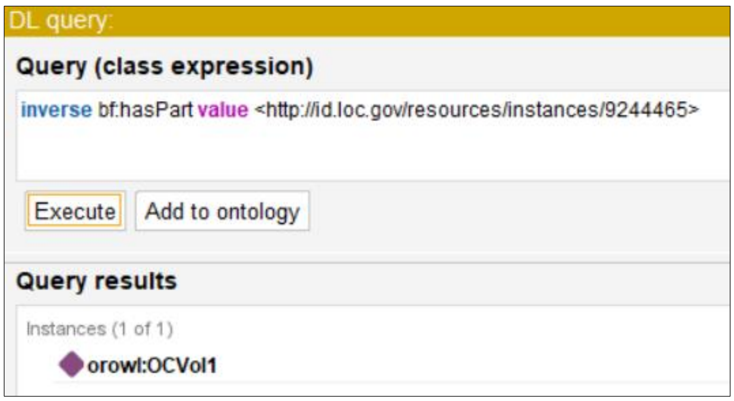
- 9244465-instance:loc (ID10-CWLC-1843)—instance of bf:Print imported from the LoC dataset into the RO, corresponding to the three-volumes edition of *Obras completas de Luís de Camões* (ID8-CWLC), published in Lisbon in 1843;
- OCVol1:orowl—individual created directly in the RO as an instance of bf:Print, corresponding to the first volume of ID10-CWLC-1843;
- OCVol1Chapter1:orowl—individual directly created in the RO as an instance of bf:Print, corresponding to the first chapter of the first volume of ID10-CWLC-1843.

Additionally, relationships represented by the property bf:hasPart were established between 9244465-instance:loc and OCVoL1:orowl, and between OCVol1:orowl and OCVol1Chapter1:orowl, as shown in figure 23.

Figure 23. Example of whole-part relationships.

Since bf:hasPart is not a transitive property, when querying "Which instances are part of ID10:CWLC-1843 (9244465-instance:loc)?", the reasoner will return only volume 1 (OCVOL1:orowl) as a result, not inferring the chapter 1 of that volume (OCVol1Chapter1:orowl) in the results. In fact, this individual is directly stated only as part of volume 1 and the property bf:hasPart is not transitive (see fig. 24).

Figure 24. Query: "What are the parts of *Obras Completas…*" – using bf:hasPart.

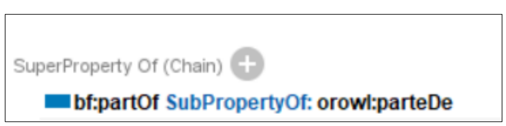


This means that it is not possible to infer that a subpart is also part of the whole just by using BF. In BF, the property bf:hasPart states that the subpart is only part of the part, but not part of the whole, because it is not transitive. The same happens with part properties of LRM and RDA ontologies.

Solution with RO Abstraction and Inference Mechanisms

To solve the lack of transitivity problem, the orowl:parteDe (part of) property was created in the RO as transitive property. This RO property can be applied directly or declared as a subproperty of the properties with "part of" meaning in the source-ontologies. In our example, we opted for the latter solution, defining a hierarchy of properties between orowl:parteDe and bf:partOf, as shown in figure 25.

Figure 25. Property hierarchy—whole-part example.



The problem can be solved through the hierarchy of properties, without having to explicitly use the orowl:parteDe property, because whenever the more specific property (bf:partOf, for example) is applied, the application of the superproperty (orowl:partDe) is inferred, and its transitivity allows to infer that the subparts are inferred parts of the whole. This is demonstrated in the query below (fig. 26) which asks, "What are the parts of ID10-CWLC-1843?" and obtains, as a result, not only the part directly related to it (OCVOL1), but also infers as a result the OCVOL1CHAPTER1 part, which is directly related to OCVOL1 only (see fig. 27).

Figure 26. Query: "What are the parts of *Obras Completas…*" - using RO property.

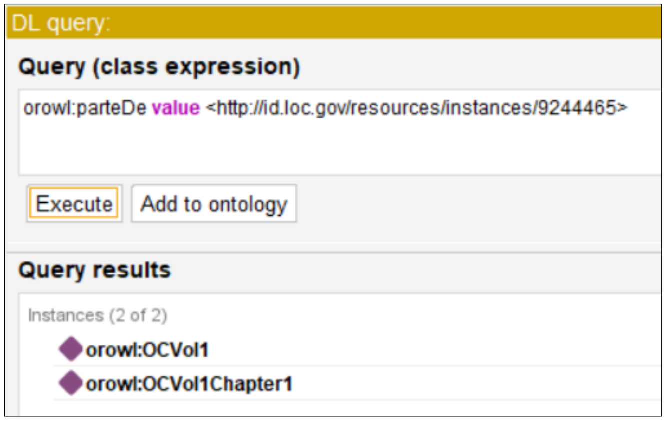
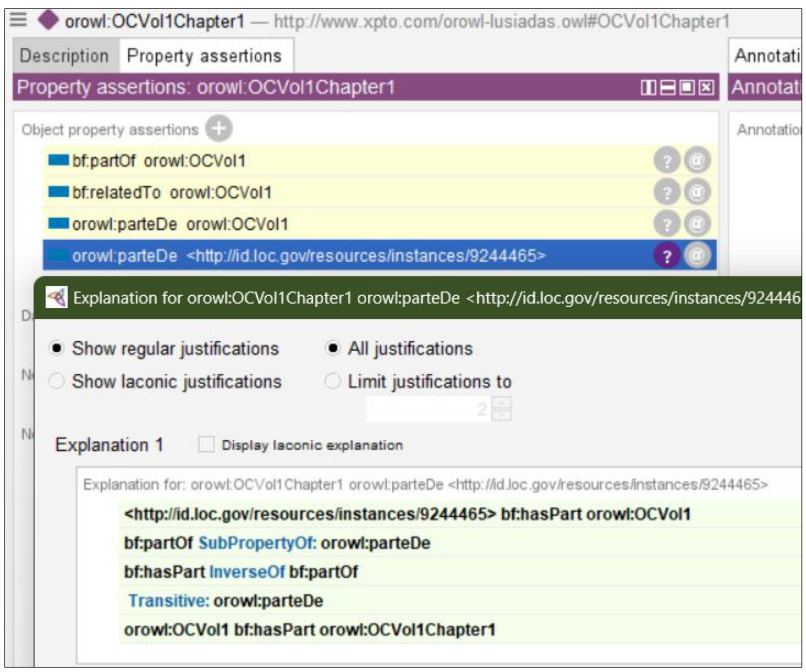


Figure 27. Reasoner explanation for inference in the whole-part example.



Lack of Nonreflexivity

It is necessary to ensure the nonreflexivity of orowl:parteDe, as this property is nonreflexive, i.e., the part cannot be part of itself. That is, the value of the subject in a declaration with predicate orowl:parteDe cannot be equal to the value of the object. In our example, the objective is to guarantee that the first volume of *Obras completas de Luís de Camões* (OCVOL1) could not be part of itself.

As mentioned before, in OWL transitive properties cannot be nonreflexive, therefore this restriction must be specified with SHACL.[56]

Solution with SHACL Constraints and Validation

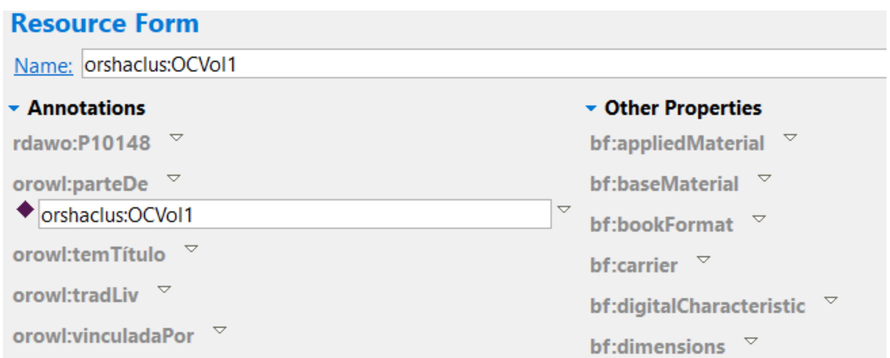
While in OWL transitive properties cannot have nonreflexive restrictions, the Dash (Data Shapes) vocabulary allows this restriction to be specified through the dash:nonRecursive element.[57] Thus, a sh:Property was created in NodeShape, orowl:Obra, applicable to orowl:parteDe, using the Dash vocabulary restriction that specifies no recursion (dash:nonRecursive), with the value True, determining that the subject of orowl:parteDe must not point to itself, as shown in figure 28.

Figure 28. SHACL SHAPE H19_2 in Turtle.

```
orowl:Obra  rdf:type sh:NodeShape ;

 dash:closedByTypes "true"^^xsd:boolean ;

 sh:property [

    sh:path orowl:parteDe ;

    dash:nonRecursive "true"^^xsd:boolean ;
```

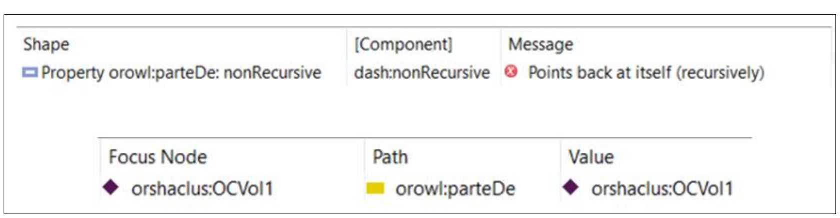
To validate this Shape a recursion error was created, declaring OCVol1 as part of itself (see fig. 29).

Figure 29. Recursion error.



As expected, the validator flags the error of violation the Shape that imposes the dash:nonRecursive restriction, as shown in figure 30.

Figure 30. SHAPE H19_2 Validation.



Lack of Asymmetry Restriction

Nonrecursiveness should be enough to avoid resorting to asymmetry restrictions. In fact, the Dash vocabulary, an extension to SHACL, provides an element for the symmetry restriction (dash:symmetric) but none for asymmetry, because it should be sufficient to declare the property in question as nonrecursive (dash:nonrecursive) in order to prevent symmetry.[58] However, the restriction dash:nonrecursive does not work in property chains, so a solution had to be found to represent asymmetry restrictions in SHACL using other elements, namely sh:disjoint.

For this reason, and since the orowl:parteDe property cannot be declared as asymmetric, since it is transitive, it was necessary to create the orowl:temParte (has part) property as distinct and disjoint (i.e., it cannot share the same value) from orowl:parteDe (part of).[59] The properties orowl:temParte and orowl:parteDe could not be declared as inverse of each other, as this would result in a symmetry effect.

Solution with SHACL Constraints and Validation

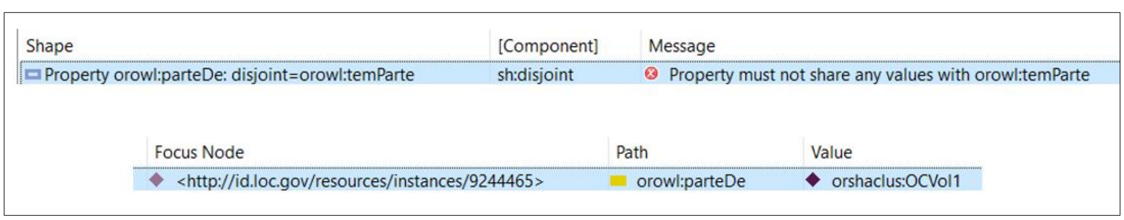
To ensure the asymmetry of orowl:parteDe, a propertyShape was created in orowl:Obra using the sh:disjoint element to establish that properties "parteDe" and "temParte" can never have the same value (see fig. 31).

Figure 31. SHACL SHAPE H19_1 in Turtle.

```
sh:property [

   sh:path orowl:parteDe ;

   sh:disjoint orowl:temParte ;
```

In order to validate this restriction, an error was created with the edition of *Obras Completas de Luís de Camões* in three volumes (9244465-instance:loc) having the first volume (OCVOL1) as part and also being declared as part of OCVOL1. The SHACL validator responded as expected, flagging the error as a violation of Shape H19_1, as shown in figure 32.

Figure 32. SHAPE H19_1 Validation.



CONCLUSION

The present research proposes to overcome barriers to interoperability of bibliographic ontologies by means of a reference ontology that operates as a semantic mediation solution, at a level of abstraction higher than the interoperating ontologies, providing semantic mechanisms that are independent of them and making better use of Semantic Web technologies.

This paper was focused especially on two types of problems/description cases—misalignment of ontologies caused by the polysemy of bf:Work in BF, and the absence of formalization of properties in whole-part relationships in LRM, RDA, and BF—which represent well the kind of interoperability issues of bibliographic ontologies that are not solvable through crosswalks, point-to-point mappings or application profiles, rather requiring semantic mechanisms more demanding and sophisticated and better aligned with principles of the Semantic Web.

The application of the RO to real-world examples taken from the LoC and BNE datasets that reflect misalignments of BF and RDA ontologies allowed us to illustrate and explain the interoperability problems and consequences of each case, as well as to demonstrate the results of using RDFS/OWL semantic mediation techniques together with SHACL when restrictions and data validation are needed.

Operating at a level higher than the source-ontologies without changing them, the RO integrates semantically data structures and concepts of the source-ontologies through the definition of new elements, allowing the inference of implicit information. The alignment between source-ontologies implemented in the RO makes use of the OWL hierarchy constructs between source-ontologies' classes and properties and the RO, as the objective is to build a bridge-ontology that does not replace or modify the source-ontologies. The alignment is always ascending, and inferences will always be made from the source-ontologies with effect on the RO, never having the risk of "hijacking" source-ontologies.

Finally, it should be underlined that the RO is not just a central ontology to which the source-ontologies elements are mapped and transcends crosswalk or application profile methods. On the one hand, the RO applies alignment techniques in which the elements of the source-ontologies are preserved. On the other hand, the RO provides for additional elements to describe the relationship between concepts of the source-ontologies that are combined in a dimension that goes beyond the simple mapping, allowing the inference of information not expressly declared, where a weaving from the "threads" of the source-ontologies results in a different "fabric."[60] The RO is this different "fabric," which does not replace the source-ontologies, nor is it limited to their mapping. This is especially evident in those cases where the RO allows for overcoming semantic omissions of source-ontologies.

To reach beyond the proof of concept, future work should expand the analysis to other bibliographic description cases, especially regarding the WEMI primary relationships. Furthermore, it would be relevant to develop a comparative analysis of the RO solutions with real-world cases of mapping between bibliographic ontologies that use transformative techniques, such as the WEMI BIBFRAME profile or the eventual expansion of LRM to solve problems caused by disjunction.[61]

APPENDIX: LOC AND BNE EXAMPLE INDIVIDUALS

WEMI	THE LUSIADS		COMPLETE WORKS BY LUIS DE CAMÕES
WORK	**ID1-LUS** **BNE (bneo:C1001):** **https://datos.bne.es/obra/XX3383808.html;** **https://datos.bne.es/resource/XX3383808.rdf**		**ID8 – CWLC** **BNE: Not represented in the dataset**
	LoC (LUS-PT) (bf:Work; bf:Text): **https://id.loc.gov/resources/works/22055979.html;** **http://id.loc.gov/resources/works/22055979.rdf**	**LoC (LUS-SPA) (bf:Work; bf:Text):** **https://id.loc.gov/resources/works/1585524.html;** **http://id.loc.gov/resources/works/1585524.rdf**	**LoC (bf:Work; bf:Text):** **http://id.loc.gov/resources/works/9244465;** **http://id.loc.gov/resources/works/9244465.rdf**
EXPRESSION	ID2–LUS-PT BNE (bneo:C1002): https://datos.bne.es/resource/XX3383808por ; https://datos.bne.es/resource/XX3383808por.rdf LoC: Not represented in the dataset	ID5–LUS-SPA BNE (bneo:C1002): https://datos.bne.es/resource/XX1909424.html; https://datos.bne.es/resource/XX1909424.rdf LoC: Not represented in the dataset	ID9-CWLC-PT BNE:Not represented in the dataset LoC: Not represented in the dataset
MANIFESTATION	ID3 – LUS, Lisboa, 1572 BNE (bneo:C1003): https://datos.bne.es/edicion/bima0000126385.html; https://datos.bne.es/resource/bima0000126385.rdf LoC (bf:Instance; bf:Print; bf:Electronic): https://id.loc.gov/resources/instances/22055979.html; http://id.loc.gov/resources/instances/22055979.rdf	ID6 – LUS, Alcalá de Henares, 1580 BNE (bneo:C1003): https://datos.bne.es/edicion/a4655350.html; https://datos.bne.es/resource/a4655350.rdf LoC (bf:Instance; bf:Print): https://id.loc.gov/resources/instances/1585524.html; http://id.loc.gov/resources/instances/1585524.rdf	ID10 – Complete Works, Lisboa, 1843 BNE (bneo:C1003): https://datos.bne.es/edicion/bimo0000740462.html; https://datos.bne.es/resource/bimo0000740462.rdf LoC (bf:Instance; bf:Print): https://id.loc.gov/resources/instances/9244465.html; http://id.loc.gov/resources/instances/9244465.rdf

<table>
<tr><th>WEMI</th><th colspan="2">THE LUSIADS</th><th>COMPLETE WORKS BY LUIS DE CAMÕES</th></tr>
<tr><td rowspan="2">WORK</td><td colspan="2">ID1-LUS

BNE (bneo:C1001):

https://datos.bne.es/obra/XX3383808.html;

https://datos.bne.es/resource/XX3383808.rdf</td><td>ID8 – CWLC

BNE: Not represented in the dataset</td></tr>
<tr><td>LoC (LUS-PT) (bf:Work; bf:Text):

https://id.loc.gov/resources/works/22055979.html;
http://id.loc.gov/resources/works/22055979.rdf</td><td>LoC (LUS-SPA) (bf:Work; bf:Text):

https://id.loc.gov/resources/works/1585524.html;

http://id.loc.gov/resources/works/1585524.rdf</td><td>LoC (bf:Work; bf:Text):
http://id.loc.gov/resources/works/9244465;

http://id.loc.gov/resources/works/9244465.rdf</td></tr>
<tr><td>ITEM</td><td>ID14 – BNE – R/14208

BNE:Not represented in the dataset

https://datos.bne.es/ejemplar/1000380071.html;

ID4 – BNP – CAM3P

ID13 – WDL14160

LoC (bf:Item):

https://id.loc.gov/resources/items/22055979-856-28.html;

http://id.loc.gov/resources/items/22055979-856-28.rdf</td><td>ID7 – BNE-R/930

BNE:Not represented in the dataset

https://datos.bne.es/ejemplar/1001917603.html ;

ID15 – LoC - PQ9203.A2 C3

LoC (bf:Item):

https://id.loc.gov/resources/items/1585524-050-11.html;

http://id.loc.gov/resources/items/1585524-050-11.rdf</td><td>ID11 – BNE U/7301 a U/7303

BNE:Not represented in the dataset

https://datos.bne.es/resource/1000363212;

ID12 – LoC PQ9195.A1

LoC (bf:Item): -
https://id.loc.gov/resources/items/9244465-050-9.html;

http://id.loc.gov/resources/items/9244465-050-9.rdf</td></tr>
</table>

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