Learning PREMIS Knowledge Base: a Tool for Humans and Machines

Integrating Original Documentation for Annotating Ontology

Angela Di Iorio
DIAG - Department of Computer, Control, and Management Engineering Antonio Ruberti, Sapienza University of Rome
Rome, Italy
angela.diiorio@uniroma1.it

Marco Schaerf
DIAG - Department of Computer, Control, and Management Engineering Antonio Ruberti, Sapienza University of Rome
Rome, Italy
marco.schaerf@uniroma1.it

ABSTRACT

Inspired by the "Knowledge Base" definition of the Open Archival Information System: "A set of information, incorporated by a person or system, that allows that person or system to understand received information", we developed a mapping model for *a)* capturing the knowledge base of the digital preservation metadata, represented by the PREMIS Data Dictionary, and *b)* generating a SKOS vocabulary, that represents the PREMIS Knowledge Base. The article proposes, the PREMIS Knowledge Base as a knowledge tool, targeted to the digital preservation community, that can be used for learning, using, and updating preservation metadata. The tool bridges the knowledge expressed by the PREMIS OWL ontology with its knowledge context, stored in a "computable form", and obtained by a semi-automatic transformation mapping from the PREMIS Data Dictionary. PREMIS Knowledge Base, as a documentation tool, provides designated community with web resources for human consultation, and as a computable knowledge tool, provides RDF resources exhibited for software agent consumption. The PREMIS Knowledge Base candidates itself to be integrated into the PREMIS OWL ontology, via annotation property, allowing ontology and related datasets to be enriched and documentend by their originationg knowledge context, and thus to be properly interpreted.

CCS CONCEPTS

• **Applied computing → Digital libraries and archives**; • **Information systems → Digital libraries and archives**;

KEYWORDS

SKOS vocabulary dataset; Linked Data; digital preservation metadata; annotation property; knowledge integration; knowledge tool

ACM Reference Format:
Angela Di Iorio and Marco Schaerf. 2018. Learning PREMIS Knowledge Base: a Tool for Humans and Machines: Integrating Original Documentation for Annotating Ontology. In *Proceedings of ACM iPRES conference (iPRES'2018),* Jennifer B. Sartor, Theo D'Hondt, and Wolfgang De Meuter (Eds.). ACM, New York, NY, USA, Article 4, 10 pages. https://doi.org/10.475/123_4

iPRES'2018, September 2018, Boston and Cambridge, Massachusetts USA

ACM ISBN 123-4567-24-567/08/06…$15.00
https://doi.org/10.475/123_4

1 INTRODUCTION

Inspired by the "Knowledge Base" definition of the Open Archival Information System [4]: "A set of information, incorporated by a person or system, that allows that person or system to understand received information" , we developed a mapping model for: *a)* capturing the knowledge base of the digital preservation metadata, represented by the PREMIS Data Dictionary (PREMIS-DD) [20] [21], and *b)* generating a SKOS [24] vocabulary, that represents the PREMIS Knowledge Base (PREMIS-KB) as a Semantic Web Technology (SemWebTech).

The PREMIS 3 OWL ontology (PREMIS-OWL3) [19] [18] even designed by the principle of maintaining the best coherence with the PREMIS-DD [9], it deviates consistently from the corresponding version of PREMIS-DD version 3 (PREMIS-DD3), and even further than the PREMIS 2 OWL ontology (PREMIS-OWL2) [5] with respect to the PREMIS-DD version 2 (PREMIS-DD2).

We observed that the amount of knowledge about the digital preservation domain metadata is being unraveled by the application of the Linked Data paradigm [2] and its disruptive potential [17].

Looking inside the PREMIS-DD, we find the Semantic Units (PREMIS-SU) that are detailed information about the digital preservation metadata and related practices. For example, the knowledge about the PREMIS-SU *fixity* [1] is written in the PREMIS-DD tabular section, in the "Special topics", and in the "Glossary section", as well as variously referred in other parts of the dictionary. In the PREMIS-OWL2 and PREMIS-OWL3 we find the declaration of the ontology class Fixity (`premis:Fixity`) as a mapping of the corresponding PREMIS-SU.

Nevertheless, the knowledge connected to the Fixity as an ontological entity is modeled differently: PREMIS-OWL2, coherently to the PREMIS-DD, models the set of PREMIS-SUs related to the *messageDigest* (see below Listing 1), and preserves at the best, the knowledge described as PREMIS-SU attributes; while PREMIS-OWL3, for being more interoperable with other vocabularies according to the Linked Data principles [3] [12], dismisses the *messageDigest* set of metadata (see below, Listing 2).

Analogously happens for other PREMIS-SUs, especially for those defined as "containers" of other PREMIS-SUs.

[1] see Data Dictionary for Preservation Metadata: PREMIS version 3.0, pages 59-63, 258, 270 http://www.loc.gov/standards/premis/v3/premis-3-0-final.pdf

It is worth noting that, the PREMIS-OWL2 has also influenced a consistent redesign of the PREMIS data model, settled since its first publication [2]. Indeed, in the PREMIS-DD3, the current PREMIS data model clearly shows the *Environment* [8] entity and it relationships, giving evidence about the significant change from the PREMIS-DD2 to the PREMIS-DD3.
Furthermore, according to the PREMIS ontology working group [19], involved in the current design of the PREMIS-OWL3, presumably the PREMIS-DD will be submitted to a new process of revision, for accommodating the advancement achieved by the PREMIS-OWL3 modeling. This fact, further demonstrates the well-established McLuhan's media theory [16], "medium is the message".
Listing 1 shows an example of RDF triples using the PREMIS-OWL2, as a vocabulary. The triples look more conforming with the structure of the PREMIS-DD, and the PREMIS-OWL2 comprehends for each class and predicate a set of annotations, which facilitates the human understandability about the meaning of each ontological entity, by providing more knowledge context.

Listing 1: RDF triples resulting from the PREMIS OWL2

```
<file1> a premis:File ;
premis:hasFixity <file1fixity> .
<file1fixity> a premis:Fixity ;
premis:hasMessageDigestAlgorithm cryptHashFunc:md5 ;
premis:hasMessageDigest
"37ba62655d93e540a8195a6f02ec8bdc"^^xsd:string ;
premis:hasMessageDigestOriginator
"PHP 5.2.10 function"^^xsd:string .
```

Listing 2 shows an example of RDF triples using the PREMIS-OWL3, as a vocabulary. The triples look simpler than the structure of the PREMIS-DD, but the knowledge context in which triples has been conceived is completely missing. Indeed, looking to the PREMIS-OWL3, we don't find annotations providing further knowledge, and the `rdfs:isDefinedBy` annotation property, redundantly refers to the ontology itself (see Table 4), without connecting additional knowledge about the meaning.

Listing 2: RDF triples resulting from the PREMIS OWL3

```
<file1> a premis:File ;
premis:hasFixity <file1fixity> .
<file1fixity> a cryptHashFunc:md5 ;
rdf:value "258622b1688250cb619f3c9ccaefb7eb" ;
dct:creator <GNUgperf31> .
```

The triples, using PREMIS-OWL3, even facilitating the process of Linked Data consumption [9], lower the level of data understandability: the implementation efforts for Linked Data consumption, as well as the proper re-use of data, lack the necessary knowledge context provided in a "computable form".
This concern has already arisen in other communities that historically deal with ever-increasing size of datasets to be analyzed. For example the biomedical research community recognized to become increasingly dependent on knowledge stored in computable form, and uses ontology [3] and related annotations for describing a comprehensive model of biological systems [13].

[2] Metadata for Digital Preservation: A Status Report on PREMIS Priscilla Caplan (FCLA) and Nancy Hoebelheinrich (Stanford) CNI Fall Task Force Meeting: December 6-7, 2004 http://www.oclc.org/research/projects/pmwg/cni2004falltf.ppt
[3] Gene Ontology, http://geneontology.org/

At some point in the future, PREMIS Linked Datasets will be published around the world, and the research community could ask: *How functional information about `premis:Fixity` was captured, structured in a computable form, and made accessible to digital preservation community?*
To answer this question, we propose PREMIS-KB as a knowledge tool, targeted to the digital preservation community, for learning, using, and updating preservation metadata. PREMIS-KB bridges the knowledge expressed by the PREMIS-OWL with its knowledge context, represented by the PREMIS-DD. The PREMIS-OWL will be provided with the PREMIS-KB, a computable representation of the PREMIS-DD.
PREMIS-KB as a "documentation tool" provides designated community with web resources for human consultation, as a "computable tool" exhibits RDF resources for software agent consumption. In the semantic web space, PREMIS-KB represents the PREMIS-DD structure as an OWL [26] ontology, and expresses the PREMIS-DD intellectual content as a SKOS [25] vocabulary.
The enrichment of PREMIS-OWL3 with annotation properties, by pointing to the PREMIS-KB, would allow to answer to the posed question.
The remainder of this paper is structured as follows.
Section 2 describes the PREMIS-KB and motivates the approach focused on the annotation properties.
Section 3 presents the main tools of the PREMIS preservation metadata standard; details the PREMIS-DD structure (subsec. 3.1); summarizes the ontologies, PREMIS-OWL2 and PREMIS-OWL3 (subsec. 3.2); compares the usage of annotation properties between the PREMIS-OWL versions (subsec. 3.3).
Section 4 presents the four rules for publishing Linked Data; describes the SKOS ability for representing semi-formal knowledge organization systems (subsec. 4.1); summarizes the structural elements for building vocabularies as Linked Open Data; focuses on the annotation property as the documentation connection for bridging the knowledge contained into the PREMIS-DD versions, and the PREMIS-OWL versions (subsec. 4.2).
Section 5 describes the approach adopted for capturing knowledge from the hierarchical structure of the PREMIS-DD and for minting the URIs, uniquely identifying each PREMIS-SU.
Section 6 describes the mapping, modeled for the automatic generation of the PREMIS-KB.
Section 7 describes how the connection, bridging the PREMIS-OWL ontological entities with the related SKOS concepts of the PREMIS-KB, could be integrated into the PREMIS-OWL.
Section 8 draws the conclusions.

2 PREMIS KNOWLEDGE BASE AND ANNOTATION PROPERTY MOTIVATION

The proposed PREMIS-KB is a representation of the PREMIS-SUs. Each PREMIS-SU is expressed as a SKOS concept, identified by its own dereferenceable URI, coined following the Linked Data best practices [2] [3] [12], and preserving provenance [30] information, about its generation. The PREMIS-KB facilitates the human access to the knowledge about the PREMIS semantics, and allows software agents to improve the interpretation of data, by enriching the knowledge context for Linked Datasets, that are produced by the

digital preservation community which uses PREMIS-OWL. As a "computable knowledge base", the PREMIS-KB contributes to allow "person or system to understand received information" [4].
According to the OAIS, we argue that the future increase, in dimension and complexity, of the Linked Datasets adopting PREMIS-OWL, will require more knowledge context for maintaining in the long-term, its specific meaning and its understandability. We believe that human and machine consumers of the Linked Datasets, using PREMIS-OWL, will benefit from: *a)* the maintenance of a PREMIS-KB, which preserves the knowledge context and its conceptual relationship to the PREMIS-OWL as a Linked Data vocabulary [22]; *b)* the computable form of the original documentation about the structural, relational and etymological evolution of the PREMIS-SUs.
In this paper we propose the PREMIS-KB, as a knowledge tool stored in a computable form, obtained by converting PREMIS-SUs as SKOS [24] concepts, and described by an OWL [29] ontology properly defined for the structure of the PREMIS-DD. The PREMIS-KB results from a well-defined mapping process, designed for the preservation metadata knowledge of the PREMIS-DD, which is structured into PREMIS-SUs. The mapping process generates SKOS concepts, expressing the PREMIS-SU knowledge, and it allows the web exhibition of the corresponding SKOS Linked Dataset, according to the Linked Data best practices.
OWL2 specifications [29] remark that software applications using OWL language [26] often need ways to associate additional information with ontologies, entities, and axioms. Indeed, the annotation property is a mechanism that doesn't contribute to the "logical" knowledge specified in the ontology [28], but is used to provide additional information about the ontological entities of the vocabulary.
In this paper, we propose a solution for annotating each ontological entity of the PREMIS-OWL3 with its originating documentation, embodied by the PREMIS-DD, a Portable Document Format (PDF) document, which is the documentation result of the conceptualization work of the PREMIS community. Conforming with OWL2 Mapping to RDF graph [27], the annotations can also be translated in triples and, in the proposed solution, the annotation properties allow to connect knowledge concepts, by dereferencing URIs of SKOS concepts, exhibited as Semantic Web information resources (web pages and RDF graphs [33]).
The result obtained can be integrated with the PREMIS-OWL. The integration would allows Linked Data consumers to discover more knowledge about the PREMIS-OWL entities, and allows Linked Data providers to reduce the effort for documenting their data: by using PREMIS-OWL as a vocabulary, connected to its originating documentation, the data will be provided with its knowledge context and its interpretation can be facilitated.

3 PREMIS OVERVIEW

The PREMIS standard [20] was developed for implementing metadata derived from concepts expressed by the Open Archival Information System (OAIS) reference model (ISO 14721) [4]. The PREMIS standard can be considered a digital preservation "knowledge base" where the reference metadata, for digital preservation practices, are identified and discussed within the community of experts and practitioners, and formally defined into a data dictionary. The PREMIS-DD is maintained [4] by the PREMIS Editorial Committee, with the support of the Library of Congress.
Since the first version of the PREMIS standard [5], its reference data model was based on five conceptual entities, influencing related digital preservation implementations. Since 2015, the PREMIS version 3 [21] changed the data model by enriching the description of the Environment [7] [8], and by specifying the Environment role in the preservation practices [6]. This change implied the embedding of the Intellectual entity in the Object entity.
Thus, the PREMIS data model is currently depicted as in the Figure 1 and described as follows:

- **Object**, a discrete unit of information subject to digital preservation. The Object has four subtypes:
  - *Intellectual Entity*, an intellectual unit for the management and the description of the content, which can be described as a category of Object to enable additional description and linking to related PREMIS entities;
    the *Environments* (i.e. hardware and software needed to use digital objects) are described as generic Intellectual Entities so that they can be described and preserved reusing the Object entity, as Representation, File or Bitstream.
  - *File* is a named and ordered sequence of bytes that is known by an operating system.
  - *Bitstream* is contiguous or non-contiguous data within a file that has meaningful common properties for preservation purposes.
  - *Representation* is the set of files, including structural metadata, needed for a complete and reasonable rendition of an Intellectual Entity.
- **Event**, an action that has an impact on an Object or an Agent.
- **Agent**, a person, organization, hardware or software associated with Events in the life of an Object, or with Rights attached to an Object.
- **Rights**, a description of one or more rights, permissions of an Object or an Agent.

In the Figure 1, the ellipses highlight the number of PREMIS-SUs associated with the relevant entity.

3.1 Structure of the PREMIS Data Dictionary

PREMIS-DD is a practical documentation resource for implementing preservation metadata in the digital preservation systems [21]. PREMIS-DD defines a core set of information elements that are defined as "Semantic Unit" (PREMIS-SU). The PREMIS-SUs, are associated with the main entities depicted by the PREMIS data model (see the number in the ellipses of the Figure 1), and each PREMIS-SU is an entry of the PREMIS-DD.
Table 1 shows and describes the attributes that a PREMIS-SU can have associated with, and shows the corresponding obligation model. Specifically, the first three attributes (Identifier, Name and Definition) are *M*andatory, while the others are *O*ptional.

[4] PREMIS Maintenance Activity and Editorial Committee, http://www.loc.gov/standards/premis/ma.html
[5] PREMIS Data Dictionary for Preservation Metadata, Version 1, http://www.loc.gov/standards/premis/v1/index.html

Table 1: Overview of PREMIS-SU attributes and related obligation model

PREMIS-SU attribute	Description	Obligation
Identifier	Identification number	*M*
Name	Descriptive name	*M*
Definition	The meaning of the PREMIS-SU	*M*
Rationale	why the PREMIS-SU is needed	*O*
Data constraints	how the value of the PREMIS-SU should be encoded (see Sect. 5.1)	*O*
Object category	specifies the type of the PREMIS Object	*O*
Applicability	whether the unit applies to a specific type of PREMIS Object	*O*
Examples	one or more examples of values the PREMIS-SU may take	*O*
Repeatability	whether a PREMIS-SU can take multiple values	*O*
Obligation	whether a value for the PREMIS-SU is mandatory or optional	*O*
Creation/Maintenance notes	notes about how the values for the PREMIS-SU may be obtained or updated	*O*
Usage notes	information about the intended use of the PREMIS-SU, or clarification of the definition	*O*

3.2 PREMIS OWL Ontology: Version 2 and Version 3

PREMIS-OWL ontology allows the interested community to express their own preservation data as RDF. The PREMIS-OWL2 ontology was published in June, 2013, and reflects at the best, the conceptual model of the PREMIS-DD version 2.2 [20].

The ontology comprehends 37 classes referring to the different entities of the PREMIS data model (see Fig. 1) and 106 properties (see Table 2), describing relationships among classes. The PREMIS-OWL2 ontology imports 24 controlled vocabularies [11], recommended by the *Data constraint* attribute of specific PREMIS-SUs. Mostly, the controlled vocabularies, are exposed as SKOS [25] concepts, and are available at the Library of Congress Linked Data Service for Authorities and Vocabularies (LOC-LDS) [14] [6].

The PREMIS-OWL3 [19] was designed for being conforming with the Linked Data principles [2] [3] [12], mainly by re-using terms from existing vocabularies, like Dublin Core Terms [10] and Provenance Ontology (PROV-O) [31], and by adopting URI identification and naming best practices. PREMIS-OWL3 was designed by adopting a simplification approach, with respect to the PREMIS-OWL2, thus *a)* the integration with other ontologies [18] was privileged, *b)* many PREMIS-SUs are not represented in the OWL document [7]. Currently the PREMIS-OWL3 is in a draft status and it was relesed to the community for a public review [8].

PREMIS-OWL3 currently comprehends 32 classes referring to the different entities of the PREMIS data model (see Fig. 1) and 37 properties (see Table 2). PREMIS-OWL3 doesn't import value vocabularies from LOC-LDS, but use them as subclasses, as instances of a class, as properties or subproperties, even though the mechanism for re-using them will be refined after the public review period.

[6]Library of Congress Linked Data Service for Authorities and Vocabularies, http://id.loc.gov/vocabulary/preservation

[7]PREMIS OWL Ontology Version 3, https://github.com/PREMIS-OWL-Revision-Team/revise-premis-owl/blob/master/premis3.owl

[8]https://github.com/PREMIS-OWL-Revision-Team/revise-premis-owl

3.3 Annotation Property in PREMIS-OWL

PREMIS-OWL2 includes annotations, that were mainly imported from the PREMIS-DD, toward `DataProperty` defined by the RDFS [35] or SKOS [25] vocabulary.

The literal value is composed by the name and the value of the PREMIS-SU's attributes, following the pattern "Attribute Name: Value". For example the *Data Constraint* attribute of the PREMIS-SUs, was mapped as follows:

```
<rdfs:comment
  rdf:datatype="http://www.w3.org/2001/XMLSchema\#string"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema\#">
Data Constraint: [Text value].
```

Table 3 shows how the PREMIS-SU attributes were mapped toward PREMIS-OWL2, as annotation properties, by using specific RDFS or SKOS vocabulary properties. The 1st column shows the PREMIS-SU attributes. The 2nd and the 3rd columns show the occurrences of each attribute in the PREMIS-DD2 and PREMIS-DD3. The 3rd column shows the Attribute Name used in the annotation property value. The 4th column shows the annotation property used by PREMIS-OWL2. The last two columns show the occurrences of corresponding Attribute Names (see the 4th column) found in the annotation properties of the PREMIS-OWL2 and PREMIS-OWL3.

It is worth noting that, PREMIS-SU attributes do not precisely correspond to the PREMIS-OWL2 Attribute Names and we have distinguished the singular/plural (i.e. Example/s) form of the attributes, with related occurrences (i.e. 15/28) found in the PREMIS-OWL2. Furthermore, `rdfs:comment` and `skos:editorialNote` are used for different PREMIS-SU attributes. In relation to the knowledge elements of the PREMIS-DD, retained by the PREMIS-OWL, Table 3 clearly shows the decrease of retention of the PREMIS-OWL2, and the annotation properties, used by the PREMIS-OWL3 do not correspond.

Table 4 details the set of annotation properties, and related occurrences (3rd column), used by the PREMIS-OWL3. The 2nd column show the value of the annotation property (the 1st row specifies the same value repeated 69 times), and the types of contents (2nd, 3rd and 4th rows).

We can observe, from the Table 3 and the Tables 2 and 4, detailing the PREMIS-OWL3, that the annotation capability, specified by the

Figure 1: Number of PREMIS-SUs for each main entity of the PREMIS Data Model version 3.0

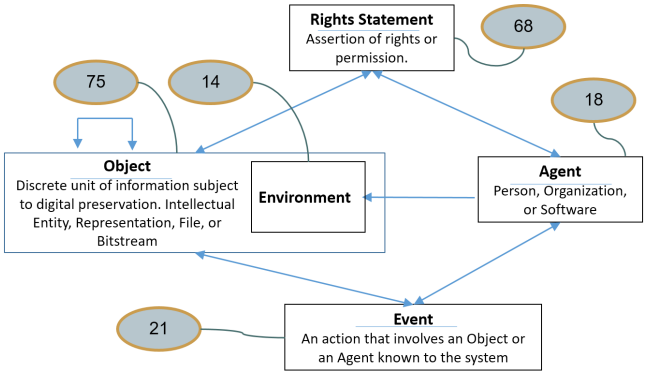


Table 2: Comparison between ontological entity occurrences between PREMIS-OWL2 and PREMIS-OWL3

PREMIS-OWL ontological entities	PREMIS-OWL ver. 2	PREMIS-OWL ver. 3
`owl:class`	37	32
`owl:ObjectProperty`	39	22
`owl:DatatypeProperty`	25	15
`owl:FunctionalProperty`	39	
`owl:InverseFunctionalProperty`	2	
`owl:AnnotationProperty`	1	

OWL2 language [29], is not properly exploited. Furthermore, the knowledge of the digital preservation domain, granularly expressed by the PREMIS-DD, is gradually not retained by the PREMIS-OWL, and in the PREMIS-OWL3 more oriented to the Linked Data paradigm, the decrease of "computable knowledge" amount is higher.

4 PUBLISHING LINKED (OPEN) DATA AND RELATED VOCABULARIES

The Resource Description Framework (RDF) [34], allows to build statements about resources in the form of an expression like:
`subject predicate object.`
The statements, or triples, can be interpreted by machines, that become capable to make connections between resources over Web protocols [33]. The `subject-predicate` of the RDF are always expressed by an URI, while the `object` can be either expressed by an URI or a "Literal value". RDF is the basic data model for publishing Linked Datasets as sets of SemWeb resources, consumable by humans and machines.
The Linked Data initiative is part of the SemWeb initiative, and consists of datasets encoded in RDF, respecting the four rules initially defined in [2] and then further detailed in [3][12][32].

(1) **Use URIs as names for things** - "not just Web documents and digital content, but also real world objects and abstract concepts".
(2) **Use HTTP URIs so that people can look up those names** - "to identify objects and abstract concepts".
(3) **When someone looks up a URI, provide useful information, using the standards (RDF*, SPARQL)** - "use of a single data model for publishing structured data on the Web a simple graph-based data model that has been designed for use in the context of the Web".
(4) **Include links to other URIs, so that they can discover more things** - "not only Web documents, but any type of thing".

All four principles are focused on the centrality of the URIs [1] necessary to the unambiguous reference of resources.
Through web protocols and URIs, RDF datasets can be interpreted by machines that check the consistency of RDF data, against referred vocabularies terms, expressed themselves as RDF datasets.
In other words, the meaning of RDF data, is expressed by vocabularies that analogously are conceptual resources described by RDF statements. The RDF triples, belonging to a vocabulary (or ontology), allow consumers (humans and machines) to interpret the meaning of Linked Data, and are the "computable form" of the knowledge necessary to interpret related RDF data.

4.1 The SKOS - Simple Knowledge Organization System

The Simple Knowledge Organization Sytem (SKOS) [24][23][25] is an RDF vocabulary for representing semi-formal knowledge organization systems (thesauri, taxonomies, classification schemes, etc.). The knowledge expressed in SKOS RDF is machine-readable and it can be exchanged between software applications and used as a SemWeb knowledge.
SKOS provides a lightweight, intuitive conceptual modeling language for developing and sharing controlled vocabularies in the SemWeb, and it can be used in combination with more-formal languages such as the Web Ontology Language (OWL) [29]. SKOS can also be seen as a bridging technology, providing the missing link between the rigorous logical formalism of ontology languages, such as OWL, and the informal and weakly-structured data.
Based on this simplified model, the SKOS representation empowers a vocabulary, like PREMIS-OWL, by representing each term in more intuitive and "familiar" way, enables a wider re-use and improves, anyway, the interoperability with a machine-understandable ability.

4.2 Vocabularies and Annotation Property

Each segment of the RDF statement, indeed, refers to vocabularies (also ontologies), usually encoded in SKOS Schema, in RDF Schema (RDFS) [35], or in the Web Ontology Language (OWL) [29].
SemWeb vocabularies define semantic entities that allow machine to interpret RDF data, and in order to be used by machines they must be produced also as RDF (official syntax RDF/XML), considering that "vocabularies are also data" [22] [22], that can also be exposed as Linked Data.
The following list presents the most used entities, defined by a vocabulary, in relation to a RDF statement:

- (RDFS, OWL) `Classes` of resources, used in RDF statements, as a `subject` or as an `object`;

Table 3: PREMIS-DD2 and PREMIS-DD3 attributes mapped toward annotation properties in PREMIS-OWL2 and PREMIS-OWL3

PREMIS-SU attributes	PREMIS-DD ver. 2	PREMIS-DD ver. 3	PREMIS-OWL2 Attribute Name	PREMIS-OWL annotation property	PREMIS-OWL ver. 2	PREMIS-OWL ver. 3
Data constraint	195	196	*Data Constraint/s:*		30/1	-
	-	-	*Extensions:*		23	-
Examples	98	110	*Example/s:*	`rdfs:comment`	15/28	-
Creation/Maintenance notes	24	22	*Creation/Maintenance Notes:*	`skos:historyNote`	16	-
Definition	195	196	*Definition:*	`skos:definition`	111	-
Rationale	85	93	*Rationale:*		55	-
	-	-	*Entity properties:*	`skos:editorialNote`	3	-
	-	-	*Entity types:*		1	-
Usage Notes	126	120	*Usage Note/s:*	`skos:scopeNote`	2/56	-

Table 4: Annotation property used in PREMIS-OWL3

PREMIS-OWL3 annotation property	Value/Type	#
`rdfs:isDefinedBy`	http://www.loc.gov/premis/rdf/v3/	69
`rdfs:label`	Name of the ontological entity	69
`rdfs:comment`	Definition of the entity	28
`rdfs:seeAlso`	Link to controlled vocabularies	17

- (RDFS, OWL) `Property` of resources used in RDF statements, as a `predicate`;
- (OWL) `ObjectProperty` connects `Class`es by URI reference, thus an URI as a RDF `subject` (the *Domain* `Class`), and an URI as a RDF `object` (the *Range* `Class`) are expected for the consistency of the assertion;
- (OWL) `DataProperty` connects a `Class` to a data value as a RDF `object`;
- (OWL) `AnnotationProperty` provides an annotation for ontologies, entities, and axioms.

The annotations can be used by OWL 2 tools to display additional information about the `subject` of the statement.
The annotation properties used for documenting OWL ontological entities are listed and described in the following Table 5, specifying if the annotation property expects a literal value or a resource URI as the *Range* of the property (the `object` of the RDF statement).

5 PREMIS SEMANTIC UNITS: ANALYSIS AND IDENTIFICATION

The "technical neutrality" of the PREMIS-DD is intended to maximize its applicability across the broad range of digital preservation contexts in which it could potentially be implemented [21].
Nevertheless, the PREMIS-DD, is structured over hierarchies of PREMIS-SUs, where the "forefathers" are the four main PREMIS entities (see Sect. 3.1), thus the PREMIS-DD structure reflects the hierarchical structure of the XML [9], that is not tailored to the RDF graph structure.
The XML style used for the PREMIS-DD was challenging for the PREMIS-OWL design [5] [9]. Analogously, exposing the PREMIS-DD as Linked Data implies the disruption of its hierarchical structure (see Sect. 5.1).
Thus, we have discretely identified each PREMIS-SU as a node in the graph of the SemWeb space, according to specific URI policies (see Sect. 5.2) and exploiting the SKOS hierarchical relationships, we have anyhow preserved the PREMIS-SUs' hierarchy.

5.1 The Structural Challenge: Data Containers and Data Values

The Linked Data generation challenges the XML hierarchical structure in which the PREMIS-DD was conceived, thus the value of the *Data Constraint* attribute influences the URI policies, as well as the maintenance of hierarchical relationships between information resources that need to be represented in a relational way. The *Data Constraint* attribute can have values, that define the relationship types among PREMIS-SUs. The following types of relationship drive the generation of links connecting related PREMIS-SUs as enriching documentation resources:

- **(C)ontainer** - *Container*: the PREMIS-SU is an umbrella for two or more semantic components and has *no value* of its own. *[PREMIS-SU is an additional documentation resource, and should be linked toward its ancestors and descendants].*
- **(D)atum** - *None*: the PREMIS-SU can take any form of value *[the value is the Range of a* `DataProperty`*, PREMIS-SU should be linked to its ancestors].*
- **(D)atum** - *Data type specification*: defines a type of data (integer, string, etc.)
  [the value is the Range of a `DataProperty`*, PREMIS-SU should be linked to its ancestors].*

[9] W3C - Extensible Markup Language (XML), http://www.w3.org/TR/2008/REC-xml-20081126/

Table 5: OWL 2 Annotation properties defined by the RDFS

Property name	Description	Domain	Range
provide a human-readable description of a resource			
rdfs:label	A human-readable name for the subject.	rdfs:Resource	rdfs:Literal
rdfs:comment	A description of the subject resource.	rdfs:Resource	rdfs:Literal
provide a machine-actionable URI as description of a resource			
rdfs:seeAlso	Further information about the subject resource.	rdfs:Resource	rdfs:Resource
rdfs:isDefinedBy	The definition of the subject resource.	rdfs:Resource	rdfs:Resource

Table 6: PREMIS-SU Containers, Data and Authority lists

Object			Agent			Event			Rights		
C	D	A	C	D	A	C	D	A	C	D	A
28	67	23	5	14	5	7	15	4	20	49	14

- **(A)uthority** - *Value should be taken from a controlled vocabulary*: the preservation repository should establish an *authority list of values* that are useful and meaningful to the repository. *[the value can be the Range of an* `ObjectProperty`*, PREMIS-SU should be linked to the suggested vocabulary].*

Table 6 shows the types of relationship, and related occurrences for each main PREMIS Entity.

5.2 URI Coinage and Disambuiguation of PREMIS Semantic Units

In order to produce PREMIS-DD as a Linked Dataset, the pattern of the URI for identifying each resource is structured maintaining the data provenance information [31]. For example the URI for the `fixity` PREMIS-SU is:
`dlcmrc-vocs_2016-PREMISDD_2017_Object_fixity`.
The URI is a "talking segmented" identifier for the PREMIS-KB:

(i) Agent: who has the main responsibility for the maintenance of the resource content (ex.: **`dlmrc`** is the Library of Congress's identifier);
(ii) Activity: the generation activity of the dataset (ex.: **`vocs_2016`** this URI leads to provenance information about the generation process producing the resource of the PREMIS-KB);
(iii) Entity: a relevant Thing in the knowledge domain is identified. Specifically we have acknowledged a PREMIS-SU as a documentation resource that we identify by means of: *a)* **`PREMISDD_2017`**, obtained by chaining the dataset name and the year of the Linked Data production; *b)* **`Object`** as a relevant and originating semantic for the PREMIS-KB Entity; *c)* **`fixity`** the PREMIS-SU name.

The PREMIS-SU's name should be unique in the PREMIS-DD context [21], this feature is preserved, when the PREMIS-SUs are used for an XML implementation, because the hierarchical system of containers disambiguates the equal names assigned to descendants. For example, the following PREMIS-SUs (and related descendants `Type` and `Value`) occur twice in the PREMIS-DD, because their own "forefathers" disambiguate the repetitions:

- `linkingEventIdentifier`: is disambiguated by `Object` and `Agent`;
- `linkingRightsStatementIdentifier`: is disambiguated by `Object` and `Agent`;
- `linkingObjectIdentifier`: is disambiguated by `Event` and `Rights`;
- `linkingAgentIdentifier`: is disambiguated by `Event` and `Rights`.

In this case, the direct relationship, between the PREMIS Entity and the PREMIS-SU name, is preserved in the URI's segment: **`Object_linkingEventIdentifier`**.
This URI coining method succeeds, because the descendants have inherited the ancestor name of their own main entity (i.e. `Object`, or `Agent`), and because each one occurs once, under its own "forefather".
Whereas, the URI coining method failed, in the case of PREMIS-SUs like `startDate` and `endDate`, where the last two segments of URI, created the same URI (i.e. `Rights_startDate`). This is due to the fact that PREMIS-SUs, `startDate` and `endDate`, occur six times under the same "forefather" `Rights`. Thus, in this specific case, it was necessary also to chain the name of the nearest container, allowing the disambiguation of the found repetitions.
The nearest containers' names, chained into the URIs are:

- `copyrightApplicableDates`,
- `licenseApplicableDates`,
- `statuteApplicableDates`,
- `otherRightsApplicableDates`,
- `termOfGrant`,
- `termOfRestriction`.

An example of the resulting URI is:
`dlcmrc-vocs_2016-PREMISDD_2017_Rights_termOfGrant_startDate`

6 MAPPING PREMIS DATA DICTIONARY AS A LINKED DATA VOCABULARY

Figure 2 graphically represents how the PREMIS-SU attributes have been mapped toward annotation properties of the RDFS ontology (`rdfs:label`) and toward SKOS documentation properties. The figure also shows how the *Object* PREMIS-SU, identified by

a PREMIS-KB prototype (**itrousr-vocs_2017-Object**)[10] is a `rdf:type` of `:PREMISSemanticUnit`, an `owl:class`, declared by the ontology representing the PREMIS-DD structure, and briefly described in the next subsection 6.1.
Table 7 shows the occurrences of RDFS and SKOS properties obtained from the PREMIS-SUs mapping, toward the PREMIS-KB.
It is worth noting that, the number of attributes in PREMIS-DD3 (see 3rd column of Table 3) is different from the PREMIS-KB properties (Table 7). This difference is due to, not only to the prototype nature of the automatic conversion process from the PREMIS-DD original document, but also to the data model differences with respect to the PREMIS-KB.
The prototype of PREMIS-KB for humans is retrievable at https://sbs.uniroma1.it/data/premisDataDictionary/local_index, and the automatic generation of the dataset for machines is under revision. The final release will follow the final release of the PREMIS-OWL3.

6.1 Ontology for PREMIS Data Dictionary Structure

Figure 3 shows the tiny ontology representing the PREMIS-DD structure. The ontology presents only two classes (`:PREMIS-DD` and `:PREMISSemanticUnit`) related by the BIBFRAME [15] property `bibFrame:partOf`. The lightpurple document shapes, identified by URIs, represent the PREMIS-SUs, as knowledge RDF resources, representing SKOS concepts and stored as documents. The originating connection between PREMIS-OWL and PREMIS-DD is defined by `prov:wasDerivedFrom`, a PROV-O [31] property expressing the derivation relationship between PREMIS-OWL and the PREMIS-DD, as a SemWeb resource.
The model, setting the connection between the ontological entities declared by the PREMIS-OWL and the PREMIS-SUs, is detailed in the Section 7.

6.2 Hierarchical Relationships Among SKOS PREMIS Semantic Units

Figure 4, shows how the SKOS concepts, representing the PREMIS-SUs, are related each other, through their hierarchical structure. The SKOS property `broader` and `broaderTransitive` connect SKOS concepts from the deeper level of the hierarchy (*statuteDocumentationIdentifier*), toward the upper levels, up to the "forefather" (*Rights*). For the sake of visibility, in the figure the inverse properties `narrower` and `narrowerTransitive` are not depicted, but the PREMIS-KB generation process automatically computes SKOS properties and related inverse properties.
Listing 3 shows an excerpt of the SKOS concept, expressing the hierarchical relationships of the PREMIS-SU Object. For space reasons only a sample of descendant relationships is provided.

Listing 3: Short SKOS example for the Object PREMIS-SU

```
<skos:Concept rdf:about="premiskb:[URIpref]-
PREMISDD_2017_Object">
<rdf:type rdf:resource=
"http://www.w3.org/2004/02/skos/core#Concept"/>
<skos:topConceptOf rdf:resource="premiskb:[URIpref]-
PREMISDD_2017-refschema"/>
<skos:prefLabel xml:lang="it">Oggetto</skos:prefLabel>
<skos:prefLabel xml:lang="en">Object</skos:prefLabel>
<skos:narrower rdf:resource="premiskb:[URIpref]-
PREMISDD_2017_Object_objectIdentifier"/>
<skos:narrowerTransitive rdf:resource="premiskb:[URIpref]-
PREMISDD_2017_Object_objectIdentifierType"/>
<skos:narrowerTransitive rdf:resource="premiskb:[URIpref]-
PREMISDD_2017_Object_objectIdentifierValue"/>
[...]
</skos:Concept>
```

[10] `itrousr`=identifier of the Sapienza Library System; `vocs_2017`=provenance information URI of the PREMIS-KB generation activity; `Object`=istance of the :PREMISSemanticUnit class

Figure 2: Mapping of PREMIS-SU attributes toward SKOS documentation properties

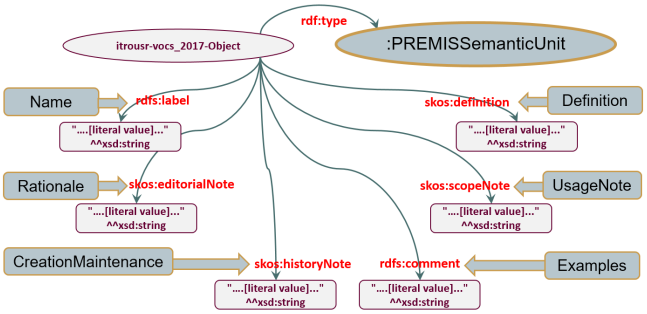


Figure 3: The ontology for the PREMIS Data Dictionary Structure and relationships with PREMIS-KB documents

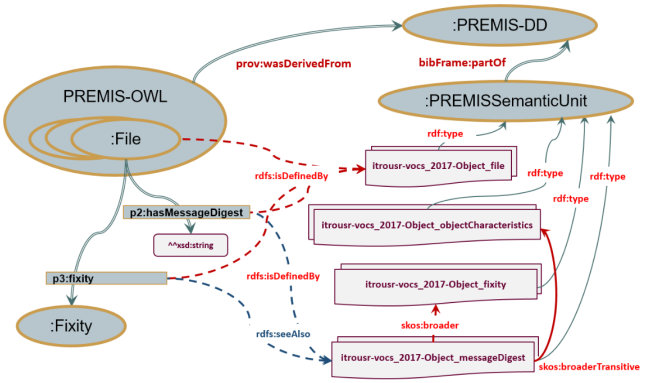
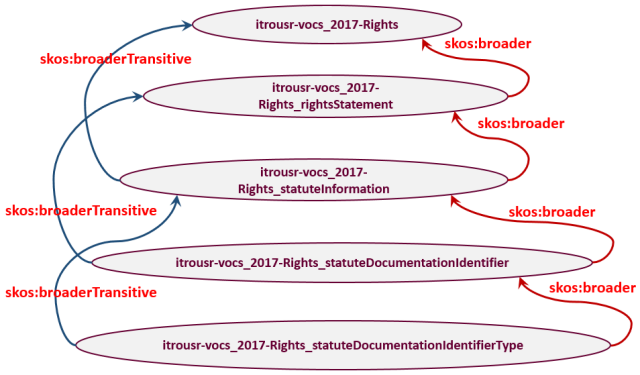


Table 7: PREMIS-KB RDFS and SKOS properties, mapped from PREMIS-SU attributes

PREMIS-KB Properties	occurrences
rdfs:comment	105
rdfs:label	205
skos:definition	205
skos:editorialNote	91
skos:historyNote	18
skos:scopeNote	78

Figure 4: PREMIS-DD structure as SKOS hierarchical relationships



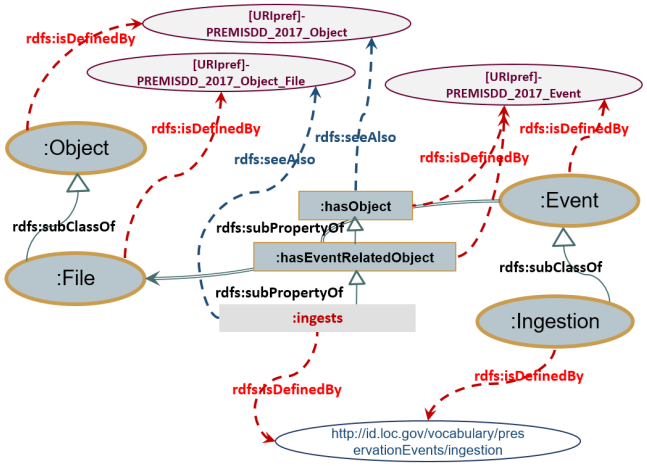


Figure 5: Integration of the PREMIS-KB into PREMIS-OWL. Example from the PREMIS-OWL2

7 BRIDGING PREMIS-OWL AND PREMIS-DD

Figure 5 depicts a sample representation of how the URIs of related PREMIS-SUs can be dereferenced from the ontological entities of the PREMIS-OWL.

The purple ellipses represent the PREMIS-SU documentation resources, expressed by the PREMIS-KB, and identified by their own URIs. The grey ellipses represent the entities of the PREMIS-OWL with the related properties.

The *Ingestion* event (`:ingests`), is modelled with respect to the main PREMIS-OWL classes: `:Object` and `:Event`.

It is worth noting that, the PREMIS-OWL Classes are connected to their originating PREMIS-SU, through a single edge labeled by the `rdfs:isDefinedBy`, while for the ObjectProperties (samples from both PREMIS-OWL2 and PREMIS-OWL3) the annotation property `rdfs:isDefinedBy` is used for documenting the *Domain*-Class and `rdfs:seeAlso` is used for the *Range*-Class.

DataProperty uses, for the *Domain*-Class, only the annotation property `rdfs:isDefinedBy`.

Considering that the property `rdfs:isDefinedBy` is a subproperty of `rdfs:seeAlso`, meaning that `rdfs:isDefinedBy` is more specific than `rdfs:seeAlso`, the `rdfs:isDefinedBy` connects the information resource that specifically defines the `subject` (i.e. the ontology class name `:Event`).

In the case of an ObjectProperties (i.e `:hasObject`) the meaning of `subject` is conveyed strictly, by `rdfs:isDefinedBy` associated with the *Domain*-Class (i.e. the ontology class name `:Event`), and loosely, by `rdfs:seeAlso` associated with the *Range*-Class (i.e. the ontology class name `:Object`). Both Classes, `:Event` and `:Object`, contribute to build a sound image of the property, and the direction of relationship is determined by the established conventional use of these annotation properties for ObjectProperty.

Listing 4 shows the corresponding RDF code of the graph of the Figure 5, and shows how annotation properties could be included into the PREMIS-OWL. The inclusion of SemWeb resources by means of the annotation properties mechanism allows to integrate the PREMIS-OWL ontological entities with their own originating knowledge context, expressed by the intellectual content of PREMIS-SUs, and represented in a "computable form" by the PREMIS-KB, as a Linked Open Vocabulary.

Listing 4: Resulting RDF triples example stating the integration of the PREMIS-OWL2 and the PREMIS-KB

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix premis: <http://www.loc.gov/premis/owl/v2> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
#---------->File class
premis:File
a owl:Class ;
rdfs:isDefinedBy
<premiskb/[URIpref]-PREMISDD_2017_Object_File> .
#---------->Event class
premis:Event
a owl:Class ;
rdfs:isDefinedBy
<premiskb/[URIpref]-PREMISDD_2017_Event> .
#---------->Ingestion subClassOf Event
premis:Ingestion
a owl:Class ;
rdfs:isDefinedBy
<http://id.loc.gov/vocabulary/preservation/eventType/ing> .
#---------->ingests subPropertyOf hasEventRelatedObject
premis:ingests
a owl:ObjectProperty ;
rdfs:subPropertyOf premis:hasEventRelatedObject ;
rdfs:domain premis:Event ;
rdfs:range premis:Object ;
rdfs:isDefinedBy
<premiskb/[URIpref]-PREMISDD_2017_Event> .
rdfs:seeAlso
<premiskb/[URIpref]-PREMISDD_2017_Object> .
```

8 CONCLUSIONS

The conversion of the PREMIS-DD PDF document, into the PREMIS-KB, stored in computable form, as a SKOS dataset and exhibited as Linked Open Vocabulary will benefit:

- the knowledge domain experts for discussing and deciding about the evolution of preservation metadata semantics, and

for maintaining the documentation about the changes occurred for each PREMIS-SU;
- the community of developers in the implementation work, because the consultation of the knowledge about PREMIS-SUs and their interrelationships, is facilitated and dynamic;
- the tasks of providing and consuming the PREMIS Linked Datasets can benefit from ontology entities already documented by information resources in a "computable form", from where both humans and machines can learn about digital preservation metadata domain;
- the maintenance and the design evolution of the PREMIS-OWL, because the integration with PREMID-DD (by means of the URI reference) also simplifies the PREMIS-OWL documentation process, avoiding duplications, omissions or incompletion of information about the ontological entities;
- the long-life learning, the continuing education and the workers' professional development about the digital preservation metadata domain, are facilitated in the rapidly changing digital environment, because the knowledge necessary to build meanings about the digital preservation practices is easily available for human, and for future machines that will be able to build SemWeb learning services.

The PREMIS-KB as a Linked Data SKOS vocabulary, also allows to manage multilingual PREMIS-SU contents (i.e. existing Japanese [11] and Spanish [12] translations), and the coinage of "talking segmented" URIs allows to access to different versions of the PREMIS-SUs, based on the changes applied to the PREMIS-DD.

The proposed integration of PREMIS-KB into the PREMIS-OWL, via annotation property, allows Linked Data consumers, to discover more information about the knowledge context of digital preservation data exhibited as Linked Data, and Linked Data providers, to reduce the effort of documenting their data. In the long-term it contributes to maintain the understandability [4] of data, and metadata, of the digital preservation knowledge domain.

PREMIS-DD is the original documentation for the semantics of the digital preservation metadata, currently represented by a static PDF document, and the PREMIS-OWL, is the set of "corresponding" semantics, in a "computable form". The current PREMIS-OWL3 shows itself more "disruptive" because it "distributes" the PREMIS semantics among other knowledge domain vocabularies, like Dublin Core, PROV-O, etc., and it flattens the hierarchical structure of the PREMIS-DD3. The PREMIS-KB and the proposed connection from PREMIS-OWL3, recovers the "intangible" relationship, between the conceptual contents represented by the hierarchy of the PREMIS-SUs and the graph of the PREMIS-OWL3 ontological entities.

REFERENCES

[1] Tim Berners-Lee. 1998. Cool URIs don't change. (1998). http://www.w3.org/Provider/Style/URI

[2] Tim Berners-Lee. 2006. Linked data-design issues. (2006). http://www.w3.org/DesignIssues/LinkedData.html

[3] Christian Bizer, Tom Heath, and Tim Berners-Lee. 2009. Linked data-the story so far. *Semantic Services, Interoperability and Web Applications: Emerging Concepts* (2009), 205–227. http://eprints.soton.ac.uk/271285/1/bizer-heath-berners-lee-ijswis-linked-data.pdf

[4] Consultative Committee for Space Data. 2012. Reference Model for an Open Archival Information System (OAIS), Recommended Practice CCSDS 650.0-M-2 Magenta Book. (2012). http://public.ccsds.org/publications/archive/652x0m1.pdf

[5] Sam Coppens, Ruben Verborgh, Sébastien Peyrard, Kevin Ford, Tom Creighton, Rebecca Guenther, Erik Mannens, and Rik Walle. 2015. PREMIS OWL. *Int. J. Digit. Libr.* 15, 2-4 (April 2015), 87–101. https://doi.org/10.1007/s00799-014-0136-9

[6] Angela Dappert and Adam Farquhar. 2016. Digital Preservation Metadata Practice for Computing Environments. In *Digital Preservation Metadata for Practitioners*. Springer, 129–138.

[7] Angela Dappert and Sébastien Peyrard. 2012. Describing digital object environments in premis. 69–76.

[8] Angela Dappert, Sébastien Peyrard, Carol CH Chou, and Janet Delve. 2013. Describing and preserving digital object environments. *New Review of Information Networking* 18, 2 (2013), 106–173.

[9] Angela Di Iorio and Bertrand Caron. 2016. PREMIS 3.0 Ontology: Improving Semantic Interoperability of Preservation Metadata. In *Proceedings of the 13th International Conference on Digital Preservation*. 32–36.

[10] Dublin Core Metadata Initiative. 2001. DCMI Metadata Terms 2012. (2001). http://dublincore.org/documents/dcmi-terms/

[11] W3C Library Linked Data Incubator Group. 2011. Library Linked Data Incubator Group: Datasets, Value Vocabularies, and Metadata Element Sets. (2011). http://www.w3.org/2005/Incubator/lld/XGR-lld-vocabdataset/

[12] Tom Heath and Christian Bizer. 2011. Linked data: Evolving the web into a global data space. *Synthesis lectures on the semantic web: theory and technology* 1, 1 (2011), 1–136.

[13] Suzanna E Lewis. 2017. The Vision and Challenges of the Gene Ontology. In *The Gene Ontology Handbook*. Springer, 291–302.

[14] Library of Congress. 2011. Linked Data Service Authorities and Vocabularies. (2011). http://id.loc.gov

[15] Library of Congress. 2016. BIBFRAME 2.0 Vocabulary - Conversion Specifications. (2016). https://www.loc.gov/bibframe/mtbf/

[16] Marshall McLuhan. 1964. *Understandig media.*

[17] Heather Lea Moulaison and Anthony J Million. 2014. The disruptive qualities of Linked Data in the library environment: Analysis and recommendations. *Cataloging & classification quarterly* 52, 4 (2014), 367–387.

[18] PREMIS 3 OWL ontology Working Group. 2017. Guidelines for using the PREMIS Version 3 OWL Ontology. (2017). http://www.loc.gov/standards/premis/ontology/pdf/premis3-owl-guidelines.pdf

[19] PREMIS 3 OWL ontology Working Group. 2017. PREMIS OWL Draft Ontology for version 3. (2017). http://www.loc.gov/standards/premis/ontology/owl-version3.html

[20] PREMIS Editorial Committee. 2012. PREMIS Data Dictionary for Preservation Metadata version 2.2. (2012). www.loc.gov/standards/premis/v2/premis-2-2.pdf

[21] PREMIS Editorial Committee. 2015. PREMIS Data Dictionary for Preservation Metadata, Version 3.0. (2015). http://www.loc.gov/standards/premis/v3/premis-3-0-final.pdf

[22] Pierre-Yves Vandenbussche, Ghislain A Atemezing, María Poveda-Villalón, and Bernard Vatant. 2017. Linked Open Vocabularies (LOV): a gateway to reusable semantic vocabularies on the Web. *Semantic Web* 8, 3 (2017), 437–452.

[23] W3C. 2004. SKOS Simple Knowledge Organization System - Home Page. (2004). https://www.w3.org/2004/02/skos/

[24] W3C. 2009. SKOS Simple Knowledge Organization System Primer. (2009). https://www.w3.org/TR/skos-primer/

[25] W3C. 2009. SKOS Simple Knowledge Organization System Reference. (2009). https://www.w3.org/TR/skos-reference/

[26] W3C. 2012. OWL 2 Web Ontology Language Document Overview (Second Edition). (2012). http://www.w3.org/TR/owl2-overview/

[27] W3C. 2012. OWL 2 Web Ontology Language Mapping to RDF Graphs (Second Edition). (2012). http://www.w3.org/TR/owl2-mapping-to-rdf/

[28] W3C. 2012. OWL 2 Web Ontology Language Primer (Second Edition). (2012). https://www.w3.org/TR/owl2-primer

[29] W3C. 2012. OWL 2 Web Ontology Language Structural Specification and Functional-Style Syntax (Second Edition). (2012). http://www.w3.org/TR/owl2-syntax/

[30] W3C. 2013. PROV-DM: The PROV Data Model. (2013). http://www.w3.org/TR/prov-dm/

[31] W3C. 2013. PROV-O: The PROV Ontology. (2013). http://www.w3.org/TR/prov-o/

[32] W3C. 2014. Best Practices for Publishing Linked Data. (2014). http://www.w3.org/TR/ld-bp/

[33] W3C. 2014. RDF 1.1 Concepts and Abstract Syntax. (2014). http://www.w3.org/TR/2014/REC-rdf11-concepts-20140225/

[34] W3C. 2014. RDF 1.1 Semantics. (2014). http://www.w3.org/TR/2014/REC-rdf11-mt-20140225/

[35] W3C. 2014. RDF Schema 1.1. (2014). http://www.w3.org/TR/2014/REC-rdf-schema-20140225/

[11] PREMIS in Japanese, http://www.jla.or.jp/portals/0/html/publish/PREMIS.pdf

[12] PREMIS in Spanish, http://www.loc.gov/standards/premis/PREMIS_es.pdf