PREMIS 3 OWL Ontology: Engaging Sets of Linked Data

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ABSTRACT

The PREMIS 3.0 Ontology Working Group recognized the need for the preservation community to be able to use Semantic Web technology to leverage systems managing the long-term preservation of digital holdings. Driven by the main principle of adherence to the PREMIS Data Dictionary, and a set of well-established Linked Data principles, the draft release of the PREMIS 3 OWL ontology comes after two years of conceptualization, discussion and experimentation. The release of the draft was followed by a public review of the revised ontology soliciting a wider discussion about the conceptual choices expressed by the ontology. This article explains how interoperability issues have been addressed, with the intent of maintaining continuity between the PREMIS Data Dictionary and the PREMIS OWL ontology.

CCS CONCEPTS

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

KEYWORDS

PREMIS ontology; Digital preservation metadata; Linked Data vocabulary; Semantic Web technology

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1 INTRODUCTION

The PREMIS OWL Ontology Working Group (PREMIS-OWG) [15] is a community interested in using Semantic Web technologies to leverage systems managing long-term digital preservation. In late 2015 it was tasked with writing an ontology for the PREMIS Data Dictionary for Preservation Metadata (PREMIS-DD), version 3.0 [17]. In December 2017, the group released a draft of the ontology [15], along with guidelines for use [14], data mapping documents and RDF examples [1].

In general, the PREMIS 3.0 OWL ontology is a semantic formalization of the PREMIS-DD and defines a conceptual model for the metadata that a digital repository needs to know for preserving objects. The foremost intent of the PREMIS-OWG was to revise the existing PREMIS OWL version [3] toward current Linked Data principles [1] [2] [11], mainly by: *a)* adopting URI identification [23] and naming best practices, and *b)* re-using terms from existing vocabularies. Other design principles were established for supporting the designated community in order to *c)* make the ontology simpler and more lightweight than the previous version, *d)* maintain coherence with the current version of the PREMIS-DD, *e)* define equivalence with other ontological entities, and *f)* provide the community with documentation and guidelines.

This set of principles, first enumerated in 2016 [4], results in the ability not only to integrate the conceptual model with the changes defined by the version 3.0 of the PREMIS-DD, but also to facilitate

[1] PREMIS OWL Ontology Version 3, https://github.com/PREMIS-OWL-Revision-Team/revise-premis-owl/tree/master/examples

the implementation and the usage of the ontology by the community. The community was given a participatory period for review of the draft and accompanying materials; it is hoped that this kind of community participation will further facilitate adoption of the ontology.

This article is structured as follows.

Section 2 explains the harmonization work between the relational structure of the PREMIS ontology and the hierarchical structure of the PREMIS-DD and explains the necessary deviations of the ontology from the data dictionary. Section 3 describes the decisions made for integrating PREMIS entities with other wide-spread ontologies, like Dublin Core [5] and PROV-O [25], and explains how to maintain the specificity of the PREMIS knowledge domain if required by the implementation. Section 4 describes some of the challenges addressed by the PREMIS-OWG, particularly in the conceptual modeling of Environments and the Rights Entity, and discusses feasible solutions and limitations. Section 5 traces future goals for further descriptive rules and integration challenges that would allow the community to extend the ontology applicability and the use of PREMIS Linked Data in relation to other knowledge domains. Finally, section 6 describes ongoing work by the group to foster widespread adoption of the ontology.

Figure 1 shows a diagram of the current PREMIS ontology.

2 RELATIONSHIP BETWEEN ONTOLOGY AND THE PREMIS DATA DICTIONARY

The PREMIS OWL Ontology attempts to represent the principles and model spelled out in the PREMIS-DD, version 3.0. The PREMIS-OWG, however, was also committed to building an ontology that implemented best practices for Linked Data to facilitate widespread use of the ontology. This is a shift in approach from the PREMIS 2.0 ontology, which was a direct translation of the PREMIS-DD into Linked Data vocabularies [21]. The PREMIS-OWG spent considerable time modeling the entities and semantic units in the Data Dictionary, building a new ontology that expresses PREMIS concepts in the language of Linked Data.

In order to model the PREMIS-DD in a Linked Data ontology, decisions needed to be made about the role played by elements and controlled vocabulary terms in the PREMIS-DD and how those would be translated from a hierarchical-based model into a graph model. Decisions were not necessarily considered to be right or wrong, and arguments can be made for doing things in different ways. The PREMIS-OWG deviated from the PREMIS-DD when concepts could either be simplified or expressed differently in the ontology, although not at the cost of specificity. These decisions were made in consultation with the PREMIS Editorial Committee to ensure that the ontology remained consistent with the spirit of the PREMIS-DD. In general, the majority of the PREMIS core concepts remain, but the ways of expressing them may differ. All the PREMIS entities are expressed as core classes in the ontology with the exception of Rights, since rights are not a thing but rather a collection of statements about terms and conditions that allow users to determine what they can do with the object.

One obvious deviation from the PREMIS-DD in the ontology is the elimination of redundant elements. The PREMIS-DD includes a number of semantic units such as *objectCharacteristics* that group together subunits. These container elements, although necessary for nesting elements together within a hierarchical structure, are redundant in an RDF [26] graph-based structure. Most of these were generally not carried over into the ontology unless it was necessary. For instance, in the PREMIS-DD *formatDesignation* groups format name, format version and format registry information together; in the ontology the metadata are grouped together under the class `dcterms:FileFormat`. Some relationships were also eliminated when they did not add additional meaning. Environment is a special kind of Intellectual Entity in the PREMIS-DD, but there is no class for it in the ontology. The PREMIS-OWG felt that being an Environment is not an intrinsic characteristic of an Object; rather this status can be inferred from relationships with other objects and therefore it is not necessary to specifically declare an Object to be an Environment.

In other cases, the ontology reflects the complexity of the PREMIS-DD. In both the PREMIS-DD and the ontology, relationships between PREMIS Entities may be stated in both directions; a choice could have been made to prefer one direction over the other (like PROV-O [2] does) for the sake of simplicity, but the ontology provides inverse properties if implementers want to use them. A major exception to this is in the Role semantic units (e.g. *linkingEnvironmentRole*, etc.), which are given in one direction, but not both, such as Object and Event, Rights and Agent. This suggests that the relationship is not necessarily reversible.

The PREMIS-OWG made some decisions specifically to support reuse of properties internal or external to the ontology, a key Linked Data principle. As a result, element names are often different from semantic unit names in the PREMIS-DD, since PREMIS-OWG chose to reuse existing vocabularies where possible. Another reason for this divergence is that the PREMIS-DD attempts to be a dictionary of non-ambiguous terms, which can be understood outside of any context and is not tied to a particular implementation, whereas the RDF constructs, especially properties, are understood inside a graph in relationship with classes. Some properties were therefore generalized to facilitate reuse rather than being tied to a specific semantic unit, and the context is understood by the subject of the assertion. For example, instead of using the semantic unit *formatVersion*, the ontology uses `premis:hasVersion`, since the subject of the statement specifies the context:

```
<pdfa1bformat> a dct:FileFormat ;
rdfs:label "Acrobat PDF/A-1b-Portable Document Format" ;
premis:hasVersion "1b" .
```

The same property could used for *environmentVersion* and understood because it is typed as a software Agent in the following example:

```
<distiller15> a prov:SoftwareAgent ;
rdfs:label "Adobe Distiller 15.0" ;
premis:hasVersion "15.0" .
```

In the same vein, other semantic units were generalized so as not to restrict their use. For example, the semantic unit *licenseTerms* becomes `premis:hasTerms`, to enable its use with another Rights basis should the need arise.

The PREMIS-OWG made some ontology choices to address the

[2] PROV-O: The PROV Ontology. Appenx B. Names of inverse properties, https://www.w3.org/TR/prov-o/#inverse-names

broadest possible range of use cases and provide flexibility in implementation. For instance, identifiers are given multiple expressions in order to address different use cases (several identifiers, non-URI identifiers, or the need for additional information about an identifier, in particular its status). Flexibility, in this case, was preferred over interoperability. The ontology also provides for some alternative simplified constructs for well-known use cases. An example is *format* semantic units, where the canonical expression is to declare a subclass of `dct:FileFormat` with `skos:closeMatch` / `skos:exactMatch` [24] pointing to similar formats described in external registries (which in the PREMIS-DD uses the semantic unit *formatRegistry*). Since many repositories express the file format by a simple MIME type, a simplified construct (the `ebucore:hasMimeType` property [7]) is suggested as a possible alternative. Finally, the ontology retains shortcuts from the PREMIS-DD such as *creatingApplication*, which enables users to record this information in the Object entity without having to create an Event.
In some cases, the ontology is more explicit than corresponding semantic units in the PREMIS-DD. This is to support the Linked Data principle of "things not strings" and the need for machine actionability. For instance, prohibitions in the PREMIS-DD are given in the semantic unit restriction, which uses free text, but in the ontology there is a specified structure. Similarly, the PREMIS-DD includes the semantic unit *otherRightBasis*, while the ontology declares explicitly a `premis:InstitutionalPolicy` to cover the most common type of "other" rights basis; we would expect other rights bases to be explicitly defined if they arise. The ontology also makes some explicit assertions to provide users with a better understanding of the meaning of certain elements. For instance, `premis:SignificantProperties` was declared a subclass of `premis:PreservationPolicy` to specify that choosing which Object characteristics are significant is a type of policy determined by the repository.

3 INTEGRATION WITH OTHER ONTOLOGIES AND VOCABULARIES

From the outset, the PREMIS-OWG planned to reuse terms from other RDF ontologies wherever possible to express concepts in the PREMIS-DD. In the case of multiple ontologies having the same term, preference was given to terms coming from stable, better known and more frequently used ontologies. For example, although a number of ontologies use the term format or fileFormat; `dct:format` and `dct:FileFormat` were selected to express the PREMIS concept of format because Dublin Core is more widely reused than other ontologies [21]. Reusing terms from other ontologies facilitates interoperability and thus encourages uptake; however, this approach must be tempered by the need to ensure that the semantics are the same as the PREMIS-DD. For instance, the PREMIS ontology integrates properties from PROV-O, an ontology that closely matches the purpose and intent of PREMIS but is more general in scope. PROV-O properties and classes are reused in the PREMIS ontology to define relationships between PREMIS entities, but PREMIS-based subclasses and subproperties have been minted to provide more specificity than PROV-O allows. For instance, `prov:wasAssociatedWith`, is used as a property to link Events to Agents; in this case implementers can add specificity, by using terms in the Library of Congress Linked Data Service (LOC-LDS) [12] eventRelatedAgentRole vocabulary [3] as subproperties, or define subproperties locally where needed.
When it comes to detailed technical metadata, the PREMIS OWL ontology should be considered as a framework for incorporating elements from other ontologies. For example, basic information about file format can be supplemented using EBUCore [8] properties such as `ebucore:frameRate`, `ebucore:bitDepth`, `ebucore:numberOfTracks`, etc. In an XML serialization of the PREMIS-DD such properties may be contained within the *objectCharacteristicsExtension* semantic unit; this unit is not needed because extensibility, for example, use of properties and classes from other ontologies, is built into RDF.
In addition to reusing terms from other ontologies, the PREMIS OWL ontology is greatly enriched by the use of the LOC-LDS preservation vocabularies at http://id.loc.gov/vocabulary/preservation. In some cases these terms are used as subclasses (for example, terms in the eventType vocabulary are declared as subclasses of `premis:Event`) or instances of a class (for example, Signature Encoding and Inhibitor Type) while in others they are used as properties or subproperties, as in the case of eventRelatedAgentRole described above. The relationshipSubType vocabulary is used to provide subproperties of a `premis:hasRelationship` property to link Objects; for example, *is Included In* is used to link Files to a Representation and *Represents* links a Representation to an Intellectual Entity. During the course of writing the ontology, the PREMIS-OWG determined that some additions and changes to the vocabularies are needed or at least may be useful. For example, the PREMIS-OWG has proposed creating a new eventOutcome vocabulary to capture outcomes such as "success" or "warning" as URIs instead of plain text.

4 CHALLENGES

As discussed above, a major aim of the PREMIS 3 OWL ontology is to incorporate Linked Data best practices while still remaining faithful to the principles and spirit of the PREMIS-DD. The resulting PREMIS 3 OWL ontology represents several years of research, negotiation, and trial-and-error for the PREMIS-OWG. Although some information such as object properties were easily mapped to other vocabularies or determined to be unique to a PREMIS vocabulary, other parts of the ontology were more of a challenge, specifically Environments and the Rights entity.
The PREMIS-DD version 3 reflected a change in the data model in terms of how hardware and software environments are described. An Environment is considered any kind of technology (e.g. hardware, software, or a combination) supporting an object in some way. An "Environment" Object can be stored by a repository like any other Object being preserved and is treated as such, and it can be described as an Intellectual Entity intended to support other Objects. Thus an Environment Object is not an intrinsic characteristic of the Object, but is considered as such if there is a dependency relationship between an Object and Environment. This was a challenge to model in the ontology, and the PREMIS-OWG decided not

[3] LOC-LDS Preservation - Event Type, http://id.loc.gov/vocabulary/preservation/eventRelatedAgentRole

to declare Environment as a subclass of Intellectual Entity. Constructs applicable only to Environments described as Intellectual Entities are used, including the semantic unit *environmentFunction*, which specifies the function and type of hardware, software or documentation. The individual concepts in the controlled vocabulary environmentFunctionType [4] are declared as subclasses of `premis:IntellectualEntity`.

The Rights entity modeling in the ontology resulted from a compromise between integration of other vocabularies and retention of the core PREMIS intent of rights metadata for digital preservation. Finding other vocabularies that model rights metadata was not difficult; there have been a number of efforts in this area, from simple Dublin Core to more complex implementations such as Creative Commons [19] and the Open Digital Rights Language (ODRL) [27] ontology [5].

ODRL appeared at first to be a good fit for the ontology, but the PREMIS-OWG ultimately concluded that the policy declarations that form the core of ODRL did not provide a framework sufficient for capturing detailed information about copyright, statute and other rights bases specified in the PREMIS-DD. Declaration of classes and properties for rights metadata were clearly needed. The resulting PREMIS 3 ontology data model for Rights was, however, heavily inspired by ODRL, particularly in two major areas: the centrality of the policy declaration and the concept of a rule class to define the actions an Agent may perform. Although the PREMIS ontology mostly uses properties and classes defined within the PREMIS-DD for rights metadata, many of these terms such as `premis:RightsBasis`, `premis:allows` and `premis:prohibits` closely match ODRL classes and properties, in order to align digital preservation rights metadata with the broader digital rights community. The `premis:RightsBasis` class is a conceptual expansion of the `odrl:Policy` class and serves as the central class from which permissions and prohibitions are defined. ODRL also illuminated some gaps in PREMIS, such as the ability to give structured metadata about permissions but not about prohibitions. The PREMIS ontology now includes a `premis:prohibits` property, a new concept introduced to address a gap in the PREMIS-DD. Other aspects of ODRL show promise for future consideration. For example, it may be of value to describe obligations of Agents in relation to preservation actions, based on ODRL's description of obligations, but that will need to await a future version of the PREMIS-DD.

Another challenge for the Rights Entity centered around how to facilitate the use of URIs from resources such as Creative Commons or Rightsstatements.org [10]. These resources are becoming more commonly utilized in preservation repositories, so it is a use case the ontology should support. The PREMIS-OWG tried a number of different approaches before determining these resources were a type of Rights basis and the Dublin Core property `dct:rights` could link them to the associated Object directly. This decision follows practice in the Europeana Data Model [9] that uses the same DC property for URI-based resources.

[4]LOC-LDS Preservation - Environment Function Type, http://id.loc.gov/vocabulary/preservation/environmentFunctionType

[5]See also the discussion in the PREMIS 3.0 Data Dictionary, page 17,http://www.loc.gov/standards/premis/v3/premis-3-0-final.pdf

5 VALIDATION

The PREMIS ontology does not have any applicability and cardinality constraints such as can be found in an XML schema. This is because of the nature of ontologies, which are designed to add meaning to assertions, not to control validity. For instance, an assertion such as:

```
premis:Representation owl:disjointWith premis:Bitstream
```

cannot be used to invalidate non-conformant statements such as:

```
<resource2> a premis:Representation, premis:Bitstream
```

Rather, this assertion simply enables a Linked Data consumer to understand and interpret the meaning of data. In this case, the inference would be that if

```
<resource2> a premis:Representation
```

exists, then the triple

```
<resource2> a premis:Bitstream
```

will not exist.

There is still a need, however, to validate this type of encoded information and correct statements like the one above, which clearly does not conform to the PREMIS-DD. The PREMIS-OWG plans to use a validation language, such as Shapes Constraint Language (SHACL) [28] or Shape Expressions (ShEx) [18] [6], for validating RDF PREMIS graphs based on a set of rules. Shapes have for RDF a similar role as XML Schema has for XML, and for the PREMIS 3 OWL ontology could be used to define the hierarchy of classes and properties, their cardinality and other constraints, and specific business rules or modeling options. Shapes can be extended with actions, which can help various processes such as transforming RDF to XML; it can also be used to define semantic actions to be executed during validation, such as ensuring that a date value is assigned to "dateCreated" in order for there to be a value for "dateModified".

An alternative to SHACL is ShEx. ShEx has common goals with SHACL (such as the description and validation of RDF graphs), but also has some important modeling and syntactic differences. Implementers could choose SHACL or ShEx depending on their RDF description and validation needs.

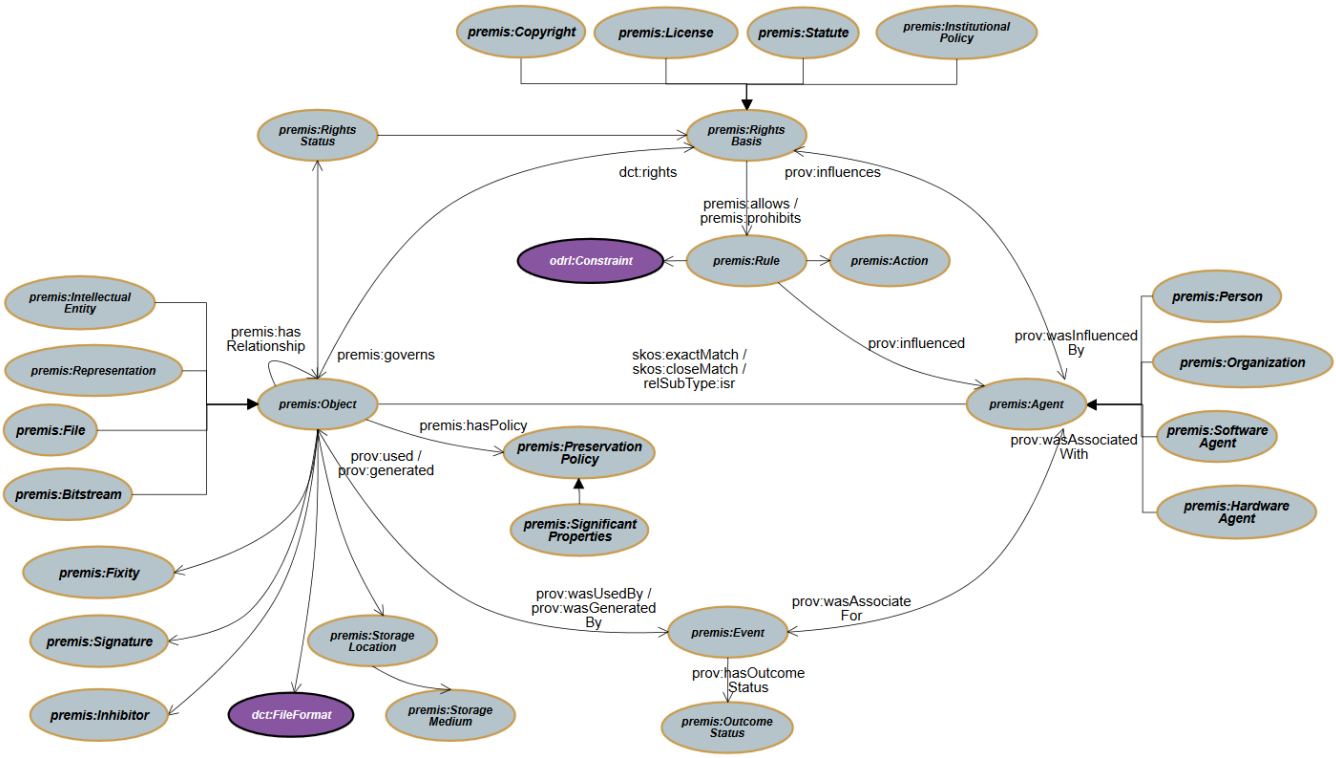
6 ONGOING WORK

The PREMIS-OWG conducted a webinar [16] during the draft review period, and hopes to foster adoption of the ontology by continuing to provide tools and resources to make the ontology more understandable and usable. As of this writing the PREMIS-OWG is finalizing the ontology based on community feedback provided in the Github repository [7], which includes the ontology and examples. Further integration with other domain-related ontologies (such as BIBFRAME [13], and PCDM [6]) is under discussion, as is developing validation methodologies as described in section 5, above. Further down the road, the PREMIS-OWG will evaluate publishing the ontology in world-wide registries, for example as a vocabulary in the Linked Open Vocabulary registry [21], or as a collection of data in the Wikidata [22] [20] collaborative platform, in order to engage more and more user communities.

[6]SHEX - SHAPE EXPRESSIONS, http://shex.io/

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

Figure 1: PREMIS 3 OWL ontology diagram



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