A semantic model for content description in the Sapienza Digital Library

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Abstract. In this paper is presented the semantic model defined for descriptive metadata of resources, managed by the Sapienza Digital Library. The semantic model is derived from the Metadata Object Descriptive Schema, a digital library descriptive standard, for library applications. The semantic model can be used as top level conceptual reference model, in order to support the implementation of semantic web technologies for digital library's descriptive metadata. The semantic model is intended to be agnostic about the technology system to be adopted. The creation of resources' connections toward the linked data cloud, as well as the opportunity of exploiting the potential of services based on the ontology use, will rely on a well-defined semantic model, which has been widely tested by the implementation of a descriptive metadata profile.

Keywords: Digital Libraries, MODS, semantic modelling, linked data, ontologies

1 Introduction

The current scenario of technologies in digital libraries management is challenging for an organization establishing a digital library. The increasing use of technologies oriented toward the Semantic Web(SW)[1] forces the digital library managers to rething the way of using and sharing resources.
The SW provides a common framework which allows data to be shared and reused across applications, enterprises, and community boundaries. Over the classic "Web of documents", the SW is a technology stack[2] which enables to develop systems supporting trusted interactions over the network, and allowing computers to do more useful work.
Respect to the "layer cake", the status of the technologies, in the digital library management, is characterized by the wide use of the Extensible Markup Language (XML) technologies. By using semantics community-based, the digital library systems are able to exchange documents in a coherent way.
At present, the Resource Description Framework(RDF) data model has started

[1] "Semantic Web, `http://www.w3.org/standards/semanticweb/`

[2] "Semantic Web "layer cake", `http://www.w3.org/2004/Talks/0319-RDF-WGs/slide4-0.html`

to be used, under the motivation of the Linked Data Initiaves(LD)[3], and it was especially adopted for the use over the web of open controlled vocabularies. In addition, plenty of ontologies is starting to be used by the designated communities.
The semantic model, presented in this paper, aims to support the provision of semantic technologies, over an existing digital library management system. The description of semantic references that are at the base of the existing system is the first step for analysing the best solution to be adopted, among the variety of approaches, for the SW technologies implementation.

2 Background and motivation

The technologies, composing the first layers of the SW stack, are summarized in order to distinguish their main characteristics and functions.
The XML technologies [4] have been conceived for managing data shaped as a hierarchical tree. XML is widely used for application contexts where is necessary to exchange data with a structure semantically pre-defined. One of the most important historical advantage is, having provided text information with a "well-formed" structure, that is named with human-readable semantics, that are community-based. The upper layers of the SW stack use the XML as official syntax.
The Resource Description Framework(RDF)[5], allows to build statements about web resources in the form of a subject-predicate-object expression. The statements can be interpreted by machines, that become capable to make connections between resources over the Web. Currently, the most significant use of the RDF, is the LD initiative.
The RDF schema(RDFS)[6] provides the framework to describe application-specific classes and properties and provides a data-modelling vocabulary for RDF data.
The Web Ontology Language(OWL), now at its second version [7], is a standard for defining ontologies that are used to capture knowledge about some domain of interest. It provides classes, properties, individuals, and data values, stored as SW documents. The OWL is a semantic markup language for publishing and sharing ontologies on the Web. OWL is developed as a vocabulary extension of RDF, and every OWL ontology is a valid RDF document. The OWL may be categorised into three species or sub-languages (OWL-Lite, OWL-DL, OWLFull for the 1st version, and OWL-EL, OWL-DL, OWL-RL for the 2nd version), that profile the ontology expressiveness, and support the computability degree.
The implementation of the technologies, from the RDF up to OWL, over a legacy system, that has used XML as format for exchanging information, requires to state at least a semantic point of reference, in order to model the corresponding

[3] "Linked Data Initiatives, `http://linkeddata.org/`
[4] "XML technology, `http://www.w3.org/standards/xml/`
[5] "Resource Description Framework, `http://www.w3.org/RDF/`
[6] "RDF Schema 1.1, `http://www.w3.org/TR/rdf-schema/`
[7] "OWL 2 Web Ontology Language, `http://www.w3.org/TR/owl2-overview/`

semantic technologies: RDF as data model, RDFS as description of RDF data, OWL to provide rich semantics for using reasoning systems.
The semantic model, presented in this paper, is indeed the reference model for implementing semantic web technologies, in the domain of the management of resources belonging to a digital library. In particular, it traces the main concepts associated with the content description used by the digital library, and is the semantic foundation, as the reference point to be considered, in the different approaches that can be undertaken for the SW technologies implementation. The following list summarizes some of the feasible implementation cases that can be provided:

- creating data model based on RDF/RDFS[17]
- creating vocabularies/ontologies based on RDFS or OWL[12]
- creating mapping from XML to RDF[2][18]
- creating mapping from Database Management System to RDF[8]
- creating an ontology-based data access system[15][4]

3 Use case overview

The Sapienza University of Rome has established its digital library by means of a research project named Sapienza Digital Library(SDL)[9]. The project vision was to provide Sapienza's community with a digital library, supporting the use of digital material managed, owned and produced by the Sapienza University[5]. The metadata framework, supporting the digital services of the produced SDL[9], was designed for managing heterogeneous resources, representing digitally the multidisciplinary community of the Sapienza University.
The SDL metadata framework is the structured container for metadata managed by the SDL services, and conceptually is based on the Open Archival Information System(OAIS)[7]) Information Package (IP). The SDL-IP has to be conforming structurally and semantically with the elements defined in the SDL metadata framework.
At the present time, the SDL framework uses the metadata elements of the Metadata Objects Description Schema(MODS) for describing the intellectual contents of the resources[9], the PREservation Metadata Implementation Strategies[10](PREMIS), necessary to support the long-term digital preservation, and the Metadata Encoding and Transmission Standard[11](METS), for packaging and connecting the different metadata, belonging to the digital resources.
These digital library standards, maintained by the Library of Congress[12], are defined by XML schemas[13], consequently the conformance with standards is based

[8] "R2RML: RDB to RDF Mapping Language, `http://www.w3.org/TR/r2rml/`
[9] "Sapienza Digital Library, `sapienzadigitallibrary.uniroma1.it`
[10] "PREMIS Preservation Metadata Maintenance Activity, `http://www.loc.gov/standards/premis/`
[11] "Metadata Encoding Transmission Standard, `www.loc.gov/standards/mets/`
[12] "Standards at the Library of Congress, `http://www.loc.gov/standards/`
[13] "W3C XML Schema - World Wide Web Consortium, `http://www.w3.org/XML/Schema`

on the production of XML files validated against the pertaining XML Schema. The semantic model, presented in Sect.4, is focused on the descriptive metadata section of the SDL framework(see next Sect. 3.1), and is the semantic summary of the MODS profile(see Sect. 3.3), that was defined for the implementation needs, and has provided consistency to the descriptive metadata which comes from different Sapienza's communities.

3.1 The SDL descriptive metadata

In the reference standard OAIS[7], the IP is a conceptual container of Content Information(CI) and Preservation Description Information(PDI), where the resulting package is viewed as being discoverable by virtue of the Descriptive Information.
In the SDL project, the OAIS IP is considered the package necessary for the management of resources during the digital life-cycle. The existence of the Descriptive Information is the pre-condition for building the SDL-IP.
In the SDL implementation, the descriptive information is coded in MODS, for describing the intellectual content of the SDL-IP.
The MODS uses libraries semantics, that are derived by the MARC 21 semantics[14] the standard format created in 1999 (a revised version for the 21st century of the MAchine Readable Cataloguing (MARC)[15] created in 1960) and widely used by libraries information systems.
The MODS semantics were used for describing the different kind of intellectual/creative works managed by the SDL. The SDL-IPs are differently characterized (still and moving images, texts, sounds, cartographics, etc.) and digitally structured (digital collections, books, images, videos, documents, hierarchies, maps). The intellectual/creative works, represented as SDL digital resources (SDL-IPs), express multidisciplinary knowledge.

3.2 The MODS standard and the linked vocabularies

In [11] is reported how during the years, had increased the emergent need of having a standard less complex than MARC, but not as simple as the widely interoperable standard, Dublin Core Metadata Element Set (DC)[16].
In order to address these community's need, the Library of Congress developed the MODS, "a schema for a bibliographic element set that may be used for a variety of purposes, and particularly for library applications"[17].
The MODS XML schema includes a subset of MARC fields, using language-based tags rather than numeric ones. The official website provides guidelines

[14] "MARC 21 Format for Bibliographic Data, `www.loc.gov/marc/bibliographic/`
[15] "MAchine Readable Cataloguing (MARC), `http://en.wikipedia.org/wiki/MARC_standards`
[16] "Dublin Core Metadata Element Set, `http://dublincore.org`
[17] "Metadata Object Description Schema, `http://www.loc.gov/standards/mods/`

primarily intended to be used for assistance in creating original MODS records, as well as converted from MARC 21 or for use in developing detailed conversion specifications. The MODS standard claims that the element set is richer than Dublin Core, more oriented to the end-user, than the full MARCXML schema, and simpler than the full MARC format. These main characteristics were, in general, deemed useful for describing at a sufficient granular level, the multidisciplinary materials to be managed in the SDL.
The descriptive metadata for a MODS resource aggregates titles and names associated with the resource, along with subjects and other data elements, that further help to describe the resource. For systems, the MODS resource description and especially its descriptive metadata aids the indexing, searching, and displaying of information about the resource. For users, a MODS resource description assists with identifying, finding, selecting, and accessing a MODS Resource. Administrative metadata provides provenance information about the descriptive metadata. It includes information, such as the individual or organization responsible for the descriptive metadata and/or the date the descriptive metadata was last modified, as well as relationships expressed in the MODS resource description.
The XML schema of MODS is deployed on 20 top elements, that are variously structured with sub-elements. The elements are repeatable, except the administrative description of the record (`recordInfo`). No element is mandatory, and the `relatedItem` element is recursive, because it can contain all the top elements of the schema, including itself.
The web availability of different mappings[18], initiaves[10], and studies extending the use of this standard over other information science disciplines, like archivist science[3] or toward museums artifacts[**?**], supports the interoperability of the semantics adopted, and consequently the probability of the information loss.
The SDL metadata framework exploits the MODS's ability of providing a mechanism to dereference the controlled vocabularies' entries, used in the XML elements, in a documented way. In SDL this ability has been exploited for using entries from the Library of Congress Linked Data Service[19], from other italian LD vocabularies[20], as well as from vocabularies locally defined[21]. The use of the `authority`, `authorityURI` and `valueURI` attributes in the XML schema, allows to record the reference to the controlled vocabulary's source authority, and specifically to its name, its URI, and the URI of the specific value when it is exposed as Linked Open Vocabularies(LOV)[22].
The granularity and the flexibility of MODS, in the use of the elements, has re-

[18] "MODS conversions, `http://www.loc.gov/standards/mods/mods-conversions.html`
[19] "Library of Congress Linked Data Service, `http://id.loc.gov/`
[20] "Nuovo Soggettario, Biblioteca Nazionale di Firenze, `http://purl.org/bncf/tid`
[21] "Sapienza Digital Library vocabularies, `http://sbs.uniroma1.it/sdl/vocabularies`
[22] "Linked Open Vocabularies (LOV), `http://lov.okfn.org/dataset/lov/`

quired the definition of a profile for the SDL implementation, in order to define the minimum obligation in using XML elements and attributes.

3.3 The SDL MODS profile

The SDL MODS profile[23] encompasses the metadata elements necessary for the metadata MODS XML coding, defines the structural and functional contexts, where elements and attributes can be used, and defines the obligation constraints of the XML elements' existence.
The principle guiding the definition of the MODS profile was to maintain and to enrich as much as descriptive information about different content types and integrate XML elements with LOV references and LOV's authority information.
The definition of the MODS profile had followed two main reference guidelines. Firstly, the "Master List of Data Elements" is a framework of elements gathered from the profiles of the different digital library projects at the Library of Congress. The objective of the list is to work towards "compatibility of metadata usage throughout the institution, support the metadata use cases, and point to areas where metadata remediation for improved consistency or enhanced interoperability might be beneficial"[24]. Secondly, the implementation guidelines of the Digital Library Federation for the implementation of shareable MODS records[25].
The existing MODS profile is applied to the following content types: books, documents, images, videos, maps, hierarchical structures (like serial publications or archival collections), and digital collections.
During the project development the profile was incremented and enriched coherently to the contents' descriptive needs. Each new integration of the specifications of the profile had entailed the conformance check on the metadata relational structure, in order to verify the consistent coexistence of different materials and descriptions, inside of the same metadata framework.
Some specifications, indeed, had required the specific profiling of metadata elements with the inclusions of sub-elements and attributes, that were shaped for the application context. The specifications had improved not only the granularity of the descriptive information, but also the accuracy and the interoperability of the contents' re-use because of the wide reference to local controlled vocabularies, and wherever possible to LOV.
Beyond the XML elements, whose semantics are defined in the MODS Schema, the profile had configured the following attributes for the local needs:

[23] "The Sapienza Digital Library MODS profile (available by the end of January 2015), `http://sbs.uniroma1.it/sdl/documentation`

[24] "Metadata for Digital Content(MDC), Developing institution-wide policies and standards at the Library of Congress, `http://www.loc.gov/standards/mdc/elements/MasterDataElementList-20120215.doc`

[25] "Digital Library Federation/Aquifer Implementation Guidelines for Shareable MODS Records, `https://wiki.dlib.indiana.edu/confluence/download/attachments/24288/DLFMODS_ImplementationGuidelines.pdf`

- `@displayLabel` the label for displaying the XML element's content. In the SDL MODS profile specification, it was used for the portal implementation to show the italian label of the field.
- `@xlink:href` the reference link associated with the XML element's content. In specific elements, it has been used for the portal implementation to activate the link over the XML elements content value.
- `@authority`, `@authorityURI`, `@valueURI`, these attributes are used extensively for referring, respectively to the authority controlled vocabulary's name, the URI/URL identifying the authority controlled vocabulary, the URI value exposed in the Linked Data Cloud.
- `@xml:lang` this elements allows for labelling the XML elements' content with a language selector. It was applied and coded extensively on the information of the existing descriptive record, and wherever it was possible, the Italian content was translated in English. The reference code used for language is the ISO-639-2[26].

The SDL MODS profile provides specifications about 28 MODS metadata elements, that are necessary to the coherent description of the SDL resources. The profile provides references to 10 controlled vocabularies, locally defined, and 15 vocabularies of third party. In addition the profile provides specifications for the customization needs of the SDL portal implementation.
The Table 1 shows the occurrences of specifications that were defined for each metadata elements. The higher number of specifications occurrences is significant because reveal the susceptibility of certain elements, respect to others for the application context. For example, four over seven `titleInfo` specifications are destined to the portal visualization requirements. The eight specifications, of the `subject` has profiled most of the sub-elements defined by the MODS schema with the specification about the controlled vocabularies, and in some case with anchors necessary to the SDL browsing services. The eight specifications of the `relatedItem`, instead reveal the extensive use of this element, for building relationships between the SDL resources. The SDL MODS provides a reference for qualifying the type of relationship.

4 The SDL semantic model for descriptive metadata

The SDL's semantic model(SDL-SM) summarizes the concepts that were specified for the implementation by the SDL MODS profile. In other words the SDL-SM represents the set of concepts laying the knowledge domain related to the digital library descriptive metadata.
The SDL-SM is meant to be agnostic about the technology system that will be implemented and can be used as top level conceptual reference model, for implementing semantic web technologies. The SDL-SM can be considered as the reference model not only for developers, but also for domain experts.

[26] "ISO 639-2 Language Codes, `http://id.loc.gov/vocabulary/iso639-2.html`

Table"1. MODS metadata elements and SDL profile specification occurences

titleInfo	**7**	originInfo/date	1	recordInfo	1
name	**2**	originInfo/place	1	note	**2**
abstract	**4**	originInfo/publisher	1	genre	**2**
accessCondition	**2**	originInfo/edition	1	subject	**8**
language	1	originInfo/issuance	1	relatedItem	**8**
typeOfResource	1	originInfo/frequency	1	part	**2**
identifier	1	physicalDescr./digitalOrigin	1	extension	1
location	**2**	physicalDescr./internetMediaType	1	targetAudience	1
tableOfContents	1	physicalDescr./form	1	classification	1
		physicalDescr./extent	**2**		

The pre-condition for re-using the concepts defined in this model is the acceptance of the core principles and best practices of the Semantic Web and Linked Data[6], in particular the use of specific policies for managing the SDL resource's identifiers building[8] is considered the point of reference for assigning the URI to the semantic concepts.
The Figure 1 outlines the concepts laying down the semantics defined in the MODS XML schema hierarchy, that were used in the SDL MODS profile.
The concepts are represented by the ovals and the bold line ovals represent the obligation constraints over the concepts. The repeatability constraint of concepts (only one concept is not repeatable: `recordInfo`) is distinguished by the ovals with underlined labels. Borrowing from the Description Logics the basic inference on concept expressions[1], each MODS top element is represented as a concept subsumption of the main concept `digitalResourceContentDescription` which in turn is a subsumption of the MODS `modsrdf:ModsResource` concept.
Analogously, the XML sub-elements (lower hierarchical levels), are considered as subsumptions of the concepts derived from the XML top elements of MODS. Indeed differently from a data model design or from an ontology definition, the properties/relationships, that relate concepts, are placed in a subsumption hierarchy[16] leaving further definition open to the implementation choices.
The specifications, defined by the MODS profile, had leveraged on the customization of some attributes, that are relevant to the exhaustive description of the resources. The attributes used for MODS profile are represented in the figure, in Entity/Relationships diagrams notation style, for highlighting the association of attribute to each related concepts.
The graphical representation of the SDL-SM respects the MODS XML schema hierarchical style, but makes evident the ambiguity points that have to be overcome in a semantic modelling. The MODS schema has defined the use of same attributes for different XML elements[27], and indeed the figure highlights the wide re-use of the same attributes (i.e. `@displayLabel`, `@type`...) in different conceptual context. This graphical evidence warns that, in this case, the seman-

[27] "Attributes Used Throughout the MODS Schema, `http://www.loc.gov/standards/mods/userguide/generalapp.html#list`

tic disambiguation of the information is contained in the value of the attribute, and not in the XML data definition. Similarly, the homonymy of the sub-elements (i.e. `@languageTerm`, `@extent`), need to be solved by inheriting the conceptual name of the higher level semantic elements. Mostly the same inheritance application coherently works for all sub-elements that cannot have sufficient semantic specification, like in the `role` case.
Another critical aspect, to be highlighted by the semantic point of view, is the recursive functionality held by the `relatedItem` element, that requires the semantic disambiguation, partially managed by the attributes' values and partially by the inheritance mechanisms of the higher level conceptual names.
The Figure 1 also shows the reference to the controlled vocabularies, used by the SDL MODS profile, and exhibits the association to the relevant concepts. The rounded rectangles containing an URI, and in close contact with some ovals (the concepts), specify that the concept's value is derived from the controlled vocabulary reachable at the specified URI. The URI in pink rounded rectangles specify SDL vocabularies, while the underlined URIs in the cyan rounded rectangles specify third party vocabularies.
The SDL-SM does not provide a further ontological modelling about relationships/properties because would imply an implementation-dependent choice. The modelling of relationships/properties is a customization task and it depends on the semantic web technology to be used. For example, the production of RDF triples can mostly depend on technology environment factors, the RDF triples could come from a Relational Database mapping or managed directly by a triple store system. The conceptual modelling of an ontology, in order to be used by reasoning systems, cannot be expressed in OWL 2 because of the hard complexity of computation, but it needs to be profiled into one of the three ontology language fragments, the OWL 2 profiles(EL, QL, RL)[28].

5 Related works and conclusion

The initiatives that can be coherently compared, because oriented toward the SW, and related to the specific library application domain of the descriptive metadata, are briefly summarized.
The draft of the MODS RDF Ontology[14] is the semantic model expression of the MODS model and is a reference for shaping MODS resources as RDF triples. The basic conceptual assumption is similar to the SDL-SM because "a MODS resource description includes descriptive metadata about a MODS resource", but the ontology (coded in OWL 1 Lite[29]) defines more prescriptive constraints. The MODS XML elements are modelled 20 classes distinguished in: 1 main class (`modsrdf:ModsResource`), 9 MODS classes as ranges for properties whose domain is `modsrdf:ModsResource`, and 10 classes imported by an

[28] "OWL 2 Web Ontology Language Profiles, `http://www.w3.org/TR/owl2-profiles/`
[29] "OWL Lite RDF Schema Features, `http://www.w3.org/TR/2004/REC-owl-features-20040210/#s3.4`

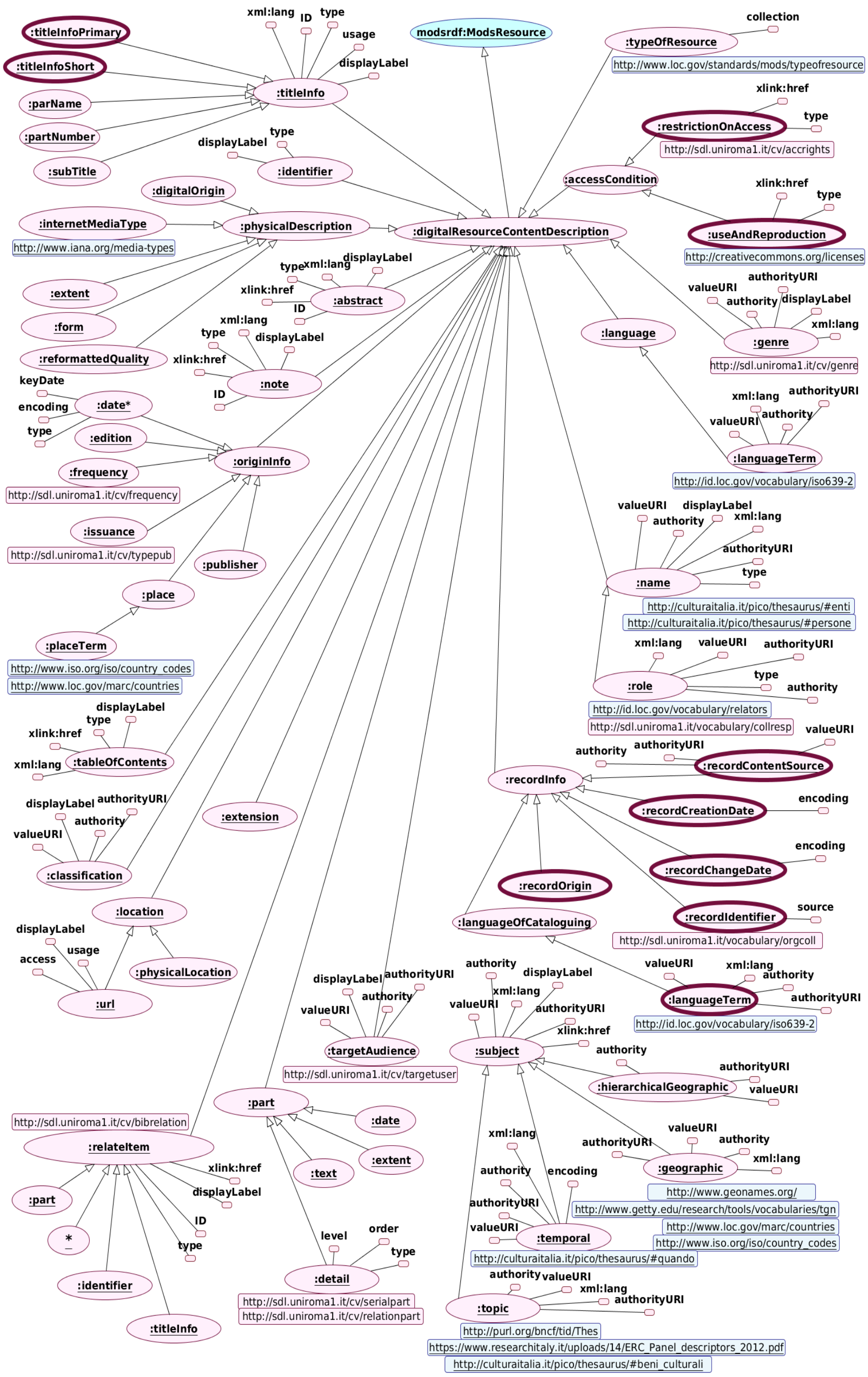

Fig. 1. The SDL's semantic model for contents' resource descriptions

external ontology. Nevertheless, mostly MODS elements are modelled in 114 `owl:ObjectProperty`, with corresponding domain and range defined by RDFS statements.
The second comparable initiative is the Bibliographic Framework Initiative (BIBFRAME)[13] where the focus is the translation of MARC 21 format to a Linked Open Data model. The BIBFRAME has defined a model consisting of 4 core classes (Creative Work, Instance, Authority, and Annotation), and a vocabulary structured over different categories of information. The BIBFRAME metamodel is designed to be lightweight, flexible and able to accommodate the declarative needs of existing descriptive standards(RDA[30], DACS[31], VRA[32], etc..) and yet-to-be-developed community vocabularies. To best accomodate these communities the BIBFRAME RDF Schema is intentionally underspecified in terms of constraints such as domain and range.
Respect to the SDL-SM, the MODS ontology has been defined by a specific technology implementation choice, considering the domain and range definition by modelling MODS elements as `owl:ObjectProperty`. While, the categories defined by the BIBFRAME can be straightforwardly mapped to SDL-SM concepts, and similarly to our approach the constraints are intentionally underspecified. At the best of our knowledge, this is the first implementation of the MODS standard, in an Italian digital library project provided with the definition of a profile for describing multidisciplinary materials of Libraries, Archives and Museums(LAM). In spite of the questionable novelty of the MODS adoption, the lesson learnt by the MODS profile implementation is to have achieved an improved descriptive granularity, and to have provided data consistency over the multidisciplinary domains.
Thanks to the MODS profile based on XML human-understandable semantic elements, that in turn are based on well-established standard descriptive semantics, like MARC 21, the SDL development has relied on a community-understanding of the data and the semantic related to it.
The SDL-SM presented in this article is a “semantic summary” of the implemented SDL MODS profile, and is considered technologically agnostic, because it stresses over basic concepts necessary to be defined when the SW technologies are adopted in a digital library environment, in the context of the intellectual contents’ description.

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