Automated interpretability of linked data ontologies:

an evaluation within the cultural heritage domain

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***Abstract*— Publication and usage of linked data has been highly pursued by cultural heritage institutions and service providers in this domain. Much research and cooperation are taking place in adapting and improving cultural heritage data models for linked data and in defining ontologies and vocabularies, as well as the setting up of services based on linked data. This article presents an evaluation of ontologies and vocabularies published as liked data, which originate from the cultural heritage domain, or are frequently used and linked to in this domain. Our study aims to evaluate their usability by crawlers operating on the web of data, according to specifications and practices of linked data, the Semantic Web and ontology reasoning. We evaluate having in mind the use case of general data consumption applications based on RDF, RDF Schema, OWL, SKOS and linked data's guidelines. We have evaluated twelve ontologies and vocabularies and identified that four were not fully compliant, and that alignments between ontologies are not included in the definitions of the ontologies. This study contributes to the research of novel services consuming linked data. It also allows to better assess the automation that can be achieved to handle the variety and large volume of linked data, when assessing the viability of new services based on linked data in cultural heritage.**

Keywords - ontologies; vocabularies; semantics; data variety; data volume; linked data.

I. Introduction

Publication and usage of linked data has been highly pursued by cultural heritage institutions and service providers in this domain. Much research and cooperation are taking place about the publication of linked data. These activities address the adaptation and improvement of current cultural heritage data models, the definition of ontologies and vocabularies, as well as the setup of novel services based on linked data[1].

Our study evaluates the usability of ontologies published in the web of data, which have originated from the cultural heritage domain, or are frequently used and linked to, in this domain. This evaluation addresses aspects relevant to the usability of the ontologies by robots operating on the web of data, according to specifications and practices of linked data, the Semantic Web and ontology reasoning.

For an effective usage of linked data originating from many sources, it is essential that applications can operate with full automation. Linked data presents challenges with data variety and volume for its reuse, that can only be fulfilled by data sources that are conformant with semantic data's underlying concepts and the web of data.

We evaluate from the perspective of applications that employ data crawling robots, and automated semantics interpretation for data consumption. For data processing, this kind of applications relies on technologies such as RDF, RDF Schema, OWL and linked data's specifications and best practices. For data interpretation, these applications rely on general-purpose semantic data technologies like SKOS and Schema.org.

This use case is motivated by our long-term goal of researching methods for efficient use of linked data as a source of descriptions of cultural heritage resources. The real-world application for these methods is within the large networks that operate based on the aggregation of data, such as Europeana in Europe, DPLA in the United States of America, Trove in Australia, Digital Library of India, and DigitalNZ in New Zealand.

We conducted this study in the context of the cultural heritage network of Europeana data providers and aggregators. Europeana has the role of facilitating the usage of digital cultural heritage resources from and about Europe [1]. Although many European cultural heritage institutions are not yet present in Europeana, it already holds data resources from over 3,700 providers, mostly libraries, museums and archives.

The informational value of existing linked data is clearly acknowledged in the cultural heritage domain. However, the usage of linked data presents many challenges in terms of technical innovation and resources. If a lot of human resources are required for using linked data, it may remain an obstacle for cultural heritage data aggregators, that, like Europeana, are already operating with limited resources, and searching for more efficient ways to perform their data aggregation tasks, while remaining sustainable.

We follow, in Section II, by describing related work on data aggregation based on linked data in cultural heritage. Section III presents the linked data crawling use cases that guide us in the design of the study. The setup and workflow of the study are presented in Section IV. Section V discusses the results, the conclusions and presents future work.

[1] Throughout this article we use the term ontology in the generic sense, including both vocabularies and ontologies

II. Related Work

Linked data has a large diversity of research topics related to our work. Scalability is one of the most addressed topics, with many facets such as indexing, federated querying, and aggregation. The reuse of published linked data by third parties has revealed data quality to be a challenge as well, at the level of semantics and at the level of syntax [2, 3, 4]. Significant work has been done to facilitate the reuse of linked data by aggregation and data cleaning [5, 6]. Reasoning on linked data is also an active research topic, and a comprehensive analysis and description of techniques has been published [7].

Regarding cultural heritage, although the use of linked data has been the focus of much research, most of the published literature addresses mainly the aspect of the publication of linked data [8, 9, 10] and does not fully address how the aggregation methods of cultural heritage can use the published linked data.

Generic technical solutions have been proposed for enabling the aggregation of linked data (for example [11]). Semantic interpretation by machines has not been addressed, however.

The study presented in this article is done in the context of the research activities of Europeana, in order to improve the network's efficiency and sustainability. Linked data has been identified in our past work as one of the technical solutions with application potential [12]. The work described in this article is the continuation of a series of experiments utilizing several web technologies for this purpose [13], particularly on the evaluation of Schema.org for cultural heritage [14] and linked data case studies [15].

III. Experiment Design and Setup

Our study aims to evaluate the usability of ontologies originated from, or used by the cultural heritage domain. We evaluate from the perspective of applications operating on the web of data, according to the best practices in ontology definitions, and specifications for linked data and the Semantic Web. In particular, we evaluate the possibilities for ontology-based automated reasoning on the available linked data, enabling the following use cases:

- Semantic Web general application – this type of application processes data solely based on the bottom and middle layers of the Semantic Web Stack [16]. These applications use general technologies, especially "meta-languages" such as RDF, RDF Schema, OWL and linked data specifications for crawling linked data. These applications require the presence of particular RDF properties in the data, which enable the crawling of linked data and the ontologies being used.

- Cross-domain semantic application – in addition to the functionality of Semantic Web general applications, this type of application processes data with additional requirements on the semantics of the data. They rely on general-purpose, widely shared ontologies like the Schema.org and SKOS (Simple Knowledge Organization System). These applications provide functionality that can be applied across different domains. In order to automatically interpret the data, these applications must either obtain linked data that uses the generic ontologies they can consume (like Schema.org), or find alignments between these ontologies and the classes and properties used in the data. They thus require the ontologies to be crawlable and to contain alignments expressed in SKOS or OWL.

TABLE I. The twelve ontologies evaluated in this study

Ontology	**Namespaces**
Dublin Core Metadata Element Set	• http://purl.org/dc/elements/1.1/
DCMI Metadata Terms	• http://purl.org/dc/terms/
The DBpedia Ontology	• http://dbpedia.org/ontology/
BIBFRAME vocabulary	• http://id.loc.gov/ontologies/bibframe/
RDA Vocabularies (Resource Description and Access)	• http://rdaregistry.info/Elements/c/ • http://rdaregistry.info/Elements/a/ • http://rdaregistry.info/Elements/e/ • http://rdaregistry.info/Elements/i/ • http://rdaregistry.info/Elements/m/ • http://rdaregistry.info/Elements/n/ • http://rdaregistry.info/Elements/p/ • http://rdaregistry.info/Elements/t/ • http://rdaregistry.info/Elements/w/ • http://rdaregistry.info/Elements/x/ • http://rdaregistry.info/Elements/u/
FOAF Vocabulary	• http://xmlns.com/foaf/0.1/
CIDOC Conceptual Reference Model	• http://www.cidoc-crm.org/cidoc-crm/
Europeana Data Model	• http://www.europeana.eu/schemas/edm/
LIDO Terminology	• http://terminology.lido-schema.org/identifier_type • http://terminology.lido-schema.org/recordMetadataDate_type • http://terminology.lido-schema.org/recordType • http://terminology.lido-schema.org/repositorySet_type • http://terminology.lido-schema.org/resourceRepresentation_type

	• http://terminology.lido-schema.org/termMaterialsTech_type
Wikidata Ontology	• http://www.wikidata.org/entity/ • http://www.wikidata.org/entity/statement/ • http://www.wikidata.org/value/ • http://www.wikidata.org/prop/direct/ • http://www.wikidata.org/prop/ • http://www.wikidata.org/prop/statement/ • http://www.wikidata.org/prop/qualifier/
GeoNames Ontology	• http://www.geonames.org/ontology#
GND Ontology	• http://d-nb.info/standards/elementset/gnd#

To assess these uses cases, we have developed and applied software that includes components for linked data crawling, reasoning on RDF data and ontologies, data processing and data analysis. This software is an extra iteration over previous work done for earlier experiments with linked data crawling [15].

As sources for our study, we analyzed the twelve ontologies that are listed in TABLE I. Since some of the ontologies are composed of several namespaces, in total our evaluation was performed on thirty-two namespaces.

The starting point for our evaluation of the ontologies is considering the scenario of an application that, while processing RDF data, encounters data elements (classes, properties, data types, etc.) for which it is unaware of their semantics. For automatically acquiring any semantics available for those data elements, the application accesses the linked data URIs of the namespace and the data element, to obtain their definitions, and then tries to reach the information and knowledge necessary for achieving its purposes.

The following section presents the results of executing this process for each of the twelve ontologies. It reports on non-conformities with linked data guidelines and characterizes the definitions of the ontologies and their data elements. The sequence of activities we performed in this study is illustrated in Figure I, along with the systems we applied and their outputs. It was only possible to evaluate eleven of the twelve ontologies due to non-conformities with the resolution of namespace URIs and unavailability of ontology definitions as RDF Schema, OWL or SKOS. Additional problems were detected with two more ontologies, but we were able to bypass these, and proceed with their evaluation. Section IV provides details about these problems and presents the complete results of the evaluation.

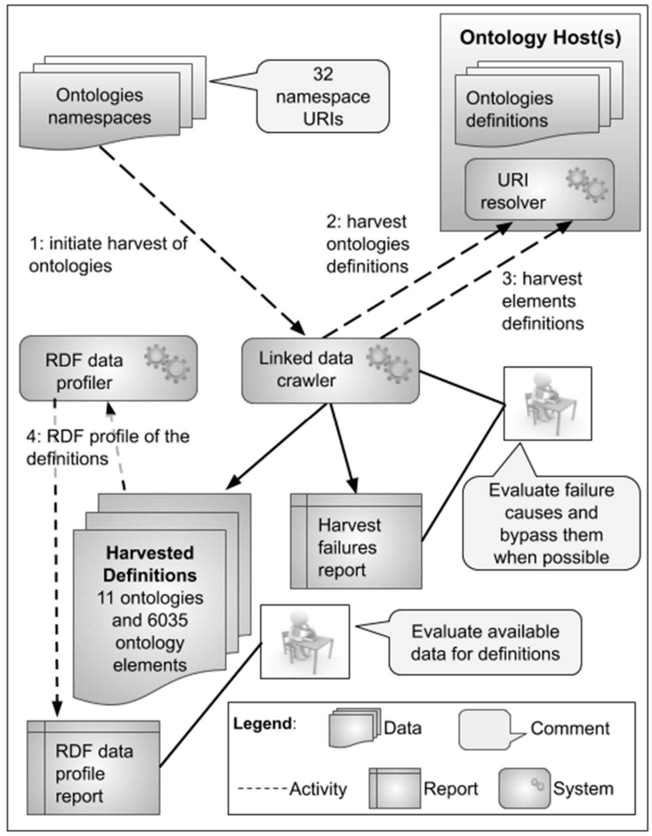

Figure 1. The setup of the study

IV. RESULTS

In this section, we present the results of the evaluation, which were gathered and checked for the last time on the 16th of August 2019.

The first phase of the study started with the inspection of the results of processing the ontologies. This was done after an initial attempt by the linked data crawler to harvest the ontologies' RDF definitions, including all their defined sub-elements. The crawl was successful for eight out of the twelve ontologies. The remaining four ontologies failed because the URIs of their namespaces did not respond correctly to the crawler's request for RDF (using HTTP content negotiation). In one of these cases, the problem was simply an incorrect *Content-Type* HTTP header being sent in the response, that did not correspond to the RDF serialization format transmitted in the response. The remaining three ontologies always responded with the human-readable page of the ontology in HTML. TABLE II provides more information about these ontologies and the aspects of non-compliance with linked data URI resolution.

We searched the HTML interface of these three ontologies and located the URLs of the definition files for two of them. We adapted the linked data crawler to bypass the problems when possible, allowing us to perform the remaining part of the evaluation with eleven ontologies.

TABLE II. NON-COMPLIANCE WITH LINKED DATA DETECTED IN FOUR OF THE ONTOLOGIES

Ontology	Detected problems
RDA Vocabularies (Resource Description and Access)	Namespace definition is not content negotiated and responds with human-readable HTML. Ontology definition is available at another URL address.
CIDOC Conceptual Reference Model	Namespace is not content negotiated and responds with human-readable HTML. Ontology definition is available at another URL address.
LIDO Terminology	Namespaces are content negotiated. They respond with RDF serialized in Turtle; however, the responses have an incorrect *Content-Type* HTTP header value of *'text/plain'*. In addition, the namespaces responses do not include the RDF resources of their defined elements, nor do they link to them. Discovering the ontology's elements can only be done via the SPARQL endpoint.
Wikidata Ontology	Some namespaces are not resolvable and return HTTP status code 400. Others are not content negotiated and respond with human-readable HTML No ontology definition could be found.

The second phase of the evaluation was done by applying a data profiler that is designed for RDF. It supports us in getting an impression of the capabilities that the definitions of these ontologies enable for automated interpretation of data. The profiler processes the harvested RDF definitions, and reports statistics on the usage of RDF classes and properties in the individual RDF triples. The reports also show how the classes and properties are present in the triples, that is, their usage as subject, predicate or object.

We focus our analysis on the data that is available about the ontologies themselves, and the sub-elements that comprise them. For supporting automated interpretation, we consider the relevant aspects to be the values for *rdf:type* assigned to the RDF resources, and also the RDF properties that are in use[2]. This section presents an analysis of the overall results for all ontologies. The data that we collected and fundaments our analysis is available online[3], and contains the details of each individual ontology.

The results for usage of the *rdf:type* in ontologies have identified various cases where ontologies do not state that they are an ontology of any kind. Three of the ontologies are of plain type *rdf:Resource* and one is a *void:Dataset*. The remaining seven cases have values expected for ontologies. TABLE III presents additional details.

TABLE III. USAGE OF THE *RDF:TYPE* PROPERTY IN THE RDF RESOURCE OF THE ELEVEN ONTOLOGIES

rdf:type of the ontology RDF resource	Used by ontologies
http://www.w3.org/2002/07/owl#Ontology	(4) 33%
http://purl.org/vocommons/voaf#Vocabulary	(3) 25%
http://www.w3.org/2000/01/rdf-schema#Resource	(3) 25%
http://rdfs.org/ns/void#Dataset	(1) 8%

Regarding the RDF properties that are being used to describe the ontologies, and which allow for automated data interpretation, we consider the relevant aspects to be:

- Stating the version of the ontology
- Stating the licenses for usage of the ontology, with machine-actionable values, such as license URIs
- Stating the elements that the ontology defines
- Stating the base address of a SPARQL endpoint where the ontology definition can be queried

We observe that the tendency is to describe the ontologies for human usage well, while properties for machine usage are less frequent or not available in some cases.

The version was stated in half of the ontologies, licenses were stated in around one third of the ontologies. For identifying all elements defined by an ontology, we have found valid mechanisms being supported by all ontologies. One ontology states the elements it defines using the 'defines' property of the OpenVocab ontology, one other ontology states the address of its SPARQL endpoint, and the remaining ontologies include, in their response to requests on the namespace URI, the statements defining all elements. TABLE IV presents all the properties in use.

[2] For readability purposes, in this text we abbreviate the RDF namespace as rdf: for http://www.w3.org/1999/02/22-rdf-syntax-ns# .

[3] The profiling results of the ontologies' RDF data is available at http://htmlpreview.github.io/?https://github.com/nfreire/data-aggregation-lab/blob/master/data-aggregation-casestudies/src/data/ontologies/OntologyResultsCsvIndex.html

TABLE IV. USAGE OF PROPERTIES IN THE RDF RESOURCES OF THE ELEVEN ONTOLOGIES

Property URIs	**Used by ontologies**
http://www.w3.org/1999/02/22-rdf-syntax-ns#type	(8) 67%
http://purl.org/dc/terms/modified	(6) 50%
http://www.w3.org/2002/07/owl#versionInfo	(6) 50%
http://purl.org/dc/terms/publisher	(6) 50%
http://purl.org/dc/terms/title	(5) 42%
http://purl.org/dc/terms/issued	(4) 33%
http://purl.org/vocab/vann/preferredNamespacePrefix	(4) 33%
http://purl.org/dc/elements/1.1/title	(4) 33%
http://xmlns.com/foaf/0.1/homepage	(4) 33%
http://www.w3.org/2000/01/rdf-schema#comment	(4) 33%
http://purl.org/vocab/vann/preferredNamespaceUri	(4) 33%
http://purl.org/dc/terms/creator	(4) 33%
http://purl.org/dc/terms/contributor	(3) 25%
http://purl.org/dc/terms/description	(3) 25%
http://www.w3.org/2002/07/owl#priorVersion	(3) 25%
http://creativecommons.org/ns#license	(3) 25%
http://purl.org/dc/elements/1.1/description	(2) 17%
http://www.w3.org/2002/07/owl#versionIRI	(2) 17%
http://www.w3.org/2000/01/rdf-schema#label	(2) 17%
http://www.w3.org/2000/01/rdf-schema#isDefinedBy	(2) 17%
http://purl.org/dc/terms/license	(1) 8%
http://purl.org/dc/terms/source	(1) 8%
http://www.w3.org/ns/adms#relatedWebPage	(1) 8%
http://purl.org/vocab/vann/example	(1) 8%
http://www.w3.org/2007/05/powder-s#describedby	(1) 8%
http://creativecommons.org/ns#licence	(1) 8%
http://open.vocab.org/terms/defines	(1) 8%
http://purl.org/dc/elements/1.1/publisher	(1) 8%
http://purl.org/vocommons/voaf#toDoList	(1) 8%
http://purl.org/dc/elements/1.1/creator	(1) 8%
http://rdfs.org/ns/void#inDataset	(1) 8%
http://purl.org/dc/terms/created	(1) 8%
http://purl.org/vocab/vann/changes	(1) 8%
http://purl.org/dc/terms/available	(1) 8%
http://w3id.org/nkos#sizeNote	(1) 8%
http://www.w3.org/ns/radion#versionNotes	(1) 8%
http://www.w3.org/ns/adms#relatedDocumentation	(1) 8%
http://www.w3.org/2002/07/owl#sameAs	(1) 8%
http://www.w3.org/2004/02/skos/core#note	(1) 8%
http://rdfs.org/ns/void#sparqlEndpoint	(1) 8%
http://purl.org/dc/elements/1.1/contributor	(1) 8%
http://purl.org/dc/elements/1.1/modified	(1) 8%
http://purl.org/dc/terms/relation	(1) 8%
http://purl.org/dc/terms/type	(1) 8%
http://purl.org/dc/terms/rights	(1) 8%
http://purl.org/dc/terms/identifier	(1) 8%
http://www.w3.org/2002/07/owl#ontologyIRI	(1) 8%

The results for usage of the *rdf:type* in ontology sub-elements show adequate values in all ontologies, either referring to OWL URIs or OpenVocab URIs. TABLE V presents additional details.

TABLE V. USAGE OF THE *RDF:TYPE* PROPERTY IN THE RDF RESOURCE OF THE 6,035 ONTOLOGY SUB-ELEMENTS

***rdf:type* of ontology sub-element's RDF resource**	**Used by ontologies**
http://www.w3.org/1999/02/22-rdf-syntax-ns#Property	(6) 50%
http://www.w3.org/2002/07/owl#Class	(6) 50%
http://www.w3.org/2002/07/owl#DatatypeProperty	(6) 50%
http://www.w3.org/2002/07/owl#ObjectProperty	(3) 25%

http://www.w3.org/2000/01/rdf-schema#Class	(3) 25%
http://www.w3.org/2002/07/owl#AnnotationProperty	(2) 17%
http://www.w3.org/2002/07/owl#FunctionalProperty	(2) 17%
http://www.w3.org/2000/01/rdf-schema#Resource	(2) 17%
http://www.w3.org/2002/07/owl#SymmetricProperty	(1) 8%
http://www.w3.org/2002/07/owl#TransitiveProperty	(1) 8%
http://www.w3.org/2002/07/owl#InverseFunctionalProperty	(1) 8%
http://purl.org/dc/terms/AgentClass	(1) 8%
http://purl.org/vocommons/voaf#Vocabulary	(1) 8%
http://www.w3.org/2000/01/rdf-schema#Datatype	(1) 8%
http://www.w3.org/2002/07/owl#Ontology	(1) 8%
http://purl.org/dc/dcam/VocabularyEncodingScheme	(1) 8%

Regarding the properties in use for describing the sub-elements, we are most interested in those that support the interpretation of the semantics of the ontology structure. If adequate properties are used, applications can use them to find relations to elements of other ontologies, and for which the application has knowledge of their semantics. Such process is based on properties from RDF, RDF Schema and OWL, in order to interpret the concepts of *equality*, *types*, *class hierarchy and inheritance*, and *property hierarchy and inheritance* in the ontology's structure. As for the main RDF resource of the ontologies (i.e. the RDF resource assigned with the URI of the namespace), the elements' definitions contain mostly properties aimed at human usage. The availability of the *rdf:type* property is much higher for the sub-elements than for the RDF resource of the ontology – only one of the ontologies is not using it.

Usage of both class/property *hierarchy and inheritance* are well-supported in all ontologies. Equality relations are rarely stated, however, particularly *equality* to concepts defined in other ontologies. Equality is neither stated for other cultural heritage ontologies nor for generic cross-domain ontologies, such as Schema.org. This is the most challenging aspect for automated interpretation.

Without alignments with concepts in other ontologies, an application is unable to know the meaning of data. Only interpretation by humans will then be possible.

TABLE VI presents all the properties in use.

TABLE VI. USAGE OF PROPERTIES IN THE RDF RESOURCES OF THE 6,035 ONTOLOGY SUB-ELEMENTS

***rdf:type* of RDF resource**	**Used by ontologies**
http://www.w3.org/1999/02/22-rdf-syntax-ns#type	(10) 83%
http://www.w3.org/2000/01/rdf-schema#label	(9) 75%
http://www.w3.org/2000/01/rdf-schema#comment	(8) 67%
http://www.w3.org/2000/01/rdf-schema#subPropertyOf	(8) 67%
http://www.w3.org/2000/01/rdf-schema#domain	(7) 58%
http://www.w3.org/2000/01/rdf-schema#subClassOf	(7) 58%
http://www.w3.org/2000/01/rdf-schema#isDefinedBy	(6) 50%
http://www.w3.org/2000/01/rdf-schema#range	(6) 50%
http://www.w3.org/2002/07/owl#equivalentClass	(5) 42%
http://www.w3.org/2002/07/owl#equivalentProperty	(5) 42%
http://www.w3.org/2002/07/owl#inverseOf	(4) 33%
http://purl.org/dc/terms/modified	(4) 33%
http://www.w3.org/2002/07/owl#disjointWith	(3) 25%
http://purl.org/dc/terms/issued	(3) 25%
http://purl.org/dc/terms/description	(3) 25%
http://www.w3.org/2000/01/rdf-schema#seeAlso	(3) 25%
http://www.w3.org/2004/02/skos/core#note	(3) 25%
http://www.w3.org/2004/02/skos/core#definition	(3) 25%
http://purl.org/dc/terms/hasVersion	(2) 17%
http://www.w3.org/2004/02/skos/core#scopeNote	(2) 17%
http://d-nb.info/standards/elementset/gnd#marc21equivalent	(1) 8%
http://metadataregistry.org/uri/profile/regap/name	(1) 8%

http://d-nb.info/standards/elementset/gnd#superPropertyOf	(1) 8%
http://purl.org/dc/terms/source	(1) 8%
http://purl.org/vocab/vann/preferredNamespacePrefix	(1) 8%
http://www.w3.org/2007/05/powder-s#describedby	(1) 8%
http://metadataregistry.org/uri/profile/regap/lexicalAlias	(1) 8%
http://open.vocab.org/terms/defines	(1) 8%
http://metadataregistry.org/uri/profile/rdakit/seeAlso	(1) 8%
http://www.w3.org/2003/06/sw-vocab-status/ns#term_status	(1) 8%
http://www.w3.org/2004/02/skos/core#example	(1) 8%
http://purl.org/dc/terms/title	(1) 8%
http://xmlns.com/foaf/0.1/homepage	(1) 8%
http://www.w3.org/2002/07/owl#sameAs	(1) 8%
http://www.w3.org/2004/02/skos/core#historyNote	(1) 8%
http://www.w3.org/2002/07/owl#deprecated	(1) 8%
http://www.w3.org/2002/07/owl#versionInfo	(1) 8%
http://www.w3.org/2004/02/skos/core#notation	(1) 8%
http://www.w3.org/2004/02/skos/core#altLabel	(1) 8%
http://metadataregistry.org/uri/profile/regap/status	(1) 8%
http://creativecommons.org/ns#license	(1) 8%
http://metadataregistry.org/uri/profile/regap/hasSubproperty	(1) 8%
http://purl.org/vocab/vann/preferredNamespaceUri	(1) 8%
http://purl.org/dc/terms/creator	(1) 8%
http://purl.org/dc/terms/publisher	(1) 8%
http://www.w3.org/2002/07/owl#complementOf	(1) 8%

V. Conclusions and Future Work

The overall conclusion we draw from this study is that the published ontologies in the cultural heritage domain are aimed at human usage, and are mostly focused on their application context (e.g. a subdomain of cultural heritage). The internal structure of the ontologies appears to be well-specified, and properties for enabling humans to learn about the ontologies (labels, descriptions, etc.) are generally available.

The automatic interpretation of linked data is not fully supported, however. In four ontologies out of the twelve in our study, we identified compliance problems with linked data specifications and best practices. In these four ontologies, the namespace URIs were not resolvable. In addition, two of these ontologies do not provide links to all their elements – this limits the possibilities for linked data crawlers to locate the elements defined by the ontology. Finally, one of the ontologies was not able to meet the minimum requirements to allow our software to process it for this study.

Regarding the two ontologies that are not crawlable, we were able to manually locate SPARQL endpoints that allow the elements' RDF resources to be obtained. One of these ontologies specified its SPARQL endpoint in its RDF resource. This suggests that linked data crawlers should complement the regular HTTP crawling with SPARQL support.

The major difficulty for automated interpretation of the evaluated ontologies is the lack of inter-ontology relations, particularly for equality and similar aspects. Cross-domain applications will not be able to use linked data expressed in these ontologies, unless human resources are committed for learning the ontologies and establishing relations between them; and implement the established relations in the application so that the interpretation of the concepts can be automated. This situation increases the development cost of cross-domain applications, and it may also be difficult to find human resources with the necessary know-how on each ontology.

Future work should explore the recent outcomes of research and innovation projects that have addressed ontology alignment in cultural heritage (for example [17]). If the alignment outcomes from these projects are available in according to linked data practices, they may support automated interpretation of cultural heritage ontologies.

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