A Survey of Multilingual OWL Ontologies in BioPortal

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Abstract. The internationalisation goal for OWL sought to offer support for multilingual ontologies. User-displayable labels were suggested as a way to realise this, by means of `rdfs:label`. However, because each label is a language-tagged string, this hampers accurate representation of strings in languages that require grammatical features such as inflected forms and gender. At least eight linguistic models have been proposed to address this key shortcoming, with OntoLex-Lemon now the de facto standard. The purpose of this survey was to determine if there has been any adoption of linguistic models within OWL ontologies. As OWL ontologies are widely used in the biomedical domain, the survey was limited to those ontologies in NCBO BioPortal, a biomedical repository. The results indicate that OntoLex-Lemon was not used in any production OWL ontology at time of review, nor that of any other linguistic model. In addition, the adoption rate of multilingualism in OWL ontologies in BioPortal was observed to be 5%, with English the primary language, followed by French and German.

Keywords: OWL ontologies · Linguistic Model · Multilingualism.

1 Introduction

There has been wide adoption of ontologies in the biomedical domain [14, 15, 40]. Multilingual ontologies are highly relevant, particularly as their use in a medical context affects a diverse range of language speakers. In the context of a global pandemic, there are requirements for biomedical and healthcare tools, as well as data integration at the national level. When considering the many languages spoken in the world, this suggests multilingual bio-ontologies will be of use. An example is OpenMRS, the medical record system used in 40 countries [31], which in turn uses SNOMED CT, a vocabulary of medical terms formalised in UMLS and OWL[1] [29]. SNOMED CT's multilingual range extends to French, Danish, Dutch, European Spanish and Swedish only [34]. The lack of broader multilinguality is recognised by SNOMED CT as a possible barrier to adoption [34]. The translation of SNOMED CT into other

[1] SNOMED CT is only available on BioPortal in UMLS format, with English labels, so it was not able to be included in the review.

languages is not without challenge. For instance, Keet and Khumalo took steps to translate SNOMED CT into isiZulu (a Niger-Congo B ('Bantu') language), with the aim to provide localised electronic health records and patient discharge note generation [17]. However, the translation of OWL ran into encoding issues due to the ubiquitous 'part of' relation as there is no single term to denote this relation in isiZulu. Instead, it is constructed depending on the category of things that play the part and the whole [16].

When developing multilingual ontologies, there are several options [2, 13, 26]. The standard approach is to set multiple language-tagged annotations using `rdfs:label` [11, 39]. The use of a linguistic model, such as OntoLex-Lemon [9, 23], is another possible approach, where each language-specific sense (from lexical entries) is associated with an ontological entity. Mapping models between classes or individuals from monolingual ontologies is also an option [38], where SKOS is typically used to align individuals [24]. Language-tagged annotations is the simplest way to model multilinguality, however its limitations are numerous, particularly when representing languages that have grammatical features such as inflected forms, gender, dependent prepositions, double negation, concordial agreement, and agglutination (see [16–18]). An example of grammatical gender is given by the "linked to" object property in the Organization Ontology[2], which has two labels in Spanish: "está relacionado con" and "está relacionada con". Use of either one is determined by the gender of the noun of the class in the domain position, or the subject of the sentence. As `rdfs:label`s are relied upon in question-answering and similar systems [10], it is more difficult to represent languages that have one or more of the above features in a way that also allows for accurate verbalisation of ontologies.

OntoLex-Lemon and its precursor, Lemon [20, 22], has been proposed as a possible solution by providing rich linguistic grounding for ontologies. Other linguistic models, such as LingInfo [6], LexOnto [8], Linguistic Information Repository (LIR) [25, 33], Linguistic Watermark 3.0 [32], LexInfo [5, 7], and GOLD [12] have been proposed to solve similar problems. OntoLex-Lemon has shown significant adoption within the Linguistic Linked Data cloud [30], with it now being the de facto model for linguistic representation [9]. As a step in the analysis of uptake of multilingual ontologies, we were interested to see if the adoption of a linguistic model such as OntoLex-Lemon has extended to OWL ontologies as well. We did this by collecting and analysing 'production' ontologies from BioPortal. Of the multilingual ontologies identified, we also wanted to identify the use of more expressive OWL profiles in these ontologies, where this expressivity allows for more complex reasoning, useful for question-answering and other natural language generation.

The primary purpose of this study was thus to identify the ratio of multilingual OWL ontologies to monolingual ones, the modelling options used for multilingual ontologies, as well as the OWL profile used. A core aspect of multilingualism for ontologies is the identification of elements using URIs. An identifier is a fragment of the URI that uniquely identifies the entity in

[2] https://lov.linkeddata.es/dataset/lov/vocabs/org

question. A URI fragment can be *opaque* (semantic-free) or *descriptive* (meaningful) [3, 19, 27]. For a descriptive identifier, there is a direct relationship between the natural language term used as an identifier and its semantics [21, 37]. If an opaque identifier is used as part of the URI, then a human agent will require an additional sign in order to interpret the URI, and this is realised using the `rdfs:label` annotation. OBO is well-known to have taken a natural language-independent approach [35], with opaque URI identifiers and mandatory labels, which also assume that if there is a translation, it would be a 1:1 translation of the term. In addition, due to OBO's different take with identifiers, we wanted to determine if this approach has extended to any other ontologies.

We also analysed coverage of each natural language compared to the total entity count within an ontology. As part of this work, we used the LLC^{lang} metric for multilinguality identified by Ell et al. [11], that measures the completeness for a given language within a corpus. The results show that there are only a few production ontologies in BioPortal that are multilingual to a greater or lesser degree. Of those multilingual ontologies, all use the multilingual labels option. Three of the ontologies had less than 5% language-specific coverage.

In the next section, the methodology for data collection and preparation is described. In Section 3, the ontologies are analysed for their multilingual aspects and discussed. We close with the conclusion in Section 4.

2 Methodology and Overview

Data collection was conducted using the REST API[3] provided by BioPortal. The steps to collect the required data are listed below.

1. Using the `/ontologies` endpoint within Postman[4], a list of ontologies were downloaded and saved as a JSON file.
2. Using the `/categories` endpoint, the process in Step 1 was repeated to get the list of categories, with both files then imported into a MySQL database.
3. A script was written which queried each ontology using the `/ontologies/{acronym}/latest_submission` and `/ontologies/{acronym}/categories` endpoints. The following data was then saved for each ontology: the list of linked categories, the ontology language used, the namespace acronym, URI, status, and description.
4. Only 'OWL' ontologies were selected, with all other formats excluded.
5. Only 'production' ontologies were selected, with all other statuses excluded.
6. Ontologies in the 'Upper Level Ontology' and 'Vocabularies' categories were then excluded.
7. Thereafter, each remaining ontology was downloaded, using the `/ontologies/{acronym}/download` endpoint.

[3] http://data.bioontology.org/documentation
[4] https://www.postman.com/

Fig. 1. Labels: an example of multilingual annotations in a language-independent ontology using a class from OBI.

BioPortal provides categories into which each ontology is classified. Ontologies in the 'Upper Level Ontology' were excluded in Step 6 as the focus was on domain ontologies. Ontologies in the 'Vocabularies' category were also excluded as these are controlled vocabularies and thesauri, which are typically lightweight ontologies at best. For Step 7, if the file size was large and resulted in timeout errors, the file was manually downloaded. If the Download endpoint returned an error for an ontology, the ontology would be manually inspected online. If the latest submitted version had an 'Error RDF' annotation, then no further download attempt was made.

Steps 1–7 were run on the 30/12/2020. Step 1 resulted in a dataset of 912 ontologies[5]. At the end of Step 7, a dataset of 220 ontologies remained. The review of ontologies for their multilingualism were conducted on this dataset. The possible options were *multilingual labels*, *linguistic models*, and *mapping models*. A diagrammatic representation of the multilingual labels option is shown in Figure 1 for the class 'Enzyme' from the Ontology for Biomedical Investigations (OBI) [4]. Alignment of monolingual instances using SKOS is shown in Figure 2. An example linguistic modelling option is shown in Figure 3 using OntoLex-Lemon for the class from Figure 1.

Each ontology file was loaded in memory, using a script to loop through each line therein. For multilingual labels, `@` and `xml:lang` was searched for, and if found, that line was saved to the database. For linguistic models, any line which contained the namespaces: `ontolex` (OntoLex-Lemon), `linginfo`, `lexonto`, `lexinfo`, `gold` and `lemon` was saved to the database. Likewise for mapping models, any line which contained `skos` was saved to the database. Thereafter, these saved rows were manually inspected for their multilingual aspects. The natural languages used in each ontology were easily identified; however, identification of those as primary language(s) was more subjective. To determine an ontology's primary language, an ontology was manually inspected, focussing on the labels used, and the consistency thereof for each of its languages. To qualify as language-independent, there would have to be near-equal support for the natural languages therein, as well as opaque URI identifiers. We applied LLC^{lang} per multilingual ontology to support identification of those as primary language ontologies.

Of the multilingual ontologies identified, the OWL profile(s) of each were then determined using the OWL Classifier [1]. Our inspection was limited to OWL 2 only. For the ontologies classified as OWL 2 Full, the profile violations for OWL

[5] The dataset is available here: https://fynbosch.com/article-2021-bioportal-review

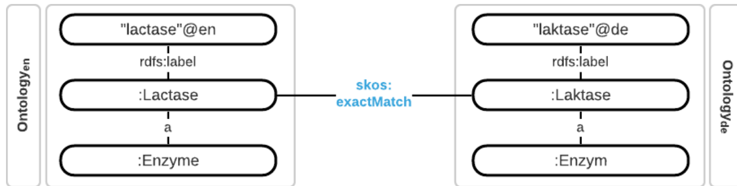

Fig. 2. Mapping model: an example using SKOS to align monolingual instances.

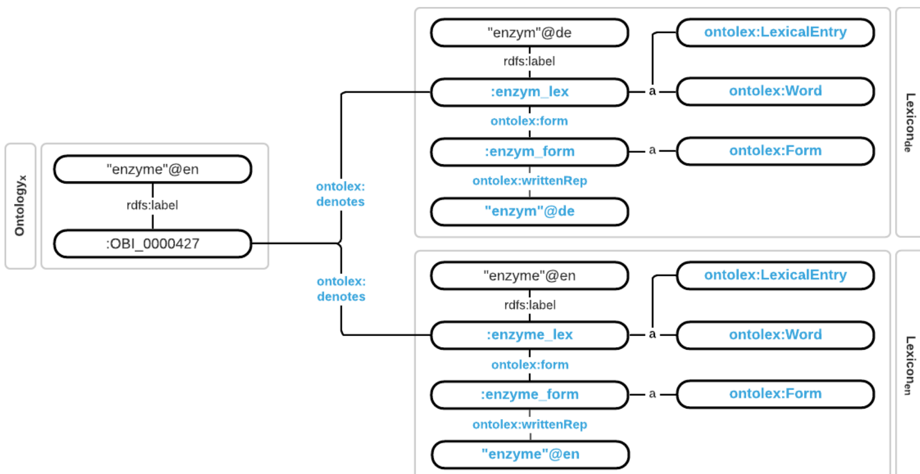

Fig. 3. Linguistic model: an example where two lexical entries from different language lexicons are associated to an OBI entity, if it were to use OntoLex-Lemon.

2 DL were examined and if determined to be related to annotations only, the ontology was reclassified as OWL 2 DL as these violations can be patched easily.

3 Assessment of Ontologies for their Multilingualism

The dataset of 220 ontologies was analysed on the different types of modelling options. Only 11 were identified as being multilingual, which are listed in Table 1. As can be observed, they all use the *multilingual labels* option and mostly *opaque* identifiers. The latter is likely a follow-on effect from OBO, which has a principle that identifiers should not have a label meaningful to humans [35, 36]. Of those ontologies identified with more than one primary language, this suggests they are language-independent. Only four ontologies were identified as being language-independent: ATOL, CIDOC-CRM, PDRO, and RADLEX. The remaining ontologies were identified as being of a primary language, with translations into other languages. Only one primary-language multilingual ontology was identified to be in a language other than English.

Table 1. Classification of Identified Multilingual Ontologies in BioPortal

Ontology	Type	Primary Language(s)	Other Language(s)	Identifiers	Modelling Option
Animal Trait Ontology for Livestock (ATOL)	OWL 2 DL†	en, fr	-	Opaque	Multilingual Labels
CIDOC Conceptual Reference Model (CIDOC-CRM)	OWL 2 Full	de, el, en, fr, pt, ru, zh	-	Opaque	Multilingual Labels
WHO COVID-19 Rapid Version CRF Semantic Data Model (COVIDCRFRAPID)	OWL 2 Full	en	pt-br	Opaque	Multilingual Labels
Clinical LABoratory Ontology (LABO)	N/A‡	en	fr	Opaque	Multilingual Labels
Ontology of Chinese Medicine for Rheumatism (OCMR)	OWL 2 DL	en	zh	Opaque	Multilingual Labels
Ontology of Units of Measure (OM)	N/A‡	en	ja	Descriptive	Multilingual Labels
Emergency Care Ontology (ONTOLURGENCES)	OWL 2 DL	fr	en	Descriptive	Multilingual Labels
The Prescription of Drugs Ontology (PDRO)	N/A‡	en, fr	-	Opaque	Multilingual Labels
Radiology Lexicon (RADLEX)	OWL 2 DL	de, en	-	Opaque	Multilingual Labels
Uber Anatomy Ontology (UBERON)	OWL 2 DL†	en	de, es, fr	Opaque	Multilingual Labels
Viral Disease Ontology Trunk (VDOT)	OWL 2 DL†	en	de	Opaque	Multilingual Labels

† Classified as OWL 2 Full, but re-classified to OWL 2 DL due to minor profile violations relating to annotations.
‡ One or more of the imported ontologies could not be loaded in the OWL Classifier, so the profile is undetermined.

We highlight the multilingual aspects of some of the identified ontologies that prompted classification as 'language-independent' or 'primary language'; Table 2 refers. Both CIDOC-CRM and RADLEX are language-independent ontologies. Although CIDOC-CRM does indeed have its `rdfs:comments` only in English, comments are ignored in parsing, whereas annotations and labels remain "first-class citizens" of the ontology, and its `rdfs:label`s were observed to provide near-complete coverage in English, French, German, Greek, Portuguese, Russian and Chinese, with opaque identifiers as well; hence, the classification as being a language-independent ontology. In RADLEX, English and German are the primary languages, with opaque identifiers. The ontology has its own annotation properties: `Preferred_name` and `Preferred_name_German`, with both observed to be used in equal proportion. The ontology also has definitions in English only, but as these are imported from Medical Subject Headings (MeSH), the ontology has been classified as a language-independent ontology.

COVIDCRFRAPID, ONTOLURGENCES and UBERON are three primary language ontologies. In COVIDCRFRAPID, in addition to English `rdfs:label`s, the occasional use of Brazilian Portuguese was also observed. The ontology also made use of `skos:prefLabel`, but only English was indicated. An OWL fragment showing multilingual annotations for COVIDCRFRAPID is shown in Listing 1.

```
Prefix(:=<http://purl.org/vodan/whocovid19crfsemdatamodel/>)

AnnotationAssertion( rdfs:label :Chest_pain "Chest pain"@en )
AnnotationAssertion( rdfs:label :Chest_pain "Dor no peito"@pt-br )
AnnotationAssertion( skos:prefLabel :Chest_pain "Chest pain"@en )
```

Listing 1. Example multilingual annotations from COVIDCRFRAPID

In ONTOLURGENCES, French is the primary language, with descriptive identifiers, also in French. The ontology made use of SKOS' `prefLabel`, `hiddenLabel` and `definition` properties, with a limited number of English `prefLabel`s observed. In UBERON, English is the primary language, with German, Spanish and French used as well. The ontology has used the OboInOwl metamodel to define SKOS-like relations for classes, such as: `oboInOwl:hasExactSynonym` and `oboInOwl:hasRelatedSynonym`. It was observed that some exact/related synonyms are provided in other languages, but not all equally. Very few of the English annotations were language-tagged.

We expand on the metrics for multilingual ontologies identified, shown in Table 2. The total number of classes, properties and named individuals for an ontology, prior to any imports, is shown in the 'Elements' column. LLC^{lang} is then applied to each applicable natural language, where its coverage is indicated as a percentage relative to the total number of elements for that ontology. Using UBERON as an example, coverage is so low for German, Spanish, and French, that it hardly qualifies as a multilingual ontology.

Table 2. Label Metrics: Language-specific Coverage Compared to Total Elements for each Ontology.

Ontology	Elements	de	el	en	es	fr	ja	pt	pt-br	ru	zh
ATOL	2 352	-	-	100%	-	100%	-	-	-	-	-
CIDOC-C.	372	92.5%	87.4%	99.7%	-	87.4%	-	87.4%	87.1%	90.9%	
COVIDC.	492	-	-	79.9%	-	-	-	-	56.7%	-	-
LABO	116	-	-	67.2%	-	13.8%	-	-	-	-	-
OCMR	3 481	-	-	5.8%	-	-	-	-	-	-	1.3%
OM	836	-	-	35.0%	-	-	3.0%	-	-	-	-
ONTOLU.	10 092	-	-	28.2%	-	99.0%	-	-	-	-	-
PDRO	239	-	-	74.1%	-	62.3%	-	-	-	-	-
RADLEX	45 852	-	-	99.7%	-	100%	-	-	-	-	-
UBERON	16 171	0.01%	-	94.0%	0.02%	0.2%	-	-	-	-	-
VDOT	116	66.4%	-	100%	-	-	-	-	-	-	-

Size of the ontology varied significantly per multilingual ontology. For example, CIDOC-CRM required only 372 annotations, but RADLEX required 45 852. RADLEX required significantly more effort to achieve complete coverage to that of CIDOC-CRM. For some smaller ontologies, such as LABO and PDRO, where there was incomplete coverage per natural language, the use of multilingualism was limited at best. Seven of the eleven multilingual ontologies were identified to have relations with OboInOwl [28] or other OBO relations. The current modelling practice for multilingual ontologies is multilingual labels, with opaque identifiers. Of the languages identified, English was predictably represented in every multilingual ontology, followed by French (6) and German (4).

Only 'production' ontologies were considered, but if ontologies with alternative statuses were also analysed, it is possible that the newer ontologies put into production in the past months may have used an alternative modelling option. The evidence indicates that there has been no uptake of any linguistic model for OWL ontologies. Likewise for mapping models, there was no use of SKOS for multilingual alignments. Due to insufficient data, we were unable to determine why this is the case from the analysis conducted. A possible reason may be insufficient tooling—there are limited tools to support the development, maintenance, and coordination of multilingual ontologies or multiple monolingual ontologies. It is unclear if the low number of multilingual ontologies is a bias in BioPortal or the resources themselves. It might be the case that there is limited need for multilingualism depending on the subject domain, such as a higher relevance in healthcare and administration rather than for biomedical research. We are currently finalising a more comprehensive review of multilingualism in ontologies, including ontologies from other subject domains. Its outcomes will be used in other ontologies and tools, such as the MoReNL project[6], whose foundations assist in the development of ontology-driven multilingual tools.

4 Conclusion

The assessment of use of multilingualism in production-level BioPortal ontologies revealed a low adoption rate. The 11 out of the 220 that were multilingual, predominantly used opaque identifiers with multilingual labels. The ratio of multilingual OWL ontologies to monolingual ones was thus identified to be 5%, however coverage of multilingual labels did not exceed 50% for 3 of these ontologies. There was also no adoption of any linguistic model. The OWL profile was identified to be primarily OWL 2 DL, but some ontologies would require minor patching of the annotations to achieve this. Of interest here is that these annotation profile violations were not identified when developing the ontology, so a better mechanism may be needed to address this.

For the modelling options, both multilingual labels and linguistic models present areas of opportunity for future research. Of the ontologies analysed, the reuse of OBO-related ontologies was observed to be substantive, and this presents the opportunity to represent the shared lexicons for each using a linguistic model.

Acknowledgements This work was financially supported by Hasso Plattner Institute for Digital Engineering through the HPI Research School at UCT [FGW] and the National Research Foundation (NRF) of South Africa (Grant Number 120852) [CMK].

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[6] http://www.meteck.org/MoReNL/

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