Pattern Comparison of is-a Concepts for Ontology Localisation

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Abstract

When a domain is represented in an OWL ontology using a natural language L_1, the perspective or viewpoint of that language is the lens through which the domain is interpreted. If this same ontology is made multilingual, annotations are typically added to each ontology element for each additional language L_n, where it is assumed there is a 1-1 mapping. As part of a larger project to localise an ontology where ontology concepts are refactored to a target viewpoint, the potential mismatches needed to be identified. In this paper, the pattern matches and mismatches when localising *is-a* concepts is detailed, with a focus on the axiomatisation of a concept, as well as any annotations thereof. Each source and target concept is abstracted to a pattern (consisting of the main axiom pattern and the superclass as a sub-pattern). Nine patterns have been identified for the axiomatisation of an *is-a* concept, and another five patterns identified for the content of the annotation, when annotating an element using the labels approach.

Keywords

OWL ontologies, patterns, ontology localisation

1. Introduction

Within an OWL ontology, there is a commitment to a conceptualisation by its logical language, with natural language used from, for example L_1, for each concept name, property name, and other axioms. To make the ontology multilingual, a natural language-specific annotation is typically added to each concept name and property name for each additional natural language, where it is assumed there is a 1-1 mapping. The result is the underlying axioms (the semantic layer of the ontology), according to L_1, remain unchanged. Ontology localisation differs to ontology multilingualisation in that it is a re-engineering activity where an ontology O is adapted so as to provide a localised view, where a localisation can pertain to a natural language, culture, or geopolitical environment [1]. For the word "view", the definition of a viewpoint is used, namely the "mental position or attitude from which a subject or question is considered" [2]. Ontology localisation, like that of ontology multilingualisation, is typically done in the annotation "layer", as adaptation of the semantic layer is a non-trivial task [1].

As part of a larger project for ontology localisation, where both the semantic and annotation layers of the ontology are adapted using an (automated) model-driven engineering approach, the types of mismatches for a concept between a source ontology and its target adaptation were

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first identified [3]. Of the axiom mismatches, the pattern (mis)matches then had to be identified, distinguishing between *is-a* and *part-of* relations. In this paper, the focus is on the *is-a* patterns of concepts when transforming an ontology to a language-specific viewpoint. By identifying the different patterns, refactoring rules can then be determined for each pattern transformation.

When considering the transformation of a concept from a source to a target viewpoint, a concept can be broadly classified by the lexicalisations of the source and target languages thereof:

1. A concept which has a lexical realisation (that is, a word or smaller unit such as a morpheme) for the natural languages used for both the source and target viewpoint.
2. A concept which has a lexical realisation in the source language; in the target language, there is no lexical realisation however the concept is known.
3. Similar to (2), except that the concept is not known in the target language.
4. For both the source and target language, the concept is known, however neither have a lexical realisation. The concept is known in a third language.

When there is no lexicalisation of a concept in a (target) language, this is known as a lexical gap. Lexical gaps can be further refined as linguistic and referential gaps, where the former refers to a concept which is known in the target language (albeit unlexicalised), and the latter, where it is not known at all [4]. Referential gaps tend to apply to concepts which are more culture-bound.

Four examples of ontology localisation differences for three target languages have been identified, presented in Table 1. For each example, the viewpoint is the natural language given for the source and target. UC1 is an example of direct equivalence, where South African English speakers use the term 'robot' when talking of a traffic light. The class from SNOMED CT serves as an example of the source concept in an ontology[1]. UC2 is another example of equivalence like that of UC1, however, as the superclass is not the same, this is indirect equivalence. UC3 is an example of granularity mismatch, where the two French terms are equivalent to the single English term. This is an oft-used example in the literature on the mismatch between a source target language, cf. [1, 5]. The class from the SWEET ontology serves as an example of the source concept[2]. UC4 is another example of granularity mismatch, except that there is differing granularity on both sides. Each share the same superclass. Due to space constraints, the axiomatisation of the source and target concepts is not given here. Please see https://fynbosch.com/article-2023-wop for the axiomatisations of each.

A concept can be thought of as a space with fuzzy boundaries, where a source viewpoint may divide the same concept space differently to that of the target viewpoint. To identify the differences between a source and target concept space, the axioms of each are abstracted to a pattern, consisting of a main pattern and a sub-pattern, where four patterns have been identified for the main pattern, and five for the sub-pattern. When considering lexicalisations as well, a further five patterns have been identified pertaining to annotations.

[1]http://purl.bioontology.org/ontology/SNOMEDCT/257720004
[2]http://sweetontology.net/realmHydroBody/River

Table 1
Examples for a source and target viewpoint. The natural language used for each is indicated by the language code in brackets.

	Source	Target	
UC1	traffic light (en)	robot (en-sa)	In South African English, a different term is used to that of British or USA English.
UC2	spoon (en)	lepel (af)	The meaning is the same, except that neither share the same hypernym when given in a dictionary. A ‘spoon’ is a utensil, while a ‘lepel’ is glossed as a ‘tool’.
UC3	river (en)	rivière, fleuve (fr)	Granularity mismatch where the concept space of French is more specific to that of English.
UC4	city, town, village, hamlet (en)	ville, village, bourg, bourgade, hameau (fr)	Granularity mismatch where French is more specific.

The remainder of the paper is structured as follows. In Section 2, related works are briefly discussed. In Section 3, a concept space, within the context of an OWL ontology, is defined. This follows with the patterns, given in Section 4. There is a discussion in Section 5 as well as an abstraction of each of the use cases. The paper concludes with Section 6.

2. Related Work

Focussing first on ontology localisation, in a paper by Cimiano et al. [1], three use cases were presented, of which only two are detailed here due. For the first use case, an ontology element is associated with three terms for Spanish, English, and Catalan respectively. The goal was a common conceptualisation between the three languages, with the result that there is a 1-1 mapping between the conceptualisation and the terms. For the second use case, Princeton WordNet [6, 7] and other language WordNets were given as an example, although WordNet is a semantic network only, and not an ontology. All the other language WordNets use the English WordNet as a pivot. In both of these use cases, adaptation of the ontology/resource is done in the annotation layer only, with the semantic layer remaining unchanged.

In a paper by Montiel-Ponsoda et al. [8], the authors proposed an approach to associate linguistic information with ontology elements, using a model called Linguistic Information Repository (LIR). Here, lexical entries are created for each viewpoint (cultural and natural language-specific), each associated with the same ontology element, and then relations are established between each of the lexical entries where appropriate. This approach affects the annotation layer only. UC3 is included as an example, however, in the case for French, there are two lexical entries for *rivière* and *fleuve*, whereas the goal of this paper is to have two classes. Brief mention is made of adapting an ontology in the semantic layer, but this is not expanded upon. Similar to LIR, OntoLex-Lemon is a model intended to represent linguistic information, where meaning of a lexical entry is given by an ontological reference [5]. UC3 is also given as an example, where the lexical entry for the term *river* and the lexical entries for *rivière* and *fleuve* are determined to be equivalent as they are each associated with the same ontological element, such as *:River* in DBPedia. However, as criticised by Hirst [9], ontological references are simply not granular enough to account for the meaning differences between natural languages. OntoLex-Lemon also has a *vartrans* module which provides for translation between source and target lexical senses. Of the examples given, a 1-1 mapping is assumed, with no mention made of lexical gaps. The categorisation of each of the translation types is given by Translation Category Reference RDF Schema (TRCAT) [10], with this categorisation determined to be insufficient in [11]. OntoLex-Lemon applies to the annotation layer only.

If ontology alignment is considered, then alignment can be done between source and target ontology elements, at class-level or at label-level [12]. However, in the examples given, it is assumed that alignment is always between two heterogenous sources, whereas this paper assumes the source ontology and the transformation thereof to be homogenous (that is, same modelling style, etcetera). If ontology design patterns (ODPs) are considered from OntologyDesignPatterns.org, there are several categories of ODPs that are relevant: re-engineering, alignment, and lexico-syntactic [13]. For re-engineering, of the ODPs given, only heterogenous sources are considered, for example, from a classification scheme to an ontology. For alignment, heterogenous sources are again the only consideration. For lexico-syntactic, an equivalence pattern is given between a source and target label, but no mention is made of lexical gaps (*fleuve* from UC3 in English) or terms with overlapping meaning (UC4). Lastly, in a paper by Fillotrani and Keet [14], correspondence patterns of mappings between TBoxes are considered, however again, the sources are heterogenous, and localisation is not considered. Of each of the localisation approaches reviewed, localisation is typically done in the annotation layer, with the underlying axioms remaining unchanged.

3. Definition of a Concept Space

Using the definition of a concept space from [3], it is extended so as to include annotations. A concept space can be defined as a 7-tuple $CS = < Co, VP, LI, SC, AP, Ind, Ann >$, where Co is the concept, represented as a natural language description, VP is the viewpoint expressed as a URI, LI is the lexical item (which may be empty if there is a lexical gap), SC is the superclass, AP is the axiom pattern, Ind is the set of individual assertions, and Ann is the set of annotations in OWL. AP is a 2-tuple $< APC, Ax >$ where APC is the set of axiom pattern classnames, and Ax is the set of axioms pertaining to the ontological commitment of each element in APC. Each element in APC is subsumed by SC.

When comparing a concept between a source and target viewpoint, a source and target concept space is paired. A paired concept space is a 3-tuple $PCS = < CS, CS', PVP >$ where CS is the source concept space, CS' is the target concept space, and $CS \neq CS'$. PVP is the paired viewpoint within which CS and CS' is considered. This is typically the viewpoint from CS', but it can also be an alternative viewpoint. A CS is visualised in Figure 1 for the concept of 'river', shown for two viewpoints: English and French.

4. Abstraction of a Concept Space to be Paired

For an *is-a* relation in an ontology, the subject or object has two parts: the axiom pattern (AP), and the superclass(es) (SC) of AP, where both are part of the ontology's TBox. To aid the

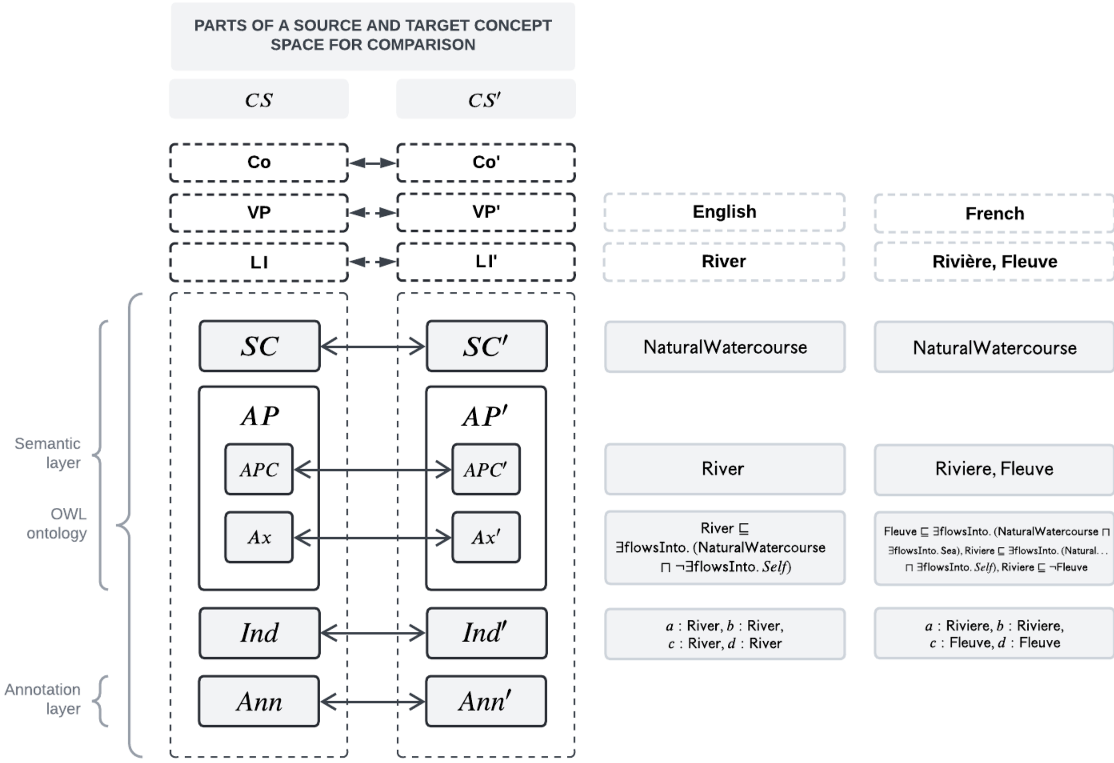

Figure 1: The parts of a source and target concept space CS and CS'. SC is the superclass, AP is the axiom pattern, consisting of a set of axiom pattern class names, APC, and axioms Ax for the ontological commitment of APC. Ind is the set of individuals asserted for each element in APC. Ann is the set of annotations for AP. The concept space for the concept lexicalised as 'river' is given for two viewpoints: English and French.

Table 2
Abstractions of a superclass using the tree from Figure 2.

	Source		Target		Source		Target
SC1	A_m	→	A'_m	**SC2**	`owl : Thing`	→	`owl : Thing`
SC3	A_1	→	A'_m	**SC4**	A_m	→	A'_0
SC5	A_0	→	B'_0	**SC6**	A_1	→	B'_m
SC7	A_1	→	B'_0	**SC8**	A_0	→	`owl : Thing`

decisionmaking process regarding the mismatches (if any), patterns were first identified for SC and AP. As a starting point, the superclass hierarchy of an ontology was abstracted to a tree, shown in Figure 2. The red shades are of the source ontology, and the green shades of the target ontology, where it is assumed that both ontologies are homogenous. Using this tree as a guide, the abstractions for a superclass are given in Table 2 for SC1–SC8.

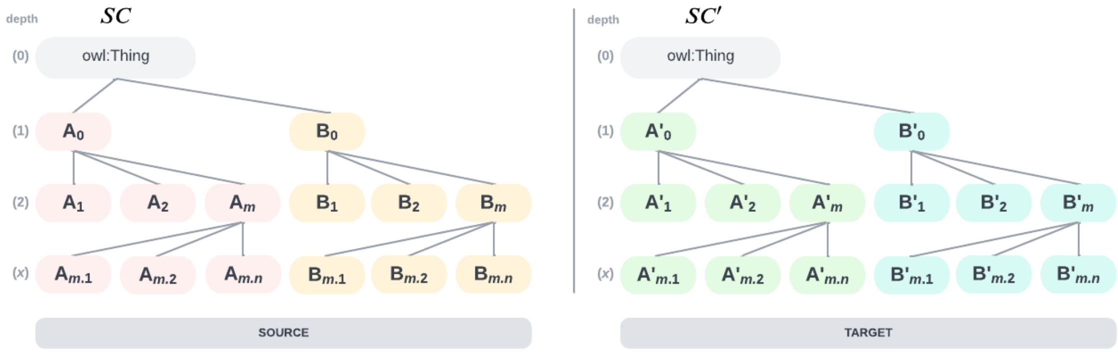

Figure 2: The superclass is abstracted to a tree, for both the source and target.

4.1. Superclass Patterns

From the superclass abstractions of SC1–SC8, superclass patterns were identified, given in *P-SC1–P-SC5*. In each pattern, the pattern name is given, as well as the possible pattern element (*PE*) variations, according to the tree of Figure 2. The superclass pattern is a sub-pattern, to be considered in conjunction with the patterns for AP. For SC1, *P-SC1* applies, for SC2, *P-SC5* applies, for SC3, *P-SC2* applies, for SC4, *P-SC3* applies, for SC5–SC7, *P-SC4* applies, and lastly, for SC8, *P-SC3* applies. For the abstraction SC8, where each has `owl : Thing` as a source and/or target, this means that there is no corresponding superclass, and the axiom pattern is a sub-class of `owl : Thing`. To localise the concept from the source to the target, refactoring actions are also proposed for selected patterns.

P-SC1: Equal source and target superclass

- *alignment pattern name:* sc-equal
- *pattern element variations:*
  1. $Src = \{A_0\}$, $Trg = \{A'_0\}$
  2. $Src = \{A_m\}$, $Trg = \{A'_m\}$, where $m \geq 1$
  3. $Src = \{A_{m.n}\}$, $Trg = \{A'_{m.n}\}$, where $m, n \geq 1$
- *equality of PE: $Src \equiv Trg$*
- *refactoring required: none*

P-SC2: Unequal source and target superclass at same depth, and shared parent

- *alignment pattern name:* sc-unequal-sameDepth-sharedParent
- *pattern element variations:*
  1. $Src = \{A_m\}$, $Trg = \{A'_n\}$, where $m, n \neq 0$ and $m \neq n$
  2. $Src = \{A_{m.n_1}\}$, $Trg = \{A'_{m.n_2}\}$, where $m \neq 0$ and $n_1 \neq n_2$
- *equality of PE: $Src \not\equiv Trg$*
- *refactoring required:* this requires two steps:
  1. Refactor the superclass of the *Src AP* to that of the *Trg AP*.

2. If the *Src* superclass no longer has any sub-classes, then remove it.

P-SC3: Unequal source and target superclass at different depth, and shared parent

- *alignment pattern name:* sc-unequal-differentDepth-sharedParent
- *pattern element variations:*
  1. $Src = \{A_m\}, Trg = \{A'_0\}$, where $m \neq 0$
  2. $Src = \{A_{m.n}\}, Trg = \{A'_m\}$, where $m \neq 0$ and $n \geq 1$
  3. $Src = \{A_{m.n}\}, Trg = \{A'_0\}$, where $m \neq 0$ and $n \geq 1$
  4. $Src = \{A_{m.n}\}, Trg = \{\texttt{owl : Thing}\}$, where $m, n \geq 0$
  5. Same as (1)–(4), but mirrored
- *equality of PE: $Src \not\equiv Trg$*
- *refactoring required:* for the *Src* or Trg with the least depth, this is possibly a lexical gap. Options include:
  1. Add a pseudo-class as a translation of the opposite superclass.
  2. Remove the extra classes, taking care to refactor any subclasses and individuals.

P-SC4: Unequal source and target superclass, and no shared parent

- *alignment pattern name:* sc-unequal-noSharedParent
- *pattern element variations:*
  1. $Src = \{A_m\}, Trg = \{B'_n\}$, where $m, n \geq 0$
- *equality of PE: $Src \not\equiv Trg$*

P-SC5: No source and target superclass

- *alignment pattern name:* sc-none
- *pattern element variations:*
  1. $Src = \{\texttt{owl : Thing}\}, Trg = \{\texttt{owl : Thing}\}$
- *equality of PE: $\emptyset$*

4.2. Axiom Patterns

The abstractions for an axiom pattern were similarly done as that for a superclass, shown in Figure 3, with red shades for the source ontology, and green shades for the target. Using this tree as a guide, the abstractions for an axiom pattern are given in Table 3 for AP1–AP6.

From the abstractions of AP1–AP6, axiom patterns were identified, given in *P-AP1–P-AP4*. For AP1, *P-AP1* and *P-AP2* applies. AP2, AP4, and AP6 are *P-AP4*. AP3 and AP5 are *P-AP3*. Due to the possible permutations of the OWL constructors, to simplify the list of pattern element variations in each *P-AP**, symbols are used for each. The symbol $\circ$ is used to represent C with no constructor or with $\neg$, the symbol is used to represent C for which there is a universal or existential restriction, and the symbol $\square$ is used to represent intersection and union.

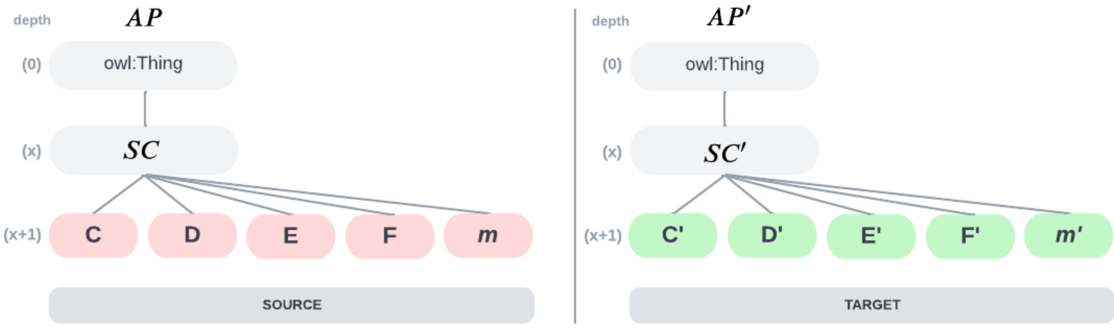

Figure 3: The axiom pattern is abstracted to a tree, for both the source and target. The superclass is at depth (x).

Table 3
Abstractions of an axiom pattern using the tree from Figure 3.

	Source		Target		Source		Target
AP1	C	$\rightarrow$	C'	**AP2**	C	$\rightarrow$	D'
AP3	C	$\rightarrow$	$C' \sqcup D'$	**AP4**	C	$\rightarrow$	$D' \sqcup E'$
AP5	$C \sqcup D$	$\rightarrow$	$D' \sqcup E'$	**AP6**	$C \sqcup D$	$\rightarrow$	$E' \sqcup F'$

P-AP1: Equal source and target axiom pattern, same superclass

- *alignment pattern name:* ap-equal-sameSuperclass
- *pattern element variations:*
  1. $Src = \{\circ C\}$, $Trg = \{\circ C'\}$, where $\circ$ is the same for Src and Trg
  2. $Src = \{R_x.C\}$, $Trg = \{R_x.C'\}$, where and x are each the same for Src and Trg
  3. $Src = \{C \square D\}$, $Trg = \{C' \square D'\}$, where $\square$ is the same for Src and Trg
- *superclass pattern variations:* P-SC1, P-SC3
- *equality of PE: $Src \equiv Trg$*
- *refactoring required:* none

P-AP2: Equal source and target axiom pattern, different superclass

- *alignment pattern name:* ap-equal-differentSuperclass
- *pattern element variations:*
  1. Same as that for *P-AP1*
- *superclass pattern variations:* P-SC2, P-SC3
- *equality of PE: $Src \equiv Trg$*
- *refactoring required:* as per the superclass

P-AP3: Unequal source and target axiom pattern, some shared classes

- *alignment pattern name:* ap-unequal-someSharedClasses

- *pattern element variations:*
  1. $Src = \{\circ C\}, Trg = \{C' \square D'\}$
  2. $Src = \{C \square D\}, Trg = \{D' \square E'\}$
- *superclass pattern variations:* P-SC1, P-SC2, P-SC3
- *equality of PE:* $Src \equiv Trg$
- *refactoring required:* this requires two steps:
  1. Remove the *Src* classes that are not shared.
  2. If there were any individuals asserted for those removed classes, then create a temporary class and assert those individuals to this new class.

P-AP4: Unequal source and target axiom pattern, no shared classes

- *alignment pattern name:* ap-unequal-noSharedClasses
- *pattern element variations:*
  1. $Src = \{\circ C\}, Trg = \{\circ D'\}$,
  2. $Src = \{\circ C\}, Trg = \{D' \square E'\}$
  3. $Src = \{C \square D\}, Trg = \{E' \square F'\}$
- *superclass pattern variations:* P-SC1, P-SC2, P-SC3, P-SC4
- *equality of PE:* $Src \equiv Trg$
- *refactoring required:* this requires two steps:
  1. Remove the *Src* classes.
  2. If there were any individuals asserted for those removed classes, then create a temporary class and assert those individuals to this new class.

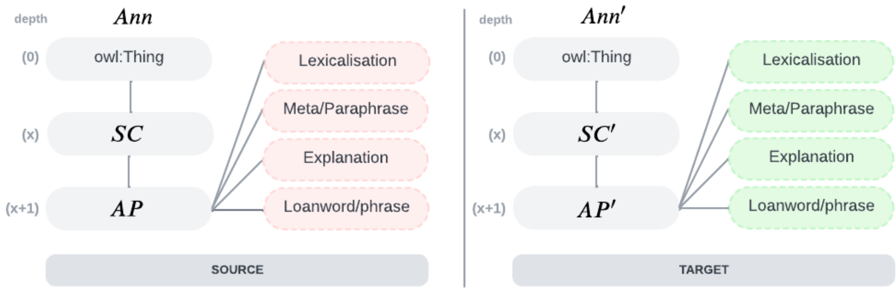

Figure 4: The possible variations of the content of one or more labels of an axiom pattern.

4.3. Annotation Patterns

The abstractions for an annotation is shown in Figure 4, again with red for the source, and green for the target. The content of a source annotation (using `rdfs : label`) can be a lexicalisation or some other lexical phrase. For the target annotation, if there is no lexicalisation, then there can be a metaphrase or paraphrase of the source annotation, or similarly an explanation thereof. A metaphrase is a word-for-word translation, and a paraphrase is a rewording of a metaphrase. Either of these would be expected for linguistic gaps, with an explanation for referential gaps, where an explanation would be more detailed than a metaphrase or paraphrase. Alternatively, a loanword or phrase can be used from the source language, or another language altogether. If there is no annotation at all for the source, then it is assumed that the URI fragment is descriptive, and meaning can be derived from it (by a human). A decision tree diagram for the selection of an appropriate annotation is given in Figure 5, reproduced from [11].

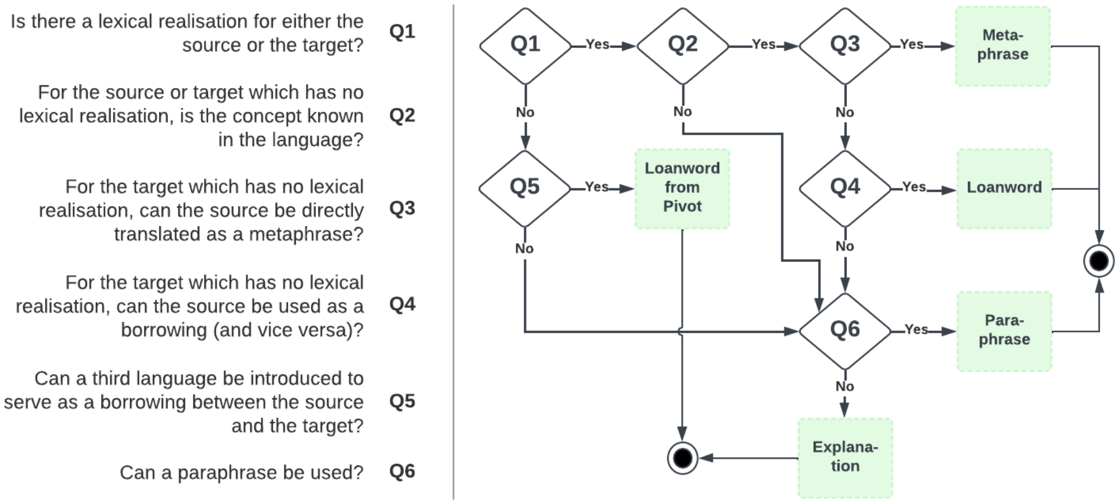

Figure 5: The decision tree diagram for determining the style of annotation to use when dealing with lexical gaps for a target viewpoint. Each green block is the proposed style to use for that question-answer selection.

P-Ann1: Both source and target have a label of similar content

- *alignment pattern name:* ann-equal-annotation
- *pattern element variations:*
    1. *Src* = lexicalisation, *Trg* = lexicalisation
    2. *Src* = meta/paraphrase, *Trg* = meta/paraphrase
    3. *Src* = explanation, *Trg* = explanation

P-Ann2: Both source and target do not have a label

- *alignment pattern name:* ann-equal-noAnnotation

P-Ann3: Both source and target do not have a label of similar content

- *alignment pattern name:* ann-unequal-annotation
- *pattern element variations:*
    1. *Src* = lexicalisation, *Trg* = meta/paraphrase
    2. *Src* = lexicalisation, *Trg* = explanation

P-Ann4: Target uses the source label

- *alignment pattern name:* ann-shared-source
- *pattern element variations:*
    1. *Src* = lexicalisation, *Trg* = lexicalisation from *Src*

P-Ann5: Both source and target use a lexicalisation from another language

- *alignment pattern name:* ann-shared-external
- *pattern element variations:*
    1. *Src* = lexicalisation of another language, *Trg* = lexicalisation from *Src*

5. Discussion

Figure 6: Comparison of each of the use cases, using the tree layout from Figures 2 and 3, where the named classes and properties are each normalised to an opaque identifier.

Revisiting the use cases, each can be mapped on the tree from Figures 2–3, and the applicable pattern identified. The mapping of each is given in Figure 6. UC1 is *P-AP1* and *P-SC1*, with UC2 being *P-AP2* and *P-SC3*. UC3 is *P-AP-4* and *P-SC1*. UC4 is both *AP-3* and *P-SC1*. The annotation pattern for each use case is assumed to be *P-Ann1*.

The use cases are all real-world examples of ontology localisation differences for a natural language viewpoint. The patterns identified for the axiom patterns assumed the source and target classes were leaf nodes in a branch (that is, there are no further sub-classes). It is expected that additional patterns will be identified so as to represent a use case such as that for ‘traditional healer’, where for the country South Africa, which would be a region-specific viewpoint, there are further sub-classes to the same concept. For the annotations, the different ‘style’ of annotation has been considered as this would be relevant in scenarios such as verbalisation or when an ontology is used for question-answering. A metaphrase would verbalise differently to that of a lexicalisation, where it is expected for the former, the generated sentence would be less readable. To deal with those concepts which do not have a lexicalisation in a target viewpoint, a decision tree diagram is given in Figure 5, so as to guide the end-user regarding the style of annotation required.

The benefits of ontology localisation is that an existing ontology can be reused, with the conceptual differences modelled for the target language (where necessary), and then a new ontology generated on the fly. Only a small selection of use cases were included here to demonstrate the variations. The evaluation of a wider variety of use cases is in progress, along with the algorithms to transform a concept in a source ontology to a target viewpoint. The focus in this paper has only been on *is-a* relations, however, *part-of* will be be addressed in future work. The focus has also been on a bottom-up approach for the axioms, so top-down will also be considered in future work. The patterns identified here differ to typical ontology design patterns in that they are not intended to guide design decisions but rather to document the possible pattern combinations when localising a concept to a target viewpoint. Once the evaluation of the localisation process is complete, it is expected that transformation patterns will be proposed for the re-engineering category of the Ontology Design Patterns repository, where the focus will be on homogenous sources.

6. Conclusion

A concept space within an ontology has been deconstructed to two parts, with each part abstracted to several patterns, and the pattern element variations given for each as well. By comparing each abstracted part, this serves to guide any refactoring that is required when localising an ontology from a source to a target viewpoint. The focus has been on the adaptation of the underlying axioms to a specific viewpoint, as an alternative to the labels approach for ontology multilingualisation, which only affects the annotation layer of the ontology, with the semantic layer typically remaining unchanged.

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