An Approach for Repairing Incoherent Ontologies

Ying Li[1] and Patrick Lambrix[1,2,3]

[1] Department of Computer and Information Science, Linköping University, Sweden
[2] The Swedish e-Science Research Centre, Linköping University, Sweden
[3] Department of Building Engineering, Energy Systems and Sustainability Science, University of Gävle, Sweden
firstname.lastname@liu.se

Abstract. The quality of ontologies and their alignments is crucial for developing high-quality ontology-based applications. In this paper we propose an approach for repairing incoherent ontologies and ontology networks that is based on axiom weakening and completion.[1]

1 Introduction

As ontologies become more prevalent and are used extensively in many different domains, the quality of ontologies and ontology networks, i.e., a set of ontologies connected through alignments, has become a key factor for supporting semantically-enabled applications. Therefore, ontologies with defects need to be repaired. One kind of defect that often occurs is the fact that the ontology or ontology network is incoherent, i.e., it contains unsatisfiable concepts. After a detection phase that finds the unsatisfiable concepts, a common method for repairing is to find justifications for the unsatisfiability and remove axioms in these justifications. For an overview of methods and examples, we refer to [6]. However, most approaches suffer the following issues. First, they are purely logic-based and therefore may remove correct axioms (e.g., [8]). Therefore, in the formalization of the repairing problem in [6] it is suggested that an oracle (e.g., a domain expert) is involved in validating logical solutions. Furthermore, removing an axiom may remove more knowledge than necessary. Sometimes it may be enough to replace an axiom with a weakened version of the axiom (e.g., [9,1]). Further, weakening axioms may also be seen as removing the axiom and then adding the weakened axiom. When adding axioms we can perform completion as defined in [6] to add more correct knowledge than just the axiom.

In this paper we propose an approach for repairing incoherent ontologies that deals with these issues using axiom weakening and completion. The approach also uses an oracle in different validation steps. Furthermore, the approach can directly be applied to ontology networks by considering the mappings in the ontologies as axioms and thus considering the ontology network as one ontology.

In this case repairing the ontology may remove or weaken both axioms in the ontologies or in the mappings. We can also define a variant of the approach that deals with mapping repair, as most current approaches assume the knowledge in the ontologies is correct and only mappings may be removed or weakened.

2 Repairing incoherence

In this paper we deal with the taxonomic part of the ontology, i.e., subsumption axioms between named concepts in the ontology. Equivalence axioms are treated as two subsumption axioms. We assume that we have a set of axioms W that when removed from the ontology lead to a coherent ontology. This set could be obtained by using a traditional approach for ontology debugging together with domain expert validation of the proposed solutions. Instead of just removing these axioms our approach will try to keep more knowledge in the ontology.

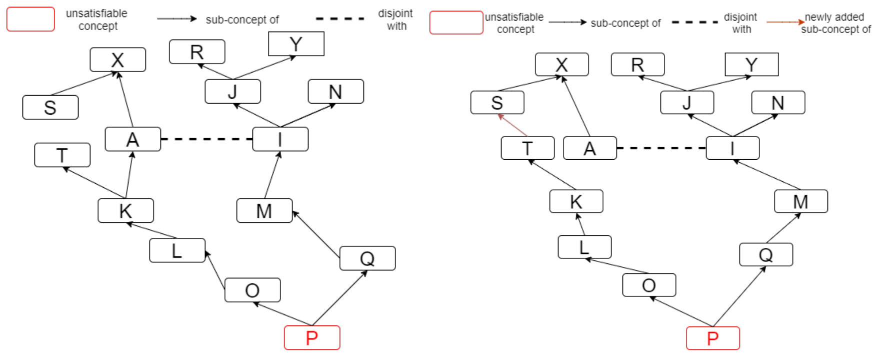
Algorithm 1 Repairing Algorithm

Input: An incoherent ontology $\mathcal{O}$, a set of unwanted axioms W
Output: A coherent ontology $\mathcal{O}_r$ that repairs $\mathcal{O}$

1: $\mathcal{O}_r \leftarrow \mathcal{O}$
2: **for each** $\alpha \sqsubseteq \beta \in W$ **do**
3: $\quad \mathcal{O}_r \leftarrow \mathcal{O}_r \backslash \{\alpha \sqsubseteq \beta\}$
4: $\quad wsup \leftarrow \{\ sp \in sup(\beta) \mid \mathcal{O}_r \nvDash \alpha \sqsubseteq sp \land \mathrm{Or}(\alpha \sqsubseteq sp) = \mathrm{True} \land \neg\, \exists\, sp' \in sup(\beta)$: $(\mathrm{Or}(\alpha \sqsubseteq sp') = \mathrm{True} \land sp' \sqsubset sp)\ \}$
5: $\quad R_w \leftarrow \varnothing$
6: $\quad$ **for each** $sp \in wsup$ **do**
7: $\qquad Source \leftarrow sup(\alpha) - sup(sp)$, $Target \leftarrow (sub(sp) - sub(\beta)) - sub(\alpha)$
8: $\qquad WR \leftarrow \{\ \alpha_w \sqsubseteq \beta_w \mid \alpha_w \in Source \land \beta_w \in Target \land \mathrm{Or}(\alpha_w \sqsubseteq \beta_w) = \mathrm{True} \land \neg\, \exists\, \alpha'_w \sqsubseteq \beta'_w$: $(\mathrm{Or}(\alpha'_w \sqsubseteq \beta'_w) = \mathrm{True} \land (\alpha_w \sqsubset \alpha'_w \lor \beta'_w \sqsubset \beta_w))$
9: $\qquad R_w \leftarrow R_w \cup WR$
10: $\quad$ **end for**
11: $\quad \mathcal{O}_r \leftarrow \mathcal{O}_r \cup R_w$
12: **end for**

Given an incoherent ontology $\mathcal{O}$, Algorithm 1 describes the general process of repairing. In the algorithm we denote with sup(A) the set of all the super-concepts of a concept A and with sub(A) the set of all the sub-concepts of A. Further, the oracle Or represents the domain expert and assigns a truth value True or False to an axiom. For every unwanted axiom $\alpha \sqsubseteq \beta$ we remove it from the ontology (line 3) and try to weaken it by finding axioms of the form $\alpha \sqsubseteq sp$ with sp a super-concept of β, that are correct according to the domain expert and retain the most knowledge. The set $wsup$ collects concepts sp that satisfy these requirements (line 4).

Further, we try to find improved axioms for a weakened axiom and collect these in the set WR. We try to improve a weakened axiom by finding an $\alpha_w \sqsubseteq \beta_w$ that is correct according to the domain expert and such that $\alpha \sqsubseteq \alpha_w$ and $\beta_w \sqsubseteq sp$. We call this completing as in [6]. In that case we know that $\alpha \sqsubseteq sp$ can be derived from these axioms. The *Source* set collects the candidates for α_w. It



(a) An incoherent ontology (b) A coherent ontology after repairing

Fig. 1. An example of repairing an incoherent ontology

contains all super-concepts of α that are not super-concepts of sp. The latter are removed to not introduce equivalence relations between concepts that are not equivalent in the original ontology. The *Target* set collects the candidates for β_w. It contains all sub-concepts of sp that are not sub-concepts of β and are not sub-concepts of α. The sub-concepts of α are removed to not introduce equivalence relations between concepts that are not equivalent in the original ontology. The sub-concepts of β are removed to not re-introduce the derivation of the unwanted axiom $\alpha \sqsubseteq \beta$. Furthermore, we also want to keep as much knowledge as possible (line 7-8). Note that it may be the case that WR contains the weakened axiom itself. R_w is the union of all the WR (lines 5 and 9). The ontology is updated by adding completed weakened axioms in case such were found (line 11). In the terminology of [6] the suggested repair by this algorithm is more complete than the repair that only removes the unwanted axioms.

We exemplify our approach using the ontology shown in Fig.1a. In this ontology, concept P is unsatisfiable (as it is sub-concept of A and I which are disjoint). A domain expert that validates the result of a debugging system may decide that $W = \{K \sqsubseteq A\}$ is a set of incorrect axioms. In Algorithm 1 this axiom is removed from the ontology. Then weakened axioms of the form $K \sqsubseteq sp$ with sp a super-concept of A are computed. These need to be true according to the domain expert and sp needs to be as specific as possible to keep as much knowledge as possible. In this case we may get $wsup = \{X\}$ representing the weakened axioms set $\{K \sqsubseteq X\}$. Then, we try to improve the weakened axioms by completing. Here, the computed source and target sets are $source_{K \sqsubseteq X} = \{K, T\}$ and $target_{K \sqsubseteq X} = \{X, S\}$. The completed axioms are then $K \sqsubseteq X$, $K \sqsubseteq S$, $T \sqsubseteq X$ and $T \sqsubseteq S$. A domain expert validates these and retains the one(s) that keep the most knowledge. Assuming $\text{Or}(T \sqsubseteq S) = \text{True}$, the completed weakened axioms set $R_{K \sqsubseteq A}$ is $\{T \sqsubseteq S\}$. The repaired ontology is shown in Fig 1b.

3 Experiment

We can use the algorithm also for ontology networks. In the first variant the network is considered as one large ontology and no distinction is made between mappings and axioms in the ontologies. In this case Algorithm 1 can be used as is. In many current approaches for alignment repair, however, only mappings are removed. In this case we can use a variant of Algorithm 1 (variant 2) that distinguishes between axioms and mappings, and only mappings are removed and weakened.

We used the ontologies MA and NCI-A from the OAEI Anatomy track [2] and alignments from 2018 generated by AML without its repair module (denoted as AML-Map) [3] and LogMapLite [5]. For each alignment together with MA and NCI-A an incoherent network was produced and repaired. We used OntoDebug in Protégé to generate maximum 9 repairs (default setting) that we could use as W in Algorithm 1. We removed the repairs with disjointness axioms. As we did not have a domain expert, we used the remaining repairs for W. For AML-Map this gave us 1 repair with only mappings (which can be used in variants 1 and 2) and 8 repairs where both axioms and mappings are used (which can only be used in variant 1). The number of axioms and mappings in a repair ranged from 1 to 4. For LogMapLite there were 3 repairs with axioms and mappings, but none with only mappings. The number of axioms and mappings in a repair was always 2. For each of the repairs generated in this session each axiom and each mapping led to 1 weakened axiom or mapping each. This means that for each suggested repair by OntoDebug it was possible to find a way to keep more knowledge in the ontology than when the axioms and mappings in the repair were removed (depending on the validation of the domain expert). Furthermore, for this example the source sets of the weakened axioms were always singletons, but the sizes of the target sets ranged from several hundreds to over 3000 elements. Thus, depending on the validation of the domain expert, more knowledge could be added to the ontology. In future work we will investigate deeper into more possible repairs and have domain experts validate the axioms and mappings in each step of the approach.

4 Conclusion and Future work

In this paper, we proposed an approach for repairing incoherent ontologies which focuses on preserving as much knowledge as possible. It combines a debugging approach, an axiom weakening approach and a completion approach together with domain expert validation. We intend to integrate the approach within the RepOSE system [7,4]. Furthermore, we will investigate the influence of other logical constructs in ontology representation languages and use our approach on ontologies that we are developing in other domains.

Acknowledgements. This work has been financially supported by the Swedish e-Science Research Centre (SeRC), the Swedish Research Council (Vetenskapsrådet, dnr 2018-04147), and the Swedish Agency for Economic and Regional Growth (Tillväxtverket).

References

1. Baader, F., Kriegel, F., Nuradiansyah, A., Peñaloza, R.: Making repairs in description logics more gentle. In: KR. pp. 319–328 (2018)
2. Dragisic, Z., Ivanova, V., Li, H., Lambrix, P.: Experiences from the anatomy track in the ontology alignment evaluation initiative. J Biomed Semant **8**(1) (2017)
3. Faria, D., Pesquita, C., Santos, E., Palmonari, M., Cruz, I.F., Couto, F.M.: The agreementmakerlight ontology matching system. In: OTM. pp. 527–541 (2013)
4. Ivanova, V., Lambrix, P.: A unified approach for aligning taxonomies and debugging taxonomies and their alignments. In: ESWC. pp. 1–15 (2013)
5. Jiménez-Ruiz, E., Grau, B.C., Cross, V.: Logmap family participation in the OAEI 2017. In: Ontology Matching Workshop. vol. 2032, pp. 153–157 (2017)
6. Lambrix, P.: Completing and debugging ontologies: state of the art and challenges (2020), arXiv:1908.03171
7. Lambrix, P., Ivanova, V.: A unified approach for debugging is-a structure and mappings in networked taxonomies. J Biomed Semant **4**, 10 (2013)
8. Pesquita, C., Faria, D., Santos, E., Couto, F.M.: To repair or not to repair: reconciling correctness and coherence in ontology reference alignments. In: Ontology Matching Workshop. pp. 13–24 (2013)
9. Troquard, N., Confalonieri, R., Galliani, P., Peñaloza, R., Porello, D., Kutz, O.: Repairing ontologies via axiom weakening. In: AAAI. pp. 1981–1988 (2018)