Semi-Automatic Revision of Formalized Knowledge

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Abstract. Quality control is an essential task within ontology development projects especially when the knowledge formalization is partially automatized. In this paper, we propose a reasoning-based, interactive approach to support the revision of formalized knowledge. In this approach, the evaluation decisions taken by a human expert are propagated in order to automatically evaluate axioms and thereby reduce the number of axioms that have to be manually evaluated. Additionally, we propose a ranking technique to further increase the effectiveness of ontology revision and provide an evaluation in terms of effort reduction and computation time with encouraging results.

1 INTRODUCTION

Constructing ontologies for real-world knowledge-intensive applications is a highly time-consuming task. The revision of ontologies is a typical part of it, since semi-automatic ontology construction, but also an extensive modification of ontologies by a human expert are error-prone tasks. One of the most practical usage scenarios for ontology revision however is ontology reuse. There are several reasons for the required manual inspection of the semantic data potentially relevant for the reuse in a new application context:

1. Ontologies often contain fragments irrelevant to the particular application scenario. Therefore, the relevant fragment has to be identified and extracted if necessary.
2. The available relevant knowledge bases tend to overlap. For instance, 25% of the available ontologies within the biomedical and chemical domain have an ontology mapping for more than the half of their concepts [2].
3. The conceptual compatibility of the selected relevant fragment and the target ontology has to be verified, since ontologies often model the same domain from different points of view and lexically similar entities can have different logical characteristics.

We propose a strategy of ontology revision support and evaluate it in an ontology reuse scenario, where the knowledge from several overlapping sources needs to be reused in a particular application context that is specified by a target ontology $\mathcal{T}$. As we show in our experiments, a proposed reasoning-based approach can reduce the effort spent on the revision of semantic resources by up to 83%.

2 REVISION OF KNOWLEDGE BASES

When considering the reuse of knowledge from foreign ontologies, a decision needs to be taken for each of its axioms whether it complies with the requirements underlying $\mathcal{T}$ such as requirements concerning the logical expressiveness within the ontology or the exact meaning of ontology entities. The proposed revision process allows an ontology engineer to select and reuse any part of the externally specified knowledge. During the revision, the expert reviews the axioms one by one while after each evaluation decision some axioms are evaluated automatically and disappear from the revision list. The automatic evaluation is based on the following assumptions:

- The requirements for the resulting ontology are known to the expert reviewing the ontology.
- The expert can only approve or decline axioms during the revision.
- Evaluation decisions cannot be changed during the revision.
- If an unevaluated axiom contradicts with the already approved ones, the expert would decline it.
- If an unevaluated axiom relationship is entailed by the already approved ones, the expert cannot decline it anymore.

The last two assumptions were adopted from the research by Meilicke et al. on ontology mapping revision [3].

The following succession operator underlies the automatic evaluation of axioms and incorporates the assumptions stated above.

Definition 1 *(Succession operator) Let $\mathcal{O}$ be a set of axioms that have to be reviewed to verify their compatibility with the target ontology $\mathcal{T}$, and let $\mathcal{V}$ be the set $\{$approved, declined, unevaluated$\}$ of evaluation values. Let Ω denote the set of all possible axiom sets satisfying the $\mathcal{SHOIQ}$ syntax restrictions. The evaluation state function $f_\mathcal{T} : \mathcal{O} \cup \mathcal{T} \rightarrow \mathcal{V}$ with $\forall_{\gamma \in \mathcal{T}} (f_\mathcal{T}(\gamma) =$ approved) can be transformed into a more advanced evaluation state function using the succession operator $\Phi : \mathcal{V}^{\mathcal{O}\cup\mathcal{T}} \rightarrow \mathcal{V}^{\mathcal{O}\cup\mathcal{T}}$ as follows:*

$$\Phi(f_\mathcal{T})(\alpha) = \begin{cases} \textit{approved} & \textit{if } f_\mathcal{T}^{-1}(\textit{approved}) \models \alpha \\ \textit{declined} & \textit{if } f_\mathcal{T}^{-1}(\textit{approved}) \cup \{\alpha\} \models \beta, \\ & \beta \in f_\mathcal{T}^{-1}(\textit{declined}) \cup \{\bot\} \\ & \textit{or } f_\mathcal{T}^{-1}(\textit{approved}) \cup \{\alpha\} \notin \Omega \\ \textit{unevaluated} & \textit{otherwise} \end{cases}$$

$\alpha >_i \beta$, iff $f_\mathcal{T}^{-1}(\text{approved}) \cup \{\alpha\} \models f_\mathcal{T}^{-1}(\text{approved}) \cup \{\beta\}$
$C \sqsubseteq D\, \forall u.(\neg C \vee D)$

Notice that due to the monotonicity of reasoning in $\mathcal{SHOIQ}$, Φ preserves the values $\{$*approved, declined*$\}$ assigned by $f_\mathcal{T}$ to the axioms and only influences the evaluation values of axioms with $f_\mathcal{T}(\alpha) =$ *unevaluated.*

3 RANKING

The impact of reasoning-based support depends on the order in which axioms are evaluated. One possibility to rank the axioms is to determine a minimal, logically non-redundant subset within the total set of unevaluated axioms which can be used to deduce the remaining unevaluated axioms. If no axioms are declined, an evaluation of the minimal set would suffice. Therefore, the minimal set should be

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Results		Cmt	MyReview	OpenConf	Pcs	Sofsem
Retrieved ontologies		3303	355	1596	3251	2674
Evaluated axioms		3426	3168	2376	3538	2791
RANDOM	Total manual decisions	1622	1658	873	1653	1399
	Total automated decisions	1804	1510	1503	1885	1392
	Implications	1205	1115	926	1376	1162
	Declines	599	395	577	509	230
	Reduction of effort	**53%**	**48%**	**63%**	**53%**	**50%**
MINSETRANK	Total manual decisions	711	773	612	704	467
	Total automated decisions	2715	2395	1764	2834	2324
	Implications	2116	2000	1187	2325	2094
	Declines	599	395	577	509	230
	Reduction of effort	**79%**	**76%**	**74%**	**80%**	**83%**

Table 1. Experimental results for supporting the revision of search results containing $\varrho(\mathcal{T})$ values for each axiom set $\mathcal{T}$.

ranked higher than the remainder in order to insure that it will be evaluated first. The ranking technique MINSETRANK is an approximation of this idea. By the means of the reduction rules shown in Table 2, a set of axioms can be reduced to a much smaller set with the same amount of information. We rank an axiom with 1, if there are no reduction rules defined for it or the defined rules are satisfied by the considered knowledge base. Otherwise we rank it with 0.

Axiom type	Reduction Rules
$C_1 \sqsubseteq C_2$	$\mathcal{O} \not\models \{C_1 \sqsubseteq C_3, C_3 \sqsubseteq C_2\}$ for any $C_3 \in \mathbf{C}/\{C \mid \mathcal{O} \models \{C \equiv C_1\} \vee \mathcal{O} \models \{C \equiv C_2\}\}$
$C_1 \sqsubseteq \neg C_2$	$\mathcal{O} \not\models \{C_1 \sqsubseteq C_3, C_2 \sqsubseteq \neg C_3\}$ for any $C_3 \in \mathbf{C}/\{C \mid \mathcal{O} \models \{C \equiv C_1\}$ $\mathcal{O} \not\models \{C_2 \sqsubseteq C_4, C_1 \sqsubseteq \neg C_4\}$ for any $C_4 \in \mathbf{C}/\{C \mid \mathcal{O} \models \{C \equiv C_2\}$
$\exists R_1.\top \sqsubseteq C_1$	$\mathcal{O} \not\models \{C_1 \sqsupseteq C_2, \exists R_1.\top \sqsubseteq C_2)$ for any $C_2 \in \mathbf{C}/\{C \mid \mathcal{O} \models \{C \equiv C_1\}$ $\mathcal{O} \not\models \{R_2 \equiv R_1^-, R_2 = R^*, \top \sqsubseteq \forall R_2.C_1\}$ for any $R_2 \in \mathbf{R}/\{R \mid \mathcal{O} \models \{R \equiv R^*\}$
$\top \sqsubseteq \forall R_1.C_1$	$\mathcal{O} \not\models \{C_1 \sqsupseteq C_2, \top \sqsubseteq \forall R_1.C_2)$ for any $C_2 \in \mathbf{C}/\{C \mid \mathcal{O} \models \{C \equiv C_1\}$ $\mathcal{O} \not\models \{R_2 \equiv R_1^-, R_2 = R^*, \exists R_2.\top \sqsubseteq C_1\}$ for any $R_2 \in \mathbf{R}/\{R \mid \mathcal{O} \models \{R \equiv R^*\}$
$R_1 \sqsubseteq R_2$	$\mathcal{O} \not\models \{R_1 \sqsubseteq R_3, R_3 \sqsubseteq R_2\}$ for any $R_3 \in \mathbf{R}/\{R \mid \mathcal{O} \models \{R \equiv R_1\} \vee \mathcal{O} \models \{R \equiv R_2\}\}$

Table 2. MINSETRANK reduction rules for different axiom types. R^* denotes one of the mutually inverse roles choosen based on the original order of the axioms as a target for domain and range axioms.

In [4], we provide further technical details on ranking as well as an extensive evaluation of MINSETRANK and two other ranking techniques in terms of effort reduction and execution time. MINSETRANK has achieved the best combined results.

4 EVALUATION

We evaluate the proposed methodology in the scenario where search engine results are considered for reuse in a particular context represented by a target ontology. The technical details about the revision-based ontology reuse approach that is deployed in this evaluation can be found in [4]. Each of the five ontologies from the OntoFarm dataset [5] shown in Table 1 is used as a target ontology in an experiment. We obtain the potential axioms for the reuse by the means of the ontology search engine Watson [1] using the name of each entity referenced in the considered target ontology as a keyword. The relative effort reduction shown in Table 1 is calculated as

$$\varrho(\mathcal{O}) = 100\% \cdot \frac{\#(\mathcal{O}) - \varepsilon(\mathcal{O})}{\#(\mathcal{O})}$$

where $\varepsilon(\mathcal{O})$ is the number of axioms that have to be evaluated by a human expert and $\#(\mathcal{O})$ the number of axioms considered in the revision. In order to measure $\varepsilon(\mathcal{O})$, we run a simulation of the evaluation where a virtual expert evaluates the axioms. We explicitly measure the effect of ranking within the same scenario and therefore repeat the same procedure but without ranking and sorting. As you can see in Table 1, we were able to reduce the effort of the evaluation by up to 83%. The ranking and sorting of axioms results in an average improvement of 25% over the non-ranking-based reasoning support.

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