Making Axiom Weakening Work in $\mathcal{SROIQ}$

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Introduction

Background

- Many methods for fixing inconsistent ontologies involve identifying and removing problematic axioms.
- This approach can lead to unnecessary information loss.
- Axiom weakening is a more information preserving approach and has previously been explored for $\mathcal{ALC}$.

In this paper

- We extend axiom weakening principles to $\mathcal{SROIQ}$, including weakening of RIAs.
- We discuss a number of scenarios where weakening can impact regularity of $\mathcal{SROIQ}$ RBoxes, and provide a framework where this is avoided.
- We perform experimental evaluation of repairing $\mathcal{SROIQ}$ ontologies with axiom weakening.

Axiom Weakening for Ontology Repair

To achieve axiom weakening, two types of refinement operators are used, a specialization operator and a generalization operator. These are used to define the axiom weakening operator. These operators need a consistent reference ontology to yield useful results. The process for repairing an inconsistent ontology proceeds as follows:

Repairing ontologies

1. Choose a consistent subset as the reference ontology.
2. Select a problematic axiom.
3. Weaken the selected axiom using the axiom weakening operator.
4. Replace the selected axiom with the weaker axiom.
5. Repeat steps 2-4 until the ontology is consistent.

Extending Axiom Weakening to $\mathcal{SROIQ}$

Difficulties

- $\mathcal{SROIQ}$ imposes global restrictions on the ontology that can not be checked by looking at axiom separately.
- Non-simple roles may not be used in cardinality constraints, Self constraints, or disjoint role axioms.
- RBoxes must be regular.

$\Rightarrow$ Adding valid axioms (e.g., weakenings) to a valid $\mathcal{SROIQ}$ ontology can make the ontology invalid.

Example: Weakening that breaks regularity

Take the ontology

$$\mathcal{O} = \{r \circ s \circ r \sqsubseteq t, \top \sqsubseteq \forall t.\{a\}, \top \sqsubseteq \exists s.\{a\}\} \ .$$

Since the range of t is restricted to the single individual a, and s contains all connections to a, $t \sqsubseteq_{\mathcal{O}} s$. The axiom $r \circ s \circ r \sqsubseteq t$ could therefore be weakened to $r \circ s \circ r \sqsubseteq s$. Yet, this would result in a non-regular RBox.

Avoiding these problems

- The allowed weakenings must be restricted to ensure the result is a $\mathcal{SROIQ}$ ontology.
- We only use simple roles whenever we have to replace roles using the refinement operators.
- For RIAs we only ever refine the super role if the RIA is simple and the sub role is simple.

$\Rightarrow$ These two rule ensure that all simple roles remain simple even after applying the weakening.

$\Rightarrow$ They further guarantee that the RBox remains regular.

Theorem

Given that the original ontology to be repair and the reference ontology are valid $\mathcal{SROIQ}$ ontologies. For every axiom ϕ of the original ontology, if ϕ' is a weakening of ϕ generated using the weakening operator, then the result of adding ϕ' to the original ontology is also a valid $\mathcal{SROIQ}$ ontology.

Experimental Evaluation

Performed experiment

1. Selected different ontologies from BioPortal.
2. Generated inconsistent ontologies by adding axioms.
3. Repaired the inconsistent ontologies using both removal and axiom weakening.
4. Compared the quality of the resulting repairs using IIC.

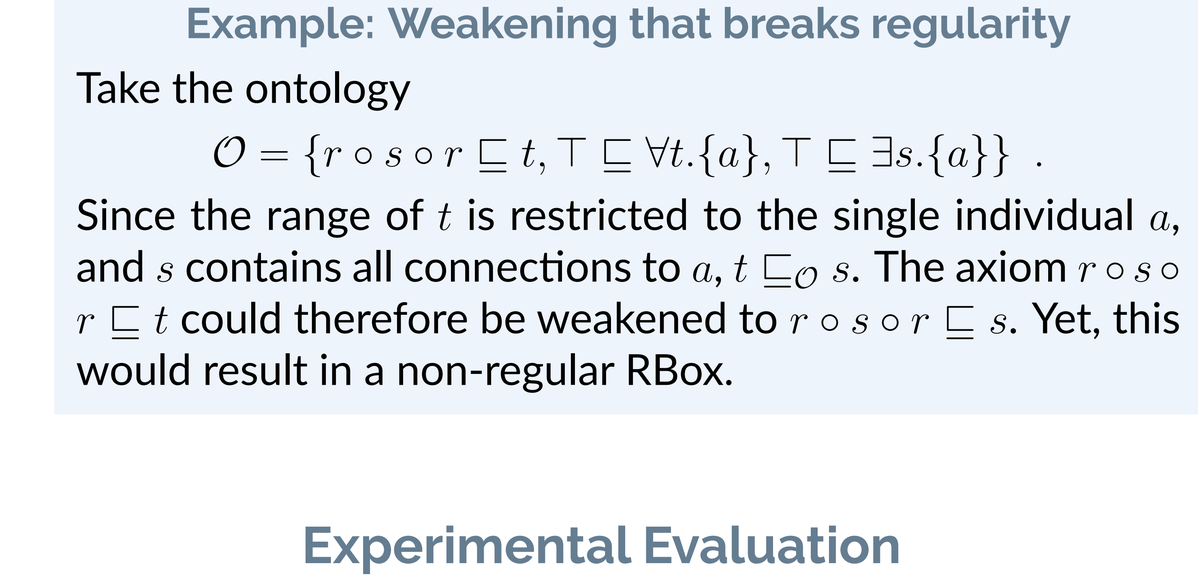

Figure 1. Mean IIC with respect to repair via removal per ontology. The error bars show the 95% confidence interval.

Conclutions and Outlook

Conclusions

- We have proposed refinement operators and an axiom weakening operator for all aspects of $\mathcal{SROIQ}$.
- Axiom weakening has been shown to be able to retain more information than removal.
- Weakening's advantage over removal is less pronounced in our experiments than previously reported.

Outlook

- Further additions to the refinement operators may be studied, e.g., using non-simple roles in certain contexts.
- Allowing more weakening for RIAs may also be considered, also to cover extended regularity conditions.
- The repair algorithm likely needs better heuristics to steer the repair process in order to achieve better repairs.
- Future work could further focus on finding more robust measures for comparing the quality of repairs.