

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

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## Introduction

### Background

- Many methods for repairing inconsistent ontologies involve identifying and removing problematic axioms.
- This approach can lead to unnecessary information loss.
- Axiom weakening is able to preserve more information 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 concept 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 of repairing an inconsistent ontology using axiom weakening proceeds as follows:

### Repairing ontologies

- Choose a consistent subset as the reference ontology.
- Select a problematic axiom.
- Weaken the selected axiom using the axiom weakening operator based on the reference ontology.
- Replace the selected axiom with the weaker axiom.
- 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 individually.
- Non-simple roles may not be used in cardinality constraints, *Self* constraints, or disjoint role axioms.
- RBoxes must be regular.

⇒ Adding valid axioms generated by weakening 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 valid  $\mathcal{SROIQ}$  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.
- ⇒ These two rule ensure that all simple roles remain simple even after applying the weakening.
- ⇒ 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  $\phi$  of the original ontology, if  $\phi'$  is a weakening of  $\phi$  generated using the weakening operator, then the result of adding  $\phi'$  to the original ontology is also a valid  $\mathcal{SROIQ}$  ontology.

## Experimental Evaluation

### Performed experiment

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

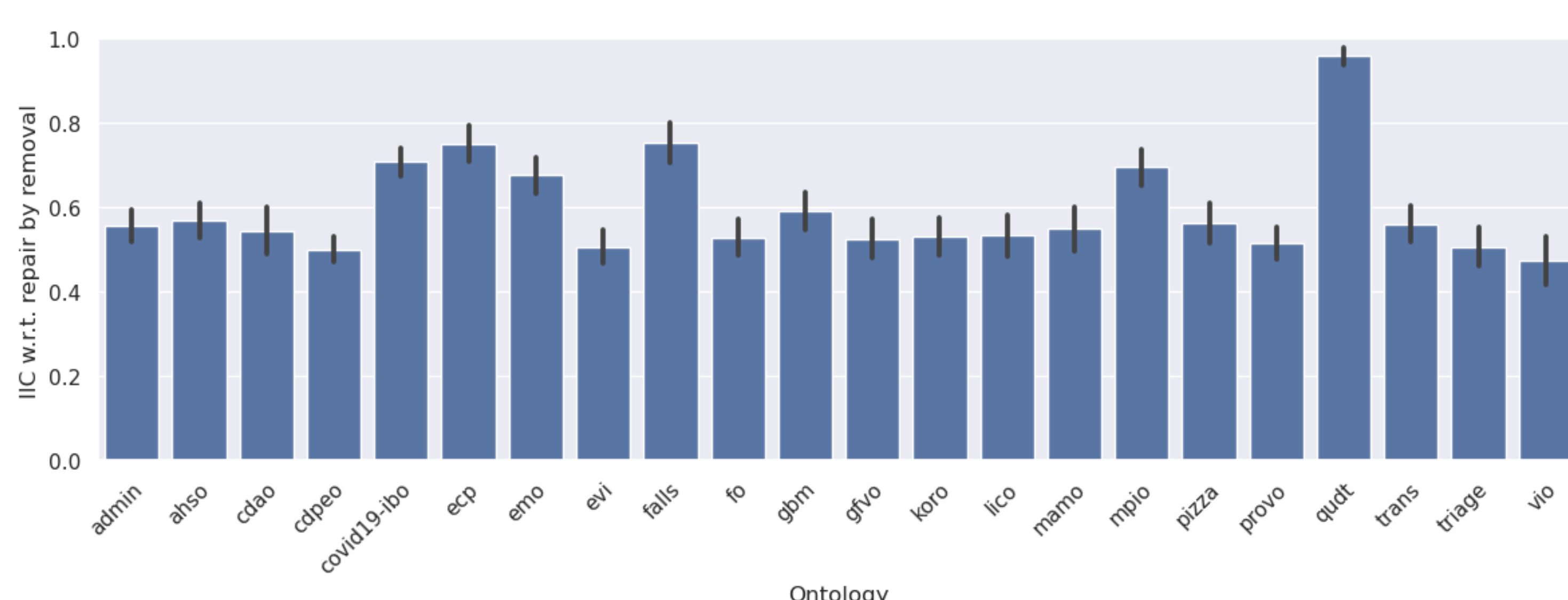


Figure 1. Mean IIC per ontology of repairs using axiom weakening with respect to repairs via removal.

## 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.