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Bachelor Thesis

Knowledge Refinement in Expressive Description Logics

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Description Logics

- Family of logics used to represent knowledge
  $\rightarrow$ aiming for favorable trade-offs between complexity and expressivity

- Individuals, e.g., $roland \quad oliver \quad nicolas \quad unibz \quad blue$
  Concepts, e.g., $Student \quad Professor \quad Person \quad University \quad Color$
  Roles, e.g., $studiesAt \quad supervisedBy \quad hasColor$

- Complex concepts, e.g., $\neg Person \quad Person \sqcap Student \quad \exists studiesAt.University$

- Axioms, e.g., $Student \sqsubseteq Person \quad Student(roland) \quad studiesAt(roland, unibz)$

Knowledge Refinement in Description Logics

- Process of iteratively modifying and improving the ontology

- Using two refinement operators
  - → specialization operator, e.g., $\mathit{Student}$ is a specialization of Person
  - → generalization operator, e.g., Person is a generalization of $\mathit{Student}$

- Using an axiom weakening operator
  - → uses the two refinement operators
  - → generates axioms that are less restrictive

Applications of Knowledge Refinement

Repairing ontologies, e.g.,

→ making inconsistent ontologies consistent

→ removing unintended consequences

Combination of conflicting knowledge

→ also for computational concept combination

Machine learning

→ learning axioms from data

Weakening in Expressive Description Logics

Extend axiom weakening to the description logic $\mathcal{SROIQ}$

Only simple roles can be used in every context

→ using a non-simple role in some places is forbidden

The graph formed by role inclusions must match some conditions

→ adding new role inclusions can cause violations

These problems have been prevented by ensuring that

→ all simple roles remain simple after refinement

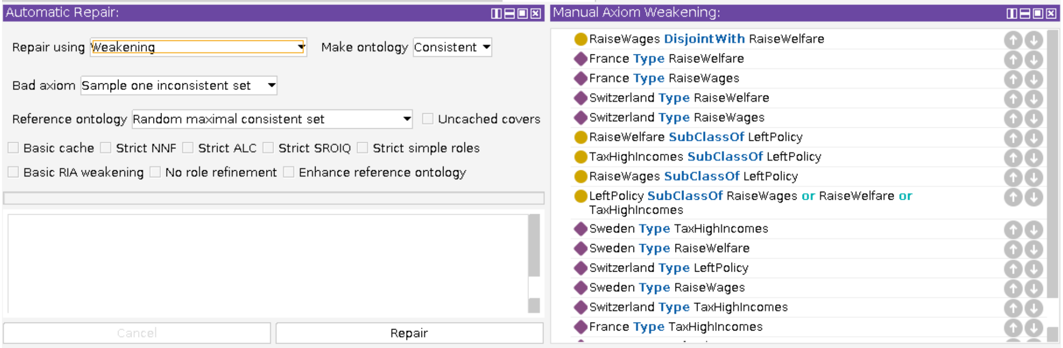
→ only simple roles are used during the refinement

A Protégé Plugin supporting Axiom Weakening

Protégé plugin for axiom weakening

→ allow computing weakening for specific axioms

→ enable automatic ontology repair



Evaluating Axiom Weakening for Ontology Repair

Repaired once using axiom weakening and once using removal

$\rightarrow$ the quality of the resulting repairs is compared

Deciding which repair is “better” is not well-defined

$\rightarrow$ we want to retain as many consequences as possible

$\rightarrow$ we focus only on subsumption between simple concepts

For comparing two repairs we define the IIC of $\mathcal{O}_1$ w.r.t $\mathcal{O}_2$

$\rightarrow$ value close to 1 for when $\mathcal{O}_1$ is better

$\rightarrow$ 0.5 if both repairs are equally “good”

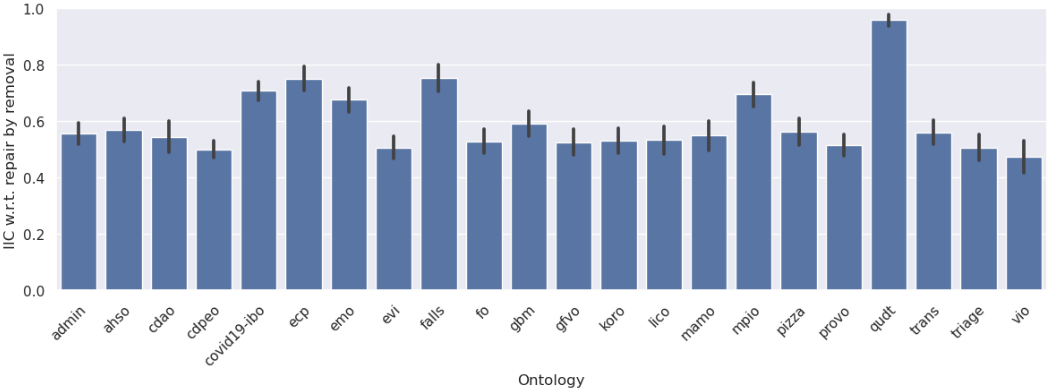
$\rightarrow$ value close to 0 for when $\mathcal{O}_2$ is better

Evaluation Results

Comparison between using axiom weakening and using removal

→ significantly better for some ontologies

→ in many cases only minor or no improvement



Outcomes of the Thesis

Extended the axiom weakening operator to $\mathcal{SROIQ}$

→ and showed that the proposed approach maintains the necessary constraints

Developed a Protégé plugin for applying these techniques

→ allowing users to easily repair ontologies and weaken axioms

Evaluated the proposed approach on real-world ontologies

→ showing that axiom weakening can outperform removal

Expressive Description Logics

- Additional kinds of concept expressions and axioms, e.g.,
  - → role inclusions, e.g., $\mathit{motherOf} \sqsubseteq \mathit{parentOf}$
  - → cardinality constraints, e.g., $\leq 1\ \mathit{studiesAt}.\mathit{University}$ $\quad \geq 2\ \mathit{supervisedBy}.\top$

- Require additional rules to guarantee decidability
  - → separation into simple and non-simple roles
  - → limits on the graph formed by role inclusions

◎ Focus on $\mathcal{SROIQ}$ and the Web Ontology Language

Implementation of Axiom Weakening

Implemented in Java using the OWL API

→ a library providing a uniform way of interfacing with reasoners

Using of-the-shelf reasoners for the Web Ontology Language

→ requires mapping between Web Ontology Language and $\mathcal{SROIQ}$

Tests to ensure correct behavior of the implementation

→ manual tests of expected operator results

→ automatically generated tests asserting general properties and invariants

Future Outlook

Study the possibility of loosening the restriction

→ refine with non-simple roles in some cases

→ more permissive weakening of role inclusions

Study better ways of guiding the repair process

→ using better heuristics, maybe domain specific

→ using user input to guide the repairs

Find better measures for comparing the quality of repairs

Study other possible applications of axiom weakening