TECHNISCHE UNIVERSITÄT DRESDEN

CPEC CENTER FOR PERSPICUOUS COMPUTING

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Explaining Description Logic Entailments in Practice with EVEE and EVONNE

3rd Workshop on Explainable Logic-Based Knowledge Representation (XLoKR'22), 31st July, 2022

Description Logics and Ontologies

Description Logics

- Well-established formalism for specifying terminological knowledge in Ontologies
- Applications in biology, medicine, semantic web, and more
  - SNOMED CT: medical, over 300,000 concepts
  - BioPortal: repository of bio-medical ontologies, currently hosting 1,004 ontologies defining 14,685,604 terms
  - MOWLCorp: ontologies obtained by web-crawling, containing 20,996 ontologies

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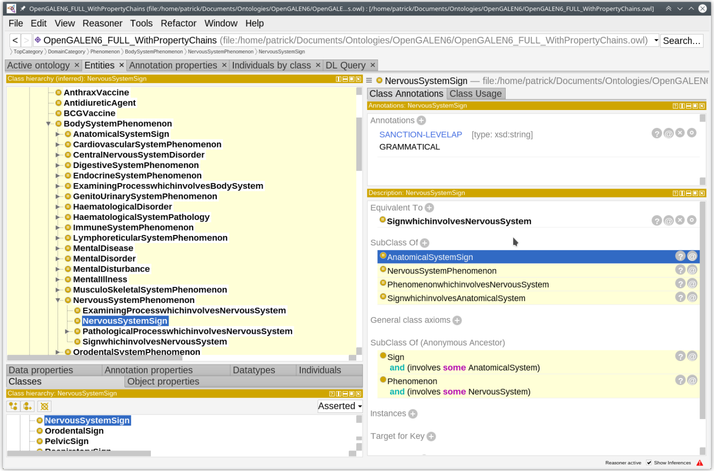
  - MOWLCorp: ontologies obtained by web-crawling, containing 20,996 ontologies
- With increasing complexity of the ontology, understanding entailments becomes both crucial and difficult
  - Requirement for tools to explain entailments

Current Explanation Tool of Choice: Justifications



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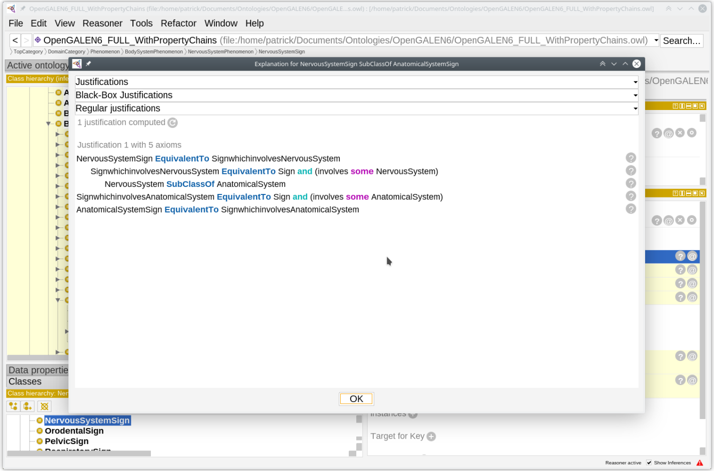

Justifications

Justifications: Minimal subsets entailing given statement

In practice often insufficient:

- can be large
- inferences often not obvious

Showing how to obtain the inference would be better

- simple reasoning steps leading to conclusion
- generally known as proof

A Proof

$$\begin{tikzcd}
(\mathsf{stefan}, \mathsf{xlokr22\text{-}9}) : \mathsf{presents} \arrow[d] & & \mathsf{xlokr22\text{-}9} : \mathsf{ScientificTalk} \arrow[dll] \\
\mathsf{stefan} : \exists \mathsf{presents}.\mathsf{ScientificTalk} \arrow[d] & & \exists \mathsf{presents}.\mathsf{ScientificTalk} \sqsubseteq \mathsf{Researcher} \arrow[dll] \\
\mathsf{stefan} : \mathsf{Researcher} & &
\end{tikzcd}$$

Meet the Family

- *data structures*
- *algorithms*
- *proof generation*

Evee-libs

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easy integration in Protégé

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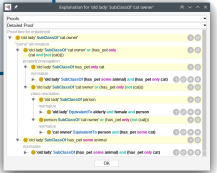
Evee-libs → Evee-protégé



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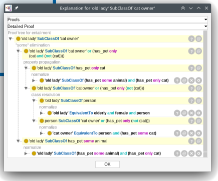
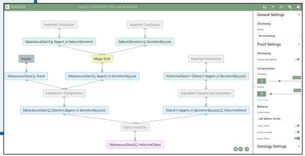


advanced web application



Proof Generation in Evee-libs

Three basic methods:

- Proofs based on ELK
- Elimination proofs based on LETHE and FAME
- Detailed proofs based on LETHE

In addition:

- Optimization criteria
  - Proof with lowest (weighted) size or depth
- Hide inferences of known terms

1. Proofs Based on ELK

ELK is the state-of-the-art reasoner for the lightweight logic $\mathcal{EL}$

- good performance on large-scale ontologies
- reasoning based on inference rules

$\mathcal{EL}$ inference rules

$$\mathsf{R}_0\ \frac{}{C \sqsubseteq C} \qquad \mathsf{R}_\top\ \frac{}{C \sqsubseteq \top} \qquad \mathsf{R}_\sqsubseteq\ \frac{C \sqsubseteq D \quad D \sqsubseteq E}{C \sqsubseteq E} \qquad \mathsf{R}^-_{\sqcap,1}\ \frac{C \sqsubseteq D \sqcap E}{C \sqsubseteq D} \qquad \mathsf{R}_\bot\ \frac{C \sqsubseteq \exists r.D \quad D \sqsubseteq \bot}{C \sqsubseteq \bot}$$

$$\mathsf{R}^-_{\sqcap,2}\ \frac{C \sqsubseteq D \sqcap E}{C \sqsubseteq E} \qquad \mathsf{R}^+_\sqcap\ \frac{C \sqsubseteq D \quad C \sqsubseteq E}{C \sqsubseteq D \sqcap E} \qquad \mathsf{R}_\exists\ \frac{C \sqsubseteq \exists r.D \quad D \sqsubseteq E}{C \sqsubseteq \exists r.E} \qquad \mathsf{R}_\mathcal{H}\ \frac{C \sqsubseteq \exists r.D \quad r \sqsubseteq s}{C \sqsubseteq \exists s.D}$$

- existing library and Protégé plugin (Kazakov, Klinov, Stupnikov 2017)
- we add support for optimized proofs (size, depth)

2. Elimination Proofs

- Support expressive DLs, no need of explicit inference rules
- Based on one type of inference:

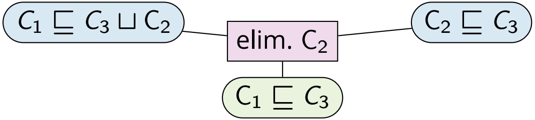
X-Elimination

$$\frac{\alpha_1, \quad \ldots, \quad \alpha_n}{\beta} \text{ eliminate } X$$

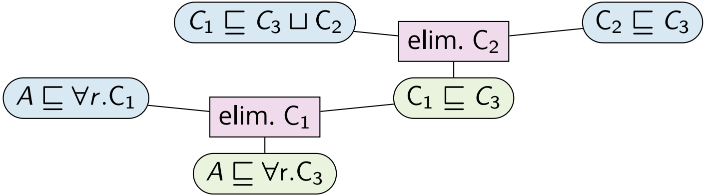
where $\alpha_1, \ldots, \alpha_n \models \beta$,
and X does not occur in β

- Eliminate symbols one by one, until only the conclusion is left
- Computed using forgetting tools LETHE and FAME

Example of an Elimination Proof



Example of an Elimination Proof



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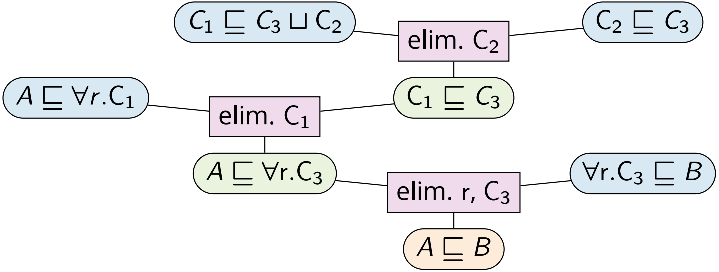

2. Elimination Proofs

The order in which we eliminate symbols affects the proof size!

How to choose a good order?

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How to choose a good order?

We implemented three strategies:

1. Use heuristics to pick next symbol (LPAR-20/XLoKR-20)
2. Use best-first search together with optimization criterion (IJCAR-22)
   - minimize number of eliminated names
   - optimize for given criterion, e.g. (weighted) tree size

3. Detailed Proofs using LETHE

- Elimination proofs give a high-level perspective on inferences
- Detailed proofs based on LETHE's inference rules
- However, several challenges needed to be solved:
  - LETHE uses a normal form, which we have to denormalize
  - optimizations need to be deactivated
  - some inferences are performed indirectly through the algorithm, which need to be translated to rule inferences

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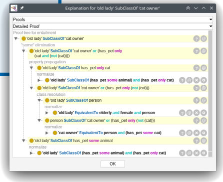
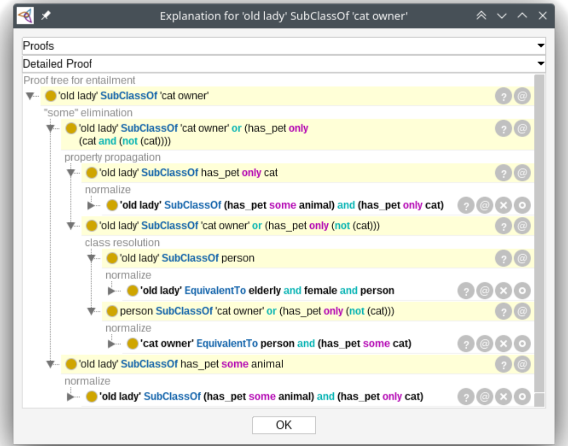


Evee-protege

- Protégé: standard editor for OWL ontologies
- Easy installation using plugin infrastructure



User Study

We performed a small user study on EVEE-protege

- Participants: 10 DL experts
- 5 Tasks + Questions
- Compare different proof methods

First conclusions:

- Preferred method is subjective
- Proof navigation in Protégé sometimes limited

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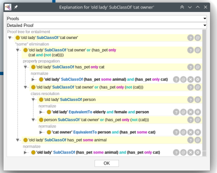

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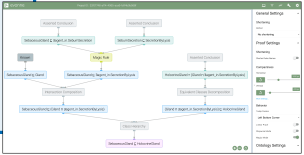
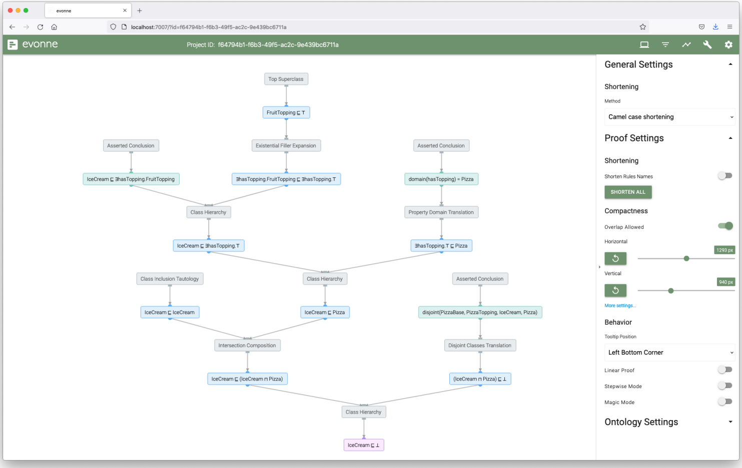


Advanced Proof Navigation with Evonne



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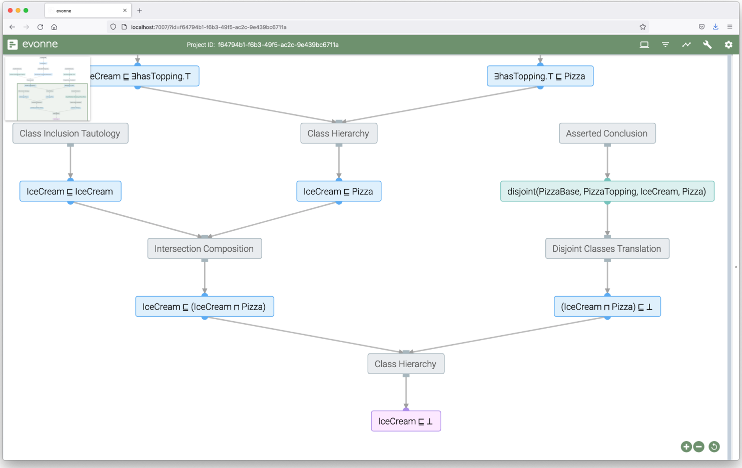

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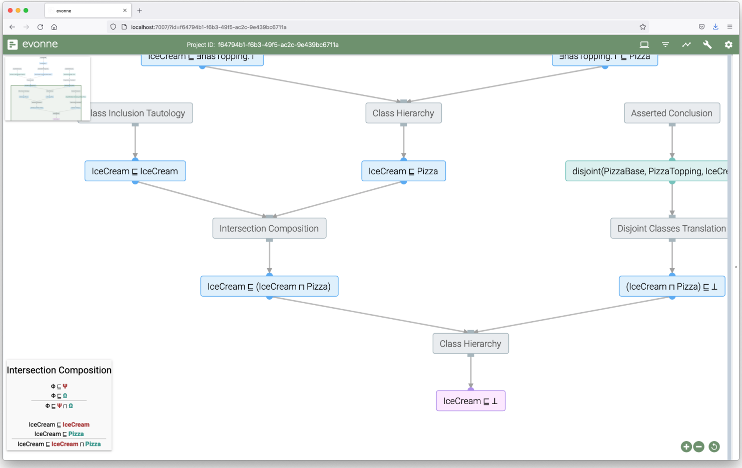

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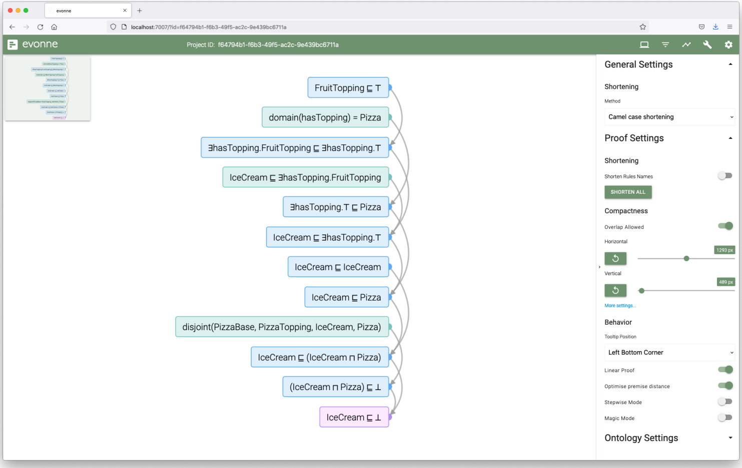

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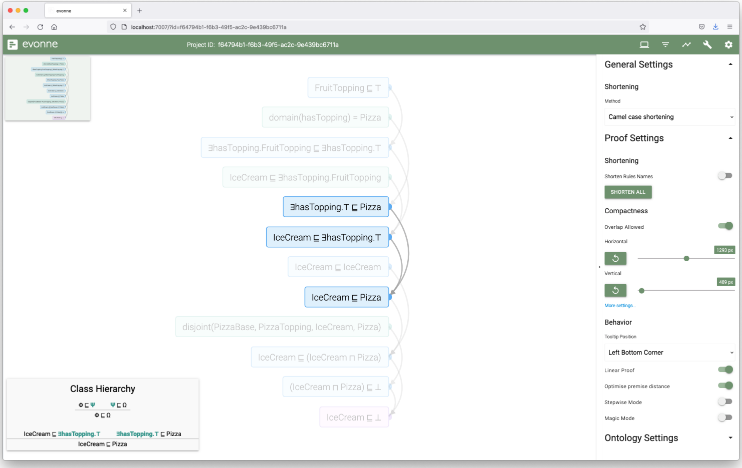

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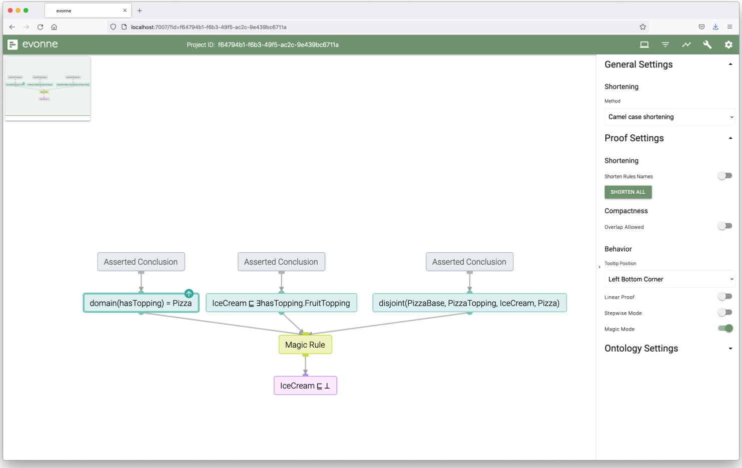

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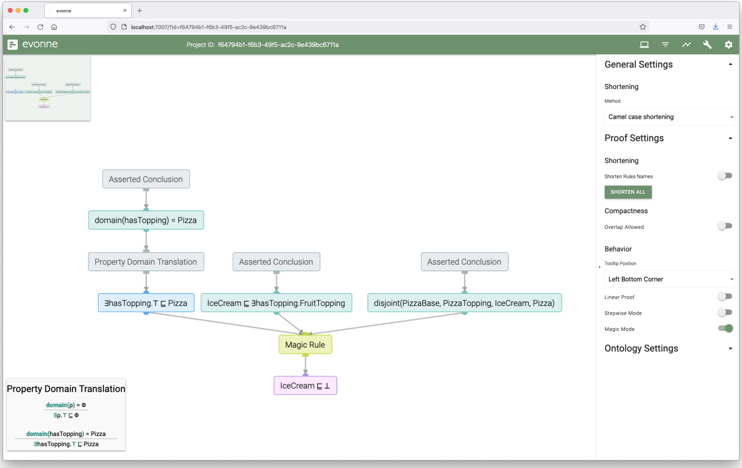

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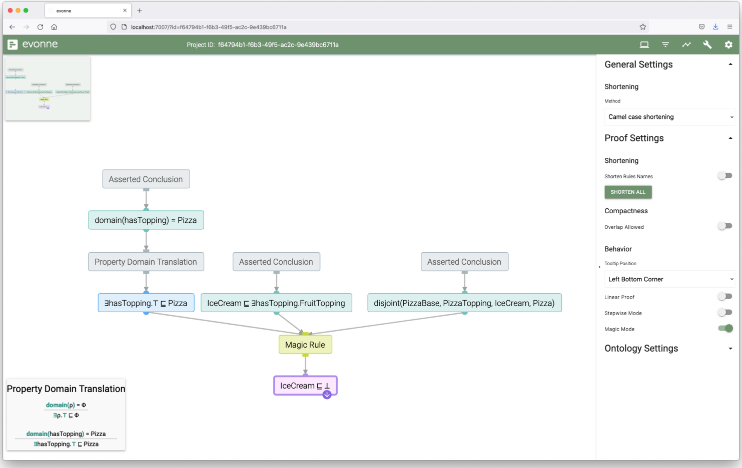

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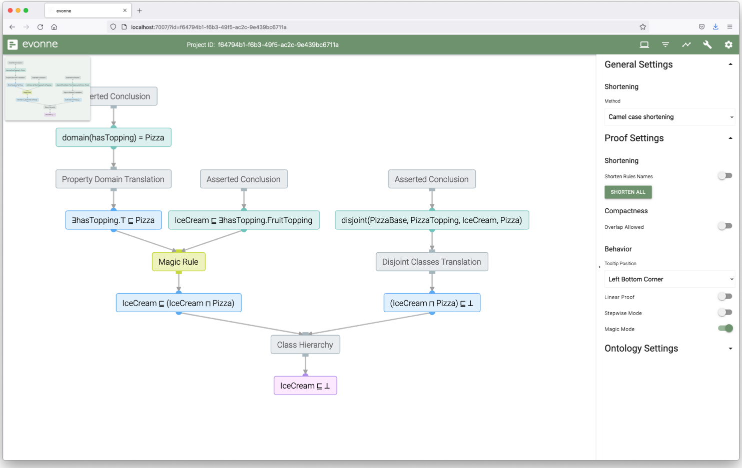

Conclusion

Proofs to explain DL entailments

- Library EVEE-libs used by frontends EVEE-protege and EVONNE
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- User study of EVONNE
- Explain also non-entailments using interpretations or abduction

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Try it out!

- You can try Evonne online
- Demo at DL (9.8., 16:00-16:30; 10.8., 10:30-11:00)

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Thank you!