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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Current Explanation Tool of Choice: Justifications
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

(stefan, xlok22-9) : presents

xlok22-9 : ScientificTalk

stefan : \exists presents.ScientificTalk

\exists presents.ScientificTalk \sqsubseteq Researcher

stefan : Researcher
Meet the Family

- data structures
- algorithms
- proof generation

Evee-libs
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Evee-protégé

easy integration in Protégé

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**Evee-lib**s

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**advanced web application**

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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**

- $R_0 \quad \frac{C \sqsubseteq C}{\top}
- R_\top \quad \frac{C \sqsubseteq \top}{\bot}
- R_D \quad \frac{C \sqsubseteq D \cap E}{C \sqsubseteq E}
- R_{\sqcap,1} \quad \frac{C \sqsubseteq D \cap E}{C \sqsubseteq D}
- R_{\sqcap,2} \quad \frac{C \sqsubseteq D \cap E}{C \sqsubseteq D}
- R_{\exists r} \quad \frac{C \sqsubseteq \exists r.D \cap \exists r.E}{C \sqsubseteq \exists r.D}
- R_{\exists s} \quad \frac{C \sqsubseteq \exists s.D}{C \sqsubseteq \exists s.D}$

- 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:

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

where \(\alpha_1, \ldots, \alpha_n \models \beta\), and \(X\) does not occur in \(\beta\)

- Eliminate symbols one by one, until only the conclusion is left
- Computed using **forgetting tools** \textsc{Lethe} and \textsc{Fame}
Example of an Elimination Proof

\[ C_1 \sqsubseteq C_3 \sqcup C_2 \]

\[ \text{elim. } C_2 \]

\[ C_1 \sqsubseteq C_3 \]

\[ C_2 \sqsubseteq C_3 \]
Example of an Elimination Proof

\[ C_1 \sqsubseteq C_3 \sqcup C_2 \]

\[ C_1 \sqsubseteq C_3 \]

\[ \text{elim. } C_2 \]

\[ A \sqsubseteq \forall r. C_1 \]

\[ \text{elim. } C_1 \]

\[ A \sqsubseteq \forall r. C_3 \]

\[ C_2 \sqsubseteq C_3 \]
Example of an Elimination Proof

\[ C_1 \sqsubseteq C_3 \sqcup C_2 \]

elim. \( C_2 \)

\[ C_2 \sqsubseteq C_3 \]

elim. \( C_1 \)

\[ C_1 \sqsubseteq C_3 \]

\[ A \sqsubseteq \forall r. C_1 \]

\[ A \sqsubseteq \forall r. C_3 \]

elim. \( r, C_3 \)

\[ \forall r. C_3 \sqsubseteq B \]

\[ A \sqsubseteq B \]
2. Elimination Proofs

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

How to choose a good order?
2. Elimination Proofs

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

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
Meet the Family

**Evee-libs**
- data structures
- algorithms
- proof generation

**easy integration in Protégé**

**Evee-protégé**
- 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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Advanced Proof Navigation with Evonne

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Advanced Proof Navigation with Evonne
Conclusion

Proofs to explain DL entailments

- Library **EVEE**-libs used by frontends **EVEE**-protege and **Evonne**
- **ELK** proofs, elimination proofs, detailed **LETHE** proofs
- Optimization w.r.t. various measures

Future work:

- User study of **Evonne**
- Explain also non-entailments using interpretations or abduction
- Try it out!
- You can try **Evonne** online
- Demo at DL (9.8., 16:00-16:30; 10.8., 10:30-11:00)

Thank you!
Conclusion

Proofs to explain DL entailments

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