Using Modular Reasoning to Improve Classification Performance of SNOMED CT Enhanced With Logical Negation and Related Advanced Description Logic Features

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Introduction

The description logic underlying SNOMED CT is based on the OWL 2 EL profile (EL++) description logic. This allows for efficient and tractable reasoning, but lacks more advanced description logic features, including universal restriction and negation. The addition of logical negation to the ontology allows creating new fully defined concepts such as “Non-bacterial infectious pneumonia”[1], as well as potentially fully defining and properly classifying existing concepts (e.g., “127302008 |Traumatic brain injury with no loss of consciousness (disorder)|”).

Currently available expressive OWL description logic reasoners such as FaCT++ and HermiT support negation and other advanced capabilities, but this additional capability typically comes with a significant performance cost, which makes them generally impractical for classifying the entire SNOMED CT ontology. On the other hand, faster OWL 2 EL reasoners, such as ELK and Snorocket, perform well in classifying SNOMED CT, but lack the advanced logic capabilities.

A novel approach to providing enhanced reasoning capability while maintaining an adequate level of performance utilizes modular combinations of OWL reasoners.[2] This approach uses a module extraction technique to divide the reasoning workload between a more expressive OWL 2 reasoner (e.g., FaCT++ or HermiT) and an efficient reasoner (e.g., ELK) and assigns the bulk of the reasoning workload to the latter. The MORe reasoner from the University of Oxford utilizes this technique.

Methods

An updated version of the MORe reasoner was developed as a plugin for the Protégé ontology editor tool. It is compatible with Protégé 5.1.0 (and later versions). The tested version of the updated MORe reasoner is based on OWL API 4.2.6 and the ELK 0.4.3, HermiT 1.3.8 and FaCT++ 1.6.5 reasoners.

An OWL 2 ontology version of the SNOMED CT Jan. 2017 International Edition was generated using the distributed Perl script. This ontology was enhanced to add the fully defined concept of “Non-bacterial infectious pneumonia” (Fig. 1).

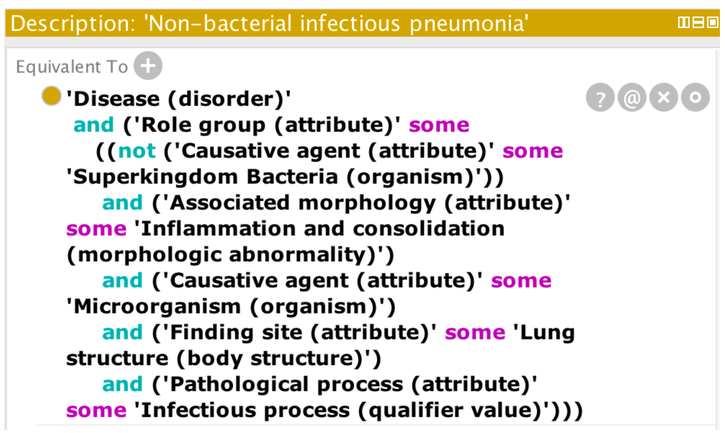

Figure 1. Definition of “Non-bacterial infectious pneumonia”

In addition, to achieve the expected classification results with the logical negation, it is necessary to add disjoint axioms between the “Bacteria” and “Virus” (and other) organism concept subhierarchies (Fig. 2). Only with the disjoint axiom does the reasoner infer that “Virus” and its subtypes are not also subtypes of “Bacteria”.

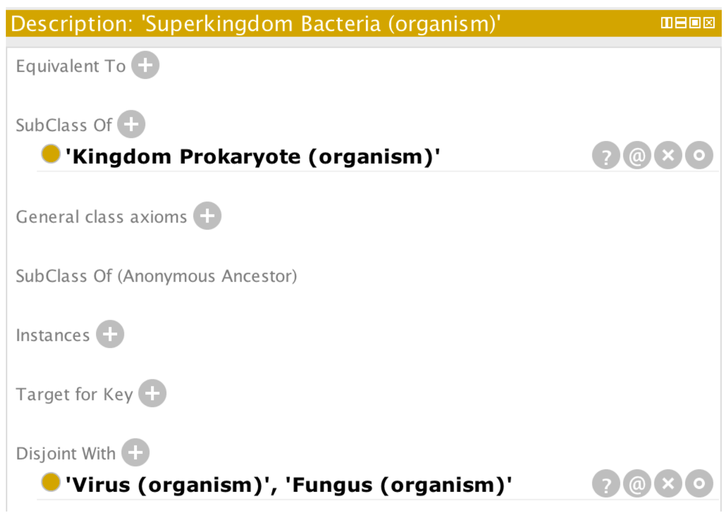

Figure 2. Disjoint axiom

And finally, it is also necessary to add a universal restriction closure axiom to the definitions of the expected subtypes of “Non-bacterial infectious pneumonia”, including “Viral pneumonia”, as only with the closure axiom does the reasoner infer that “Viral pneumonia” does not have additional unknown causative agents which may be a type of bacteria or other “non-viral” organism (Fig. 3).

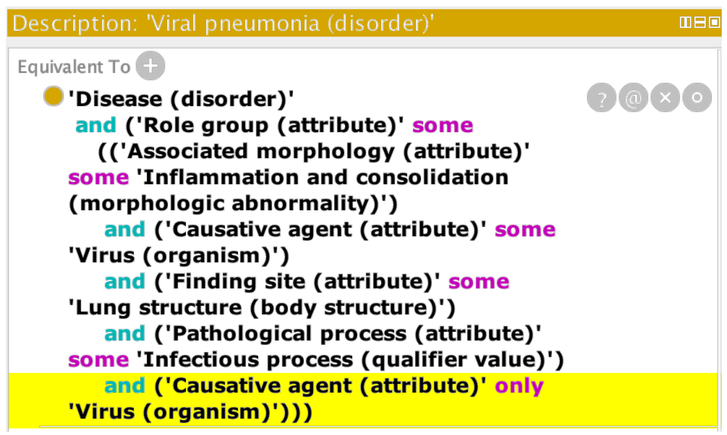

Figure 3. Universal restriction closure axiom (highlighted) added to definition of “Viral pneumonia”

Results

Classification of the entire SNOMED CT ontology with the single additional negated concept of “Non-bacterial infectious pneumonia” and the supporting additional logic was performed using the expressive OWL 2 reasoner FaCT++ in approx. 11.9 minutes. Classifying the same ontology using the MORe reasoner combining the ELK and FaCT++ reasoners was performed in 5.2 minutes, a 56% reduction in classification time.

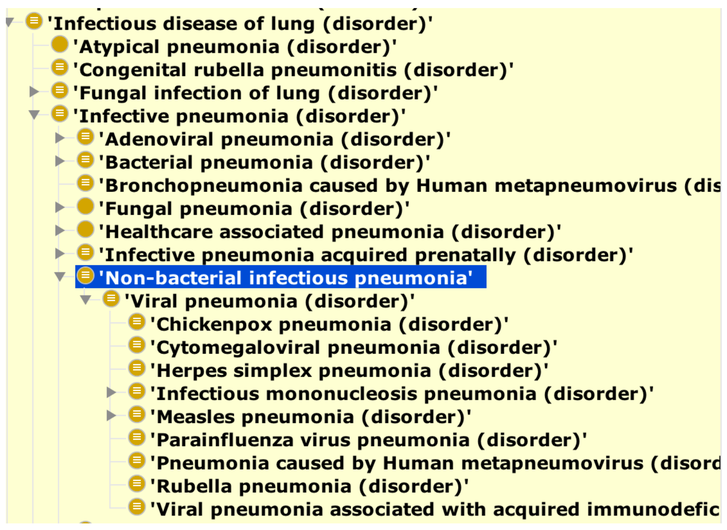

Figure 4. Results of classification showing the placement of the new “Non-bacterial infectious pneumonia” concept in the hierarchy

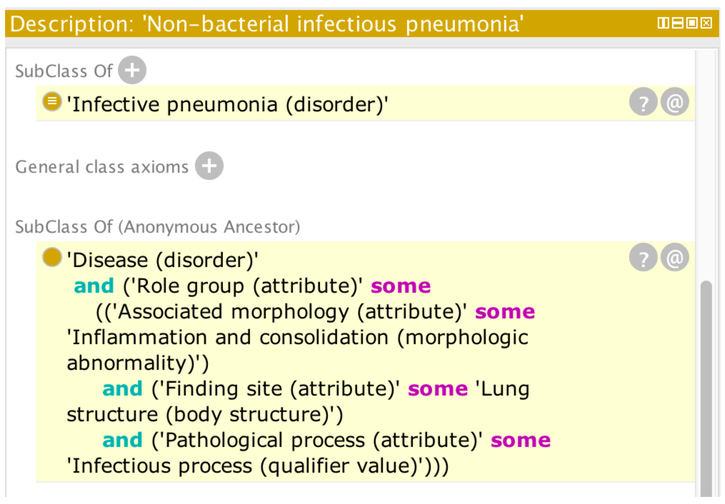

Figure 5. Results of classification showing the inferred subclasses of “Non-bacterial infectious pneumonia”

Further independent testing has been performed using the same version of the updated MORe reasoner for classifying the Singapore Drug Dictionary extension to SNOMED CT, which uses a large number of universal restriction axioms. Using FaCT++ 1.6.5, the classification completed in approx. 14 hours. Using the updated MORe reasoner with FaCT++ the classification completed in approx. 7 hours, showing a similar performance improvement of approx. 50%.

Discussion

The preliminary results of this experiment with the modular reasoning technique and the current version of the updated MORe reasoner, in particular, are encouraging. Further experiments are needed with larger numbers of fully defined concepts requiring negation and other description logic features beyond the capability of EL++. The Singapore Drug dictionary is one example, but testing of other augmented ontologies that use a different mix of description logic features is needed.

Further enhancements to the underlying logic of the MORe reasoner also should be made. The modularization strategy used to distribute the reasoning workload between the reasoners is a likely candidate for significant further improvement.

Conclusion

The initial results of using the modular combination of reasoners for reducing ontology classification time are promising. On tests with two different ontologies, including one with a large number of universal restriction axioms, the performance gain was 50% or greater. Continuing future work is planned to explore using different strategies for module segmentation and potentially different combinations of reasoners in order to achieve further performance improvements. It is also planned to test this reasoning strategy with additional ontology enhancements containing various types and amounts of description logic features extending beyond EL++. If successful, this work may be able to provide support for the effort that is currently underway to explore enhancements to the underlying description logic foundation of SNOMED CT.

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References

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2. Romero AA, Grau BC, Horrocks I. MORe: Modular Combination of OWL Reasoners for Ontology Classification. In Proceedings of the 11th International Semantic Web Conference (ISWC 2012). Springer. 2012.