PMS 509 Knowledge Technologies
Homework II
Academic Year: 2024-2025
Out: December 4, 2024
Due: January 6, 2025 at 23:59
Total Mark: 30%

1. Consider the following RDF graph G:

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix ex: <http://middle-earth.org/> .

ex:Thorin rdf:type ex:Dwarf .
ex:Thrain rdf:Type ex:Dwarf .

ex:Thorin ex:hasFather ex:Thrain .
ex:Thrain ex:hasFather ex:Thor .

ex:Thorin ex:hasTitle "King under the Mountain" .
```

   Express the query "Find all the dwarfs, their fathers and optionally their title" using the algebraic formalism of the paper

   > Jorge Perez, Marcelo Arenas, and Claudio Gutierrez. *Semantics and Complexity of SPARQL*. Proceedings of ISWC 2006.

   which we discussed in class and it is available at `https://marceloarenas.cl/publications/iswc06.pdf`. What is the answer to this query? Show all the steps of its evaluation using the algebra developed in the paper.

   (30 marks)

2. "Translate" the following sentences into $\mathcal{ALCQO}$. If you think that the given sentence cannot be translated into $\mathcal{ALCQO}$, then you should give a translation into first-order logic (remember: $\mathcal{ALCQO}$, like all DLs we studied, is a subset of first-order logic).

   (a) All students are clever.
   (b) There exists one student.
   (c) There exists one clever student.
   (d) Every student likes some student
   (e) Every student likes some other student
   (f) There exists one student that all other students like him.
   (g) Giannis is a student.
   (h) Giannis doesn't follow the Knowledge Technologies module.
   (i) None of the students likes Giannis.
   (j) Giannis has at least one sister.
   (k) Giannis doesn't have a sister.
   (l) Giannis has at most one sister.
   (m) Every student follows at least one module.

(n) Only one student failed the Knowledge Technologies module.

(o) None of the students failed the Knowledge Technologies module but at least one student failed at the Database module.

(p) Every student that follows the Knowledge Technologies module follows also the Logic Programming module.

(q) None of the students can fool all the other students.

(r) A biped is an animal that has exactly two legs.

(s) A triangle is a polygon with exactly three edges and exactly three vertices which are line segments.

(t) A right-angled triangle is a triangle in which one angle is a right angle.

(40 marks)

3. Prove or disprove the following subsumption statements of $\mathcal{ALC}$ where $\mathtt{A}$ and $\mathtt{B}$ is a concept and $\mathtt{R}$ a role:

$$\forall \mathtt{R}.(\mathtt{A} \sqcup \mathtt{B}) \sqsubseteq \forall \mathtt{R}.\mathtt{A} \sqcup \forall \mathtt{R}.\mathtt{B}, \quad \exists \mathtt{R}.(\mathtt{A} \sqcup \mathtt{B}) \sqsubseteq \exists \mathtt{R}.\mathtt{A} \sqcup \exists \mathtt{R}.\mathtt{B}$$

Your proof must use the semantics of $\mathcal{ALC}$.

(20 marks)

4. Describe yourself using exactly 10 $\mathcal{ALCQ}$ expressions. Provide next to each expression the intended meaning in natural language.

(10 marks)

5. Consider the following English sentences:

- Mario is a person.
- Mario has three distinct pets: Yoshi, Francis and Roger.
- Yoshi, Francis and Roger are animals.
- A person which has at least three pets that are animals is an animal lover.
- Mario is an animal lover.

Now answer the following questions:

(a) Give an $\mathcal{ALCQ}$ knowledge base KB which formalizes the first four of the above sentences and an $\mathcal{ALCQ}$ formula ϕ that formalizes the fifth sentence.

(b) Use tableau techniques to prove that $KB \models \phi$.

The description logic $\mathcal{ALCQ}$ has been covered in class. The tableau proof techniques for it have not been covered in class but are covered in the paper: "Franz Baader. Description Logics. In Reasoning Web: Semantic Technologies for Information Systems, 5th International Summer School 2009, volume 5689 of Lecture Notes in Computer Science, pages 1-39. Springer-Verlag, 2009." It is available from `https://lat.inf.tu-dresden.de/research/papers/2009/Baader09.pdf`.

(10+30=40 marks)

6. Consider the following KB:

(a) $RRated \sqsubseteq ThrillerMovie$

(b) $ThrillerMovie \sqsubseteq Movie$

(c) $RRated \equiv (\exists hasScript.ThrillerScript) \sqcup (\forall hasViolenceLevel.High)$

(d) $Person \sqsubseteq \neg Movie$

(e) $\exists hasViolenceLevel.\top \sqsubseteq Movie$

Explain why $Person \sqsubseteq \bot$ is a logical consequence of this KB. Suggest a modification on the above statements to resolve this issue while keeping the statement $Person \sqsubseteq \neg Movie$. Justify your decision.

(10 marks)