M2R Exam
Fundamentals of data processing and distributed knowledge
Semantics of Distributed Knowledge part

Duration : 3h
All documents allowed – *No* communication device allowed

January 2025

Note: Read all the questions carefully before answering. Justify your answers with respect to the semantics: this is the semantics that justifies their correctness.

Time and points are indicative.

Course questions [Expectation: 30mn; 5pts]

Here I give only three examples, but it should be around 10 questions, the answers are in the course in general.

Answers to these questions are generally short (if the answer is more than three sentences, it is probably wrong, except for the last one). They are related to the course content.

1. For what is it useful to query different sources?

2. What does it means for a structure (formula, theory, network, etc.) to be inconsistent?

3. In modal logic, is $S \models S'$ defined by $\forall M, M \models S \Rightarrow M \models S'$ or by $\forall M, \forall w \in W_M, M, w \models S \Rightarrow M, w \models S'$? Does one expression implies the other? Why?

Application [Expectation: 2h; 15pts]

Semantics

Consider the ontology O_3 made of:

$$\mathsf{o3{:}SmallParty} \sqsubseteq \mathsf{o3{:}Party} \qquad \mathsf{o3{:}LargeParty} \sqsubseteq \mathsf{o3{:}Party}$$
$$\mathsf{o3{:}SmallParty} \sqsubseteq \exists_{<3}\mathsf{oo{:}member} \qquad \mathsf{o3{:}LargeParty} \sqsubseteq \exists_{\geq 3}\mathsf{oo{:}member}$$

$\sqsubseteq$ is rdfs:subClassOf, $\exists_{<n}p$ is owl:maxQualifiedCardinality with $c = \mathsf{owl{:}Thing}$, $\exists_{\geq n}p$ is owl:minQualifiedCardinality with $c = \mathsf{owl{:}Thing}$, $\not\approx$ is owl:differentFrom, and $\sqcap$ is owl:intersectionOf.

4. What does $\mathsf{o3{:}LargeParty} \sqsubseteq \mathsf{o3{:}Party} \sqcap \exists_{\geq 3}\mathsf{oo{:}member}$ means (in English)?

5. Does $O_3 \models_{OWL} \mathsf{o3{:}SmallParty\ owl{:}disjointWith\ o3{:}LargeParty}$? Explain why.

6. Consider the RDF statements (as G_3):

d:Group1 rdf:type o3:Party	d:Group2 rdf:type o3:SmallParty	d:Group3 rdf:type o3:Party
d:Group1 oo:member d:Peter	d:Peter owl:differentFrom d:Mai	d:Group3 oo:member d:Rajiv
d:Group1 oo:member d:Mai	d:Mai owl:differentFrom d:Rajiv	d:Group3 oo:member d:Régine
d:Group1 oo:member d:Rajiv	d:Rajiv owl:differentFrom d:Régine	d:Group3 oo:member d:Aïcha
d:Group1 oo:member d:Régine	d:Régine owl:differentFrom d:Aïcha	d:Aïcha owl:differentFrom d:Rajiv

Does $O_3 \cup G_3 \models_{OWL}$ d:Group1 rdf:type o3:SmallParty or $O_3 \cup G_3 \models_{OWL}$ d:Group1 rdf:type o3:LargeParty? Justify why.

7. Does $O_3 \cup G_3 \models_{OWL}$ d:Group3 rdf:type o3:SmallParty or $O_3 \cup G_3 \models_{OWL}$ d:Group3 rdf:type o3:LargeParty? Justify why.

Networks of ontologies and queries

We have three agents having three ontologies O_1, O_2 and O_3 and three alignments $A_{1,2}$, $A_{2,3}$, and $A_{3,1}$. Each agent (a_i) considers the network made of its ontology (O_i) and data (G_i):

O_1	O_2	O_3
o1:SmallGroup $\sqsubseteq$ o1:Group o1:BigGroup $\sqsubseteq$ o1:Group	o2:Single $\sqsubseteq$ o2:Booking o2:Single $\sqsubseteq$ $\exists_{<2}$oo:member o2:Group $\sqsubseteq$ o2:Booking o2:Group $\sqsubseteq$ $\exists_{\geq 2}$oo:member	As above

To which are associated the following graphs:

G_1	G_2	G_3
d:Group1 rdf:type o1:BigGroup d:Group2 rdf:type o1:SmallGroup d:Group3 rdf:type o1:BigGroup	d:Group1 rdf:type o2:Group d:Group2 rdf:type o2:Single d:Group3 rdf:type o2:Group	As above

These ontologies are aligned with the following alignments:

$A_{1,2}$	$A_{2,3}$	$A_{3,1}$
o1:Group $\leq$ o2:Single	o2:Booking $\leq$ o3:LargeParty	o3:SmallParty $\leq$ o1:SmallGroup

We consider the network of ontologies $\langle \Omega, \Lambda \rangle = \langle \{O_1 \cup G_1, O_2 \cup G_2, O_3 \cup G_3\}, \{A_{1,2}, A_{2,3}, A_{3,1}\} \rangle$

8. Is the network $\langle \Omega, \Lambda \rangle$ in normal form? If not, can you put it in it?

9. Can one of the agents infer correspondences between the two others' ontologies, i.e. $\exists i, j, k; \langle \{O_i\}, \{A_{k,i}, A_{i,j}\} \rangle \models_{\Delta} \mu_{k,j}$, and which correspondences?

10. Compute the closure of the network $\langle \{O_1, O_2, O_3\}, \{A_{1,2}, A_{2,3}, A_{3,1}\} \rangle$

11. Is there any incoherent class (that cannot contain an instance in any model) in this network? Explain why?

12. Is the network $\langle \Omega, \Lambda \rangle$ consistent?

13. Can one of these agents detect an inconsistency from $\langle \{O_i \cup G_i\}, \{A_{k,i}, A_{i,j}\} \rangle$? Why?

14. Consider the query $q[?x]$ as:

    SELECT $?x$ WHERE $?x$ rdf:type o3:LargeParty.

    Can you provide the results of $\mathcal{A}(q[?x], G_3)$, $\mathcal{A}(q[?x], O_3)$, $\mathcal{A}(q[?x], O_3 \cup G_3)$, $\mathcal{A}^O(q[?x], O_3 \cup G_3,)$, $\mathcal{A}^O(q[?x], \{O_1 \cup G_1, O_2 \cup G_2\}, \{A_{2,3}^{-1}, A_{3,1}\})$?

Cultural knowledge evolution game and belief revision

Consider the game in which an agent (a_j) asks another (a_i) to provide an object belonging to one of its classes (c_j) (all objects are shared). Agents use alignments between each other to answer the question (if $O_i \cup G_i \models_{OWL} x$ rdf:type c_i and $\langle c_i, \leq, c_j \rangle \in A_{i,j}$, then it will provide x as an answer). The first agent (a_j), decides if the result is correct depending on if $O_j \cup G_j \models_{OWL} x$ rdf:type c_j and notifies the success or failure to a_i. This latter agent will use the adaptation operator refadd provided in the course which will replace the faulty correspondence by its most specific more general and its most general more specific correspondences that have not been proved incorrect.

If agent a_3 asks a_2 for an object in class o3:LargeParty,

15. Which object can a_2 return?

16. What happens if it returns d:Group3?

17. What happens if it returns d:Group2?

18. In case of failure, what would be the changes in the network? Does it render the resulting network of ontologies consistent?

19. More generally, what are the maximal consistent subnetworks of $\langle \Omega, \Lambda \rangle$?

20. What kind of revision did the agent perform?

Open question [Expectation: 15mn; 3pts]

As can be seen from above, in a distributed knowledge system, agents need the system to be in a closed form to safely determine if it is consistent, and thus represent something. It can also be observed, that agents confronted with the reality are able to restore consistency, without knowing it. On the one hand, agents who care about consistency need deductively closed knowledge. On the other one, agents may just ignore consistency and run into it. Can you think of intermediate positions between these two extremes? Could there be alternative options? What could they be useful for?