

Corrected and annotated M2R Exam

Fundamentals of data processing and distributed knowledge

Semantics of Distributed Knowledge part

Duration : 2h15

All documents allowed – *No* communication device allowed

January 2022

Note: Read all the questions carefully before answering. Do not hesitate to justify your answers.
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 mean 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 imply the other? Why?

Application

[Expectation: 1h45; 15pts]

We will consider three simple sources about sports.

Triple/graphs

Here are three sets of triples:

G_2

d:football rdf:type o2:outdry
d:handball rdf:type o2:indry
d:natation rdf:type o2:inwet

G_1

d:football o1:influences d:handball
d:handball o1:influences d:waterpolo
d:natation o1:influences d:waterpolo

G_3

d:football rdf:type o3:grdcoll
d:natation rdf:type o3:wtrind
d:waterpolo rdf:type o3:wtrcoll

4. Draw the RDF graphs corresponding to G_1 and G_3 .
5. Does $G_1 \models_{RDF} \text{d:waterpolo rdf:type o1:wet}$?
6. Does $G_1 \cup G_3 \models_{RDF} \text{d:waterpolo rdf:type o3:wtrcoll. d:handball o1:influences d:waterpolo}$?

Ontologies

Each source has a different ontology based on different criteria. They consider sports as either individual or collective, wet or dry, indoor or outdoor, ball-based or not, etc.

Consider the ontologies O_1 , O_2 and O_3 ($\sqsubseteq = \text{rdfs:subClassOf}$, $\perp = \text{owl:disjointWith}$):

O_2	O_1	O_3
$\text{o2:outdoor} \sqsubseteq \text{o2:sport}$	$\text{o1:dry} \sqsubseteq \text{o1:sport}$	$\text{o3:ground} \sqsubseteq \text{o3:sport}$
$\text{o2:indoor} \sqsubseteq \text{o2:sport}$	$\text{o1:wet} \sqsubseteq \text{o1:sport}$	$\text{o3:water} \sqsubseteq \text{o3:sport}$
$\text{o2:outdoor} \perp \text{o2:indoor}$	$\text{o1:dry} \perp \text{o1:wet}$	$\text{o3:ground} \perp \text{o3:water}$
$\text{o2:outdry} \sqsubseteq \text{o2:outdoor}$	$\text{o1:dryball} \sqsubseteq \text{o1:dry}$	$\text{o3:grdcoll} \sqsubseteq \text{o3:ground}$
$\text{o2:outwet} \sqsubseteq \text{o2:outdoor}$	$\text{o1:drynob} \sqsubseteq \text{o1:dry}$	$\text{o3:grdind} \sqsubseteq \text{o3:ground}$
$\text{o2:outdry} \perp \text{o2:outwet}$	$\text{o1:dryball} \perp \text{o1:drynob}$	$\text{o3:grdcoll} \perp \text{o3:grdind}$
$\text{o2:indry} \sqsubseteq \text{o2:indoor}$	$\text{o1:wetball} \sqsubseteq \text{o1:wet}$	$\text{o3:wtrcoll} \sqsubseteq \text{o3:water}$
$\text{o2:inwet} \sqsubseteq \text{o2:indoor}$	$\text{o1:wetnob} \sqsubseteq \text{o1:wet}$	$\text{o3:wtrind} \sqsubseteq \text{o3:water}$
$\text{o2:indry} \perp \text{o2:inwet}$	$\text{o1:wetball} \perp \text{o1:wetnob}$	$\text{o3:wtrcoll} \perp \text{o3:wtrind}$

7. Draw the ontologies as three RDF graphs representing their hierarchy.
8. Does $O_1 \models_{OWL} \text{o1:wetball} \perp \text{o1:dry}$?
9. Does $G_1 \cup O_1 \models_{OWL} \text{d:waterpolo} \text{ rdf:type } \text{o1:wet}$?
10. Does $G_1 \cup G_3 \cup O_1 \cup O_3 \models_{OWL} \text{d:waterpolo} \text{ rdf:type } \text{o3:water} . \text{d:handball} \text{ o1:influences } \text{d:waterpolo}$?

Query

Some agents would like to take advantage of these three sources and answer queries. Consider the three following queries:

q_1	q_2	q_3
SELECT $?x, ?y$ WHERE $?x \text{ o1:influences } ?y$	SELECT $?x, ?y$ WHERE $?x \text{ o1:influences } ?y$ $?y \text{ rdf:type } \text{o3:water}$	SELECT $?x, ?y$ WHERE $?x \text{ o1:influences } ?y$ $?x \text{ rdf:type } \text{o1:dry}$ $?y \text{ rdf:type } \text{o1:wet}$

11. What are the results of evaluating q_1 , q_2 and q_3 against $O_1 \cup G_1$ ($\mathcal{A}(q[?x, ?y], O_1 \cup G_1)$)?
12. What are the results of evaluating q_1 , q_2 and q_3 against $O_1 \cup O_2 \cup O_3 \cup G_1 \cup G_2 \cup G_3$ ($\mathcal{A}^{O_1 \cup O_2 \cup O_3}(q[?x, ?y], G_1 \cup G_2 \cup G_3)$)?

Alignments

Consider the following alignments between O_1 and the two other ontologies:

$$A_{12} = \{\text{o1:sport} \geq \text{o2:sport}, \text{o1:sport} \leq \text{o2:sport}, \text{o1:dry} \geq \text{o2:outdry}, \text{o1:wetball} \geq \text{o2:inwet}\}$$

$$A_{13} = \{\text{o1:sport} \geq \text{o3:sport}, \text{o1:sport} \leq \text{o3:sport}, \text{o1:dry} \geq \text{o3:ground}, \text{o1:wet} \geq \text{o3:water}\}$$

13. Does $A_{13} \models_{\Delta} \langle \text{o1:wet}, \geq, \text{o3:wtrcoll} \rangle$?
14. Does $\langle \{O_1 \cup G_1, O_3 \cup G_3\}, \{A_{13}\} \rangle \models_{\Delta} \text{d:waterpolo} \text{ rdf:type } \text{o1:wet}$
(or $\langle \text{d:waterpolo}, \text{rdf:type}, \text{o1:wet} \rangle \in Cn_{\langle \{O_1 \cup G_1, O_3 \cup G_3\}, \{A_{13}\} \rangle}^{\omega}(O_1)$)?

Alignment creation game

In the alignment creation game, agents know the leaf class names of other agents' ontologies, but not the definition of these classes, nor subclass (subsumption). The game is played in the following way:

- an agent a asks another agent b to show some object of class c_b ;
- agent b answers with an object o ;
- agent a identifies in its own ontology the most specific class c'_a to which o belongs;
- if A_{ab} does not entail any correspondence $\langle c_a, \geq, c_b \rangle$, then the outcome of the game is UNKNOWN and agent a adds $\langle c'_a, \geq, c_b \rangle$ to A_{ab} ;
- if $\langle c_a, \geq, c_b \rangle \in A_{ab}$ then
 - If $c'_a \sqsubseteq c_a$, then the game is a SUCCESS;
 - Otherwise, the game is a FAILURE and agent a replaces $\langle c'_a, \geq, c_b \rangle$ in A_{ab} by $\langle c''_a, \geq, c_b \rangle$ with c''_a the most specific superclass of c_a and c'_a .

Consider A_{12} between O_1 and O_2 and that agent 1 has received from agent 2 the following set of objects:

c_2	Object	c'_1	status	action
o2:outdry	d:marathon	o1:drynob		
o2:outwet	d:triathlon	o1:drynob		
o2:indry	d:basket	o1:dryball		
o2:inwet	d:diving	o1:drynob		
o2:inwet	d:waterpolo	o1:wetball		
o2:indry	d:judo	o1:drynob		

15. Trace the game by showing how it evolves the alignment A_{12} . I.e. fill the table above (status=SUCCESS, FAILURE, UNKNOWN).
16. What is the content of A'_{12} , the evolution of A_{12} after these 6 games?
17. Is the proposed adaptation always correct?
18. Does it converge to a stable alignment?

Query evaluation revisited

19. Provide a decomposition of query q_3 that an agent using ontology O_1 could use in order to evaluate it with respect the alignments A'_{12} and A_{13} ?
20. Provide the answer of each subquery and how it provides an answer to q_3 .

Epistemic logic model of agent knowledge

21. Provide a multi-agent epistemic axiomatisation T (translation) of $O_1 \cup G_1$, $O_2 \cup G_2$ and $O_3 \cup G_3$ as knowledge and A'_{12} and A_{13} as beliefs.
22. Does $T \models_{DEL} B_1 o_1:influences(d:handball, d:waterpolo) \wedge B_1 o_1:dry(d:handball) \wedge B_1 o_1:wet(d:waterpolo)$?