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

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

January 2023

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; 4pts]

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?

   For accessing/retrieving more information.

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

   It has no model.

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?

   The latter. It entails the former because it will also consider worlds in structures which do not universally satisfy S.

Application [Expectation: 2h; 14pts]

Triple/graphs

Here is a set of triples (called G):

G

d:Ringo o2:likes d:Laura
d:Ringo o2:likes d:Max
d:Max o2:likes d:Laura
d:Laura o2:likes d:Max
d:Laura o2:likes d:Julia

d:Laura o2:hobby d:SurfRidingChamrousse
d:Laura o2:hobby d:ReadingMadameBovary
d:Ringo o2:hobby d:DrumPlaying
d:Max o2:hobby d:HorseRidingCamargue

4. Draw the RDF graphs corresponding to G.

Ontologies

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

O_1

o1:InDoorSport $\sqsubseteq$ o1:Sport
o1:OutDoorSport $\sqsubseteq$ o1:Sport
o1:WinterSport $\sqsubseteq$ o1:OutDoorSport

O_3

o3:PerformingArt $\sqsubseteq$ o3:Art
o3:Literature $\sqsubseteq$ o3:Art
o3:Gaming $\sqsubseteq$ o3:Art

O_2

o2:Person $\sqsubseteq$ foaf:Person
o2:hobby rdfs:domain o2:Person
o2:hobby rdfs:range o2:Activity
o2:Entertainment $\sqsubseteq$ o2:Activity
o2:Sport $\sqsubseteq$ o2:Activity
o2:Person $\sqsubseteq$ $\exists_{=1}$o2:hobby.o2:Activity
o2:Sportperson $\sqsubseteq$ o2:Person $\sqcap$ $\exists_{\geq 1}$o2:hobby.o1:Sport
o2:Geek $\sqsubseteq$ o2:Person $\sqcap$ $\exists_{\geq 1}$o2:hobby.o3:Art
o2:SportFanatic $\sqsubseteq$ o2:Sportperson $\sqcap$ $\forall$o2:likes.o2:SportPerson

and its connection to G ($\in$= rdf:type):

O_1

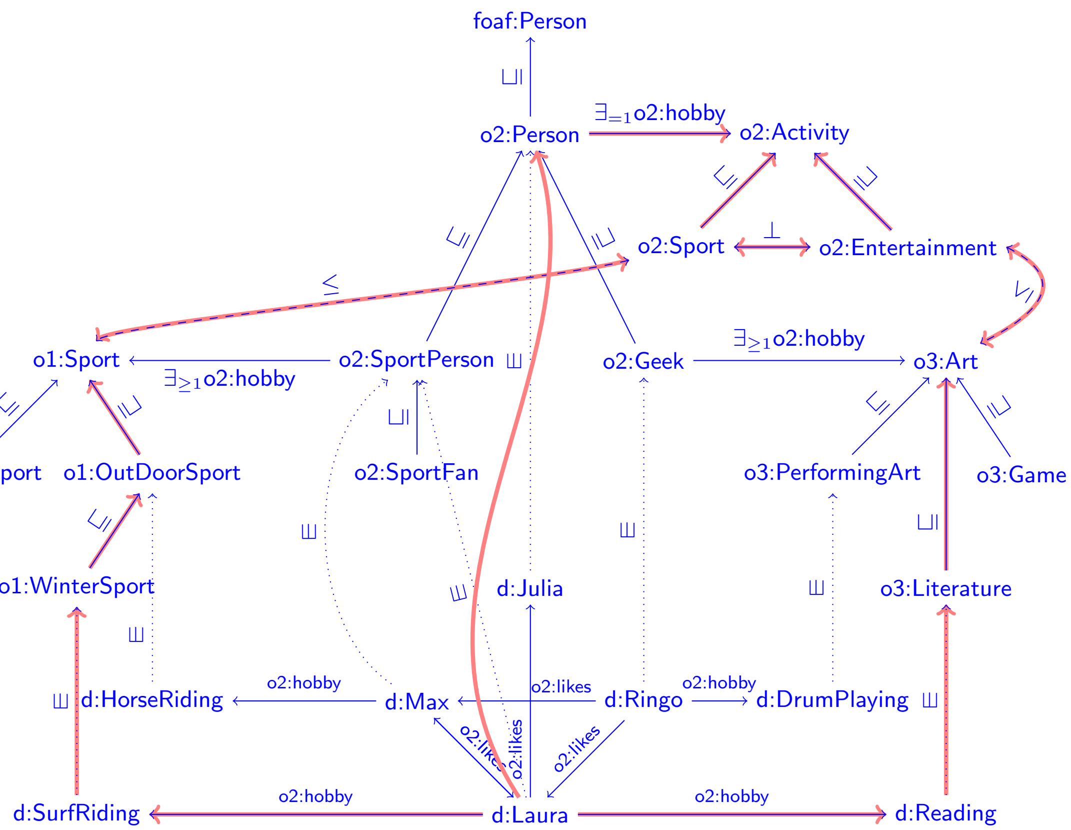
d:SurfRidingChamrousse $\in$ o1:WinterSport
d:HorseRidingCamargue $\in$ o1:OutDoorSport
d:SailingPaladru $\in$ o1:OutDoorSport

O_2

d:Laura $\in$ o2:Person
d:Ringo $\in$ o2:Person
d:Max $\in$ o2:Person
d:Julia $\in$ o2:Person

O_3

d:ReadingMadameBovary $\in$ o3:Literature
d:DrumPlaying $\in$ o3:PerformingArt



5. Is $G \cup O_2$ consistent? Either provide a model or discuss the constraints that could prevent one to exists and why they are violated or not.

Yes. It is possible to provide a model in which each individual is interpreted as itself, except d:SurfRidingChamrousse and d:ReadingMadameBovary interpreted as the same element of Δ. Indeed, each of d:SurfRidingChamrousse, d:ReadingMadameBovary, d:HorseRidingCamargue and d:DrumPlaying are interpreted as elements of [o2:Activity] (because of the rdfs:range constraint). Moreover, d:SurfRidingChamrousse and d:ReadingMadameBovary are both related to d:Laura by o2:hobby, hence they are interpreted as the same object (due to the $\exists_{=1}$o2:hobby constraint on o2:Person). There is an additional o2:Activity (or one of the existing ones) related to d:Julia by o2:hobby ($\exists o \in [o2 : Activity]$; $\langle$d:Julia$, o\rangle \in$ [[o2:hobby]]). This would satisfy all constraints of these ontologies and be a model for RDF or for OWL.

6. Does $G \cup O_2 \models_{RDF}$ d:SurfRidingChamrousse owl:sameAs d:ReadingMadameBovary?

   No. Because there is no owl:sameAs statement in $G \cup O_2$ (see graph above).

7. Does $G \cup O_2 \models_{OWL}$ d:SurfRidingChamrousse owl:sameAs d:ReadingMadameBovary?

   Yes. For the same reason as in Question 5 (d:Laura being a o2:Person, o2:Person having at most one o2:Activity as o2:hobby, d:SurfRidingChamrousse and d:ReadingMadameBovary being o2:Activity and d:Laura's o2:hobby). More semantically, $G \cup O_2$ contains d:Laura $\sqsubseteq$ o2:Person which entails that $|\{x; \langle$d:Laura, o2:hobby$, x\rangle\}| = 1$. $\langle$d:Laura, o2:hobby, d:SurfRidingChamrousse$\rangle \in$ G and $\langle$d:Laura, o2:hobby, d:ReadingMadameBovary$\rangle \in G$ thus d:SurfRidingChamrousse and d:ReadingMadameBovary are o2:Activity because of the rdfs:range constraint. Hence, in any model of $G \cup O_2$, d:SurfRidingChamrousse$^\iota$ = d:ReadingMadameBovary$^\iota$, thus $G \cup O_2 \models_{OWL}$ d:SurfRidingChamrousse owl:sameAs d:ReadingMadameBovary.

8. Does $G \cup O_2 \models_{OWL}$ d:Max rdf:type o2:SportFanatic?

   No (and this holds for the same reasons for the two next questions). Indeed, nothing prevents to build a model such that d:HorseRidingCamargue$^\iota \in [\neg$o1:Sport] (because O_1 is not taken into account). In such a case, d:Max$^\iota \notin$ [o2:SportPerson], and hence d:Max$^\iota \notin$ [o2:SportFanatic].

9. Does $G \cup O_2 \models_{OWL}$ d:Ringo rdf:type o2:SportFanatic?

   No, for the same reason as above with d:DrumPlaying.

10. Does $G \cup O_2 \models_{OWL}$ d:Laura rdf:type $\neg$o2:SportFanatic?

    Neither. For that purpose, it would be necessary that either $G \cup O_2 \models_{OWL}$ d:Laura rdf:type $\neg$o2:Sportperson or $G \cup O_2 \models_{OWL}$ d:Laura rdf:type $\exists_{\geq 1}$o2:likes.$\neg$o2:Sportperson. For the first assertion, it does not hold as nothing prevents that d:SurfRiding$^\iota \in$ [o1:Sport]. The second assertion does not hold either because in the same way, nothing prevents that there exists $o \in$ [o1:Sport] such that $\langle$d:Julia$^\iota, o\rangle \in$ [[o2:hobby]]. Hence, it is possible to build models not satisfying this assertion.

11. Does $O_2 \models_{OWL}$ o2:SportFanatic $\sqsubseteq$ o2:Sportperson?

    Yes. o2:SportFanatic $\sqsubseteq$ o2:Sportperson $\sqcap$ $\forall$o2:likes.o2:SportPerson $\in O_2$, hence in any model of O_2, [o2:SportFanatic] $\subseteq$ [o2:Sportperson] $\cap$ [$\forall$o2:likes.o2:SportPerson], thus [o2:SportFanatic] $\subseteq$ [o2:Sportperson] which means that $O_2 \models_{OWL}$ o2:SportFanatic $\sqsubseteq$ o2:Sportperson.

12. Does $O_2 \models_{OWL}$ o2:Sportperson $\sqsubseteq$ o2:SportFanatic?

    No. For this it would be necessary that all sport person only likes sport persons. Actually, in G there is the example of d:Laura such as for all models of $G \cup O_2$, d:Laura$^\iota \in$ [o2:SportPerson], $\langle$d:Laura$^\iota$, d:Julia$^\iota\rangle \in$ [[o2:likes]] and d:Julia$^\iota \in$ [o2:Person]. The latter statement constrains that there exists a unique $o \in \Delta$ such that $\langle$d:Julia$^\iota, o\rangle \in$ [[o2:hobby]]. It is possible to take $o \in$ o2:Entertainment, i.e. $o \notin$ o2:Sport. Hence, this model does not satisfy d:Julia $\sqsubseteq$ o2:SportPerson because d:Julia does not have a o2:Sport as o2:hobby. That would be a model of $G \cup O_2$, thus a model of O_2 in which a o2:SportPerson (d:Laura) is not a o2:SportFanatic.

Alignments

Consider the following alignments:

A_{12}	A_{23}
o1:Sport $\leq$ o2:Sport	o2:Entertainment $\geq$ o3:Art

13. Does $A_{23} \models_\Delta$ o2:Activity $\geq$ o3:PerformingArt?

    Yes. In any model of of O_2, $[\text{o2:Entertainment}]_2 \subseteq [\text{o2:Activity}]_2$ and in any model of O_3, $[\text{o3:PerformingArt}]_3 \subseteq [\text{o3:Art}]_3$. A model of A_{23} is a pair of models of O_2 and O_3 such that $[\text{o3:Art}]_3 \subseteq \text{o2:Entertainment}]_2$. Hence, in any model of A_{23}, $[\text{o3:PerformingArt}]_3 \subseteq [\text{o2:Activity}]_2$, and thus $A_{23} \models_\Delta$ o2:Activity $\geq$ o3:PerformingArt.

14. Does $A_{12} \models_\Delta$ o2:Sportperson $\sqsubseteq$ o2:Person $\sqcap \exists_{\geq 1}$o2:hobby.o2:Sport?

    No. A_{12} selects pairs of models in which $[\text{o2:Sport}]_2 \supseteq [\text{o1:Sport}]_1$. Elements of o2:Sportperson must have at least one o2:hobby which is a o1:Sport. But there may be o2:Sport which are not o1:Sport. Hence it is possible to satisfy $[\text{o2:Person}]_2 \cap \{o; |\{h \in [\text{o2:Sport}]_2; \langle o, h\rangle \in [[\text{o2:hobby}]]_2\}| \geq 1\}$ but not $[\text{o2:Person}]_2 \cap \{o; |\{h \in [\text{o1:Sport}]_1; \langle o, h\rangle \in [[\text{o2:hobby}]]_2\}| \geq 1\}$.

Belief revision

Consider that we add:

o2:Sport owl:disjointWith o2:Entertainment.

to O_2.

15. Does this make $G \cup O_2$ inconsistent? Why?

    No. This could be the case if one individual would necessarily (in all models) belong to both o2:Sport and o2:Entertainment. The only such candidates in G would be the four persons, but nothing constrain them to be activities, and the four hobbies. However, none of these activities are entailed by $G \cup O_2$ to belong to any of o2:Sport or o2:Entertainment.

16. Does $\langle\{O_1, O_2 \cup G, O_3\}\{A_{12}, A_{23}\}\rangle \models_\Delta$ o1:Sport $\perp$ o3:Art?

    Yes. The models of the network (which are triples of models of O_1, $G \cup O_2$ and O_3 respectively) are individual models of the ontologies satisfying the alignments. Hence, they satisfy $[\text{o1:Sport}]_1 \subseteq [\text{o2:Sport}]_2$ and $[\text{o2:Entertainment}]_2 \supseteq [\text{o3:Art}]_3$ but they also satisfy $[\text{o2:Sport}]_2 \cap [\text{o2:Entertainment}]_2 = \varnothing$. Thus, they all satisfy $[\text{o1:Sport}]_1 \cap [\text{o3:Art}]_3 = \varnothing$ which means that they entail o1:Sport $\perp$ o3:Art.

17. Does this make $\langle\{O_1, O_2 \cup G, O_3\}\{A_{12}, A_{23}\}\rangle$ inconsistent? Why?

    Yes. Because in all models of the network we have: $\text{d:SurfRidingChamrousse}^\iota \in [\text{o1:Sport}]_1$ hence $\text{d:SurfRidingChamrousse}^\iota \in [\text{o2:Sport}]_2$ (for satisfying A_{12}) and $\text{d:ReadingMadameBovary}^\iota \in [\text{o3:Art}]_3$ and thus $\text{d:ReadingMadameBovary}^\iota \in [\text{o2:Entertainment}]_2$ for satisfying A_{23}. But as of Question 7, $G \cup O_2 \models_{OWL}$ d:SurfRidingChamrousse owl:sameAs d:ReadingMadameBovary, thus for all models of this network $\text{d:ReadingMadameBovary}^\iota \in [\text{o2:Sport}]_2 \cap [\text{o2:Entertainment}]_2$ and $[\text{o2:Sport}]_2 \cap [\text{o2:Entertainment}]_2 = \varnothing$. So the network has no model.

18. What are the statements that can be suppressed to restore consistency?

    These are all the 14 statements in red in the diagram above.

Epistemic logic

19. Model the ontologies (without the last axiom added to O_2) and alignments in epistemic logic as in Section 7.6 of the course (Modelling the alignment repair game). This means that three agents are considered each one having an ontology.

Here are the knowledge axioms provided by τ:

K_1 $\mathsf{o1{:}InDoorSport} \sqsubseteq \mathsf{o1{:}Sport}$
K_1 $\mathsf{o1{:}OutDoorSport} \sqsubseteq \mathsf{o1{:}Sport}$
K_1 $\mathsf{o1{:}WinterSport} \sqsubseteq \mathsf{o1{:}OutDoorSport}$
K_1 $\mathsf{o1{:}WinterSport(d{:}SurfRidingChamrousse)}$
K_1 $\mathsf{o1{:}OutDoorSport(d{:}HorseRidingCamargue)}$
K_1 $\mathsf{o1{:}OutDoorSport(d{:}SailingPaladru)}$
K_3 $\mathsf{o3{:}Literature(d{:}ReadingMadameBovary)}$
K_3 $\mathsf{o3{:}PerformingArt(d{:}DrumPlaying)}$
K_3 $\mathsf{o3{:}PerformingArt} \sqsubseteq \mathsf{o3{:}Art}$
K_3 $\mathsf{o3{:}Literature} \sqsubseteq \mathsf{o3{:}Art}$
K_3 $\mathsf{o3{:}Gaming} \sqsubseteq \mathsf{o3{:}Art}$
K_2 $\mathsf{o2{:}Person} \sqsubseteq \mathsf{foaf{:}Person}$
K_2 o2:hobby rdfs:domain o2:Person
K_2 o2:hobby rdfs:range o2:Activity
K_2 $\mathsf{o2{:}Entertainment} \sqsubseteq \mathsf{o2{:}Activity}$
K_2 $\mathsf{o2{:}Sport} \sqsubseteq \mathsf{o2{:}Activity}$
K_2 $\mathsf{o2{:}Person(d{:}Laura)}$
K_2 $\mathsf{o2{:}Person(d{:}Ringo)}$
K_2 $\mathsf{o2{:}Person(d{:}Max)}$
K_2 $\mathsf{o2{:}Person(d{:}Julia)}$

these axioms were not specified in the course and no semantics was given to them:

K_2 $\mathsf{o2{:}Person} \sqsubseteq \exists_{=1}\mathsf{o2{:}hobby.o2{:}Activity}$
K_2 $\mathsf{o2{:}Geek} \sqsubseteq \mathsf{o2{:}Person} \sqcap \exists_{\geq 1}\mathsf{o2{:}hobby.o3{:}Art}$
K_2 $\mathsf{o2{:}Sportperson} \sqsubseteq \mathsf{o2{:}Person} \sqcap \exists_{\geq 1}\mathsf{o2{:}hobby.o1{:}Sport}$
K_2 $\mathsf{o2{:}SportFanatic} \sqsubseteq \mathsf{o2{:}Sportperson} \sqcap \forall \mathsf{o2{:}likes.o2{:}SportPerson}$
K_2 $\mathsf{o2{:}likes(d{:}Ringo, d{:}Laura)}$
K_2 $\mathsf{o2{:}likes(d{:}Ringo, d{:}Max)}$
K_2 $\mathsf{o2{:}likes(d{:}Max, d{:}Laura)}$
K_2 $\mathsf{o2{:}likes(d{:}Laura, d{:}Max)}$
K_2 $\mathsf{o2{:}likes(d{:}Laura, d{:}Julia)}$
K_2 $\mathsf{o2{:}hobby(d{:}Laura, d{:}SurfRidingChamrousse)}$
K_2 $\mathsf{o2{:}hobby(d{:}Laura, d{:}ReadingMadameBovary)}$
K_2 $\mathsf{o2{:}hobby(d{:}Ringo, d{:}DrumPlaying)}$
K_2 $\mathsf{o2{:}hobby(d{:}Max, d{:}HorseRidingCamargue)}$

and for the beliefs:

B_1 $\mathsf{o1{:}Sport} \sqsubseteq \mathsf{o2{:}Sport}$
B_2 $\mathsf{o1{:}Sport} \sqsubseteq \mathsf{o2{:}Sport}$
B_3 $\mathsf{o2{:}Entertainment} \sqsubseteq \mathsf{o3{:}Art}$
B_2 $\mathsf{o2{:}Entertainment} \sqsubseteq \mathsf{o3{:}Art}$

20. What would the effect of the announcement of o2:Sport owl:disjointWith o2:Entertainment be?

The result of the announcement is that each agent suppress from its models all worlds in which the intersection between the interpretation of the two classes is not empty. Agents 1 and 3 do not have constraints on o2:Activity, hence this should not change what they entail except the fact that the announced formula is now knowledge for them. In what concerns Agent 2, in all its models it holds that:

$\mathsf{o2{:}Person} \sqsubseteq \exists_{=1}\mathsf{o2{:}hobby.o2{:}Activity}$
$\mathsf{o2{:}Person(d{:}Laura)}$
$\mathsf{o2{:}Entertainment} \sqsubseteq \mathsf{o2{:}Activity}$
$\mathsf{o2{:}Sport} \sqsubseteq \mathsf{o2{:}Activity}$
o2:Sport owl:disjointWith o2:Entertainment
$\mathsf{o2{:}hobby(d{:}Laura, d{:}SurfRidingChamrousse)}$
$\mathsf{o2{:}hobby(d{:}Laura, d{:}ReadingMadameBovary)}$

Moreover, in the most plausible worlds of its information cell holds:

$\mathsf{o1{:}Sport} \sqsubseteq \mathsf{o2{:}Sport}$
$\mathsf{o2{:}Entertainment} \sqsubseteq \mathsf{o3{:}Art}$

However, nothing constrain that (only known by 3):

$\mathsf{o3{:}Literature(d{:}ReadingMadameBovary)}$
$\mathsf{o3{:}PerformingArt} \sqsubseteq \mathsf{o3{:}Art}$
$\mathsf{o3{:}Literature} \sqsubseteq \mathsf{o3{:}Art}$

Nor that (only known by 1):

$\mathsf{o1{:}WinterSport(d{:}SurfRidingChamrousse)}$
$\mathsf{o1{:}OutDoorSport} \sqsubseteq \mathsf{o1{:}Sport}$
$\mathsf{o1{:}WinterSport} \sqsubseteq \mathsf{o1{:}OutDoorSport}$

The announcement will destroy all the worlds in which all this information holds together because it is inconsistent with it. There will however remain worlds in which this is true

Open question [Expectation: 20mn; 3pts]

A type of belief revision is partial meet revision which computes the intersection between selected maximal consistent subtheories. One problem is to define how to select these subtheories. Cultural knowledge evolution applies a simple adaptation operator (similar to selecting one theory) to restore local consistency. Could you image how to use the cultural knowledge evolution approach to 'perform' partial meet revision?

> One can consider that each agent choose at random one maximal consistent sub-theory. This would make a maxichoice revision. Then, following the cultural evolution, some of these theories will have to be changed again because they are not good enough. This means that some of them would be abandoned. The remaining ones would be those theories consider by the set of agents. In this sense, natural selection, or rather cultural selection, would play the rôle of the selection operation of partial meet revision.
>
> Of course, since agents would not be forced to adopt the intersection of the theories, this is not *stricto sensu* partial meet revision.