M2R Exam – Semantic web: from XML to OWL
Semantic web part

Duration : 1h

Documents allowed – no communication device allowed

October 2016

Note: Read all the questions carefully before answering.

RDF

Consider the graph G describing holiday packages:

```
_:b1 rdf:type o:Package .
_:b1 o:destination d:Salvador .
_:b1 o:accomodation d:PousadaDesArts .
d:PousadaDesArts rdf:type o:Pousada .
_:b1 o:activity _:b2 .
_:b2 rdf:type o:Swimming .
_:b3 rdf:type o:Package .
_:b3 o:destination d:Moskow .
_:b3 o:accomodation d:Metropol .
d:Metropol rdf:type o:GrandHotel .
_:b3 o:activity d:VolgaCruise .
d:VolgaCruise rdf:type o:Cruise .
_:b4 rdf:type o:Package .
_:b4 o:destination d:Kobe .
_:b4 o:accomodation d:ToyofukuRyokan .
d:ToyofukuRyokan rdf:type o:Ryokan .
_:b4 o:activity _:b5 .
_:b5 rdf:type o:SwordFighting .
```

WARNING: the initial subject mentioned `o:type`, instead of `rdf:type`, this was a mistake.

1. Draw the graph G.

   The graph of Figure 1 corresponds to G.

2. Define an RDF-interpretation $\mathcal{I}$ of G.

   WARNING: actually this would be an interpretation of G's vocabulary ($V(G)$). For the next question, I need a model.

   $\mathcal{I} = \langle I_R, I_P, I_{EXT}, \iota\rangle$ such that:

$$
\begin{aligned}
I_R &\supseteq I_P \cup \{B, C, D\} \\
&\quad \cup \{\iota(\mathtt{o{:}Package}), \iota(\mathtt{o{:}Pousada}), \iota(\mathtt{o{:}GdHotel}), \iota(\mathtt{o{:}Ryokan}), \iota(\mathtt{o{:}Swimming}), \\
&\qquad \iota(\mathtt{o{:}Cruise}), \iota(\mathtt{oSwordFighting}), \iota(\mathtt{d{:}Salvador}), \iota(\mathtt{d{:}Moskow}), \iota(\mathtt{d{:}Kobe})\} \\
I_P &\supseteq \{\iota(\mathtt{rdf{:}type}), \iota(\mathtt{o{:}destination}), \iota(\mathtt{o{:}accomodation}), \iota(\mathtt{o{:}activity})\} \\
I_{EXT}(\iota(\mathtt{rdf{:}type})) &\supseteq \{\langle B, \iota(\mathtt{o{:}Package})\rangle, \langle C, \iota(\mathtt{o{:}Swimming})\rangle, \langle \iota(\mathtt{d{:}VolgaCruise}), \iota(\mathtt{o{:}Cruise})\rangle, \\
&\quad \langle D, \iota(\mathtt{o{:}SwordFighting})\rangle, \langle \iota(\mathtt{d{:}PousadaDesArts}), \iota(\mathtt{o{:}Pousada})\rangle, \\
&\quad \langle \iota(\mathtt{d{:}Metropol}), \iota(\mathtt{o{:}GrandHotel})\rangle, \langle \iota(\mathtt{d{:}ToyofukuRyokan}), \iota(\mathtt{o{:}Ryokan})\rangle\} \\
I_{EXT}(\iota(\mathtt{o{:}destination})) &\supseteq \{\langle B, \iota(\mathtt{d{:}Salvador})\rangle, \langle B, \iota(\mathtt{d{:}Moskow})\rangle, \langle B, \iota(\mathtt{d{:}Kobe})\rangle\} \\
I_{EXT}(\iota(\mathtt{o{:}accomodation})) &\supseteq \{\langle B, \iota(\mathtt{d{:}PousadaDesArts})\rangle, \langle B, \iota(\mathtt{d{:}Metropol})\rangle, \langle B, \iota(\mathtt{d{:}ToyofukuRyokan})\rangle\} \\
I_{EXT}(\iota(\mathtt{o{:}activity})) &\supseteq \{\langle B, C\rangle, \langle B, \iota(\mathtt{d{:}VolgaCruise})\rangle, \langle B, D\rangle\}
\end{aligned}
$$

   It is possible to replace $\iota(\dots)$ by $a, b, \dots$ if it makes you more comfortable. This interpretation is a bit peculiar as it interprets all packages as the same with three destinations, but nothing prohibits this.

3. Given the following graph H:

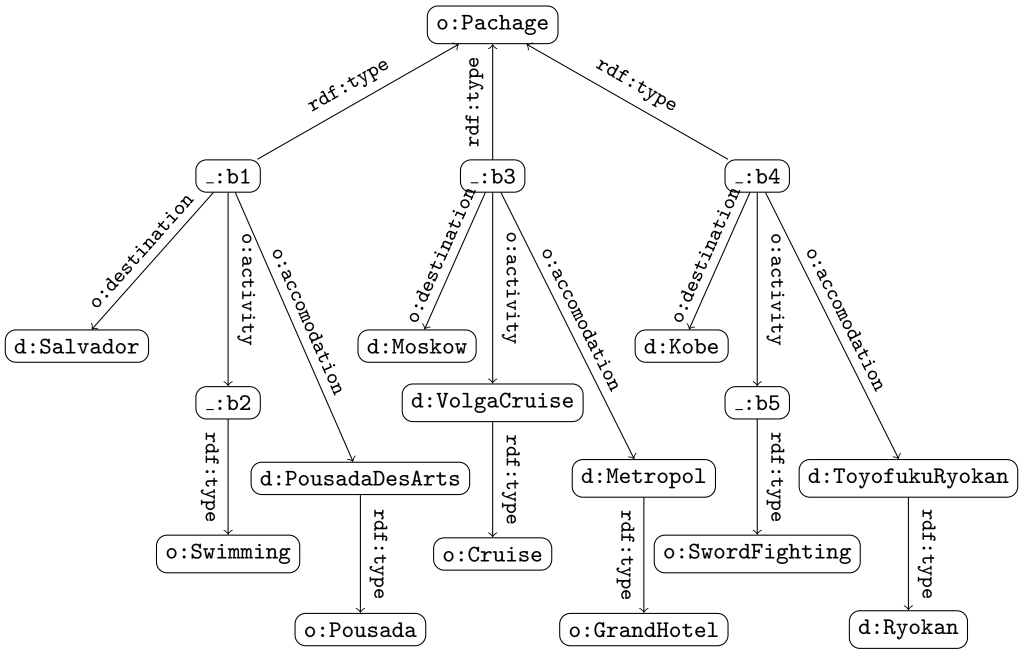

Figure 1: RDF graph G.

```
_:x rdf:type o:Package .
_:x o:accomodation _:acc .
_:x o:activity _:act .
```

Does your interpretation satisfies H (said otherwise, is $\mathcal{I}$ a model of H)?

Yes, $\mathcal{I}$ a model of H as it is possible to find an extension ι' of ι to $\{\texttt{\_:x}, \texttt{\_:act}, \texttt{\_:acc}\}$ satisfying all triples of H. This is the case, for instance if one takes: $\iota' = \iota \cup \{\langle \texttt{\_:x}, B\rangle, \langle \texttt{\_:act}, C\rangle, \langle \texttt{\_:acc}, \texttt{d:PousadaDesArts}\rangle\}$.

4. Does $G \models H$? Show it.

   Any model of G is indeed a model of H. For any model $m = \langle I_R, I_P, I_{EXT}, \iota\rangle$ of G, ι can be extended into ι' such that:

$$\langle \iota'(\texttt{\_:b1}), \iota(\texttt{o:Package})\rangle \in I_{EXT}(\iota(\texttt{rdf:type}))$$
$$\langle \iota'(\texttt{\_:b1}), \iota(\texttt{d:PousadaDesArts})\rangle \in I_{EXT}(\iota(\texttt{o:accomodation}))$$
$$\langle \iota'(\texttt{\_:b1}), \iota'(\texttt{\_:b2})\rangle \in I_{EXT}(\iota(\texttt{o:activity}))$$

   so it is possible to define the extension ι'' of ι' to $\{\texttt{\_:x}, \texttt{\_:act}, \texttt{\_:acc}\}$ such that: $\iota''(\texttt{\_:x}) = \iota'(\texttt{\_:b1})$, $\iota''(\texttt{\_:act}) = \iota'(\texttt{\_:b2})$, and $\iota''(\texttt{\_:acc}) = \iota(\texttt{d:PousadaDesArts})$. ι'' is an extendion of ι and it satisfies all triples of H, hence, m is a model of H. This can also be achieved by showing that there is an RDF-homomorphism from H to G or that an instance of H is a subgraph of G.

5. Given the following graph K:

```
_:y rdf:type o:Package .
_:y o:accomodation _:acc .
_:acc rdf:type o:Local .
_:y o:activity _:act .
_:act rdf:type o:Sport .
```

Does $G \models K$? Tell why.

No, because there is no reference to `o:Sport` in the graph G, hence it is impossible to find an RDF-homomorphism from an instance of K to a subgraph of G as it would need to map the node labelled by `o:Sport` to a node with the same label (see also answer to Question 7).

RDFS and OWL interpretation

Consider the ontology O made of the following statements:

```
o:accomodation rdfs:range o:Accomodation .
o:Local rdfs:subClassOf o:Accomodation .
o:Pousada rdfs:subClassOf o:Local .
o:Ryokan rdfs:subClassOf o:Local .
o:GrandHotel rdfs:subClassOf Accomodation .

o:activity rdfs:range o:Activity .
o:Sport rdfs:subClassOf o:Activity .
o:Swimming rdfs:subClassOf o:Sport .
o:SwordFighting rdfs:subClassOf o:Sport .
o:Visit rdfs:subClassOf o:Activity .
o:Cruising rdfs:subClassOf o:Visit .
```

6. Does $G \models_{RDFS}$ `o:Package rdf:type rdfs:Class`?
   Does $O \models_{RDFS}$ `o:Package rdf:type rdfs:Class`?

   $G \models_{RDFS}$ `o:Package rdf:type rdfs:Class`

   Because `o:Package` is the `rdf:type` of items, this entails that it is a class. Indeed, by the RDF semantics (1), $\langle \iota'(\_\texttt{:b1}), \iota(\texttt{o:Pachage})\rangle \in I_{EXT}(\iota(\texttt{rdf:type}))$; but all axiomatic triples are satisfied (2c) and in particular $\langle$`rdf:type rdfs:range rdfs:Class`$\rangle$ which means that (6c), $\iota(\texttt{o:Package}) \in I_{CEXT}(\iota(\texttt{rdfs:Class}))$ and (6c) $\langle \iota(\texttt{o:Package}), \iota(\texttt{rdfs:Class})\rangle \in I_{EXT}(\iota(\texttt{rdf:type}))$. Since, this is true for all models of G, this means that all these models satisfy $\langle$`o:Package rdf:type rdfs:Class`$\rangle$.

   $O \not\models_{RDFS}$ `o:Package rdf:type rdfs:Class`

   Because, since there is no mention of `o:Package` in O, this does not allow to entail anything about it. More precisely, there is no constraint in O preventing that $\iota(\texttt{o:Package}) \in I_R \setminus Class$.

7. Does $O \cup G \models_{RDF} K$? $O \cup G \models_{RDFS} K$? Explain why.

   $O \cup G \not\models_{RDF} K$

   For this to be satisfied, it would be necessary that an instance of K be a subgraph of $O \cup G$. This would necessitate a triple whose predicate is `rdf:type` and whose object be `o:Sport`. But no such triple exist either in O or in G.

   $O \cup G \models_{RDFS} K$

   Indeed, if one computes the (partial) closure of $O \cup G$, then it contains $\langle \_\texttt{:b5}, \texttt{rdf:type}, \texttt{o:Sport}\rangle$ (and $\langle \texttt{d:ToyofukuRyokan}, \texttt{rdf:type}, \texttt{o:Local}\rangle$) by rule [RDFS11] because, G contains $\langle \_\texttt{:b5}, \texttt{rdf:type}, \texttt{o:SwordFighting}\rangle$ (and $\langle \texttt{d:ToyofukuRyokan}, \texttt{rdf:type}, \texttt{o:Ryokan}\rangle$) and O contains $\langle \texttt{o:Ryokan}, \texttt{rdfs:subClassOf}, \texttt{o:Local}\rangle$ (and $\langle \texttt{o:SwordFighting}, \texttt{rdfs:subClassOf}, \texttt{o:Sport}\rangle$). Thus, it is possible to define an RDF-homomorphism $h : K \to cl(O \cup G)$ such that $h(\_\texttt{:y}) = \_\texttt{:b4}$, $h(\_\texttt{:acc}) = \texttt{d:ToyofukuRyokan}$, $h(\_\texttt{:act}) = \_\texttt{:b5}$ and $h(K) \in cl(O \cup G)$. h is indeed an homomorphism as it preserves the graph structure of K.

8. Given the OWL axiom (making the OWL ontology O'):

$$\begin{aligned}\texttt{o:TonicPackage} \equiv\ & \texttt{o:Package} \\ & \sqcap \exists \texttt{o:accomodation}.(\texttt{o:Local} \sqcap \geq_1 \texttt{o:swimmingPool}) \\ & \sqcap \exists \texttt{o:activity}.\texttt{o:Sport}\end{aligned}$$

Give the OWL interpretation of TonicPackage ($E_C(\texttt{o:TonicPackage})$).

WARNING: The initial exam was not using $\geq_1$ but an equivalent formulation. It will, of course, be corrected accordingly.

$$\begin{aligned}
E_C(\texttt{o:TonicPackage}) = \; & E_C(\texttt{o:Package} \\
& \quad \sqcap \exists \texttt{o:accomodation}.(\texttt{o:Local} \sqcap \geq_1 \texttt{o:swimmingPool}) \\
& \quad \sqcap \exists \texttt{o:activity}.\texttt{o:Sport}) \\
= \; & E_C(\texttt{o:Package}) \\
& \cap E_C(\exists \texttt{o:accomodation}.(\texttt{o:Local} \sqcap \geq_1 \texttt{o:swimmingPool})) \\
& \cap E_C(\exists \texttt{o:activity}.\texttt{o:Sport})) \\
= \; & E_C(\texttt{o:Package}) \\
& \cap \{x | \langle x, y\rangle \in E_R(\texttt{o:accomodation}) \wedge y \in E_C(\texttt{o:Local} \sqcap \geq_1 \texttt{o:swimmingPool})\} \\
& \cap \{x | \langle x, y\rangle \in E_R(\texttt{o:activity}) \wedge y \in E_C(\texttt{o:Sport})\} \\
= \; & E_C(\texttt{o:Package}) \\
& \cap \{x | \langle x, y\rangle \in E_R(\texttt{o:accomodation}) \wedge y \in E_C(\texttt{o:Local}) \cap E_C(\geq_1 \texttt{o:swimmingPool})\} \\
& \cap \{x | \langle x, y\rangle \in E_R(\texttt{o:activity}) \wedge y \in E_C(\texttt{o:Sport})\} \\
= \; & E_C(\texttt{o:Package}) \\
& \cap \{x | \langle x, y\rangle \in E_R(\texttt{o:accomodation}) \\
& \quad \wedge y \in E_C(\texttt{o:Local}) \cap \{z | \#\{\langle z, t\rangle \in E_R(\texttt{o:swimmingPool})\} \geq 1\}\} \\
& \cap \{x | \langle x, y\rangle \in E_R(\texttt{o:activity}) \wedge y \in E_C(\texttt{o:Sport})\}
\end{aligned}$$

9. Does $O \cup O' \cup G \models_{OWL}$ `_:b1 rdf:type o:TonicPackage`? Tell why.

   WARNING: The initial exam was referring to `_:b1` instead of `_:b`, so answers taking this into account are accepted.

   The definition of `o:TonicPackage` constraints its instances have an accomodation that has at least one swimming pool. However, neither O nor G refer to `o:swimmingPool`, hence there can be models of $O \cup O' \cup G$ in which $E_C(\texttt{o:swimmingPool}) = \varnothing$ and thus $E_C(\texttt{o:TonicPackage}) = \varnothing$. Obviously, such models do not satisfy `_:b1 rdf:type o:TonicPackage`. Hence this statement is not a consequence.

10. Can you express a SPARQL query returning all `o:TonicPackage` as defined in the OWL axiom of question 8?

```
SELECT ?p
WHERE {
   ?p rdf:type o:Package .
   ?p o:accomodation ?acc .
   ?acc rdf:type o:Local .
   ?acc o:swimmingPool ?sw .
   ?p o:activity ?act .
   ?act rdf:type o:Sport .
}
```