SAARLAND UNIVERSITY
Prof. Dr. Jana Koehler
Prof. Dr. Jörg Hoffmann

ARTIFICIAL INTELLIGENCE

Theoretical Exercise Sheet 6

Solutions due Tuesday, June 16th, 23:59
Total points of the sheet: 26

Exercise 1: TBox Description — 12 points

(i) Construct a TBox that contains definitions for

`Mother`	`Grandfather`	`Father`
`Aunt`	`Grandmother`	`Uncle`
`Mother-of-at-least-one-male`		

while `Male`, `Female`, and `Person` are concept names and `hasChild`, `isBrotherOf` and `isSisterOf` are role names.

Solution:

$$\begin{aligned}
\texttt{Mother} &\equiv \texttt{Person} \sqcap \texttt{Female} \sqcap \exists \texttt{hasChild}.\top \\
\texttt{Grandfather} &\equiv \texttt{Person} \sqcap \texttt{Male} \sqcap \exists \texttt{hasChild}.(\texttt{Father} \sqcup \texttt{Mother}) \\
\texttt{Father} &\equiv \texttt{Person} \sqcap \texttt{Male} \sqcap \exists \texttt{hasChild}.\top \\
\texttt{Aunt} &\equiv \texttt{Person} \sqcap \texttt{Female} \sqcap \exists \texttt{isSisterOf}.(\texttt{Father} \sqcup \texttt{Mother}) \\
\texttt{Grandmother} &\equiv \texttt{Person} \sqcap \texttt{Female} \sqcap \exists \texttt{hasChild}.(\texttt{Father} \sqcup \texttt{Mother}) \\
\texttt{Uncle} &\equiv \texttt{Person} \sqcap \texttt{Male} \sqcap \exists \texttt{isBrotherOf}.(\texttt{Father} \sqcup \texttt{Mother}) \\
\texttt{Mother-of-at-least-one-male} &\equiv \texttt{Person} \sqcap \texttt{Female} \sqcap \exists \texttt{hasChild}.(\texttt{Male})
\end{aligned}$$

3.5 points

(ii) Formulate the following assertions in natural language:

1. $\texttt{Parent} \equiv \texttt{Person} \sqcap \exists \texttt{hasChild}.(\text{Person})$
2. $\texttt{ProudGranddad} \equiv \texttt{Person} \sqcap \texttt{Male} \sqcap \exists\, \texttt{hasChild}.(\forall \texttt{hasChild}.(\texttt{ComputerScienceStudent}))$

Solution:

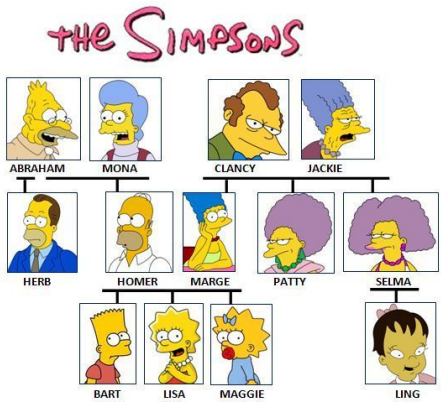
1. *A parent is a person with at least one child which is a person.*

0.5 points

2. *A proud grand-dad is a person who is male with at least one child whose children are all computer science students.*

1 point

You are given the following Simpsons family tree:



(iii) State all possible A-Box membership assertions of concepts for Marge, Lisa and Abraham.

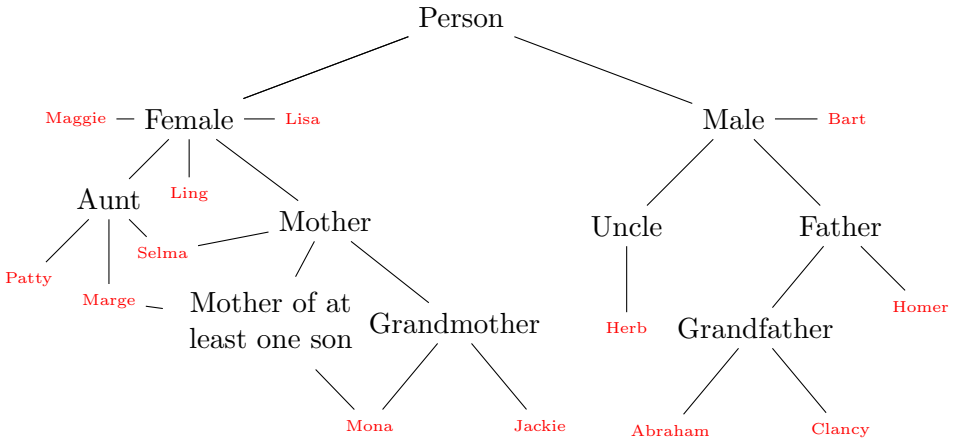
Solution:

$$
\begin{aligned}
Marge &: \texttt{Person} \\
Marge &: \texttt{Female} \\
Marge &: \texttt{Mother} \\
Marge &: \texttt{Mother-of-at-least-one-male} \\
Marge &: \texttt{Aunt} \\
Lisa &: \texttt{Person} \\
Lisa &: \texttt{Female} \\
Abraham &: \texttt{Person} \\
Abraham &: \texttt{Male} \\
Abraham &: \texttt{Father} \\
Abraham &: \texttt{Grandfather}
\end{aligned}
$$

3 points; 1 for each person

(iv) Further, draw a Tree structure displaying dependencies of the T-Box concepts and connect all the A-Box People in the family tree to all their lowest corresponding concepts (careful, there might be more than one for some people!). As a guide, consider the example of Marko and Fluffy in the lecture notes. In this exercise it is however not necessary to include roles.

Solution:



4 points (2 for correct tree structure, 2 for correct assignment of people)

Total points: 12

Exercise 2: Chaotic Metro Plan 6 points

Consider the given metro plan and

- Concept Names:

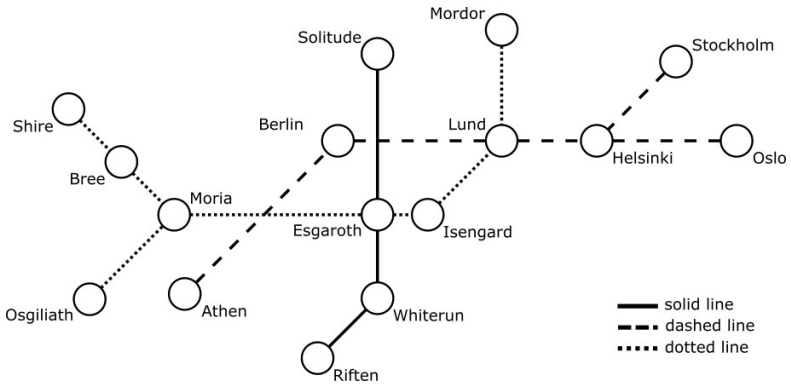
`Station`	the set of metro stations
`ExchangeStation`	the set of metro stations where to change line
`SolidLineStation`	the set of stations on the solid line
`DashedLineStation`	the set of stations on the dashed line
`DottedLineStation`	the set of stations on the dotted line

- Role Names:

`next` the relation between one station and its next stations

- Individual Names:

  `Isengard` the station called "Isengard"
  `Bree` the station called "Bree"
  ...



Specify suitable concept definition for the following assertions:

1. Set of stations which are on both the solid and dashed line
2. Set of exchange stations on the solid line
3. Set of stations which have a next station on the dashed line
4. The set of end stations
5. Exchange stations of the dashed and dotted line (`DashedDottedExchangeStation`)
6. A solid line station is a station
7. Everything next to something is a station
8. Everything that has something next must be a station
9. "Lund" is a station of the dashed line
10. "Esgaroth" is an exchange station between the dotted and the solid line
11. "Berlin" is the stop that follows "Athen"
12. "Moria" is not the next stop of "Helsinki"

Solution:

1. SolidLineStation $\sqcap$ DashedLineStation
2. ExchangeStation $\sqcap$ SolidLineStation
3. Station $\sqcap \exists$next.DashedLineStation
4. Station $\sqcap \forall$next.$\bot$
5. DashedLineStation $\sqcap$ DottedLineStation
6. SolidLineStation $\sqsubseteq$ Station
7. $\top \sqsubseteq \forall$next.Station
8. $\exists$next.$\top \sqsubseteq$ Station
9. Lund:DashedLineStation
10. Esgaroth:SolidDottedExchangeStation
11. (Athen,Berlin):next
12. (Helsinki,Moria):$\neg$next

0.5 points each
Total points: 6

Exercise 3: Subsumptions 8 points

You are given the following $\mathcal{ALS}$ Knowledge base $\mathcal{K}$ with the following concepts

Vehicle, Car, Wheel, Engine, Human, Driver, Adult, Child

the role names

hasPart, poweredBy, controls

and the following assertions

1. Car $\equiv$ Vehicle $\sqcap \exists$*hasPart*.Wheel $\sqcap \exists$*poweredBy*.Engine
2. Driver $\equiv$ Human $\sqcap \exists$*controls*.Vehicle
3. Driver $\sqcap \exists$*controls*.Car $\sqsubseteq$ Adult
4. Human $\sqsubseteq \neg$Vehicle
5. Adult $\equiv$ Human $\sqcap \neg$Child

6. $\texttt{Wheel} \sqcap \texttt{Engine} \sqsubseteq \neg\texttt{Human}$

7. $\texttt{Human} \sqsupseteq \texttt{Adult} \sqcup \texttt{Child}$

Now answer the following questions:

1. Give an example of an instance which shows that the following statement does not hold and briefly explain why (by stating appropriate assertions):
   Human is subsumed by Adult with respect to $\mathcal{K}$.

   Solution:
   Let Karl be a ***Child****. Then Karl is a* ***Human*** *(by the 7th assertion), but Karl is not an Adult (by the 5th assertion).*

   2 points, one for each assertion

2. Show by reformulating using the rules from the lectures and the assumptions above, that the following subsumption holds. In each step explain briefly (or by giving the number of the assertion you are using) why you can reformulate it in this manner.
   $\texttt{Human} \sqcap \exists \textit{controls}.(\texttt{Vehicle} \sqcap \exists \textit{hasPart}.\texttt{Wheel} \sqcap \exists \textit{poweredBy}.\texttt{Engine})$ is subsumed by Adult wrt $\mathcal{K}$.

   Solution: *We can show this by the following reformulation:*

   $$\begin{aligned}
   &\texttt{Human} \sqcap \exists \textit{controls}.(\texttt{Vehicle} \sqcap \exists \textit{hasPart}.\texttt{Wheel} \sqcap \exists \textit{poweredBy}.\texttt{Engine}) \sqcap \\
   &\quad \exists \textit{controls}.(\texttt{Vehicle} \sqcap \exists \textit{hasPart}.\texttt{Wheel} \sqcap \exists \textit{poweredBy}.\texttt{Engine}) \\
   \overset{\textit{slide42}}{\sqsubseteq}\ &\texttt{Human} \sqcap \exists \textit{controls}.\texttt{Vehicle} \sqcap \\
   &\quad \exists \textit{controls}.(\texttt{Vehicle} \sqcap \exists \textit{hasPart}.\texttt{Wheel} \sqcap \exists \textit{poweredBy}.\texttt{Engine}) \\
   \overset{1.}{\equiv}\ &(\texttt{Human} \sqcap \exists \textit{controls}.\texttt{Vehicle}) \sqcap \exists \textit{controls}(\texttt{Car}) \\
   \overset{2.}{\equiv}\ &\texttt{Driver} \sqcap \exists \textit{controls}(\texttt{Car}) \\
   \overset{3.}{\sqsubseteq}\ &\texttt{Adult}
   \end{aligned}$$

   6 points, one for each reformulation and two for duplicating the second disjunct

   Total points: 8

Submission Instructions

Solutions need to be packaged into a `.zip` file and uploaded in the AI CMS. The `.zip` file has to contain a single folder with name:
`AI2020_TE6_mat1_mat2_mat3` where `mat1, mat2, mat3` are the matriculation numbers of the students who submit together. This folder must contain the following files:

- `authors.txt` listing the names and matriculation numbers of all students who submit together. Use one line per student and no spaces: Name;Matriculation number.
- The `.pdf` file containing your solutions.

Do not add any other folder or sub folder, this means place all files directly into `AI2020_TE6_mat1_mat2_mat3`. Do not place any file outside of `AI2020_TE6_mat1_mat2_mat3`.

Only one student of each group needs to do the submission! Remember that this sheet can be submitted in groups of up to three members (all members of the group must however be assigned to the same tutorial).