Exercises on Description Logics and Frames

Exercise 1

Express the following sentences in terms of the description logic $\mathcal{ALC}$ (see slides):

a. All employees are humans.

b. A mother is a female who has a child.

c. A parent is a mother or a father.

d. A grandmother is a mother who has a child who is a parent.

e. Only humans have children that are humans.

Exercise 2

A knowledge base in description logics consists of a TBox and an ABox, i.e. KB = (TBox, ABox).

a. Construct a TBox describing a university. Use concept names such as **University**, **Faculty**, **Education**, **Lecturer**, **Student**, and role names such as **teaches**, **works-for** and **studies-at**.

b. Extend the TBox from the previous item to a knowledge base by constructing an appropriate ABox.

Exercise 3

Consider the following knowledge base in description logic:

$$
\begin{array}{l}
\text{Female} \sqsubseteq \text{Human} \\
\text{Child} \sqsubseteq \text{Human} \\
\text{Works} \sqsubseteq \text{Human} \\
\text{StudiesAtUni} \sqsubseteq \text{Human} \\
\text{SuccessfullMan} \equiv \neg\text{Female} \sqcap \text{InBusiness} \sqcap \exists\text{married.Lawyer} \sqcap \exists\text{child.}(\text{StudiesAtUni} \sqcup \text{Works}) \\
\text{Pedro} : \neg\text{Female} \\
\text{Pedro} : \text{InBusiness} \\
\text{Mary} : \text{Lawyer} \\
\text{John} : \text{Works} \\
(\text{Pedro}, \text{Mary}) : \text{married} \\
(\text{Pedro}, \text{John}) : \text{child}
\end{array}
$$

a. Translate this knowledge base to predicate logic.

b. Use resolution to derive that Pedro is a successful man.

Exercise 4

Which of the following statements are true? Explain your answer.

a. $\forall r.(A \sqcap B) \sqsubseteq \forall r.A \sqcap \forall r.B$

b. $\forall r.A \sqcap \forall r.B \sqsubseteq \forall r.(A \sqcap B)$

c. $\forall r.(A \sqcup B) \sqsubseteq \forall r.A \sqcup \forall r.B$

d. $\forall r.A \sqcup \forall r.B \sqsubseteq \forall r.(A \sqcup B)$

e. $\exists r.(A \sqcap B) \sqsubseteq \exists r.A \sqcap \exists r.B$

f. $\exists r.A \sqcap \exists r.B \sqsubseteq \exists r.(A \sqcap B)$

h. $\exists r.(A \sqcup B) \sqsubseteq \exists r.A \sqcup \exists r.B$

g. $\exists r.A \sqcup \exists r.B \sqsubseteq \exists r.(A \sqcup B)$

Exercise 5

a. Consider the following three frames frame taxonomy T:

class car **is**
  superclass nil;
  wheels = 4;
  seats = 4
end

class sportscar **is**
  superclass car;
  seats = 2
end

instance Rolls-Royce **is**
  instance-of car;
  max-speed = enough
end

Translate the information in the three frames to the description logics $\mathcal{ALC}$. Is the resulting set of formulae consistent or inconsistent? Explain your answer.

b. Consider the following algorithm for single inheritance with exceptions:

```
function Inherit(frame, attr-value-pairs)

   if frame = nil then
     return(attr-value-pairs)
   end;
   pairs ← AttributePart(frame);
   attr-value-pairs ← attr-value-pairs ∪
                      NewAttributes(pairs, attr-value-pairs);
   return(Inherit(Superframe(frame), attr-value-pairs))
end
```

Dealing with exceptions is a form of non-monotonic reasoning. In the algorithm, the function `NewAttributes` removes attribute–value pairs from `pairs` that already occur in the parameter `attr-value-pairs`.

The algorithm operates on a tree-shaped taxonomy, but it is easy to extend it for graph-shaped taxonomies. Indicate how you can do this. Give an example showing that the extended algorithm is not always able to yield correct results for multiple inheritance with exceptions. Discuss ways to resolve these problems.

Exercise 6

a. Consider a frame formalism where attributes can have more than one value at the same time, i.e. all attributes are multi-valued. An attribute is in that case an expression of the following form: $a = \{c_1, \ldots, c_n\}$, $n \geq 1$, where a corresponds to an attribute name and $c_1, \ldots, c_n$ are constants.

Now, consider the following frame:

class F_1 **is**
  superclass F_2;
  $a = \{c_1, c_2, c_3\}$
end

where the keyword **class** indicates that F_1 is a class that has the (not shown) class F_2 as a superclass. Translate the frame to predicate logic.

Next, give an algorithm for inheritance in a tree-shaped taxonomy containing multi-valued attributes that is able to give correct results for inheritance.

b. Consider the following set of frames:

class polyhedron **is**
  superclass nil;
end

class prism **is**
  superclass polyhedron;
  base = (**default** 9);
  height = (**value** 2.9);
  volume = (**demon if-needed** V(base,height))
end

class cube **is**
  superclass prism;
  edge = (**default** 3);
  volume = (**default** 27);
  base = (**demon if-needed** O(edge));
  height = (**demon if-needed** H(edge))
end

instance cube1 **is**
  instance-of cube;
  edge = (**value** 2);
  volume = (**default** 9)
end

Here we make use of so-called *demons*, i.e. procedures that from the values of attributes that act as argument to the demon are able to compute values for the associated attributes. We make a distinction between 'value', 'default' and 'demon' *facets* of an attribute. These facets are processed in a particular order during inheritance. In this case, the demon V is defined as follows: $V(x, y) = x \cdot y$, the demon O as $O(x) = x^2$, and the demon H as $H(x) = x$.

Give a description of a particular form of inheritance that does implement a particular order in the processing of the facets such that the instance 'cube1' obtains the correct values for its attributes.

Give all the attributes with their values that are obtained by inheritance for the instance 'cube1'. Explain how the results were obtained.