Artificial Intelligence

Exercise sheet 2
Predicate Logic, Reasoning & Search Methods

1 Predicate Logic

> *Note: This is a group task, you may solve it in groups up to the size of two people, everybody must however be able to explain all parts of the implementation*

You'll have to extend/adapt the object model from the last exercise (propositional logic).

Exercise 1.1 - Syntax (9 points)

Extend the object model from the exercise of propositional logic **to capture the syntax of predicate logic**. Again, you do not need to implement a parser (the object model can be created programmatically), but the object model must be serializable (you can use textual representation, i.e. "and" representing $\wedge$).

Test your implementation by representing a formula containing **at least one function symbol** and **one quantification**.

2 Reasoning

Note: This is an individual task, you should answer it with your own words.

You'll have to use an integrated development environment (IDE) to **create** and **reason** over a Description Logic (DL) Knowledge Base (KB).

Exercise 2.1 and 2.2 both should be solve in the Protégé Ontology Editor [1], where you can download the Protégé Desktop [2].

You can use the vocabulary in exercise 2.2 to express the knowledge base you'll have to model in exercise 2.1; you may also define your own vocabulary. Protégé offers a lot of graphical support for creating your knowledge base, if you prefer writing the restrictions by hand, the following table outlines some keywords.

DL Syntax	**Protégé Syntax**
Class1 $\sqcap$ Class2	Class1 and Class2
$\exists$ property.Class	property some Class
$\forall$ property.Class	property only Class
$\geq n$ property.Class	property min n Class
$= n$ property.Class	property exactly n Class
$\leq n$ property.Class	property max n Class

For modeling the ontology, the "Entities" tab of the Protégé should be enough, define all properties as "object properties". For querying use the "DL Query" Tab.

Exercise 2.1 (8 points)

Please familiarize yourself with Protégé and represent the following natural language sentences using it. Please use the vocabulary from Exercise 2.2 to describe it.

1. An opera is a musical performance.
2. All actors of an opera are singer.
3. At least one musical ensemble of an opera is an orchestra.
4. A rock concert is another musical performance.
5. Rock concerts and operas are disjoint to each other.

[1] Protégé homepage: `http://protege.stanford.edu`

[2] tutorial available at `http://owl.cs.manchester.ac.uk/publications/talks-and-tutorials/protg-owl-tutorial/`

Exercise 2.2 (8 points)

Please check all Description Logics statements which are entailed by your statements from Exercise 2.1. Please answer if the following statements are entailed or not:

1. MusicalPerformance $\sqsubseteq$ Opera
2. Opera $\sqsubseteq$ MusicalPerformance
3. $\forall$ hasActor.Singer $\sqsubseteq$ Opera
4. Opera $\sqsubseteq$ MusicalPerformance $\sqcap$ $\forall$ hasActor.Singer $\sqcap$ $\exists$ hasMusicalEnsemble.Orchestra
5. Opera $\sqsubseteq$ MusicalPerformance $\sqcap \geq 1$ hasMusicalEnsemble $\sqcap \forall$ hasActor.Singer
6. hasMusicalEnsemble $\sqsubseteq$ Opera
7. Opera $\sqsubseteq$ MusicalPerformance $\sqcap$ $\exists$ hasMusicalEnsemble.Orchestra
8. Opera $\sqsubseteq$ MusicalPerformance $\sqcap = 1$ hasMusicalEnsemble $\sqcap \forall$ hasActor.Singer
9. Opera $\sqsubseteq$ MusicalPerformance $\sqcap$ $\forall$ hasMusicalEnsemble.Orchestra $\sqcap$ $\exists$ hasActor.Singer
10. Opera $\sqsubseteq$ RockConcert
11. RockConcert $\sqsubseteq \neg$ Opera

3 Search Methods

Note: This is an individual task, you should answer it with your own words.

Exercise 3.1 (3 points)

Summarize in a table the most important aspects of the different search strategies and algorithms presented in the lecture.

Exercise 3.2 (9 points)

Given a map of several cities in Spain shown at Figure 3.1 and the road distances between the cities are shown at Table 3.1:

1. Describe the correspondent graph for the search of the shortest path between **Palencia** and **Barcelona**. Justify the selection of the search algorithm and apply it.
2. Which method would you apply to find the path between the aforementioned cities with the minimum number of cities in between? Describe the reason of your choice.

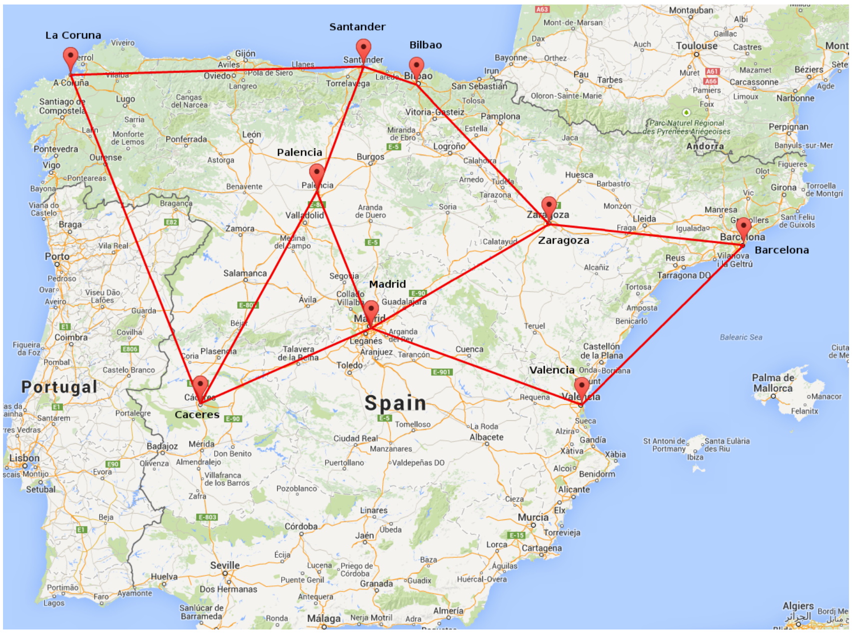

Figure 3.1: Map of several Cities in Spain

	La Coruña	Santander	Bilbao	Palencia	Zaragoza	Cáreces	Madrid	Valencia	Barcelona
La Coruña	-	488	-	-	-	585	-	-	-
Santander	488	-	111	203	-	-	-	-	-
Bilbao	-	111	-	-	323	-	-	-	-
Palencia	-	203	-	-	-	368	239	-	-
Zaragoza	-	-	323	-	-	-	322	-	299
Cáreces	585	-	-	368	-	-	299	-	-
Madrid	-	-	-	239	322	299	-	350	-
Valencia	-	-	-	-	-	-	350	-	352
Barcelona	-	-	-	-	299	-	-	352	-

Table 3.1: Road Distance between the Cities

Exercise 3.3 (8 points)

Table 3.2 shows the estimated flight distance from various cities to Barcelona.

	Bilbao	Cáreces	Madrid	Palencia	Santander	Valencia	Zaragoza	La Coruña
Barcelona	502	850	550	580	605	303	275	1000

Table 3.2: Flight Distance to Barcelona

Using the estimated distance between the cities as the heuristic function, explain which algorithm guarantees the optimal solution for the shortest path problem (**Palencia** - **Barcelona**). Justify your decision and create the search graph with the selected algorithm.