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**Exercise 1** Given the following *ALC* TBox:

- $A \sqsubseteq \neg F$
- $B \sqsubseteq C \sqcap G$
- $C \sqsubseteq F \sqcup \exists R.G$
- $D \sqsubseteq E \sqcap F$
- $E \sqsubseteq \exists R.A$
- $F \sqsubseteq \forall R.B$
- $G \sqsubseteq \forall R.\neg G$

- (a) tell whether the TBox  $\mathcal{T}$  is satisfiable, and if so, show a model for  $\mathcal{T}$ ;
- (b) tell whether the concept  $B$  is satisfiable with respect to  $\mathcal{T}$ , and if so, show a model for  $\mathcal{T}$  where  $B$  is satisfiable;
- (c) tell whether the concept  $D$  is satisfiable with respect to  $\mathcal{T}$ , and if so, show a model for  $\mathcal{T}$  where  $D$  is satisfiable;
- (d) given the ABox  $\mathcal{A} = \{G(a), R(a, b)\}$ , tell whether the knowledge base  $\langle \mathcal{T}, \mathcal{A} \rangle$  entails the assertion  $G(b)$ , explaining your answer.

**Exercise 2** Given the following ASP program P:

```

r(x,y) :- p(x,y,z).
s(y,z) :- p(x,y,z).
t(x,z) :- p(x,y,z).
u(x,y,z) :- r(x,y), s(y,z).
v1(x,y,z) :- u(x,y,z), not t(x,z).
v2(x,y,z) :- u(x,y,z), not r(x,y).
w(x,y) :- u(x,y,z), not v1(x,y,z).
w(x,z) :- w(x,y), w(z,y).
p(a,b,c). p(d,e,f). p(f,b,d).
    
```

- (a) tell whether P is stratified;
- (b) compute the answer sets of P.

**Exercise 3**

We want to formalize knowledge about the domain of movies. In particular, we want to formalize the following statements:

1. every director is a person;
  2. every actor is a person;
  3. the property “worked in” has domain person and range movie;
  4. the property “acted in” has domain actor and range movie;
  5. the property “directed by” has domain movie and range director;
  6. the property “acted in” is a subproperty of “worked in”;
  7. if a director was born in a European country, she/he is a European director;
  8. an actor-director is a director who is also an actor;
  9. every movie directed by an actor-director is a special movie;
  10. every movie directed by a European director is a European movie.
- (a) Choose the most appropriate knowledge representation language for expressing the above knowledge among the following ones: *ALC*, Datalog, Datalog with constraints, ASP, OWL, *DL-Lite<sub>R</sub>*, *EL*, *RL*, RDFS, motivating your choice;
  - (b) express the above knowledge in the formalism chosen at the previous point.

**Exercise 4**

- (a) Write an RDF/RDFS model representing the following statements about URIs **Employee**, **Manager**, **Division**, **TopManager**, **Person**, **Man**, **Woman**, **City**, **livesIn**, **worksWith**, **isManagerOf**, **leadsDivision**, **worksInDivision**, **locatedIn**, **Ann**, **Bob**, **Jane**, **Joe**, **Rome**, **Naples**, **Milan**, **ABC**, **XYZ**.
  1. **Employee**, **Manager**, **TopManager**, **Division**, **Man**, **Woman** and **City** are classes;
  2. **TopManager** is a subclass of **Manager** which is a subclass of **Employee**;

3. `worksWith`, `livesIn`, `isManagerOf`, `leadsDivision` and `locatedIn` are properties;
4. `isManagerOf` is a subproperty of `worksWith`;
5. `isManagerOf` has domain `Manager` and range `Employee`;
6. `worksInDivision` has domain `Employee` and range `Division`;
7. `worksWith` has domain `Employee` and range `Employee`;
8. `livesIn` has domain `Person` and range `City`;
9. `locatedIn` has domain `Division` and range `City`;
10. Jane is a manager;
11. Bob and Ann are employees;
12. Joe is manager of Bob;
13. Jane lives in Rome;
14. Mary leads division XYZ of the company;
15. division ABC is located in Milan.

- (b) Write SPARQL queries corresponding to the following requests: (b1) return all the managers of the male employees that live in Milan; (b2) return the cities of the divisions for which at least a female employee works; (b3) return every manager that works in a division located in Naples, and, optionally, the city where the manager lives.

### Exercise 5

- (a) Write an OWL ontology that formalizes the domain described at point (a) of Exercise 4.
- (b) Add to the above ontology the axioms formalizing the following statements:

1. every manager leads at most one division;
2. `City` and `Division` are disjoint classes;
3. a `SpecialDivision` is a division for which at least four managers work;
4. a `SpecialManager` is a manager that manages at least two male employees and at least two female employees;
5. a `RomanEmployee` is an employee who works in a division located in Rome and lives in Rome.

Then, tell whether the resulting OWL ontology is redundant, i.e.: can some of the axioms constituting the ontology be deleted without changing the meaning of the ontology? if so, identify and list such axioms.

### Exercise 6

Axiomatize the following scenario, appropriately with action precondition and effect axioms, and obtain successor state axioms.

Fluents:

- `doorOpen(s)` - The door is open in situation `s`.
- `robotCloseToDoor(s)` - The robot is close to the door in situation `s`.
- `objectCloseToDoor(s)` - The object is close to the door in situation `s`.

Actions:

- `openDoor` - The robot opens the door. This can be done if the robot is close to the door and the door is closed, and has the effect that the door will be open.
- `closeDoor` - The robot closes the door. This can be done if the robot is close to the door and the door is open, and has the effect that the door will be closed.
- `moveCloseToDoor` - The robot moves close to the door. This can always be done, and has the effect that the robot will be close to the door.
- `moveObject` - The robot pushes the object out of the room. This requires that the object is close to the door, the robot is close to the door and the door is open, and has the effect that the object will be not close to the door.

Initial situation description: Initially the robot is not close to the door, the door is closed, and the object is close to the door.