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Exercises for the practical classes of Knowledge Representation and Reasoning

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Contents

Preface

This document contains a collection of exercises for the subject "Knowledge Representation and Reasoning" of the *Master Degree (MSc) in Information Systems and Computer Engineering*, based on the book *Knowledge representation and reasoning*, by Ronald Brachman and Hector Levesque.

Some of these exercises are taken from the book, some are available in the internet and some I created to use in the practical classes or exams.

1 Introduction

Exercise 1.1 (new)
Explain why an AI system needs knowledge representation and reasoning.

Exercise 1.2 (new)
Explain the need for reasoning in a knowledge-based system.

Exercise 1.3 (new)
Comment the following statement: “The use of meaningful names to represent terms and predicates in a logic representation makes inference easier for the reasoning mechanism.”.

Exercise 1.4 (new)
Explain why logic is such an important language for the area of knowledge representation and reasoning.

2 The Language of First-Order Logic

Exercise 2.1 (new)
Distinguish between *function symbols* and *predicate symbols* in first-order logic. Give one suitable example for each of them.

Exercise 2.2 (new)
In propositional logic an interpretation is composed only by its interpretation function (that is, it does not have a domain). Explain why.

Exercise 2.3 (new)
Explain why it does not make sense to consider an equality function in propositional logic.

Exercise 2.4 (new)
Is first order logic an adequate language to represent a knowledge base about time (time points, time intervals, etc)? Explain why.

Exercise 2.5 (Ch 2, Ex 1)
For each of the following sentences, give a logical interpretation that makes that sentence false and the other two sentences true:

1. $\forall x \forall y \forall z[(P(x, y) \wedge P(y, z)) \supset P(x, z)]$
2. $\forall x \forall y[(P(x, y) \wedge P(y, x)) \supset (x = y)]$
3. $\forall x \forall y[P(a, y) \supset P(x, b)]$

Exercise 2.6 (Ch 2, Ex 4)
In a certain town, there are the following regulations concerning the town barber:

- Anyone who does not shave himself must be shaved by the barber
- Whomever the barber shaves, must not shave himself.

Show that no barber can fulfill these requirements. That is, formulate the requirements as sentences of FOL and show that in any interpretation where the first regulation is true, the second one must be false. (This is called the barber's paradox and was formulated by Bertrand Russel.)

Hint: introduce a constant $barber$ for the *unique* barber and a binary predicate $Shaves(x, y)$ meaning that x shaves y.

Exercise 2.7 (from `http://www.cs.nott.ac.uk/~nza/G53KRR/`)
Consider the following set of sentences:

S1 Andrew is the father of Bob.

S2 Bob is the father of Chris.

S3 Every grandfather is someone´s father.

S4 Andrew is a grandfather of Chris.

1. Translate these sentences into first-order logic, using binary predicates $Father$ and $Grandfather$ and constants a, b, c for Andrew, Bob and Chris.
2. Show semantically (by reasoning about interpretations) that **S1**-**S3** do not logically entail **S4**.
3. Write in first-order logic an additional sentence that defines a general property of grandfathers, and show that **S1**-**S3** together with this new sentence entail **S4**.

Exercise 2.8 (Ch 2, Ex 1)
Consider the following set of sentences:

S1 Five is larger than three.

S2 Three is larger than one.

S3 For every number there is another number that is larger than it (the first number).

S4 Five, three and one are numbers.

S5 Five is larger than one.

1. Translate these sentences into first-order logic.
2. Show semantically (by reasoning about interpretations) that **S1**-**S4** do not logically entail **S5**.
3. Write in first-order logic an additional sentence that defines a general property of numbers, and show that **S1**-**S4** together with this new sentence entail **S5**.

Exercise 2.9 (new)
Consider the following set of sentences:

S1 Jack is Rob's brother.

S2 Rob is Mike's brother.

S3 If one person is someone else's brother, then this second person also is a brother to the first one.

S4 Jack, Rob and Mike are people.

S5 Jack is Mike's brother.

1. Translate these sentences into first-order logic.
2. Show semantically (by reasoning about interpretations) that **S1**-**S4** do not logically entail **S5**.
3. Write in first-order logic an additional sentence that defines a general property of brothers, and show that **S1**-**S4** together with this new sentence entail **S5**.

Exercise 2.10 (new)
Consider the following set of sentences:

S1 Neil likes every person that is nice.

S2 Mike is not annoying.

S3 If a person is not annoying, then that person is nice.

S4 If a person is nice, then there is some other person that likes her.

S5 Neil is a person.

S6 Neil likes Mike.

1. Translate these sentences into first-order logic.
2. Show semantically (by reasoning about interpretations) that **S1**-**S5** do not logically entail **S6**.
3. Write in first-order logic an additional sentence, and show that **S1**-**S5** together with this new sentence entail **S6**.

3 Expressing Knowledge

Exercise 3.1 (Ch 3, Ex 1)
Consider the following piece of knowledge:

> Tony, Mike and John belong to the Alpine Club. Every member of the Alpine Club who is not a skier is a mountain climber. Mountain climbers do not like rain, and anyone who does not like snow is not a skier. Mike dislikes whatever Tony likes, and likes whatever Tony dislikes. Tony likes rain and snow.

1. Prove that the given sentences logically entail that there is a member of the Alpine Club who is a mountain climber but not a skier.
2. Suppose we had been told that Mike likes whatever Tony dislikes, but we had not been told that Mike dislikes whatever Tony likes. Prove that the resulting set of sentences no longer logically entails that there is a member of the Alpine Club who is a mountain climber but not a skier.

4 Resolution

Exercise 4.1 (new)
There is one possible refinement to resolution that consists in eliminating pure clauses from the initial set of clauses (pure clauses are the ones that contain some literal p such that $\neg p$ does not appear anywhere). Explain why this refinement does not change the results obtainable by resolution.

Exercise 4.2 (new)
Define what is a formula in conjunctive normal form. Give one example.

Exercise 4.3 (new)
Explain what it means to say that resolutions is not complete, but is refutation complete. State the consequences of this fact for the proofs made using resolution.

Exercise 4.4 (new)
Explain why automated reasoning systems based on logic (propositional or first order logic) make proofs using resolution and not the logic's semantic system.

Exercise 4.5 (Ch 4, Ex 1)
Determine whether the following sentence is valid using resolution:

$$\exists x \forall y \forall z ((P(y) \supset Q(z)) \supset (P(x) \supset Q(x)))$$

Exercise 4.6 (Ch 4, Ex 2, follow-up of Ch 3, Ex 1)
Use resolution to prove that there exists a member of the Alpine club who is a climber but not a skier.

Exercise 4.7 (new)
Consider the following set of sentences.
Using resolution, prove that $Mammal(winnie)$.

S1 $\forall x[(Animal(x) \land HasHair(x)) \supset Mammal(x)]$

S2 $\forall x[Bear(x) \supset (Animal(x) \land HasHair(x))]$

S3 $\forall x[Rabbit(x) \supset Mammal(x)]$

S4 $Bear(winnie)$

S5 $Rabbit(bugsbunny)$

S6 $Animal(sylvester) \land HasHair(sylvester)$

Exercise 4.8 (new)
Consider the following set of sentences.
Using resolution, prove that $Thick(lordOfTheRings) \land \neg Thick(time)$.

S1 $\forall x[(Book(x) \wedge ManyPages(x)) \supset Thick(x)]$

S2 $\forall x[Magazine(x) \supset (\neg Thick(x) \wedge \neg Book(x))]$

S3 $Book(lordOfTheRings) \wedge Magazine(time)$

S4 $ManyPages(lordOfTheRings)$

Exercise 4.9 (new)
Consider the following set of sentences. Using resolution, prove that $R(a, f(f(a))$.

S1 $\forall x, y, z[(R(x, y) \wedge R(y, z)) \supset R(x, z)]$

S2 $\forall x[R(x, f(x)) \supset R(f(x), f(f(x)))]$

S3 $R(a, f(a))$

Exercise 4.10 (new)
Using resolution, prove that the formula

$$((P \supset \neg R) \wedge (\neg P \supset R)) \supset (\neg(P \wedge R) \wedge \neg(\neg P \wedge \neg R))$$

is a theorem.

5 Reasoning with Horn Clauses

Exercise 5.1 (new)
Explain what is a Horn clause. In particular, explain its difference to a (general) clause.

Exercise 5.2 (new)
Explain how the formulas $A \to B$ and $A \vee B$ would look like as Horn clauses.

Exercise 5.3 (new)
Explain the reason why it is necessary to use at least one positive clause when performing resolution with Horn clauses. In particular, explane why it is not possible to use two negative clauses when applying resolution with Horn clauses.

Exercise 5.4 (new)
Explain why resolution using Horn clauses is more efficient than general resolution (using any types of clauses).

Exercise 5.5 (from `http://www.cse.psu.edu/~catuscia/teaching/cg428/exercises/`)
Assume given a set of facts of the form `father(name1,name2)`, meaning that `name1` is the father of `name2`.

1. Define a predicate `brother(X,Y)` which holds iff `X` and `Y` are brothers.
2. Define a predicate `cousin(X,Y)` which holds iff `X` and `Y` are cousins.
3. Define a predicate `grandson(X,Y)` which holds iff `X` is a grandson of `Y`.
4. Define a predicate `descendant(X,Y)` which holds iff `X` is a descendant of `Y`.
5. Consider the following genealogical tree:

```
father(a,b).  % 1
father(a,c).  % 2
father(b,d).  % 3
father(b,e).  % 4
father(c,f).  % 5
```

whose graphical representation is:

```
      a
     / \
    b   c
   / \  |
  d   e f
```

Say which answers, and in which order, are generated by your definitions for the queries, assuming that you ask for all the solutions (using `;`).

```
?- brother(X,Y).
?- cousin(X,Y).
?- grandson(X,Y).
?- descendant(X,Y).
```

Exercise 5.6 (from `http://www.cse.psu.edu/~catuscia/teaching/cg428/exercises/`)
Define a predicate `mylength(L,N)` which holds iff `N` is the length of the list `L`.

Exercise 5.7 (from `http://www.cse.psu.edu/~catuscia/teaching/cg428/exercises/`)
Define a predicate `sumlist(L,N)` which, given a list of integers `L`, returns the sum `N` of all the elements of `L`.

Exercise 5.8 (from `http://www.cse.psu.edu/~catuscia/teaching/cg428/exercises/`)
Define a predicate `occurrences(X,L,N)` which holds iff the element `X` occurs `N` times in the list `L`.

Exercise 5.9 (from `http://www.cse.psu.edu/~catuscia/teaching/cg428/exercises/`)
Define a predicate `occurs(L,N,X)` which holds iff `X` is the element occurring in position `N` of the list `L`.

Exercise 5.10 (from `http://www.cse.psu.edu/~catuscia/teaching/cg428/exercises/`)
Define a predicate `mymerge(L,K,M)` which, given two ordered lists of integers `L` and `K`, returns an ordered list `M` containing all the elements of `L` and `K`.

Exercise 5.11 (new)
Define a Prolog predicate `invertList(List,Tsil)`, which is true if `Tsil` corresponds to `List` with its elements reversed. You can generate either a recursive or iterative process.

Exercise 5.12 (new)
Define a Prolog predicate `remove(Xs,X,Ys)`, which is true if `Ys` is the result of removing all occurrences of `X` from list `Xs`. You can generate either a recursive or iterative process.

Exercise 5.13 (new)
Explain why the following program for `minimum3` does not produce the expected results.

```
/*
  minimum3(X,Y,Min) :- Min is the minimum of numbers X and Y.
*/
minimum3(X,Y,X) :- X =< Y, !.
minimum3(X,Y,Y).
```

Exercise 5.14 (new)
Explain the problem with Prolog´s cut in the following program:

```
/*
  member3(X,L) :- X is a member of L.
*/
member3(X,[X|_]) :- !.
member3(X,[_|Ys]) :- member3(X,Ys).
```

Note: think about what happens in two different situations: when we need to know if a given element is a member of a list; and when we need to generate all the members of a given list.

6 Procedural Control of Reasoning

Exercise 6.1 (new)
Explain the difference between the following two Prolog rules for identifying a person´s american cousins:

R1 `americanCousin(X,Y) :- american(X), cousin(X,Y).`

R2 `americanCousin(X,Y) :- cousin(X,Y), american(X).`

Exercise 6.2 (new)
Explain why variables in Prolog should be unified as soon as possible.

Exercise 6.3 (new)
Explain why the order of the clauses in a Prolog program can influence its efficiency.

7 Rules in Production Systems

Exercise 7.1 (new)
A *production system* is a forward-chaining reasoning system that uses rules of a certain form called *production rules* as its representation of general knowledge. Its basic operation cycle consists of three steps (1-recognize; 2-resolve conflict; 3-act) that are repeated until no more rules are applicable to the WM, at which point the system halts. Briefly explain each of the three steps.

Exercise 7.2 (new)
Explain why conflict resolution is necessary in production systems. Name and explain two different conflict resolution strategies used by these systems.

Exercise 7.3 (new)
In production systems, production rules have an antecedent and a consequent. Describe what can appear in each component of a production rule and give an example of one production rule.

Exercise 7.4 (new)
Production systems use forward-chaining or backward-chaining? Explain why.

Exercise 7.5 (from `http://www.cs.nott.ac.uk/~nza/G53KRR`)
Explain the notions of rule matching, rule instance, conflict set, and conflict resolution strategy in rule-based systems. Give two examples of common conflict resolution strategies. Illustrate your answers on the following example of rules and working memory elements. State what the conflict set is for the current state of the working memory and which rules will be fired first under each conflict resolution strategy. You can also refer to the conflict set at the next cycle, after the selected rules are fired.

F1 $animal(tiger)$
F2 $animal(cat)$
F3 $large(tiger)$
F4 $eatsMeat(tiger)$
F5 $eatsMeat(cat)$
R1 $\forall x[(animal(x) \land large(x) \land eatsMeat(x)) \supset dangerous(x)]$
R2 $\forall x[animal(x) \supset breathesOxygen(x)]$
R3 $\forall x[dangerous(x) \supset runAwayNow]$

Exercise 7.6 (from `http://www.cs.nott.ac.uk/~nza/G53KRR`)
Explain how decision tables can be used for knowledge elicitation and designing a rule-based expert system.

Exercise 7.7 (from `http://www.cs.nott.ac.uk/~nza/G53KRR`)
Suppose that all you have to work with in designing a rule-based expert system for recognising spam email is the following set of correctly classified messages. Produce a decision table based on this set of examples. Do not include irrelevant checks in the rules.

Message1 Properties: has an attachment, does not contain images, sender is in the receiver's address book, subject line contains "Prize". Decision: spam.

Message2 Properties: no attachments, contains images, sender is not in the receiver's address book, subject line contains "Goods". Decision: spam.

Message3 Properties: has an attachment, contains images, sender is in the receiver's address book, subject line contains "Prize". Decision: spam.

Message4 Properties: no attachments, does not contain images, sender is not in the receiver's address book, subject line does not contain "Prize"or "Goods". Decision: not spam.

Message5 Properties: has an attachment, does not contain images, sender is not in the receiver's address book, subject line contains "Prize". Decision: spam.

Message6 Properties: has no attachments, contains images, sender is in the receiver's address book, subject line contains "Goods". Decision: not spam.

Message7 Properties: has no attachments, does not contain images, sender is not in the receiver's address book, subject line contains "Goods". Decision: spam.

Message8 Properties: has no attachments, contains images, sender is not in the receiver's address book, subject line does not contain "Prize"or "Goods". Decision: not spam.

8 Object-Oriented Representation

Exercise 8.1 (new)
Explain the difference between **if-added** and **if-needed** procedures in frames.

Exercise 8.2 (new)
Explain the difference between frame systems and object oriented programming

Exercise 8.3 (new)
Explain the similarities between frame systems and object oriented programming.

Exercise 8.4 (new)
Consider the following information.

> There are several types of planes: passenger, recreational and military planes. Different types of planes are distinguished according to the people that they transport: people in general, tourists or military personnel, respectively. Each plane can have zero or more motors. Gliders are recreational planes without motor, while passenger planes generally have two motors. The total weight of a plane can be estimated by summing the plane´s weight to the weight of its passengers and its cargo. "Hawk" is a recreational plane and "Enolagay" is a military plane.

1. Represent the hierarchy implicit in this information.
2. Design a set of frames and slots to represent this information.
3. Write in English pseudo-code the **if-added** or **if-needed** procedures that would appear in your representation.

Exercise 8.5 (new)
Consider the following information.

> We need to represent information about several kinds of geometric shapes, namely how many sides they have, their color, area and perimeter. We want to represent circles, rectangles and right triangles. For each of these types of geometric shapes we want to be able to calculate its area and its perimeter. R1 is a blue rectangle that measures 10cm by 5cm.

1. Represent the hierarchy implicit in this information.
2. Design a set of frames and slots to represent this information.
3. Write in English pseudo-code the **if-added** or **if-needed** procedures that would appear in your representation.

Exercise 8.6 (new)
We are interested in representing information about several kinds of people, namely their hair color, their body mass index (BMI), and the interpretation of this index. Someone's BMI is calculated as the person's weight in kilos divided by the square of the person's height in meters. The interpretation of BMI is as follows: BMI less than 18,5 — underweight; BMI between 18,5 and 25 — normal weight; BMI between 25 and 29,9 — overweight; BMI over 30 — obesity. Jack is a person with brown hair.

1. Represent the hierarchy implicit in this information.
2. Design a set of frames and slots to represent this information.
3. Invent the values that are needed to calculate and interpret Jack's BMI.
4. Write in English pseudo-code the **if-added** or **if-needed** procedures that would appear in your representation.

Exercise 8.7 (new)
We are interested in representing information about several types of insurances, that are differentiated according to the type of object that is insured. In particular, we are interested in representing insurance for the filling of the house, insurance for the walls of the house and auto insurance. There are also multi-risk home insurances, which include both insurance for the filling of the house and insurance for the walls of the house. The prize for each type of insurance is calculated as a percentage of the insured value: 0.5% for the walls, 1% for the filling and 2% for auto insurance. GingerbreadHouse is a house and has a multi-risk insurance. Herbie is an automobile.

1. Represent the hierarchy implicit in this information.
2. Design a set of frames and slots to represent this information.
3. Write in English pseudo-code the **if-added** or **if-needed** procedures that would appear in your representation.
4. Invent the values that are needed to calculate the value of the insurance for GingerbreadHouse, represent them, and calculate the value of the insurance.

Exercise 8.8 (Ch 8, Ex 1)
Consider a possible frame-based application for a classroom scheduler.
We want to build a program that helps schedule rooms for classes of various sizes at a university, using the sort of frame technology (frames slots and attached procedures) discussed in the text. Slots of frames might be used to record when and where a class is to be held, the capacity of a room, and so on, and **if-added** and other procedures might be used to encode constraints as well as to fill in implied values when the KB is updated. In this problem, we want to consider updating the KB in several ways: (1) asserting that a class of a given size is to be held in a given room at a given time; the system would either go ahead and add this to its schedule or alert the user that it was not possible to do so; (2) asserting that a class of a given size is to be held at a given time, with the system providing a suitable room (if one is available) when queried; (3) asserting that a class of a given size is desired, with the system providing a time and a place when queried.

1. Design a set of frames and slots to represent the schedule and any ancillary information needed by the assistant.

2. For all slots of all frames, write in English pseudo-code the **if-added** or **if-needed** procedures that would appear there. Annotate these procedures with comments explaining why they are there (e.g., what constraints they are enforcing).

3. Briefly explain how your system would work (what procedures would fire and why they do) on concrete examples of your choosing, illustrating each of the three situations mentioned in the description of the application.

9 Structured Descriptions

Exercise 9.1 (new)
What is the point of description logics (DL)? Why don't knowledge representation professionals use first-order logic for everything?

Exercise 9.2 (new)
Explain how concept classification can be considered as a form of reasoning in description logics.

Exercise 9.3 (new)
Explain in which situations a formula $a \rightarrow b$ is true in description logics.

Exercise 9.4 (new)
Explique quando é que uma fórmula do tipo $d1 \sqsubseteq d2$ tem o valor verdadeiro nas lógicas descritivas.

Exercise 9.5 (from `http://www.cs.nott.ac.uk/~nza/G53KRR`)
Assume that you have an atomic concept `Woman`, roles `Child` and `Employer`, and a constant `ist` for Instituto Superior Técnico. Define the following concepts:

1. Extra-busy is a working mother employed by Instituto Superior Técnico.
2. Someone all of whose children only have female children themselves (that is a person who only has granddaughters, if he or she has any grandchildren).
3. Someone who has children, and all of whose children have children.

Exercise 9.6 (from `http://www.cs.nott.ac.uk/~nza/G53KRR`)
Answer the following questions:

1. Do $d1 \sqsubseteq d2$ and $d2 \sqsubseteq d3$ entail $d1 \sqsubseteq d3$?
2. Do $c \rightarrow d1$ and $d2 \sqsubseteq d1$ entail $c \rightarrow d2$?
3. Do $c \rightarrow d1$ and $d1 \sqsubseteq d2$ entail $c \rightarrow d2$?

Exercise 9.7 (from `http://www.cs.nott.ac.uk/~nza/G53KRR`)
Consider a description logic with the following definition of a concept (note that it is slightly different from the one in the textbook, namely the first concept constructor is new and the forth concept constructor is different from [EXISTS n r]):

- $\top$ is a special atomic concept which describes any object (it is a property which is trivially true for everything).
- An atomic concept is a concept.

- If r is a role and b is a concept, then `[ALL` r b`]` is a concept (describing objects all of whose r-successors are described by b).
- If r is a role and b is a concept, then `[EXISTS` r b`]` is a concept (describing objects which have at least one r-successor which is described by b).
- If r is a role and c is a constant, then `[FILLS` r c`]` is a concept (describing objects which have an r-successor denoted by c).
- If $b_1, \ldots, b_n$ are concepts, `[AND` b_1 `...`b_n`]` is a concept (describing objects which are described by all of $b_1, \ldots, b_n$).

and the following definition of a sentence:

- If b_1 and b_2 are concepts then $b_1 \sqsubseteq b_2$ is a sentence (all b_1s are b_2s).
- If b_1 and b_2 are concepts then $b_1 \doteq b_2$ is a sentence (b_1 is equivalent to b_2).
- If c is a constant and b a concept then $c \to b$ is a sentence (the individual denoted by c satisfies the description expressed by b).

1. Given the atomic concepts `Female`, `Male`, `Person` roles `:Child`, `:Sibling` and constant `alice`, define in the description logic above the following concepts:
   (a) "Mother of Alice" (someone female whose child is Alice).
   (b) "Parent" (someone who has a child).
   (c) "Uncle" (someone male who has a sibling who has a child).
2. Using the same atomic concepts, translate the following sentences into description logic:
   (a) Every grandparent is a parent.
   (b) Alice is a grandmother.

Exercise 9.8 (from `http://www.cs.nott.ac.uk/~nza/G53KRR`)
Recall the description logic DL given in the textbook.
Concepts:

- An atomic concept is a concept.
- If r is a role and b is a concept, then `[ALL` r b`]` is a concept (e.g. `[ALL :Child Girl]` describes someone all of whose children are girls).
- If r is a role and n is a positive integer, then `[EXISTS` n r`]` is a concept (e.g. `[EXISTS 2 :Child]` describes someone who has at least 2 children).
- If r is a role and c is a constant, then `[FILLS` r c`]` is a concept (e.g. `[FILLS :Child john]` describes someone whose child is John).
- If $b_1, \ldots, b_n$ are concepts, `[AND` b_1 `...`b_n`]` is a concept.

Sentences:

- If b_1 and b_2 are concepts then $b_1 \sqsubseteq b_2$ is a sentence (all b_1s are b_2s).
- If b_1 and b_2 are concepts then $b_1 \doteq b_2$ is a sentence (b_1 is equivalent to b_2).
- If c is a constant and b a concept then $c \rightarrow b$ is a sentence (the individual denoted by c satisfies the description expressed by b).

1. Express the following concepts and sentences in DL using constants `john`, `krr`, roles `:Module` and `:Supervision` and atomic concepts `Academic`, `Lecturer`, `Compulsory`:

   C1 Concept of an academic who has some project students (supervises the students).

   C2 Concept of an academic who teaches at least two modules.

   C3 Concept of an academic who teaches only compulsory modules.

   C4 Concept of someone who teaches KRR.

   S1 A lecturer is an academic who has at least 8 project students and teaches at least 2 modules.

   S2 John teaches at least 3 modules and they are all compulsory.

2. At the moment the logic does not contain concept negation `NOT`. It also cannot say that there exists some individual connected by a role which is in a concept b (namely, we have `[ALL` r b`]` but no `[EXISTS` r b`]`). If we add concept negation `NOT`, with the obvious meaning that `[NOT` b`]` is a concept containing all individuals which are not in b, explain how we can then define `[EXISTS` r b`]`.

Exercise 9.9 (new)
Express the following concepts and sentences in DL using the constants, roles and atomic concepts that you find the most useful.

> Computers have at least one input device and one output device, which are input devices and output devices, respectively. Keyboards and mice are different types of input devices. Screens and columns are different types of output devices. C1 is a computer whose keyboard is K1.

What can be inferred about K1?

Exercise 9.10 (new)
Express the following concepts and sentences in DL using the constants, roles and atomic concepts that you find the most useful.

> There are several types of drinks: water, alcoholic drinks and fruit drinks. Drinks are described by their ingredients, which are edible stuff. Alcoholic drinks are also described by their alcohol contents, which is an integer. W1 is a wine whose alcohol contents is 12. F2 is a fruit drink containing water, pineapple juice and coconut juice.

What can be inferred about F2?

Exercise 9.11 (new)
Express the following concepts and sentences in DL using the constants, roles and atomic concepts that you find the most useful. Start by drawing the hierarchy that is implicit in your representation. In the end, indicate what can be inferred from the information that you represented.

> We want to represent information about people and the relationships between them. Mothers are women with children. Uncles are men whose siblings have children. Grandparents are people whose children have children. Mary is the mother of Rita. Nick is Mary's brother. Joan is the mother of Mary and Nick.

Exercise 9.12 (new)
Express the following concepts and sentences in DL using the constants, roles and atomic concepts that you find the most useful. Explicitly state what can be inferred from this information.

> Trees have a trunk and several branches and roots (which are trunks, branches and roots, respectively). Fruit trees are trees that grow fruits. Orange trees are trees that grow oranges. O1 is an orange tree with trunk T1 that grew orange O2.

Exercise 9.13 (new)
Express the following concepts and sentences in the description logic presented in the book, using the constants, roles and concepts that you find the most useful. Start by drawing the hierarchy implicit in this information. In the end, explicitly state what can be inferred from your representation.

> We need to represent information about electronic devices (ED) and its use. Tablets are EDs with a touch-sensitive screen. Computers are EDs with at least one processor and a (non-touch-sensitive) screen. "c1"is a computer and "t1" is a tablet.

Exercise 9.14 (new)
Express the following concepts and sentences in the description logic presented in the book, using the constants, roles and concepts that you find the most useful. Start by drawing the hierarchy implicit in this information. In the end, explicitly state what can be inferred from your representation.

> It is intended to represent information about logic gates: AND, OR and NOT gates. Logic gates have at least one input and exactly one output, all of which are logical values. The possible logical values are TRUE and FALSE. AND gates have two inputs and one output. A1 is an AND gate with inputs TRUE and FALSE.

10 Inheritance

Exercise 10.1 (new)
Explain the difference between *strict inheritance* and *defeasible inheritance*. Explain the main problem that can arise when using defeasible inheritance.

Exercise 10.2 (new)
Explain why the concept of inheritance is useful. Explain the difference between single and multiple inheritance and state a problem that can arise when using multiple inheritance.

Exercise 10.3 (new)
Name and explain the two initial strategies for defeasible inheritance discussed in the book.

Exercise 10.4 (new)
Give an example of an inheritance network where the inheritance mechanisms studied in chapter 10 of the book can find the desired extension but default logic cannot. Explain why this happens.

Exercise 10.5 (new)
Under what circumstances do a credulous reasoner and a skeptical reasoner believe in exactly the same conclusions?

Exercise 10.6 (Ch 10, Ex 1)
Consider the following collection of assertions:

George is a Marine.

George is a chaplain.

A Marine is typically a beer drinker.

A chaplain is typically not a beer drinker.

A beer drinker is typically overweight.

A Marine is typically not overweight.

1. Represent the assertions in an inheritance network.
2. What are the credulous extensions of the network?
3. Which of them are preferred extensions?
4. Give a conclusion that a credulous reasoner might make but that a skeptical reasoner would not.

Exercise 10.7 (new)
Consider the following collection of assertions:

a is a B.

a is a C.

Bs are typically Es.

Cs are typically not Es.

Cs are typically Ds.

Ds are typically Es.

1. Represent the assertions in an inheritance network.
2. What are the credulous extensions of the network?
3. Which of them are preferred extensions?
4. Give a conclusion that a credulous reasoner might make but that a skeptical reasoner would not.

Exercise 10.8 (Ch 10, Ex 1)
Consider the following collection of assertions:

Dick is a Quaker.

Dick is a Republican.

Quakers are typically pacifists.

Republicans are typically not pacifists.

Republicans are typically promilitary.

Pacifists are typically not promilitary.

Promilitary (people) are typically politically active.

Pacifists are typically politically active.

1. Represent the assertions in an inheritance network.
2. What are the credulous extensions of the network?
3. Which of them are preferred extensions?
4. Give a conclusion that a credulous reasoner might make but that a skeptical reasoner would not.

Exercise 10.9 (new)
Consider the following collection of assertions:

a is a C.

a is a D.

b is a E.

Cs are typically Es.

Ds are typically not Es.

Es are typically not Fs.

1. Represent the assertions in an inheritance network.
2. What are the credulous extensions of the network?
3. Which of them are preferred extensions?
4. Give a conclusion that a credulous reasoner might make but that a skeptical reasoner would not.

11 Defaults

Exercise 11.1 (new)
Explain the need for default reasoning. Use a suitable example.

Exercise 11.2 (new)
Explain the difference between a generic rule and a universal rule. Give a suitable example for each of them.

Exercise 11.3 (new)
Explain what the closed world assumption is and why it can be considered as a non-monotonic reasoning mechanism.

Exercise 11.4 (new)
Say if each of the following default rules makes sense, from a representational point of view. Justify your answer.

1. $\frac{A(x) : B(x) \land C(x)}{B(x)}$
2. $\frac{A(x) : B(x)}{A(x)}$
3. $\frac{A(x) : B(x)}{B(x)}$
4. $\frac{A(x) : B(x)}{C(x)}$
5. $\frac{: \neg A(x)}{A(x)}$
6. $\frac{: A(x)}{A(x)}$
7. $\frac{A(x) :}{B(x)}$

Exercise 11.5 (Ch 11, Ex 1)
Although the inheritance networks of Chapter 10 are in a sense much weaker than the other formalisms considered in this chapter for default reasoning, they use default assertions more fully. Consider the following assertions:

> Canadians are typically not francophones.
>
> All Quebecois are Canadians.
>
> Quebecois are typically francophones.
>
> Robert is a Quebecois.

Here is a case where it seems plausible to conclude by default that Robert is a francophone.

1. Represent these assertions in an inheritance network (treating the second assertion as defeasible), and argue that it unambiguously supports the conclusion that Robert is a francophone.

2. Represent these assertions in first-order logic using two abnormality predicates, one for Canadians and one for Quebecois, and argue that, as it stands, minimizing abnormality would not be sufficient to conclude that Robert is a francophone.

3. Show that minimizing abnormality would work if we add the assertion
"All Quebecois are abnormal Canadians",
but will not work if we only add
"Quebecois are typically abnormal Canadians".

4. Repeat the exercise in default logic. Represent the assertions as two facts and two normal default rules, and argue that the result has two extensions. Eliminate the ambiguity using a non-normal default rule.

5. Write a variable-free version of the assertions in autoepistemic logic, and show that the procedure described in the text generates two stable expansions. How can the unwanted expansion be eliminated?

Exercise 11.6 (from `http://www.cs.nott.ac.uk/~nza/G53KRR`)
Consider the following knowledge base:

$$\begin{aligned} KB = \{ & NorthOf(coimbra, faro), \\ & NorthOf(chaves, porto), \\ & NorthOf(coimbra, lisboa), \\ & NorthOf(chaves, coimbra), \\ & \forall x \forall y \forall z [(NorthOf(x,y) \land NorthOf(y,z)) \supset NorthOf(x,z)]\} \end{aligned}$$

1. Does it hold that $KB \models_{CWA} NorthOf(chaves, faro)$? Explain why.

2. Does it hold that $KB \models_{CWA} \neg NorthOf(chaves, faro)$? Explain why.

3. Does it hold that $KB \models_{CWA} NorthOf(porto, faro)$? Explain why.

4. Does it hold that $KB \models_{CWA} \neg NorthOf(porto, faro)$? Explain why.

Exercise 11.7 (from `http://www.cs.nott.ac.uk/~nza/G53KRR`)
For the following KB:

$$\begin{aligned} KB = \{ & SouthOf(milan, paris), \\ & SouthOf(milan, london), \\ & SouthOf(milan, moscow), \\ & paris \neq london, \\ & london \neq moscow, \\ & paris \neq moscow, \\ & \neg WarmerThan(milan, paris) \lor \neg WarmerThan(milan, london), \\ & \forall x[(SouthOf(milan, x) \land \neg Ab(x)) \supset WarmerThan(milan, x)]\} \end{aligned}$$

state whether the following sentences are minimally entailed, and explain why:

1. $WarmerThan(milan, moscow)$
2. $WarmerThan(milan, london)$

Exercise 11.8 (from `http://www.cs.nott.ac.uk/~nza/G53KRR`)
Consider the following knowledge base:

S1 Cats usually don't attack people.

S2 Wild cats are cats.

S3 Wild cats when threatened attack people.

S4 a is a cat.

S5 b is a wild cat and is different from a.

S6 b is threatened.

1. Translate this knowledge base into first-order logic, using the circumscription approach to translate the default rule **S1**. Translate **S2** and **S3** as normal first order implications, which are true without exceptions. Use unary predicates C for cat, W for wild cat, A for attack people, T for being threatened.
2. Does this knowledge base minimally entail $\neg A(a)$ (a does not attack people)? Why?
3. Does this knowledge base minimally entail $\neg A(b)$ (b does not attack people)? Why?
4. Translate this knowledge base into default logic.
5. What can you conclude about a and b using default logic?
6. Translate this knowledge base into autoepistemic logic.
7. What can you conclude about a and b using autoepistemic logic? Why?

Exercise 11.9 (new)
Consider the following knowledge base:

S1 Birds usually fly

S2 Penguins are birds

S3 Parrots are birds

S4 Penguins do not fly

S5 Bob is a penguin

S6 Carl is a parrot

S7 Carl is different from Bob

1. Translate this knowledge base into first-order logic, using the circumscription approach to translate the default rule **S1**.
2. Does this knowledge base minimally entail that Bob flies? Justify your answer.
3. Does this knowledge base minimally entail that Carl flies? Justify your answer.
4. Translate this knowledge base into default logic.
5. What can you conclude about Bob and Carl using default logic? Justify your answer.
6. Translate this knowledge base into autoepistemic logic.
7. What can you conclude about Bob and Carl using autoepistemic logic? Justify your answer.

Exercise 11.10 (new)
Consider the following knowledge base:

S1 Mollusks usually have a shell.

S2 Cephalopods are mollusks.

S3 Cephalopods usually do not have a shell.

S4 All nautilus are cephalopods.

S5 Nautilus usually have a shell.

S6 Nau is a nautilus.

1. Translate this knowledge base into first-order logic, using the circumscription approach to translate the default rules.
2. Does this knowledge base minimally entail that Nau has a shell? Justify your answer.
3. Translate this knowledge base into default logic.
4. What can you conclude about Nau using default logic? Justify your answer.
5. Translate this knowledge base into autoepistemic logic.
6. What can you conclude about Nau using autoepistemic logic? Justify your answer.

Exercise 11.11 (new)
Consider the following knowledge base:

S1 Eggs usually have cholesterol.

S2 Normal eggs are eggs.

S3 Brudy eggs are eggs.

S4 Brudy eggs do not have cholesterol.

S5 O1 is a normal egg.

S6 B1 is a Brudy egg.

S7 O1 and B1 are different from each other.

1. Translate this knowledge base into first-order logic, using the circumscription approach to translate the default rules.
2. Does this knowledge base minimally entail that O1 and B1 have cholesterol? Justify your answer.
3. Translate this knowledge base into default logic.
4. What can you conclude about O1 and B1 using default logic? Justify your answer.
5. Translate this knowledge base into autoepistemic logic.
6. What can you conclude about O1 and B1 using autoepistemic logic? Justify your answer.

12 Vagueness, Uncertainty, and Degrees of Belief

Exercise 12.1 (new)
Explain the notion of a *vague predicate*. Give an example of a vague predicate along with its *degree curve*.

Exercise 12.2 (new)
Explain how conjunctions and disjunctions are handled in fuzzy logics.

Exercise 12.3 (new)
Explain the meaning of the two values used in Dempster-Shafer theories to represent degrees of belief.

Exercise 12.4 (new)
Explain the need for fuzzy reasoning systems, that is, explain why we sometimes need to consider that something is not 100% true nor 100% false.

Exercise 12.5 (Ch 12, Ex 2)
Consider the following example:

> Metastatic cancer (a) is a possible cause of a brain tumor (c) and is also an explanation for an increased total serum calcium (b). In turn, either of these could cause a patient to fall into occasional coma (d). Severe headache (e) could also be explained by a brain tumor (c).

1. Represent these causal links in a belief network. Let a stand for 'metastatic cancer', b for 'increased total serum calcium', c for 'brain tumor', d for 'occasional coma', and e for 'severe headaches'.
2. Give an example of an independence assumption that is implicit in this network.
3. Suppose the following probabilities are given:

   $Pr(a) = 0.2$

   $Pr(b|a) = 0.8$

   $Pr(b|\neg a) = 0.2$

   $Pr(c|a) = 0.2$

   $Pr(c|\neg a) = 0.05$

   $Pr(e|c) = 0.8$

   $Pr(e|\neg c) = 0.6$

   $Pr(d|b \wedge c) = 0.8$

   $Pr(d|b \wedge \neg c) = 0.8$

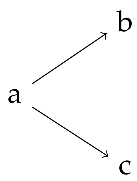
   $Pr(d|\neg b \wedge c) = 0.8$

   $Pr(d|\neg b \wedge \neg c) = 0.05$

and assume that it is also given that some patient is suffering from severe headaches (e) but has not fallen into a coma ($\neg d$). Calculate joint probabilities for the eight remaining possibilities (that is, according to whether a, b, and c are true or false).

4. According to the numbers given, the a priori probability that the patient has metastatic cancer is 0.2. Given that the patient is suffering from severe headaches but has not fallen into a coma, are we now more or less inclined to believe that the patient has cancer? Explain.

Exercise 12.6 (from `http://www.cs.nott.ac.uk/~nza/G53KRR`)
Given the following belief network:



And the following probabilities:

$$Pr(a) = 1/5$$

$$Pr(b|a) = 2/3$$

$$Pr(b|\neg a) = 1/6$$

$$Pr(c|a) = 1/6$$

$$Pr(c|\neg a) = 2/3$$

1. Give an example of an independence assumption that is implicit in this network.
2. What is the probability that a, b and c are all true?
3. What is the probability that a, b and c are all false?
4. What is the probability of $b \wedge c$?
5. Is $b \wedge c$ more probable given that a is true or given that a is false?

Exercise 12.7 (new)
Consider that a influences c and d. b also influences d. The following probabilities are given:

$$Pr(a) = 1/3$$

$$Pr(b) = 1/6$$

$$Pr(c|a) = 2/3$$

$$Pr(c|\neg a) = 1/6$$

$Pr(d|a \wedge b) = 1/6$

$Pr(d|a \wedge \neg b) = 2/6$

$Pr(d|\neg a \wedge b) = 1/6$

$Pr(d|\neg a \wedge \neg b) = 3/6$

1. Represent these causal links in a belief network.
2. Give an example of an independence assumption that is implicit in this network.
3. What is the probability that a, b and c are all true?
4. What is the probability that a, b and d are all false?
5. What is the probability of $c \wedge \neg d$?

Exercise 12.8 (new)
Consider the following information:
Michael usually has a headache (ha) if he has a cold (c) or if he worked late the previous night (lpn). If Michael has a headache, he will probably be grumpy (gr).

1. Represent these causal links in a belief network.
2. Give an example of an independence assumption that is implicit in this network.
3. The following probabilities are given:

   $Pr(c) = 0.1$
   $Pr(lpn) = 0.3$
   $Pr(ha|c \wedge lpn) = 0.9$
   $Pr(ha|c \wedge \neg lpn) = 0.7$
   $Pr(ha|\neg c \wedge lpn) = 0.6$
   $Pr(ha|\neg c \wedge \neg lpn) = 0.01$
   $Pr(gr|ha) = 0.6$
   $Pr(gr|\neg ha) = 0.1$

   What is the probability that ha, c e gr are all true?
4. What is the probability that lpn, ha e gr are all false?
5. What is the probability of $lpn \wedge \neg gr$?

Exercise 12.9 (Adapted from Ch 12, Ex 4)
Consider the following information:
Sore elbows (soe) and sore hands (soh) can be the result of arthritis (a). Arthritis is also a possible cause of tennis elbow (tel), which in turn may cause sore elbows. Ultra-dry hands (dh) can also cause sore hands.

1. Represent these causal links in a belief network.
2. Give an example of an independence assumption that is implicit in this network.
3. The following probabilities are given:

   $Pr(a) = 0.001$
   $Pr(dh) = 0.01$
   $Pr(tel|a) = 0.0001$
   $Pr(tel|\neg a) = 0.01$
   $Pr(soh|a \wedge dh) = Pr(soe|a \wedge tel) = 0.1$
   $Pr(soh|a \wedge \neg dh) = Pr(soe|a \wedge \neg tel) = 0.99$
   $Pr(soh|\neg a \wedge dh) = Pr(soe|\neg a \wedge tel) = 0.99$
   $Pr(soh|\neg a \wedge \neg dh) = Pr(soe|\neg a \wedge \neg tel) = 0.00001$

   What is the probability that a, dh, tel and soh are all true?
4. What is the probability that a, dh, tel and soe are all false?
5. What is the probability of $a \wedge \neg dh$?

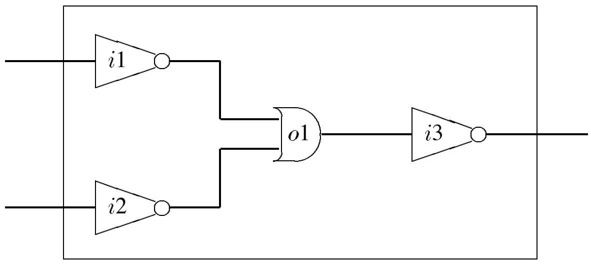
13 Explanation and Diagnosis

Exercise 13.1 (new)
Explain why we can say that, in some sense, abductive reasoning is the converse of deductive reasoning. Include in your explanation one example application for each type of reasoning.

Exercise 13.2 (new)
Explain the difference between *abductive diagnosis* and *consistency-based diagnosis*.

Exercise 13.3 (new)
Explain the use of abductive reasoning. Give an example of a situation where it would be useful.

Exercise 13.4 (Ch 13, Ex 3)
Consider the binary circuit for logical AND depicted in this figure, where $i1$, $i2$ and $i3$ are logical inverters, and $o1$ is an OR gate.



1. Write sentences describing this circuit: its components, connectivity, and normal behaviour.

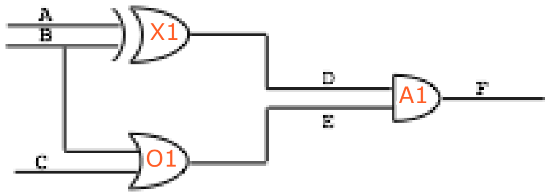
2. Write a sentence for a fault model saying that a faulty inverter has its output the same as its input.

3. Assuming the above fault model and that the output is 1 given inputs of 0 and 1, generate the three abductive explanations for this behaviour.

4. Generate the three consistency-based diagnoses for this circuit under the same conditions.

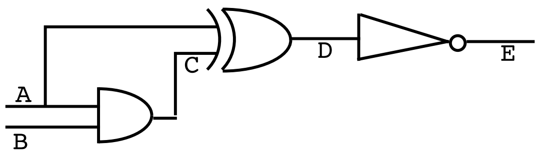
5. Compare the abductive and consistency-based diagnoses and explain informally why they are different.

Exercise 13.5 (new)
Consider the binary circuit depicted in this figure, using the usual notation for logical gates.



1. Write sentences describing this circuit: its components, connectivity, and normal behaviour.
2. Write sentences for a fault model saying that a faulty OR has its output the same as its first input and that a faulty XOR has its output the same as its second input.
3. Assuming the above fault model and that the output is 0 given inputs of $A = 1$, $B = 0$ and $C = 1$, generate the abductive explanations for this behaviour.
4. Generate the consistency-based diagnoses for this circuit under the same conditions.

Exercise 13.6 (new)
Consider the binary circuit depicted in this figure, using the usual notation for logical gates.



1. Write sentences describing this circuit: its components, connectivity, and normal behaviour.
2. Write sentences for a fault model saying that a faulty AND has its output the same as its first input and that a faulty XOR has its output the same as its second input.
3. Assuming the above fault model and that the output is 0 given inputs of $A = 1$ and $B = 1$, generate the abductive explanations and the consistency-based diagnoses for this behavior.

14 Actions

Exercise 14.1 (new)
Explain why the *frame axioms* are needed in situation calculus. Give an illustrating example.

Exercise 14.2 (new)
Explain what are the *fluents* in situation calculus. Give an illustrating example.

Exercise 14.3 (new)
Explain two of the limitations of situational calculus.

Exercise 14.4 (new)
Comment the following statement: "situational calculus uses as a representation language a fragment of first order logic, namely propositional logic".

Exercise 14.5 (Ch 14, Ex 1)
In the exercises below, and in the follow-up exercises of Chapter 15, we consider three application domains where we would like to be able to reason about action and change:

Pots of water: Consider a world with pots that may contain water. There is a single fluent $Contains$, where $Contains(p, w, s)$ is intended to say that a pot p contains w litres of water in situation s. There are only two possible actions, which can always be executed: $empty(p)$ which discards all the water contained in the pot p, and $transfer(p, p')$, which pours as much water as possible without spilling from pot p to p', with no change when $p = p'$. To simplify the formalization, we assume that the usual arithmetic constants, functions and predicates are also available. (You may assume that axioms for these have already been provided or built-in.)

1. Write the precondition axioms for the actions.
2. Write the effect axioms for the actions.
3. Show how successor state axioms for the fluents would be derived from these effect axioms.
4. Show how frame axioms are logically entailed by the successor state axioms.

Exercise 14.6 (from `http://www.ime.usp.br/~liamf/cursoLegolog`)
Consider a world consisting of way stations connected by pathways that can run north, east, south and west; at any location, there may not be pathways leading in all of the directions. You wish to navigate a robot around this world. The state of the robot is governed by two fluents:

- $Location(x, s)$ — the robot is located at way station x in situation s

- $Direction(x, s)$ — the robot is facing direction x ($north$, $east$, $south$, $west$) in situation s

The robot is capable of performing the following actions:

- $forward$ which takes it to the next station in the direction it is facing
- $turnClockwise$ changes its direction 90 degrees by turning in a clockwise direction

You may also assume the following relations:

- $Connected(x, y, direction)$ — the robot can go from location x to location y by moving forward if it is facing $direction$
- $Clockwise(x, y)$ — when facing direction x a clockwise turn by 90 degrees will make it face direction y

There are also constant symbols for each of the way stations but for our purposes here it is sufficient to distinguish only two of them: $home$ and $depot$.

1. Write the precondition axioms for the actions.
2. Write the effect axioms for the actions.
3. Write the successor state axioms for $Location$ which can be derived from the previous axioms.

Exercise 14.7 (new)
Consider a situation where you want a robot to make a simple eggnog (egg yolk mixed with sugar). The robot can have or not have a bowl, have or not have egg yolks, have or not have sugar. The state of the robot is controlled in the world by the following fluents:

- $HasBowl(x, s)$ — the robot has bowl x in situation s.
- $HasYolk(x, s)$ — the robot has yolk x in situation s.
- $HasSugar(x, s)$ — the robot has sugar x in situation s.
- $HasYolkInBowl(x, y, s)$ — the robot has yolk x in bowl y in situation s.
- $HasSugarInBowl(x, y, s)$ — the robot has sugar x in bowl y in situation s.
- $HasEggnogInBowl(x, y, s)$ — the robot has eggnog x in bowl y in situation s.

The robot can perform the following actions:

- $grabBowl$ the robot grabs a bowl.
- $putYolk$ the robot puts the yolk in the bowl.
- $putSugar$ the robot puts the sugar in the bowl.

- $makeEggnog$ the robot mixes the yolk with the sugar in the bowl.

We can also assume that:

- The robot can always grab a bowl (and he has a bowl after that).
- If the robot has a yolk and has a bowl, he can put the yolk in the bowl.
- If the robot has sugar and has a bowl, he can put the sugar in the bowl.
- If the yolk and the sugar are in the bowl, the robot can mix them together.

1. Write the precondition axioms for the actions.
2. Write the effect axioms for the actions.
3. Write the successor state axioms for $HasSugarInBowl$ which can be derived from the previous axioms.

15 Planning

Exercise 15.1 (new)
Explain the difference between *progressive planning* and *regressive planning*.

Exercise 15.2 (new)
Explain why it is not practical to use resolution theorem proving over the situation calculus for planning.

Exercise 15.3 (new)
Explain what is the *STRIPS assumption*, that is, what assumptions the STRIPS system is based on.

Exercise 15.4 (new)
Explain why in *STRIPS* it is not necessary to have situations as an argument for the operators.

Exercise 15.5 (Ch 15, Ex 1)
This exercise is a continuation of exercise 14.5. For each application, we consider a planning problem involving an initial setup and a goal.

Pots of water: Imagine that in the initial situation, we have two pots, a 5-litre one filled with water, and an empty 2-litre one. Our goal is to obtain 1 litre of water in the 2-litre pot.

1. Write a sentence of the situation calculus of the form $\exists x.\alpha$ which asserts the existence of the final goal situation.
2. Write a ground situation term e (that is, a term that is either $S0$ or of the form $do(a, e')$ where a is a ground action term and e' is itself a ground situation term) such that e denotes the desired goal situation.
3. Explain how you could use Resolution to automatically solve the problem for any initial state: how would you generate the clauses, and assuming the process stops, how would you extract the necessary moves? Explain why you need to use the successor state axioms, and not just effect axioms.
4. Suppose we were interested in formalizing the problem using a STRIPS representation. Decide what the operators should be, and then write the precondition, add list, and delete list for each operator. You may change the language as necessary.
5. Consider the database corresponding to the initial state of the problem. For each STRIPS operator, and each binding of its variables such that the precondition is satisfied, state what the database progressed through this operator would be.
6. Consider the final goal state of the problem. For each STRIPS operator, describe the bindings of its variables for which the operator can be the final action of a plan, and in those cases, what the goal regressed through the operator would be.

Exercise 15.6 (from `http://www.ime.usp.br/~liamf/cursoLegolog`)
This exercise is a continuation of exercise 14.6. In the initial situation the robot is located at $home$ facing $north$. You are to consider navigating the robot so that it ends up being located at $depot$.

1. Write a sentence of the situation calculus whose only situation term is $S0$, describing the initial situation.
2. Write a sentence of the situation calculus of the form $\exists x.\alpha$ which asserts the existence of the final goal situation.
3. Suppose that we were interested in formalizing the problem using a STRIPS representation. Decide what the operators should be, and then write the precondition, add list, and delete list for each operator. You may change the language as necessary.
4. Consider the database corresponding to the initial state of the problem. For each STRIPS operator, and each binding of its variables such that the precondition is satisfied, state what the database progressed through this operator would be.

Exercise 15.7 (new)
This exercise is a continuation of exercise 14.7. In the initial situation the robot $HasYolk$ and $HasSugar$. We want the robot to make eggnog.

1. Write a sentence of the situation calculus whose only situation term is $S0$, that describes the initial situation.
2. Write a sentence of the situation calculus of the form $\exists x.\alpha$ which asserts the existence of the final goal situation.
3. Suppose we were interested in formalizing the problem using a STRIPS representation. Decide what the operators should be, and then write the precondition, add list, and delete list for each operator.
4. Consider the database corresponding to the initial state of the problem. For **one** STRIPS operator of your choice, and **one** binding of its variables such that the precondition is satisfied, state what the database progressed through this operator would be.

16 The Tradeoff between Expressiveness and Tractability

Exercise 16.1 (new)
Explain the meaning of the phrase: "A fundamental fact of life is that there is a trade-off between the expressiveness of the representation language and the tractability of the associated reasoning task".

Exercise 16.2 (new)
Explain why reasoning by cases is hard and can in some situations cause intractability.

Exercise 16.3 (new)
Explain the need for the development of limited representation languages, instead of more generic languages. Illustrate with an example.

Exercise 16.4 (new)
Explain the reason why the limited languages that we studied (eg. Horn clauses, description logics) do not allow for the representation of disjunctions.