Obligatory assignment for Module 3: *Knowledge representation and reasoning*

1 Knowledge Representation and Reasoning

Exercise 1 (Deductive reasoning within syllogisms) A syllogism is a particular argument with the following characteristics: ***(i)*** it has exactly two premises, ***(ii)*** it involves exactly three terms, and ***(iii)*** each sentence (premises and conclusion) is of the form *"all/some X are (not) Y"*[1] (with X and Y some of the allowed terms). Here are some examples, with the terms being A, B and C.

- $\begin{array}{l} \text{All } A \text{ are } B. \\ \text{All } B \text{ are } C. \\ \hline \text{All } A \text{ are } C. \end{array}$
- $\begin{array}{l} \text{All } A \text{ are } B. \\ \text{All } C \text{ are } B. \\ \hline \text{All } A \text{ are } C. \end{array}$

Note how the first syllogism is *deductive*: the truth of the premises guarantees the truth of the conclusion. Indeed, if every A-object is also a B-object (first premise) and every B-object is also a C-object (second premise), then every A-object is a C-object.[2] Note also how the second syllogism is *not deductive* because there are *counterexamples*: situations in which both premises are true and yet the conclusion is false. For this particular syllogism, counterexamples exist because, even if every A-object is a B-object and every C-object is a B-object, there might A-objects that are not C-objects (e.g., all dogs are mammals and all cats are mammals, and yet not all dogs are cats).

Consider the following syllogisms.

(i) $\begin{array}{l} \text{All } C \text{ are } B. \\ \text{All } A \text{ are not } B. \\ \hline \text{Some } A \text{ are } C. \end{array}$ ***(ii)*** $\begin{array}{l} \text{Some } A \text{ are } B. \\ \text{Some } A \text{ are } C. \\ \hline \text{All } B \text{ are } C. \end{array}$ ***(iii)*** $\begin{array}{l} \text{No } B \text{ are } C. \\ \text{All } A \text{ are } B. \\ \hline \text{No } A \text{ are } C. \end{array}$ ***(iv)*** $\begin{array}{l} \text{Some } B \text{ are } C. \\ \text{All } A \text{ are } C. \\ \hline \text{Some } B \text{ are } A. \end{array}$

Indicate whether each one of these syllogisms is deductive. If you claim the syllogism is deductive, justify your answer; if you claim it is not, provide a counterexample. ♦

Exercise 2 (Inductive reasoning and deductive reasoning) An inductive argument can be understood as a generalisation: transferring properties of an individual to the whole group. In general, in an inductive argument, the truth of the premises does not guarantee the truth of the conclusion: observing that some rabbits are white is not enough to guarantee that all rabbits are white.

Still, for certain groups of rabbits, and using a certain form of generalisation, observing that some rabbits are white is actually enough to guarantee that all rabbits in the group are white.[3] Which *structure* should the group have, and *which rabbits* should you test so you can guarantee, from the fact that the tested ones are white, that all the others are also white? (Hint: look for *mathematical induction* or, more generally, *structural* induction.) Justify your answer. ♦

2 AI and logic

Exercise 3 (Valid inference in propositional logic) Recall that an inference is valid (equivalently, the argument is deductive) when the truth of the premises guarantees the truth of the conclusion. Within propositional logic, this means that an inference is valid when the conclusion is true in *all valuations/situations* that make *all the premises* true. Let $\varphi_1, \ldots, \varphi_n / \psi$ be an inference.

[1] So, the allowed sentences are *"all X are Y"*, *"all X are not Y"*, *"some X are Y"* and *"some X are not Y"*. Observe how the second sentence, *"all X are not Y"*, is equivalent to (the probably easier to understand) *"No X is Y"*.

[2] Interestingly, this is the case *regardless* of what A, B and C stand for.

[3] Think, e.g., of *biological inheritance*.

(i) If the conclusion ψ is true in every valuation/situation, what can we say about the validity of the inference?

(ii) If the conclusion ψ also occurs in the premises, what can we say about the validity of the inference?

(iii) If there is no valuation/situation that makes *all* premises true, what can we say about the validity of the inference?

In each case, justify your answer. ♦

Exercise 4 (Building a knowledge base) During the lecture you saw how to use Prolog for defining both facts and rules. Facts are written as "`loves(vincent,mia).`", with this one indicating that Vincent loves Mia. Rules are written as "`jealous(X,Y) :- loves(X,Z), loves(Y,Z).`", with this one indicating that a given X is jealous of a given Y if X loves some Z that is also loved by Y (or, more precisely, that a given X is jealous of a given Y if there is a Z such that X loves Z *and* Y loves Z).

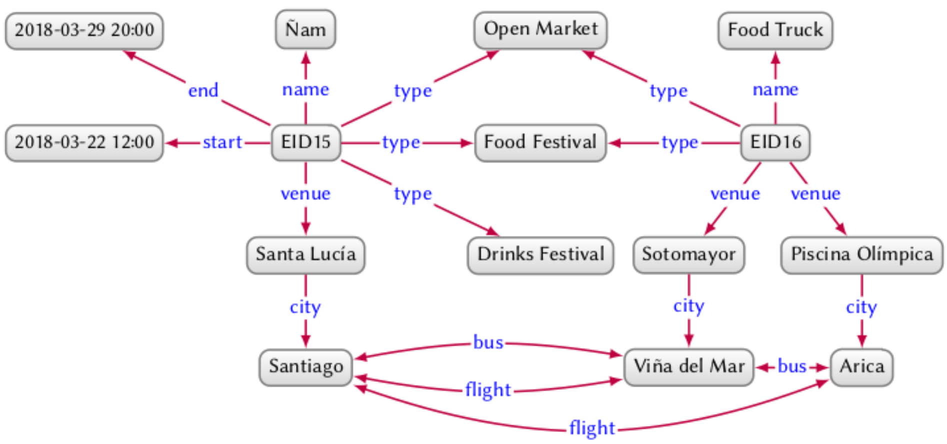
Assume you will have facts specifying whether people are female/male (e.g., "`female(marge).`"), who is whose parent (e.g., "`parent_of(marge,bart).`") and who is married with whom (e.g., "`married_with(marge,homer).`"). To simplify the job, you also have the rules "`married(X,Y) :- married_with(X,Y).`" and "`married(X,Y) :- married_with(Y,X).`", which together indicate that X and Y are married if X is married with Y *or* if Y is married with X. With these tools, define rules for the relationships below[4].

(i) "`step_mother_of(X,Y)`",
(ii) "`step_father_of(X,Y)`",
(iii) "`half_sister_of(X,Y)`",
(iv) "`half_brother_of(X,Y)`",
(v) "`ancestor_of(X,Y)`". ♦

3 AI and knowledge graphs

Exercise 5 (Infoboxes) Consider the infobox on the Wikipedia page for Batman. It contains information extracted from Batman's Wikidata entry and its DBpedia page. Identify the source of each piece of information in the infobox (i.e., look for the information in Wikidata and DBpedia). Then draw the knowledge graph the infobox displays ignoring *Abilities* and *Notable aliases*. ♦

Exercise 6 (Deduction in knowledge graphs) Consider the following knowledge graph (Hogan et al. 2020, Page 7), with *EID15* and *EID16* being labels for events.



The graph provides more information than what it explicitly states. For example, we can *deduce* that the **Ñam** event is located in Santiago, even though there is no edge of the form "$\boxed{\textbf{Ñam}}$–*location*→$\boxed{\textbf{Santiago}}$". To extract such information, we use our understanding that every event whose venue is **Santa Lucía** is located in **Santa Lucía**, and that anything that occurs in **Santa Lucía** occurs in **Santiago**.

Consider the following queries:

(i) Is there an airport in/near **Viña del Mar**?

[4] If required, you can use the operator "`\=`" to indicate that two objects are different (e.g., "`X\=Y`" expresses that X is different from Y). Additionally, you can also define *intermediate* relationships, in case you find it useful.

(ii) Is there an event that has both a **food festival** and a **drinks festival**?

(iii) Is there a food festival on Santiago on **27th of March, 2018**?

(iv) Is **Arica** hosting an **open market**?

(v) Which are the events being hold on the **25th of March, 2018**?

Each one of these queries can be answered with the information the knowledge graph provides. Yet, the answer is only implicit. In each case, make explicit the additional information one uses for answering the query. ♦

References

A. Hogan, E. Blomqvist, M. Cochez, C. d'Amato, G. de Melo, C. Gutiérrez, J. E. L. Gayo, S. Kirrane, S. Neumaier, A. Polleres, R. Navigli, A. N. Ngomo, S. M. Rashid, A. Rula, L. Schmelzeisen, J. F. Sequeda, S. Staab, and A. Zimmermann. Knowledge graphs. *CoRR*, abs/2003.02320, 2020. URL https://arxiv.org/abs/2003.02320.