Logics and symbolic AI: Knowledge representation and reasoning

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Objective of the course

- Providing the bases of symbolic artificial intelligence.
- Detailing a few selected advanced topics.
- Acquiring skills to
  - understand different kinds of logic families,
  - formulate reasoning in such formal languages, and
  - manipulate tools to represent knowledge and its adaptation to imprecise and incomplete domains through the use of OWL, Protegé and fuzzyDL.

Prerequisite: Basic knowledge in computer sciences and algebra.

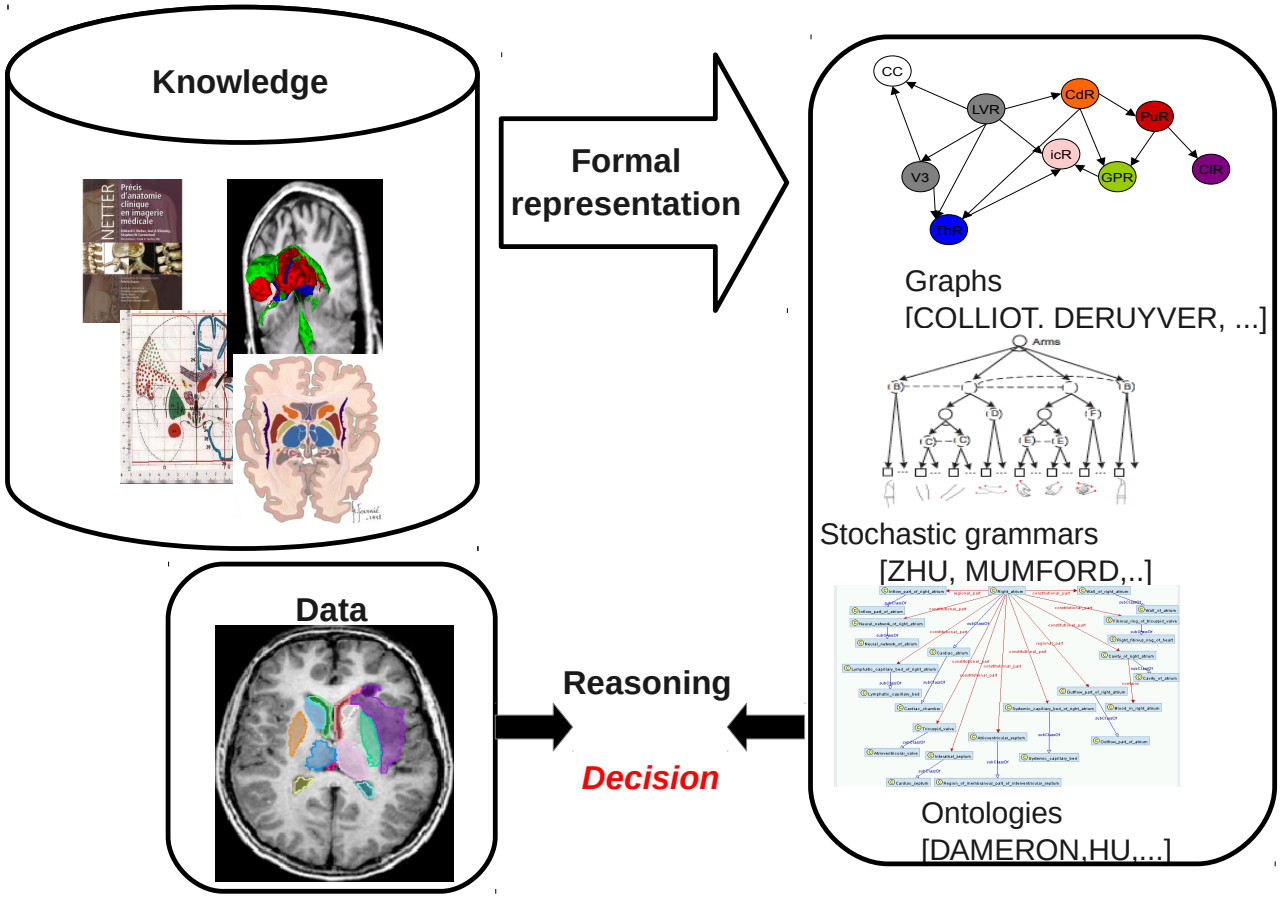
Course content

- Introduction
- Reminder on bases on logics (syntax, semantics...) and overview of several logics (propositional, first order, modal...)
- Symbolic learning: formal concept analysis, decision trees
- Description logics, fuzzy logics, ontologies and Knowledge Graphs
- Some typical examples in AI: revision, merging, abduction, with illustrations on preference modeling and image understanding
- Tutorial on ontology engineering and design. Building your own ontologies using (Fuzzy) OWL, Protegé and fuzzyDL for real life knowledge graph problems- (practical work, including a report at the end of the course)
  - `https://protege.stanford.edu/`
  - follow the "download" link (do NOT use the WebProtege version)

Pedagogy

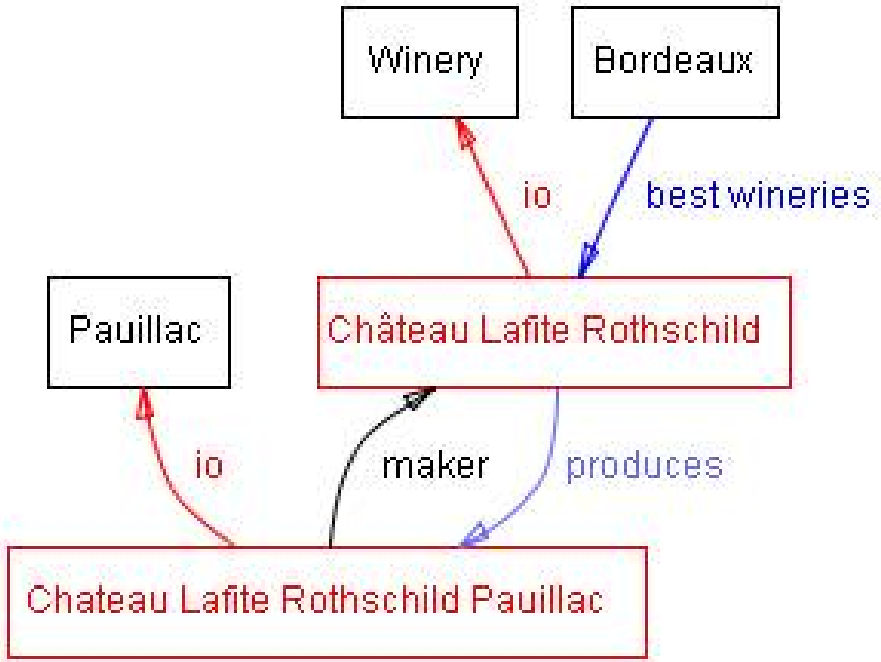
- Courses: methods, applicative examples in various domains.
- Practical work on ontologies.
- Evaluation:
  - written exercices (50%), and
  - reports handed in after the practical work, which will require to create a couple of ontologies as part of a decision support system of a freely elected domain problem (50%).

Representation and reasoning



(Inexact) graph matching, alignment and instanciation of models (ontologies, conceptual graphs...), constraint satisfaction problems, logic-based spatial reasoning...

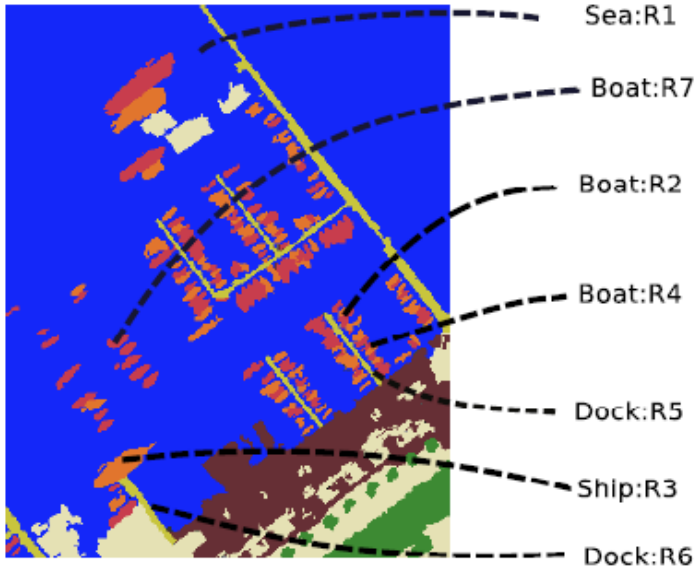
An example of ontology



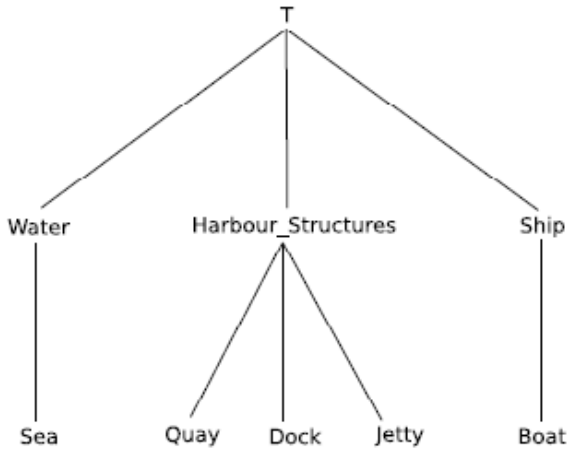
(black for classes and red for instances)

Source: https://protege.stanford.edu/

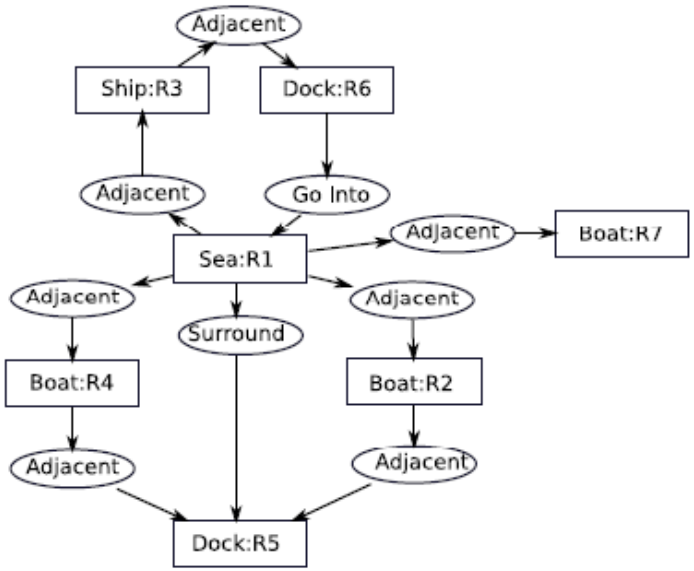
(a) Example image.



(b) Labeled image: The blue regions represent the sea, the red and orange represent ships or boats and the yellow regions represent the docks.

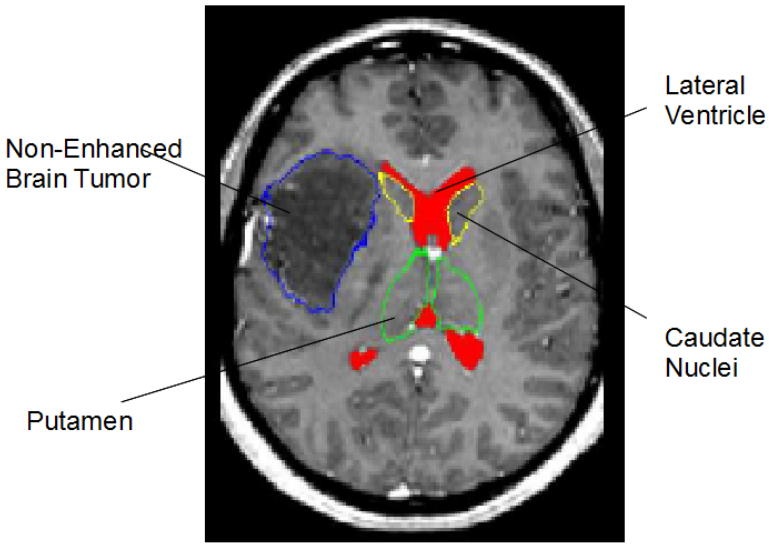


(c) Concept hierarchy T_C in the context of harbors.



(d) Conceptual graph representing the spatial organization of some elements of Figure 5.8(b).

Abductive reasoning: example in image understanding



Pathological brain with a tumor

$$\mathcal{K} \models (\gamma \rightarrow \mathcal{O})$$

Compute the "best" explanation to the observations taking into account the expert knowledge (e.g. formalized in description logic).

Merging: example

- At a meeting of a block of flat co-owners, the chairman proposes for the coming year the construction of a swimming-pool, of a tennis-court and of a private-car-park.
- The chairman outlines that building two items or more will have an important impact on the rent.
- There are four co-owners. Two of the co-owners want to build the three items and do not care about the rent increase.
- The third one thinks that building any item will cause at some time an increase of the rent and wants to pay the lowest rent so he is opposed to any construction.
- The last one thinks that the block really needs a tennis-court and a private-car-park but does not want a high rent increase.

What will be the best solution?

$\Rightarrow$ Formalization in propositional logic.

Revision: example

- Two satellites, Unit A and Unit B, orbit around Mars; the satellites are programmed to land while transmitting their status to Earth.
- Earth has received a transmission from one of the satellites, communicating that it is still in orbit; however, due to interference, it is not known which satellite sent the signal.
- Subsequently, Earth receives the communication that Unit A has landed.

1. Initial set of beliefs: either one of the two satellites is still in orbit.
2. New piece of information: Unit A has landed, and is therefore not in orbit.
3. What is the rational revised belief?