Logic: Introductory Lecture

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Descrete Mathematics and Logic — BSc course

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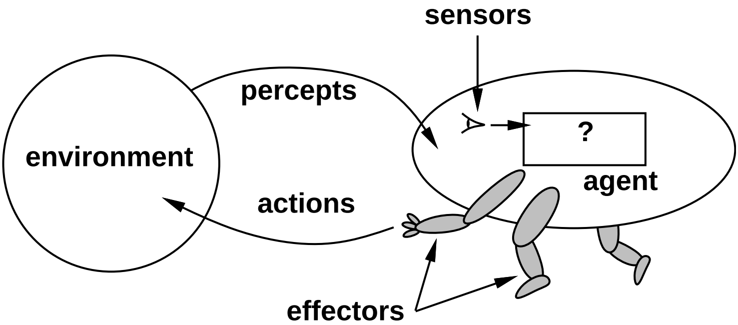
Systems $\Longleftrightarrow$ Agents



An agent

Consider, e.g., the task of designing an automated vehicle:

Percepts: video, accelerometers, gauges, engine sensors, keyboard, GPS, . . .

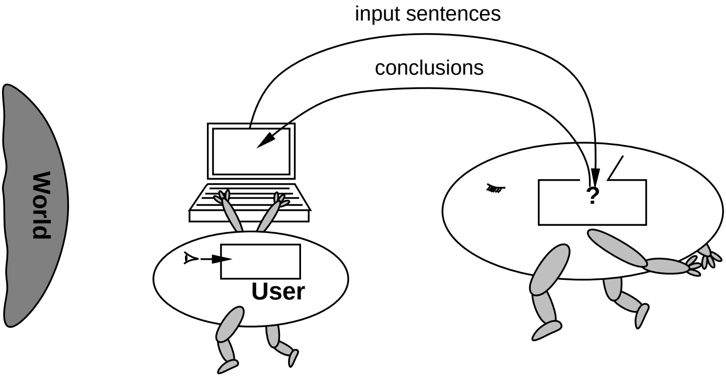
Actions: steer, accelerate, brake, horn, speak/display, . . .

Goals: safety, reach destination, maximize profits, obey laws, passenger comfort, . . .

Environment: US urban streets, freeways, traffic, pedestrians, weather, customers, . . .

Rational Agents

An Agent as Reasoning module of a Rational Agent.



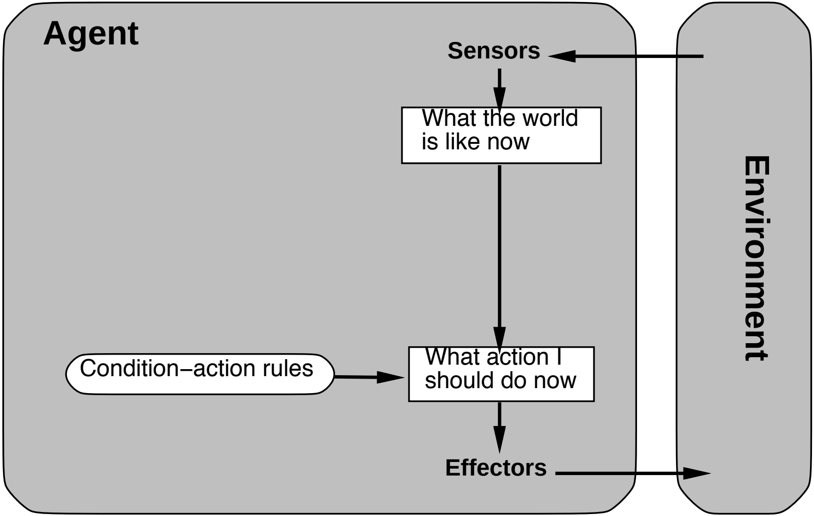
Intelligent Agents

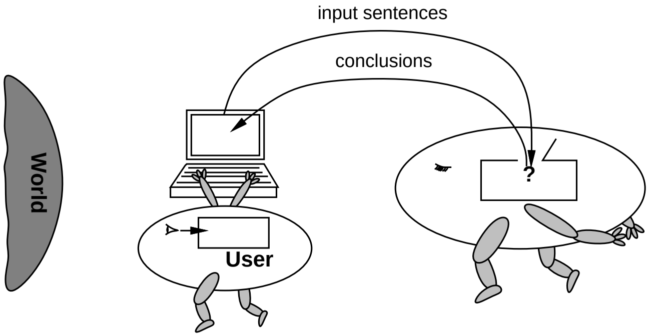
- An *Intelligent Agent* is an entity that perceives and acts according to an *internal declarative body of knowledge*.
- Abstractly, an agent is a function from perceptions and internal declarative knowledge to actions:

$$f : \mathcal{P} \times \mathcal{K} \rightarrow \mathcal{A}$$

  For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance
- An Intelligent Agent as *Representation* and *Reasoning* module: a **Logic System**.
- *Logic*: a well formalized part of agent *knowledge* and *reasoning*.

Non-Intelligent Agents: Reflex Agents





- The goal of an *Intelligent Information Agent* is to manage, process, and access Information – e.g., a "clever" database system.

Processing Knowledge = “Reasoning”

Representation alone is not useful.

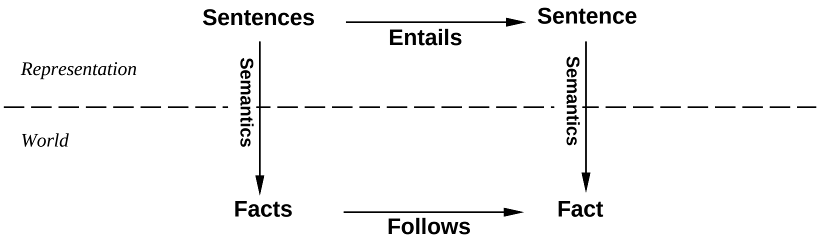
We want to be able to access represented knowledge and to *process* it.

- access alone is, in general, insufficient
- *implicit* knowledge has to be made explicit

$\rightsquigarrow$ *deduction methods*

  - the results should only depend on the semantics
  - and not on accidental syntactic differences in representations

Logic



A logic allows the axiomatization of the domain information, and the drawing of conclusions from that information.

- Syntax
- Semantics
- Logical inference = *reasoning*

Important Questions

- **Expressive Power** of representation language

⇝ able to *represent* the domain problem

- **Soundness** of entailment procedure

⇝ *no false* conclusions are drawn

- **Completeness** of entailment procedure

⇝ *all correct* conclusions are drawn

- **Decidability** of entailment problem

⇝ there exists a (terminating) algorithm to compute entailment

- **Complexity**

⇝ computational resources needed for computing the solution

What is a Logic

Clearly distinguish the definitions of:

- the *formal language*
  - Syntax
  - Semantics
- the *reasoning problem* (e.g., entailment)
  - Decidability
  - Computational Complexity
- the *problem solving procedure*
  - Soundness and Completeness
  - (Asymptotic) Complexity

The ideal Logic

- Expressive
- With decidable reasoning problems
- With sound and complete reasoning procedures
- With efficient reasoning procedures – possibly sub-optimal

Goals of research in the field

- Study how **declarative knowledge** can be *formally defined* using a logic-based approach.
- Give a *computational* account to it, in order to reproduce it in a computing device.

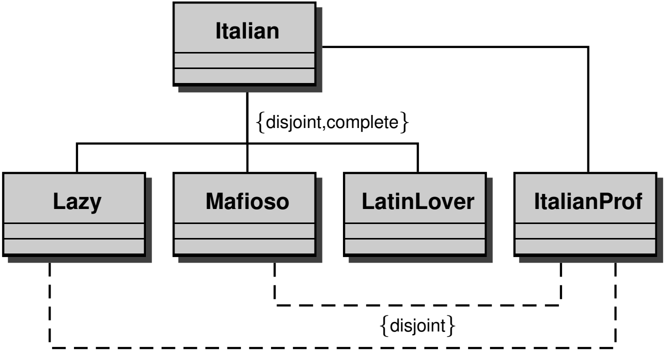
Historical View

- The study of logic was begun by the ancient Greeks whose educational system stressed competences in reasoning and in the use of language.
- The formalization of logic began in the nineteenth century as mathematicians attempted to clarify the foundations of mathematics.
- The discovery of non-Euclidean geometries: replacing Euclid's parallel axiom with another axiom resulted in a different theory of geometry.
- Logical systems—axioms and rules of inference—were developed with the understanding that different sets of axioms would lead to different theorems.

Historical View

- During the first half of the twentieth century, logic became a full-fledged topic of modern mathematics.
- The research into the foundations of mathematics was called Hilbert's program, (after David Hilbert).
- The main goal was to prove that mathematics, starting with arithmetic, could be axiomatized.
- In 1931, Kurt Gödel showed that this goal cannot be achieved: any axiomatic system for arithmetic is incomplete since true statements cannot be proved within the system.
- Logic is nowdays applied in computer science leading to the development of many new systems of logic that did not exist before.

Reasoning at the Conceptual Level



implies

ItalianProf $\Longrightarrow$ LatinLover

Main topics of the course

- Classical Logic
    - Propositional Logic
        - Foundations
        - Deduction
    - First Order Logic
        - Foundations
        - Use of FOL
- Logic applied to Conceptual Modelling
    - ER
    - UML