ARTIFICIAL INTELLIGENCE

LEI/3, LMA/3, MBE/1

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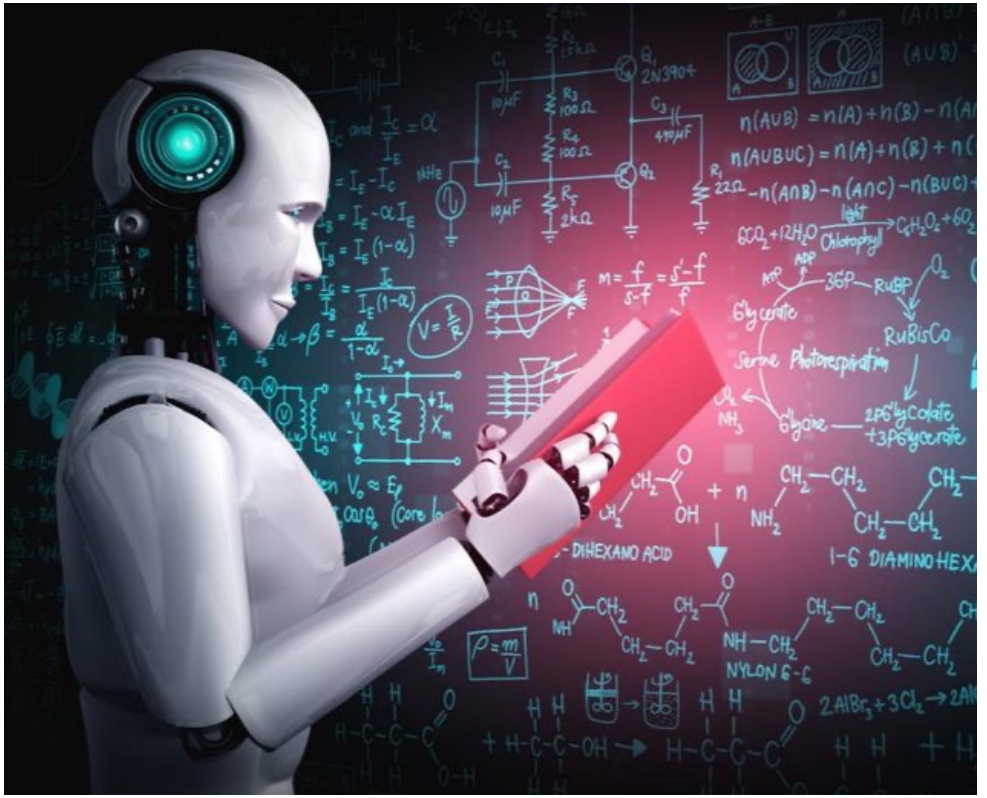
Artificial Intelligence



- **Long-term goal**: develop automata that behave in an intelligent way:
  - Ability to Reason
  - Ability to Learn (Adapt)
  - Ability to Communicate
  - Ability to Interact
- Inputs:
  - Questions, Requests, Preferences
- Outputs:
  - Actions, Answers, Plans and Decisions
- An intelligent agent must be able to reason about a potential action before executing it:
  - Analyze the state of the world
  - Sets its own goals
  - Infer new knowledge
- The ability to represent knowledge is the key requirement
  - Syntax? Semantics?

Knowledge Representation

- Konrad proposed a first taxonomy for computer users, broadly divided into three types:
  - Engineer
  - Writer
  - Scientist



- Engineer
  - In the earliest times of computer science, the processing/storage capabilities were very short
    - The focus was given to pragmatism, in which the information should be easily processed by the machine (highly structured, poor versatility)
      - Compiler programmers, file systems, hackers, and relational database systems
- Writer
  - Upon the appearance of Internet, computers are mostly regarded as a way to primary communicate information/knowledge.
    - The amount of information available grows exponentially, using formats such as XML, UNL, CSV,…
  - Information Society Era

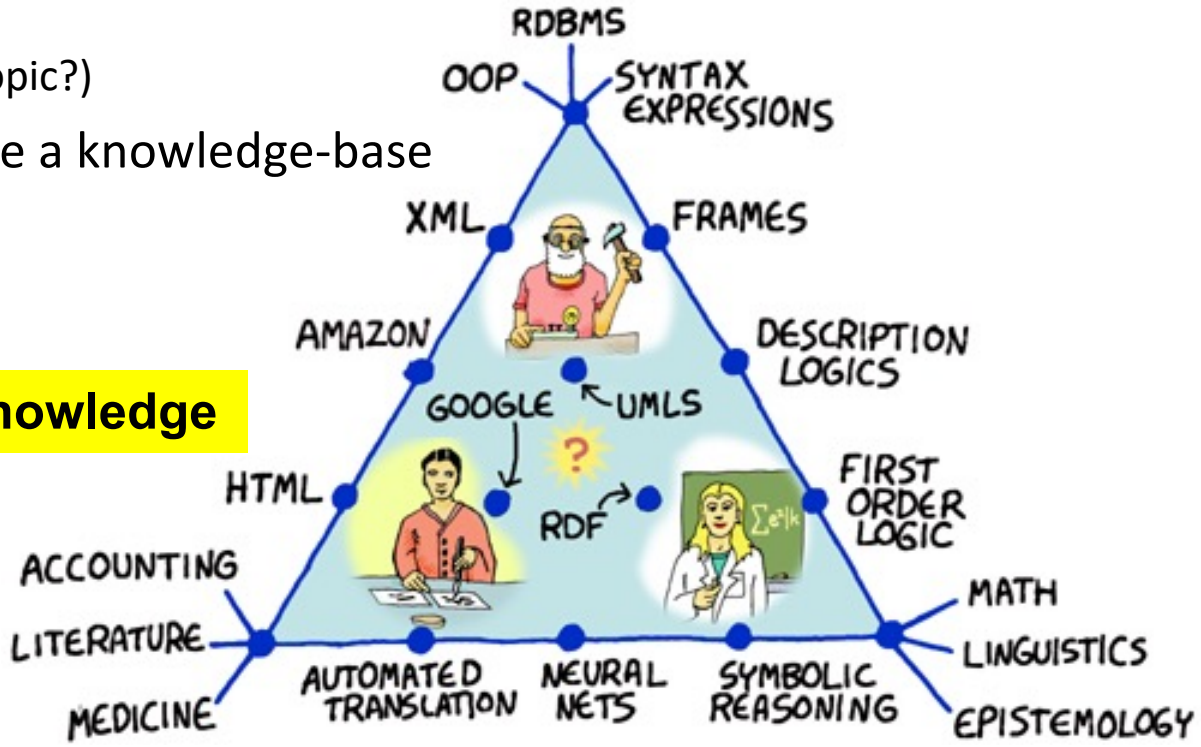
Knowledge Representation

- Scientist
  - The focus is given to semantics, and in finding appropriate high-level ways to store and process knowledge. It will support the evolution into the "Knowledge Society".
- The diagram at right shows the relation between the three kinds of users
  - Corners → Earliest Paradigms
  - Nucleus → Full knowledge (Utopic?)
- Thus, it is required to formalize a knowledge-base
  - Used to infer new knowledge:

{Knowledge Base} |= Inferred Knowledge

Language?

How can be defined?



Source: https://www.researchgate.net/figure/Knowledge-representation_fig1_262108850

Knowledge Representation

- For an intelligent agent, there is an infinity of domains with knowledge to be represented
  - Physical World
    - temperature (01/12/2021, 18:55, 1.27N, -0.45W, 27.2º)
  - Rules
    - IF temperature(day, _, _, _, _) > 26 AND temperature(day+1, _, _, _, _)>26 THEN RAISE ”Alarm”
  - Own and Adversarial knowledge
    - Profit(Own, 270€), Profit(Opponent, 214€)
- Facts
  - In order to represent facts, a formal language can be used (**first-order predicate logic**), composed of **objects**, **properties**, **relations** and **rules**
  - **Objects:** are denoted in italic and non-capitalized fonts
    - *josemateus* refer the subject “José Mateus”
  - **Properties:** composed of a predicate and an argument. The former defines the property and the latter is an object
    - masculino(*josemateus*)
  - **Relations:** describe properties with more than one argument
    - casal(*josemateus*, *mariafrancisca*)

Knowledge Base

- In this setting, one knowledge-based is a set of facts and rules:
  - masculino(josé)
  - masculino(pedro)
  - masculino(joão)
  - feminino(ana)
  - feminino(maria)
  - feminino(rita)
  - progenitor(josé, ana)
  - progenitor(maria, ana)
  - progenitor(joão, josé)
  - progenitor(rita, josé)

Facts

- **Rules** allow to infer new knowledge and enable to reduce the amount of explicit facts in the knowledge-base
- The arguments are **variables**, and are denoted by capitalized letters
  - feminino(X) AND progenitor(X, Y) → mae(X, Y
  - progenitor(X,Y) AND progenitor(Y,Z) AND masculino(X) → avô(X,Z)

Deduction

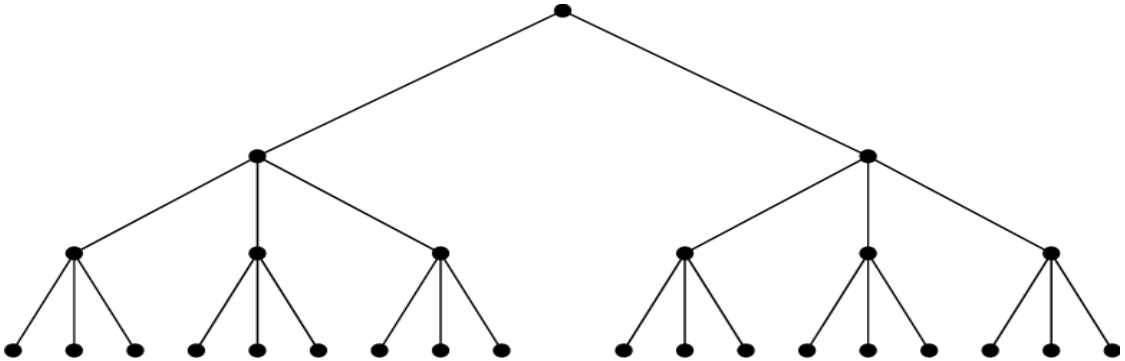
- There are two main forms of deduction:
  - **Forward** and **Backward**
- Forward Deduction
  - Used to prove facts. The starting point is a set of facts, assumed as true, that guarantee the inferred fact.
  - Rule: A^1 AND A^2 … AND A^n → A
  - Facts: a^1 AND a^2 … AND a^n
  - Inferred fact: a
  - Example:
    - feminino(*ana*)
    - progenitor(*ana*, *hugo*)
    - feminino(X) AND progenitor (X, Y) → mae(X,Y)
    - Inferred fact: mae(*ana*, *hugo*)
- Forward deduction is not directed, in the sense that potentially enables the inference of (many) irrelevant facts.

Deduction

- Backward Deduction
  - It starts by the conclusion in which the agent is interested and – applying rules in an inverse way, the conclusion can be asserted/proved.
- Example: avô(*joao*, *jose*)?
  - We know that progenitor(X,Y) AND progenitor(Y,Z) AND masculino(X) → avô(X,Z)
  - Thereby, it is required to prove that:
    - progenitor(*joão*,B) AND progenitor(B,*josé)* AND masculino(*joão*)
- In each deduction step, **facts or rules can be used**:
  - Previous goal:
    - A^1 AND B
  - Fact
    - A^1
  - New goal:
    - B
- The process is concluded (with success) if all facts are verified/proved.
  - Final goal: A
  - Fact: a
  - **Result TRUE**

Deduction

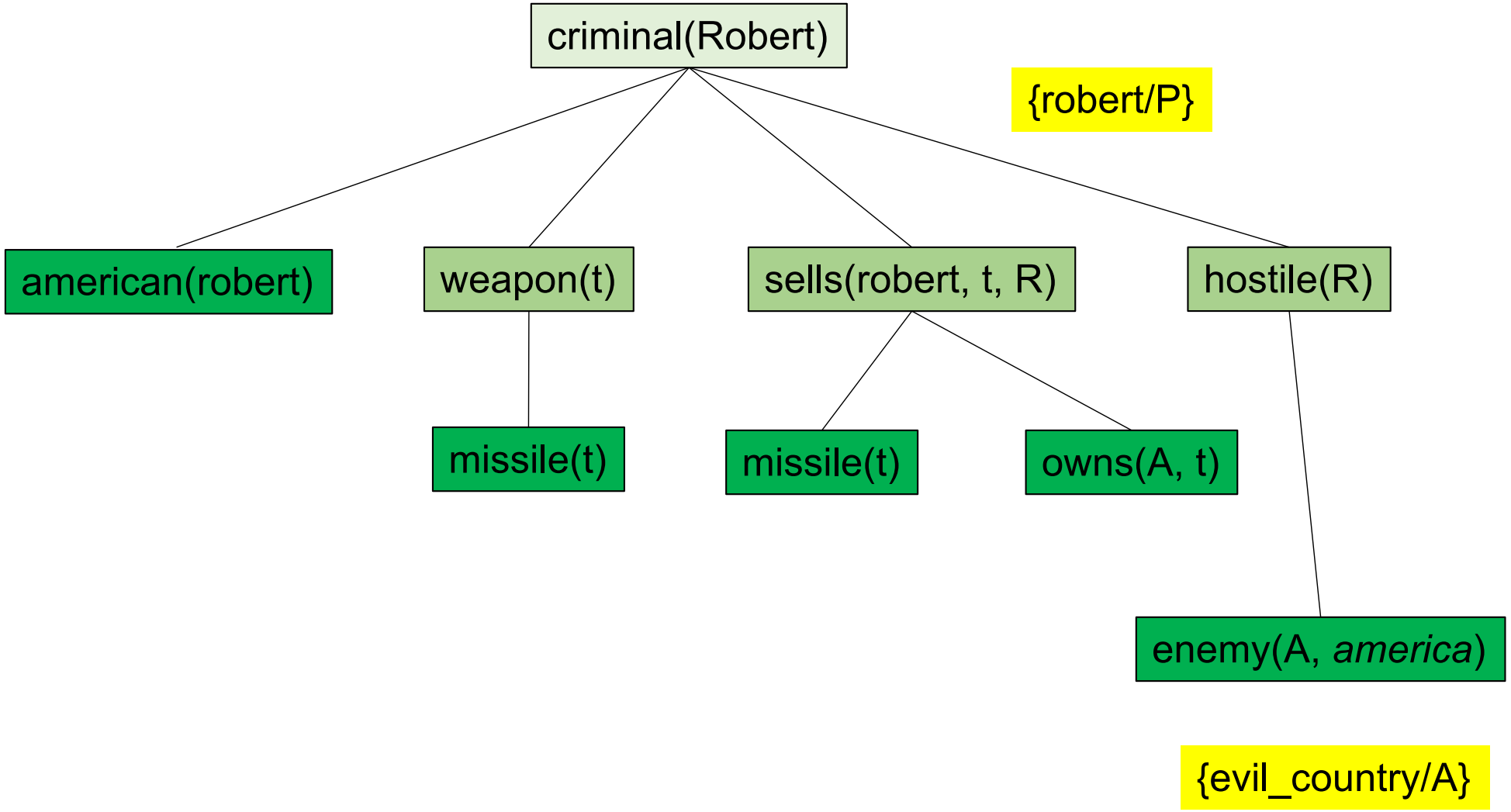
- Deduction using Rules:
  - Previous Goal: A^1 AND B
  - Rule C → A
  - New Goal: C AND B
- In each step, facts or rules are used, in order to achieve the goal.
- Every time that – in a single step –more than one rule or fact that can be used, there are different possibilities for deduction.
- **Deduction Tree**
  - Describes the set of possibilities (paths) to prove a fact. The proof is attempted in a DFS paradigm.
    - In practice, this occurs when the Knowledge-base has OR facts/rules.
    - The fact is proved if a proof is completed in a single branch



Inverse Deduction Example

- Let's consider the following knowledge-base:
- american (P) AND weapon(Q) AND sells (P, Q, R) AND hostile(R) → criminal(P) (1)
- owns(evil_country, t) (2)
- missile(t) (3)
- missile(P) AND owns (evil_country, P) → sells (*robert*, P, evil_country) (4)
- missile(P) → weapon (P) (5)
- enemy(P, *america*) →hostile(P) (6)
- enemy (evil_country, *america*) (7)
- american(*robert*). (8)
- Answer the following question: "*Is Robert a Criminal?*",. i.e., criminal(*robert*)
- We will take the goal fact. And from that, we should infer other facts, and at last, we will either end-up in a contradiction or prove that facts true.
- So our goal fact is "Robert is Criminal".
  - We should either, proof that this is TRUE, or find a contradiction.

Inverse Deduction Example



Deduction Exercises

- Consider the following knowledge-base:
- progenitor(jock, morgan); progenitor(jock, alasdair); progenitor(clark, ann)
- progenitor(jock, hamish); progenitor(mairi, morgan); progenitor(albert, ann)
- progenitor(mairi, alasdair); progenitor(mairi, hamish); progenitor(hamish, albert)
- progenitor(fergus, jock); progenitor(rhoda, jock); progenitor(hamish,clark)
- progenitor(fergus, flora); progenitor(rhoda, flora)
- masculino(fergus); masculino(jock); masculino(alasdair); masculino(hamish)
- feminino(rhoda); feminino(mairi); feminino(morgan); feminino(flora)
- masculino(albert); masculino(dock); feminino(ann); feminino(clark)
- progenitor(A,B) AND feminino(A) → mae(A,B)
- progenitor(A,B) AND masculino(A)→pai(A,B)
- progenitor(A,B) AND progenitor(B,C) AND masculino(A) → avô(A,C)
- progenitor(A,B) AND progenitor(B,C) AND feminino(A) → avó(A,C)
- pai(A,B) → antepassado(A, B)
- pai(A,B) AND antepassado(B,C) → antepassado(A,C)

Deduction Exercises

- Define rules to represent the following relationships:
  - Tio; Filho(a); Sobrinho; Irmão; Primo
- Using Inverse Deduction, answer the following questions:
  - "Mairi é antepassado de Ann"?
  - Quais os filhos de "Jock"?
  - Quais os primos de "Flora" ?
- Let's consider a propositional language where:
  - p means "Paola is happy",
  - q means "Paola paints a picture",
  - r means "Renzo is happy".
  - Formalize the following sentences:
    - "if Paola is happy and paints a picture then Renzo isn't happy"
    - "if Paola is happy, then she paints a picture"
    - "Paola is happy only if she paints a picture"
- Let a ="Aldo is Italian" and b ="Bob is English". Formalize the following sentences:
  - "Aldo isn't Italian"
  - "Aldo is Italian while Bob is English"
  - "If Aldo is Italian then Bob is not English"
  - "Aldo is Italian or if Aldo isn't Italian then Bob is English"
  - "Either Aldo is Italian and Bob is English, or neither Aldo is Italian nor Bob is English"