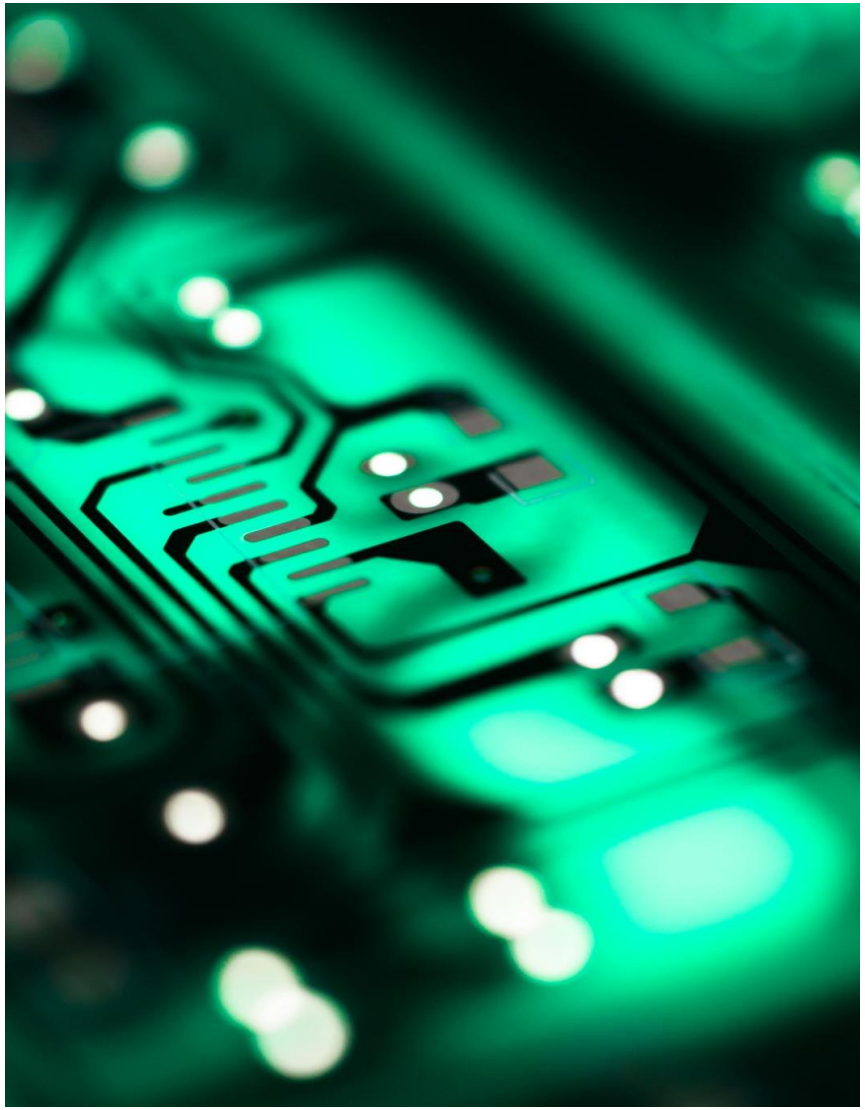
Introduction
Artificial Intelligence

Knowledge Representation



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Motivation

- We would like to build a system that:
  - we could **TELL** a set of facts
    - This system we call a Knowledge Base (KB)
      - Ali is a Student.
      - All students go to school.
  - we could **ASK** questions, and receive correct answers
    - Is Ali a student?
  - can automatically **ADD** more facts in it
    - Ali goes to school.

Motivation

- AI can (also) be viewed as study of intelligent behavior achieved through computational means.

- Knowledge representation and reasoning is the study of how to reason (compute) with knowledge in order to decide what to do.

- But, before reasoning with knowledge, first we need to represent (encode) it.

- **Knowledge Representation** is concerned with presenting real-world information in a form that the computer can 'understand' and use to 'solve' real-life problems or 'handle' real-life task.

fundamentals

- Knowledge generally emerges as follows:

  data ➔ information ➔ knowledge

  - Data: Collection of (disconnected) facts
    - Temperature drops to 10^{o}C.
    - It starts raining.

  - Information emerges when relationships among facts are established
    - Temperature dropped to 10^{o}C AND then it started raining.

  - Knowledge emerges when relationships among patterns are identified and understood
    - **Rain pattern:** If the humidity is very high and temperature drops substantially then atmosphere is unlikely to hold moisture, so it rains.

Fundamentals

- We understand through knowledge different kinds of facts about something (the world)

- Knowledge is necessary for intelligent behavior
  - If I get tired, I'd like to take rest. [If I get tired, I'd like to work hard!!!]

- A knowledge representation is encoding of knowledge (in some appropriate way)

Types of Knowledge

- **A priori knowledge**
  - Comes before knowledge perceived through senses
  - Considered to be universally true (***All bachelors are unmarried***)
  - A person who knows (a priori) that "All bachelors are unmarried" need not have experienced the married status.

- **A posteriori knowledge**
  - Knowledge verifiable through senses
  - May not always be reliable (Some bachelors are very happy)

- **Procedural knowledge**
  - Knowing HOW to do something: to determine if A is taller than B, first determine heights of A & B

- **Declarative knowledge**
  - Knowing that something is true/false

Needs for KR

- **Knowledge base, reasoning and language**
  - To draw (rational) inference, we first need to be able to state the **rules** and the known **facts** about a problem
  - The internal representation of facts and rules is called a knowledge base (KB)
  - The KB is the starting point for all reasoning that we may want to perform
  - Therefore, we need a kind of language that allows us to express what we know.

KR Languages

- Assumption of (traditional) AI work is that:
  - Knowledge may be represented as “symbol structures”
    - complex data structures, representing bits of knowledge (objects, concepts, facts, rules, strategies..)
    - For example,
      - “red” could represent color red
      - “car1” could represent my car
      - red(car1) could represent fact that my car is red.

- Intelligent behavior can be achieved through manipulation of symbol structures
  - But, in which language these symbol structures be expressed?

KR Languages

- **Possibility 1: Natural languages**
  - Very expressive, but notoriously ambiguous
    - Inference would be very difficult.

    (Inference means conclusion that's drawn from evidence and reasoning.)
  - So, not a good choice

  Example.
- The man saw the girl with the telescope.

  It is ambiguous whether the man saw the girl carrying a telescope or he saw her through his telescope.

- The car hit the pole while it was moving.

This sentence has semantic ambiguity because the interpretations can be "The car, while moving, hit the pole" and "The car hit the pole while the pole was moving".

- The horse ran up the hill. It was very steep. It soon got tired.

Here, the anaphoric reference of "it" in two situations cause ambiguity.

KR Languages

- **Possibility 2: Programming languages**
  - Very precise, but lack expressiveness
    - Not all kind of required knowledge can be represented
  - So, again, not a good choice

- **Possibility 3: Formalisms, e.g. logic**, which balance the above trade-offs.

Characteristics of KR

- Ideally, a KR language should have
  - Representational Adequacy/expressiveness
  - Clear syntax/semantics
  - Inferential adequacy
  - Inferential efficiency
  - Naturalness
  - Consistency

In practice no one language is perfect, and different languages are suitable for different problems

Representational Adequacy

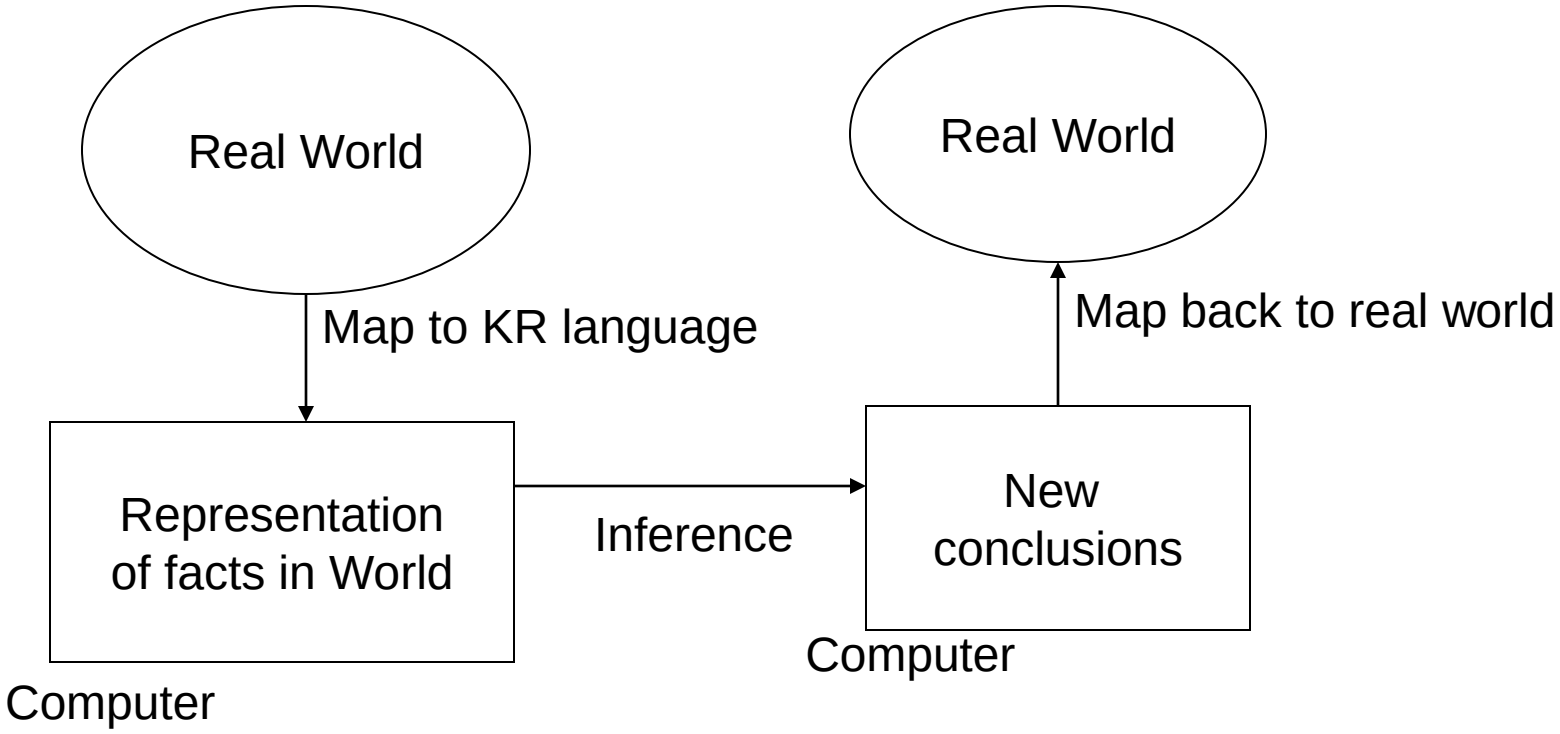
- Consider the following facts:
  - Sun is shining.
  - Most people believe earth is moving.
  - Ahmed will finish his job before evening.

- *How do we represent all kind of facts?*
  - **These can be represented as natural language strings**
    - **But hard then to manipulate and draw conclusions**
    - Hard to understood by machines

- Some notations/languages only allow you to represent certain things
  - Time, beliefs, uncertainty, all hard to represent

Well-defined syntax/semantics

- Knowledge representation languages should have precise syntax and semantics
- You must know exactly what an expression means in terms of objects in the real world



Well defined syntax/semantics

- Suppose we have decided that “red1” refers to a dark red color, “car1” is my car, car2 is another.

- Syntax of a language will tell you which of the following is legal: `red1(car1)`, `red1 car1`, `car1(red1)`, `red1(car1 & car2)`?

- Semantics of a language tells you exactly what an expression means - e.g., `Pred(Arg)` means that the property referred to by `Pred` applies to the object referred to by `Arg`

  - E.g., property “dark red” applies to my car

Natural Representation

- It would be helpful if our representation scheme is quite usual and natural for human readers
- Could represent the fact that my car is red using the notation:
  - **abc ← xyz**
    - where abc refers to my car, xyz refers to redness and ← used in some way to associate properties to objects
- But this wouldn't be very helpful

Inferential Adequacy

- Representing knowledge would not be very interesting unless you can use it to make inferences:
  - **Draw new conclusions from existing facts**
    - If its raining, Hassan never goes out
    - It's raining today
    - so..

- Inferential adequacy refers to how easy it is to draw inferences using represented knowledge
  - Representing everything as natural language strings has good representational adequacy and naturalness, but very poor inferential adequacy.

Inferential Efficiency

- You may be able, in principle, to make complex deductions/assumptions given knowledge represented in a sophisticated language. But it may be just too inefficient.

- Generally, the more complex the possible deductions, the less efficient will be the reasoner.

- Representation and inference system should be sufficient for the task, without being hopelessly inefficient.

Consistency

- A consistent KR system would help avoid redundant information
  - Hassan is clever
  - Hassan is smart
- A consistent KR system would also help avoid conflicting information
  - Hassan is clever
  - Hassan is dull-minded

Logic as a KR Language

- A Logic is a formal language, which
  - has precise syntax and semantics
    - **Syntax:** what expressions are allowed in the language
    - **Semantics:** what they mean in terms of mapping to real world
  - supports sound inference
    - How can we draw new conclusions from existing statements (proof theory)

- Different logics exist
  - propositional logic
  - predicate logic
  - temporal logic
  - fuzzy logic (etc.)

Propositional Logic (PL)

- Proposition is a statement which has a truth value (True or False)
  - Teaching is a noble profession.

- **Propositional logic**
  - A simple language useful to express key ideas and definitions
  - User defines a set of propositional symbols, like p and q
  - User also defines the semantics of each propositional symbol:

    - **p means** "It is hot"
    - **q means** "It is humid"

How to express NL in Logic?

- Pick the smallest/atomic statements without **and**, **or**, etc. about which you could answer the question
  - is it true?

- Use propositional variables to stand for these statements and connect them with the relevant logical connectives.

From Logic to NL

p: It is hot

q: It is humid

r: It is raining

$(p \wedge q) \rightarrow r$

If it is hot and humid, then it is raining.

$q \rightarrow p$

If it is humid, then it is hot.

Practice example

M: I have money

L: I like the LG-mobile

B: I will buy the LG-mobile

T: I find a touch screen

$(M \wedge L \wedge T) \rightarrow B$

If I have money and I like the LG-mobile and I find a touch screen, then I will buy the LG-mobile

If I have money and I like the LG-mobile, then I will buy it if I find a touch screen

The same logical formula can be expressed in different ways

Practice example

If it rains, then I will stay at home.

p : It rains
q : I will stay at home

The sentence is of the form: “If p then q”.

- $p \rightarrow q$

If I will do a job, then I will earn money.

a : I will do a job
b : I will earn money

- $a \rightarrow b$

Practice example

He is poor but honest.

x : He is poor
y : He is honest
The given sentence is: “He is poor but honest.”
We can replace “but” with “and” as both sides must be true.

- $x \wedge y$

Neither it is hot nor cold today.

m : It is hot today
n : It is cold today
This sentence is of the form: “Neither m nor n”.
We can write it as “Not m and Not n”.

- $\sim m \wedge \sim n$

Practice example

He goes to play a match if and only if it does not rain.

p : He goes to play a match
q : It does not rain

The sentence is of the form: “p if and only if q”.

- $p \leftrightarrow q$

It is false that he is poor or clever but not honest.

We can replace “but” with “and”.
So, the sentence is: “It is false that he is poor and not honest.”
p : He is poor
q : He is honest

- $\sim(p \wedge \sim q)$

QUIZ ?
(Next Class)