Representation, Reasoning & Logic

22 December 2020 12:08

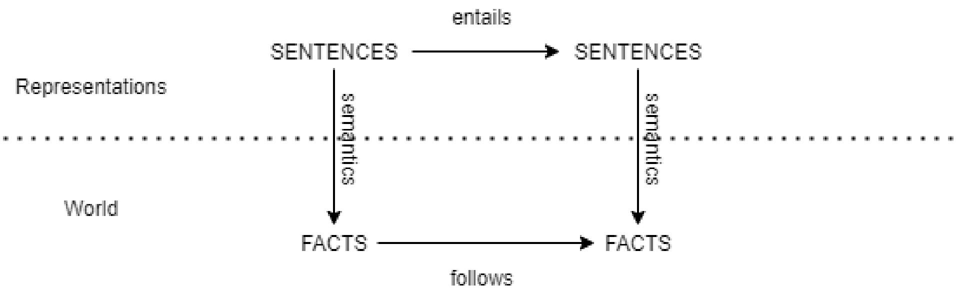
The object of knowledge representation is to *express knowledge in computer-tractable form*, such that it can help the agent to perform well.

There are two aspects that are key in knowledge representation - **syntax** and **semantics**

- The syntax of a language describes the possible configurations that can constitute sentences. E.g. although X, Y and > are valid symbols in a language, X Y > might not be syntactically correct, whereas X > Y might be.
- Semantics determines the facts in the world to which the sentences refer. Without semantics a sentence is just an arrangement of electrons or a collection of marks on a page. With semantics, each statement makes a claim about the world. With semantics, we can say that when a particular configuration exists within an agent, the agent believes the corresponding sentence.

Provided we have a precisely syntax and semantics, we can call the language a logic.

From the syntax and semantics, we can derive an inference mechanism, that uses the logic.

- Facts are parts of the world
- Representations are encoded in some way that can be physically stored in an agent
- Because sentences are physical configurations of parts of the agent, reasoning must be a process of constructing new physical configurations from old ones. Proper reasoning should ensure that the new configurations represent facts that actually follow from the facts that the old configurations represent
- 

An inference procedure can do two things:
1) Given a KB, generate new sentences that are entailed by KB
2) Given a KB and a new sentence alpha, decide whether or not KB entails alpha.

Entailment

We want to generate new sentences that are necessarily true, given that the old sentences are true. This relationship between sentences is called **entailment**, and mirrors the relations of facts following from each other.

KB |= alpha

Entailment is important since it provides a strong way of showing that if certain propositions are true, then some other proposition must be true

- KB entails sentence alpha if and only if alpha is true in all worlds where KB is true

- e.g. if the KB has "James is male" and "James is 34" then the KB entails "James is male or 34"
- Semantics give mapping of sentences to facts
- Logical inference generates sentences that are entailed by existing sentences and should ensure relationship mirrored in real world
- By considering the semantics of a language we can extract the proof theory of the language – what reasoning steps are sound

Inference procedures that generate only entailed sentences are sound or truth preserving

Inference

The term "inference" generally covers any processes by which conclusions can be reached. We are mainly concerned with sound reasoning, which is called "logical inference", or "deduction". Logical inference is a process that implements the entailment relation between sentences.

if i can derive alpha from KB, then we would write:

$$\mathrm{KB} \vdash_i \alpha$$

means that sentence "alpha can be derived from KB by inference procedure i", or "i derives alpha from KB"

- **Soundness**: i is sound if whenever KB |-i alpha, it is also true that KB |= alpha
- **Completeness**: i is complete if whenever KB |= alpha, it is also true that:
    - $\mathrm{KB} \vdash_i \alpha$

We need a logic which is expressive enough to say almost anything of interest and for which there exists a sound and complete inference procedure. That is, the procedure will answer any question whose answer follows from what is known by the KB

Logics

A formal system for describing states of affairs, consisting of

1) the syntax of the language, which describes how to make sentences
2) the semantics of the language, which states the systematic constraints on how sentences relate to states of affairs
3) The proof theory, a set of rules for deducing the entailments of a set of sentences.

there are two main types of logic - propositional and first-order logic

Propositional logic

Symbols represent whole propositions, or facts. We combine propositions with Boolean connectives to generate sentences with more complex meanings.

- Negation - if S is a sentence, then not S is a sentence
- Conjunction - if S and B are sentences then S and B is a sentence
- Disjunction - if S and B are sentences then S or B is a sentence
- Implication - if S and B are sentences then S ==> B is a sentence
- Equivalence is S and B are sentences then S <=> B is a sentence

This creates a lot of problems - we need a lot of rules and logic to create a semi competent agent.

E.g. in Wumpus World, rule "Don't go forward if a wumpus is in front of you" requires 64 rules - 16 squares with 4 orientations

First-Order Logic

Represents the world in terms of objects and predicates on objects, e.g. properties of objects or relations between objects, as well as using connectives and quantifiers, which allow sentences to be written about everything in the universe at once.

Summary

We have introduced the idea of a KBA, and showed how we can define a logic with which the agent can reason about the world and be guaranteed to draw correct conclusions, given correct premises. We have also showed how an agent can turn this knowledge into action

- Intelligent agents need knowledge about the world in order to reach good decisions
- Knowledge is contained in agents in the form of **sentences** in a **knowledge representation language**, stored in a knowledge base
- A knowledge based agent is composed of a knowledge base and an **inference mechanism**. It operates by storing sentences about the world in its knowledge base, using the inference mechanism to infer new sentences, and using them to decide what action to take.
- A representation language is defined by its syntax and semantics, which specify the structure of sentences and how they relate to facts in the world
- The interpretation of a sentence is the fact to which it refers/ *If it refers to a fact that is part of the actual world then it is true.*
- *Inference is the process of deriving new sentences from old ones*/ We try to design sound inference processes that derive true conclusions given true premises. An inference process is complete if it can derive all true conclusions from a set of premises.
- A sentence that is *true in all worlds under all interpretations is called valid*. If an implication sentence can be shown to be valid, then we can derive its consequent if we know its premise. The ability to show validity independent of meaning is essential
- Different logics make different commitments about what the world is made of and what kinds of beliefs we can have regarding facts
- Logics are useful for the commitments they do not make, because the lack of commitment gives the knowledge base writer more freedom
- Propositional logic commits only to the existence of facts that may or may not be the case in the world being represented. It has a simple syntax and semantics, but suffices to illustrate the process of inference.
- Propositional logic can accomodate certain inferences needed by a logical agent, but quickly becomes impractical for even very small worlds.

Questions

What if we expand our knowledge base from our initial knowledge using entailment, but then the premises change. Does it invalidate all the entailed knowledge?

E.g. we instantiate our agent with some knowledge about the world in its KB, like "the earth is spherical", "pi = 3.141592", "g = 9.81", and from this knowledge the agent can deduce other things. What happens if we then discover that the earth is flat, or g = 10? This would invalidate all the new knowledge that the agent has.

What does it do? Does it keep a track of where it gained its knowledge from, and delete all knowledge that stems from the incorrect fact? This could get confusing if you deduce facts from your existing knowledge, then use those facts to deduce more information, and so on and so on, until you have a sprawling KB based on a faulty premise.