

Knowledge representation and reasoning (KRR)

References

1. Ronald J. Brachman, Hector J. Levesque. Knowledge representation and reasoning, Morgan Kaufmann, 2004.
2. Stuart J. Russell, Peter Norvig. Artificial Intelligence - a modern approach, 3rd edition, Pearson, 2010.

Introduction

Intelligence ^{Explen.}_{dictionary} the ability to understand easily and well, to understand what is essential, to solve new situations or problems from previous experiences.

The intelligent behavior is clearly conditioned by knowledge. Artificial intelligence (AI) studies the intelligent behavior acquired through computational means.

KRR is an area of AI concerned with the study of how an agent (e.g. human, hardware, software) uses what it knows when it decides what to do. It is the study of thinking as a computational process.

Knowledge

In an informal description, Knowledge is a relation between a knower and a proposition. The proposition is the idea expressed by a simple declarative sentence.

John knows that Mary will come to the party.
knower relation proposition

Propositions are abstract entities that can be true or false, right or wrong.

There may be different types of relationships between an agent and a proposition:

John knows/hopes/doubts/regrets that Mary will come to the party.

However, what matters about the propositions is their truth value. There are statements containing knowledge, which is not explicitly mentioned in propositions:

John knows how to get there.

In this case, we can imagine the implicit propositions:

John knows how to get to the party, he goes two blocks past the park, he turns left...

On the other hand, in sentences like "John knows George well", it is not clear if any useful propositions are involved.

There are attitudes expressed by sentences like:

John is absolutely certain/confident/of the opinion that... that differ only in the level of conviction attributed to a fact. The judgement may not be always exact.

Representation

It means a relationship between two domains, where the first takes the place of the second. The first one is more concrete, accessible than the second.

We shall consider the symbolic representation, that is a character or a group of characters from a predefined alphabet.

7, VII, seven - represent number 7

John - represents something concrete

righteousness, truth - represent abstractions

John loves Mary - symbolic representation of an abstract statement

Knowledge representation is the field that studies the use of formal symbols to represent a collection of propositions made by an agent.

Reasoning

It means the formal manipulation of the formal symbols that represent a collection of statements considered to be true, in order to produce representations of new symbols.

Therefore, the symbols must be "accessible" enough to be able to manipulate them (i.e. move, take apart, copy, concatenate), so that representations of new propositions may be constructed.

For instance, if we have the propositions.

John loves Mary.

Mary comes to the party.

after a series of steps in reasoning, we can produce the sentence

Someone John loves comes to the party..

Reasoning is a form of calculation over symbols standing for propositions (rather than numbers in arithmetic) (Gottfried Leibniz).

Why is KRR relevant for AI?

- Because in some situations it is useful to describe the behavior of a complex system in terms like believes, desires, intends, hopes etc.

For example, if we play chess against the computer - in order to help us make the next move, it would be useful to understand the program's behaviour in terms of immediate goals pursued relative to its long-term intentions.

"It moved this way because it believed that the queen was vulnerable..."

- A knowledge base is a collection of symbolic structures that represent the knowledge but also the reasoning made during the system operation.

The behavior of a knowledge-based system is conditioned not only by the represented facts (that can be retrieved like in a database). Through reasoning, the "beliefs" of the system go beyond these.

A significant part of AI involves knowledge-based systems. Expert systems are a classical example, but applications of knowledge-based systems can be found in the areas of language understanding, diagnosis, planning.

Other AI systems are knowledge-based to a lesser extent - e.g. some games or high-level vision systems.

There are also AI systems that are not knowledge-based at all - for example low-level speech, vision. These systems encode the knowledge directly in the program.

Open question: How much of the intelligent behavior should be knowledge-based? The most serious challenge to the KRR is the connectionist approach, that computes weights between artificial neurons.

What are the advantages of a knowledge-based system?

Wouldn't it be more efficient to "compile" the knowledge-base (KB) and then distribute it to the procedures that need it? (this approach is known as procedural knowledge).

Why should we retrieve facts from the KB and make reasonings in the runtime to decide next actions?

Hubert Dreyfus observed a paradox of expert systems. These systems claim to be superior because are knowledge-based. But experts do not reason - they just see the solution. Novices are the ones who reason.

Dreyfus considers to be wrong the directions that attempts to copy the human intelligent behavior.

By design, a knowledge-based system has the ability to learn facts about the world and, consequently, to adjust its behavior.

The ability to make the behavior dependent on the knowledge is desirable when we cannot specify in advance how the knowledge will be used. This approach has some advantages:

- we can add new tasks and make them dependent on previous knowledge;
- we can extend the behavior by adding new beliefs;
- we can explain the behavior of the system.

The evaluation

$$\text{Final grade} = 50\% \text{ Exam} + 50\% \text{ Lab}$$
$$\text{Exam} \geq 3$$

- The exam
- in the session
 - written
 - 2 hours
 - open book — no electronic devices

- The lab
- programming language Prolog (for any other language, the grades are at most 8)
 - 2 presentations
 - the first presentation during the 4th lab → grade G_1
 - the second presentation during the 7th lab → grade G_2
 - the lab grade = $\frac{G_1 + G_2}{2}$