32002: Artificial intelligence **Spring 2014**

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3.1 Considerations for Knowledge Representation

The following are the aspects of knowledge representation:

- What is Knowledge?
- What is a Knowledge Representation?
- Requirements of a Knowledge Representation
- Practical Aspects of good Representations
- Knowledge Representation in Natural Language
- Databases as a Knowledge Representation
- Frame Based Systems and Semantic Networks
- First Order Logic as a Representation
- Rule Based Systems
- Which Knowledge Representation is Best?

3.1.1 Defining the Knowledge

1. The act or state of knowing; clear perception of fact, truth, or duty; certain apprehension; familiar cognizance; cognition. [1913 Webster]

   Knowledge, which is the highest degree of the speculative faculties, consists in the perception of the truth of affirmative or negative propositions. –Locke. [1913 Webster]

2. That which is or may be known; the object of an act of knowing; a cognition; – chiefly used in the plural. [1913 Webster]

3. That which is gained and preserved by knowing; instruction; acquaintance; enlightenment; learning; scholarship; erudition. [1913 Webster]

3.1.2 Objective of Knowledge Representation

- to express knowledge in a computer tractable form, so that it can be used to enable AI agents to perform properly. A knowledge representation language is defined by two aspects:

- **Syntax:** The syntax of a language defines which configurations of the components of the language constitute valid sentences.
- **Semantics:** The semantics defines which facts in the world the sentences refer to, and hence the statement about the world that each sentence makes.

3.1.3 Requirements of a Knowledge Representation

A good knowledge representation system for any particular domain should possess the following properties:

- **Representational Adequacy** – the ability to represent all the different kinds of knowledge that might be needed in that domain.
- **Inferential Adequacy** – the ability to manipulate the representational structures to derive new structures (corresponding to new knowledge) from existing structures.
- **Inferential Efficiency** – the ability to incorporate additional information into the knowledge structure which can be used to focus the attention of the inference mechanisms in the most promising directions.
- **Acquisitional Efficiency** – the ability to acquire new information easily. Ideally the agent should be able to control its own knowledge acquisition, but direct insertion of information by a 'knowledge engineer' would be acceptable.

3.1.4 Components of a Representation

For analysis purposes it is useful to be able to break any knowledge representation down into their four fundamental components:

- *Lexical* part - that determines which symbols or words are used in the representation's vocabulary.
- *Structural* or syntactic part - that describes the constraints on how the symbols can be arranged, i.e. a grammar.
- *Semantic* part - that establishes a way of associating real world meanings with the representations.
- *Procedural* part - that specifies the access procedures that enables ways of creating and modifying representations and answering questions using them, i.e. how we generate and compute things with the representation.

3.2 Knowledge Representation in Natural Language

Humans usually use natural language (English, Hindi, Chinese, etc.) to represent knowledge, so why not use that to represent knowledge in our AI systems?

Advantages of Natural Language are:

- It is too expressive - we can express virtually everything in natural language (real world situations, pictures, symbols, ideas, emotions, reasoning, ...).
- Most humans use it as their knowledge representation of choice (how many text books are not written in natural language?).

Disadvantages:

- Both the syntax and semantics are very complex and not fully understood.
- There is little uniformity in the structure of sentences.
- The natural language is often ambiguous – in fact, it is usually ambiguous.

3.3 Physical Symbol System Hypothesis

Symbols lie at the root of intelligent action, which is, of course, the primary topic of artificial intelligence. For that matter, it is a primary question for the entire computer science. For all information processed by computers, at the service ends we measure the intelligence of a system by its ability to achieve stated ends in the face of variations, difficulties and complexities posed by the task environment.

3.3.1 Formal System

The *physical symbol system hypothesis* was formulated by *Allen Newell* and *Herbert Simon* in 1975.

Its claim implies both that human thinking is a kind of symbol manipulation (because a symbol system is necessary for intelligence) and that machines can be intelligent (because a symbol system is sufficient for intelligence).

As per the the Physical Symbol System Hypothesis, *symbol manipulation* was the essence of both human and machine intelligence. A physical symbol system has the necessary and sufficient means for general intelligent action. Second, experiments carried out at the same time found that, for difficult problems in logic, planning or any kind of "puzzle solving", people used this kind of symbol processing as well.

By "necessary"in above means that any system that exhibits general intelligence will prove upon analysis to be a physical symbol system. By "sufficient"means that any physical symbol system can be organized to exhibit general intelligence.

AI researchers were able to simulate the step-by-step problem solving skills of people with computer programs. This line of research suggested that human problem solving consisted primarily of the manipulation of high level symbols.

Of course, the hypothesis has also been criticized strongly by various researchers, but is in fact a core part of AI research.

References

[1] Chowdhary K.R. (2020) Logic and Reasoning Patterns. In: Fundamentals of Artificial Intelligence. Springer, New Delhi. `https://doi.org/10.1007/978-81-322-3972-7_1`