Sborník vědeckých prací Vysoké školy báňské - Technické univerzity Ostrava
číslo 2, rok 2006, ročník LII, řada strojní
článek č. 1549

Tomáš SALOKY [*], Ján PITEĽ[**], Kamil ŽIDEK[***]

SOME PROBLEMS OF KNOWLEDGE -BASED INFORMATION PROCESSING

NIEKTORÉ PROLÉMY SPRACOVANIA INFORMÁCIE ZALOŽENÉ NA ZNALOSTIACH

Abstract

There are two important ways how to implement intelligence from the computational point of view. One is based on symbolism, and the other, based on connectionism. The former approach (symbolic) models intelligence using symbols, while the latter using connections and associated weights (subsymbolic approach). Evolving by different routes, they both have achieved many successes in practical applications. The paper deals with some problems of artificial intelligence (AI) implementation within symbolic approach.

Abstrakt

V súčasnosti existujú (z výpočtového hľadiska) dva zásadné prístupy k implementovaniu inteligencie. Jeden je založený na symbolizme, druhý na konekcionizme. Prvý prístup (symbolický) modeluje inteligenciu použitím symbolov, zatiaľ čo druhý využíva spojenia a asociované váhy (subsymbolický prístup). Hoci sa vyvíjali rôznymi cestami, oba dosiahli významné úspechy v praktických aplikáciách. Príspevok sa zaoberá niektorými problémami implementovania umelej inteligencie v rámci symbolického prístupu.

1 INTRODUCTION

Artificial intelligence (AI) is concerned with intelligent behavior primarily with nonnumerical processes that involve complexity, uncertainty, and ambiguity and for which known algorithmic solutions do not usually exist. AI deals with the use of computers in tasks that are normally considered to require knowledge, perception, reasoning, learning, understanding and similar cognitive abilities. AI provides techniques for flexible, non-numerical problem-solving. These techniques include symbolic information processing, heuristic programming, knowledge representation, and automated reasoning. No other fields or alternative technologies exist with comparable capabilities. And nearly all complicated problems require most of these techniques. Many forces combine to identify AI as the central technology for exploitation. Systems that reason and choose appropriate courses of action can be faster, cheaper, and more effective and viable than rigid ones. To make such choices in realistically complex situations, the system needs at least rudimentary understanding of mundane phenomena.

[*] Prof., Ing., CSc., Department of Automation and Control, Faculty of Mechanical Engineering, Technical University of Košice, Park Komenského 9, Košice, tel. (+421) 55 602 2342, e-mail tomas.saloky@tuke.sk
[**] Ing., PhD., Department of Automation and Control, Faculty of Mechanical Engineering, Technical University of Košice, Park Komenského 9, Košice, e-mail jan.pitel@tuke.sk
[***] Ing., PhD., Department of Automation and Control, Faculty of Mechanical Engineering, Technical University of Košice, Park Komenského 9, Košice, e-mail kamil.zidek@tuke.sk

Research in AI is focused on developing computational approaches to intelligent behavior. This research has two goals:

- making machines and computational processes more useful, and
- understanding intelligence.

2 SYMBOLIC APPROACH

Currently, the dominant approach to artificial intelligence involves the construction of representational formalisms and the corresponding search based mechanisms. The guiding principle of this representational AI methodology is the physical symbol system hypothesis, first articulated by Newell and Simon (1976). This hypothesis states that: "The necessary and sufficient condition for a physical system to exhibit general intelligent action is that it be a physical symbol system." Sufficient means that intelligence can be achieved by any appropriately organized physical symbol system. Necessary means that any agent that exhibits general intelligence must be an instance of a physical symbol system. The necessity of the physical symbol system hypothesis requires that any intelligent agent, whether human, space alien, or computer, achieve intelligence through the physical implementation of operations on symbol structures. General intelligent action means the same scope of action seen in human action. Within physical limits, the system exhibits behavior appropriate to its ends and adaptive to the demands of its environment.

Both AI and cognitive science have explored the territory delineated by the physical symbol system hypothesis; both have supported its conjectures and clarified its scope. Newell and Simon have summarized the arguments for both the necessity and sufficiency of the hypothesis (Newell and Simon 1976; Newell 1981; Simon 1991).

The physical symbol system hypothesis leads to four significant methodological commitments:

- the use of symbols and systems of symbols (representations) to describe the world;
- the design of search mechanisms, especially heuristic search, to explore the environment;
- the disembodiment of cognitive architecture, by which we mean that an appropriately designed symbol system can provide a full causal account of intelligence, regardless of its medium of implementation; and
- the empirical view of computer programs as experiments. As an empirical science, AI takes a constructive approach: we attempt to understand intelligence by building a working model of it.

The earliest AI programs were able to prove theorems. Yet, the theorem-proving approach turns out unsuccessful in building a general system which can solve difficult problems consistently. In the 1970s, it began to be realized that intelligent behavior can be displayed by a computer program if the domain it deals with is sufficiently narrowed. This concept has much to do with a new transformation in the field of AI, namely, the transformation from the logic-oriented toward the knowledge-based approach. The knowledge rather than the inference mechanism makes the system intelligent. However, much human knowledge can only be represented symbolically.

Areas of AI research (AI technologies) include: expert systems, natural language processing, speech recognition, computer vision, robotics (intelligent robots), intelligent computer-assisted instruction, automatic programming, and planning and decision support.

In spite of the variety of problems addressed in AI research, a number of important features emerge that seem common to all decisions of the field, these include:

- The use of computers to do symbolic reasoning.
- A focus on problems that do not respond to algorithmic solutions. This underlies the reliance on heuristic search as an AI problem-solving technique.

- A concern with problem solving using inexact, missing, or poorly defined information and the use of representational formalisms that enables the programmer to compensate for these problems.
- An effort to capture and manipulate the significant qualitative features of a situation rather than relying on numeric methods.
- An attempt to deal with issues of semantic meaning as well as syntactic form.
- Answers that are neither exact nor optimal, but are in some sense "sufficient." This is a result of the essential reliance on heuristic problem-solving, methods in situations where optimal or exact results are either too expensive or not possible.
- The use of large amounts of domain-specific knowledge in solving problems. This is the basis of expert systems.
- The use of meta-level knowledge to effect more sophisticated control of problem-solving strategies. Although this is a very difficult problem, addressed in relatively few current systems, it is emerging as an essential area of research.

3 KNOWLEDGE-BASED INFORMATION PROCESSING

A knowledge-based system is a computer program that acquires, represents, and uses knowledge for a specific purpose. Its basic structure, consists of a knowledge base which stores knowledge and an inference engine which makes inference using the knowledge. However, the power of such a system derives from the knowledge it possesses rather than from the inference method it employs.

A conventional computer program is characterized by algorithmic processing of data. In this programming paradigm, the knowledge concerning how to do things is encoded as a bunch of procedures, which are executed step by step to deal with the data entered. In knowledge-based programming, on the other hand, we represent what we know in a declarative manner and the knowledge is invoked under a certain inference strategy or driven heuristically. Although this paradigm does not exclude procedural representation, the emphasis on declarative representation is its main feature. Another important distinction between the two programming paradigms is the feature of separating knowledge from control. In knowledge-based systems, knowledge is stored in the knowledge base while control strategies reside in the separate inference engine. This separation benefits the development and maintenance of the system because when knowledge is updated, the inference engine can be left alone, and when the inference process is changed, the knowledge base is not affected. Because of separation, a knowledge base can be run by different inference engines and an inference engine can drive different knowledge bases. This programming style revolutionizes the conventional procedurally oriented approach in which problem-solving knowledge and control knowledge are intermingled, and it is very difficult to manipulate one part without touching the other. As a consequence, a lot of time and effort can be saved using the knowledge-based approach. The comparison of knowledge-based and data-oriented information processing is provided in Table 1.

Tab. 1 Comparison of knowledge-based and data-oriented information processing.

Knowledge-Based Processing	Data-Oriented Processing
Declarative knowledge	Procedural knowledge
Separating control from knowledge	Integrating control and knowledge
Strategic and heuristic processing	Algorithmic processing
Symbolic processing (dominant)	Numerical processing (dominant)
Explanation capability	No explanation

Knowledge representation and reasoning with the knowledge are two major building blocks of every contemporary AI system. Capturing the essential features of a knowledge-domain in a form convenient for later knowledge processing is the first constructive step towards the building of an intelligent, knowledge-based system belonging to the knowledge acquisition phase of the building process. Here, a form has to be found for the abstract representation of facts and the relationship between the facts that will cover as much of domain knowledge as possible.

Domain knowledge means the knowledge specific to the domain in which the problem is defined. Researchers have recognized two important kinds of knowledge in building a knowledge-based system: deep knowledge and surface knowledge.

Surface knowledge is the heuristic, experiential knowledge learned after solving a large number of problems. It is the knowledge that human experts often rely on. It usually offers a quick, satisfactory solution, which is not necessarily the best though. The main problem with surface knowledge is its inadequacy in dealing with novel situations.

Deep knowledge refers to the basic laws of nature and the fundamental structural and behavioral principles of the domain. Invocation of deep knowledge for problem solving is sometimes called reasoning from first principles. In comparison with surface knowledge, deep knowledge has a stronger formal basis. It allows the derivation of a solution even for a novel situation, but the process may be time-consuming. One way to make it more efficient for use is to compile it. However, compiled deep knowledge may not correspond to surface knowledge since they come from different sources. In addition, there is no guarantee that every piece of surface knowledge can be proven based on deep knowledge. What is important in practice is how the two kinds of knowledge can be integrated so as to optimize the system performance.

Furthermore, methods of knowledge representation should in no way be domain or content restricted. This is because their generality simplifies the approach of reasoning with the knowledge and the associated process of iference. However, the generality should not be too wide. This was proven through the building of general problem solvers which turned out to be not really general because of the too general methods they employed in defining and solving the problem.

In addition to the confined generality, a knowledge representation method should include the representation of qualitative and semantic knowledge, as well as meta-knowledge. With reference to this, possible knowledge levels to be dealt with in the AI, as depicted in Fig. 1 should be kept in mind.

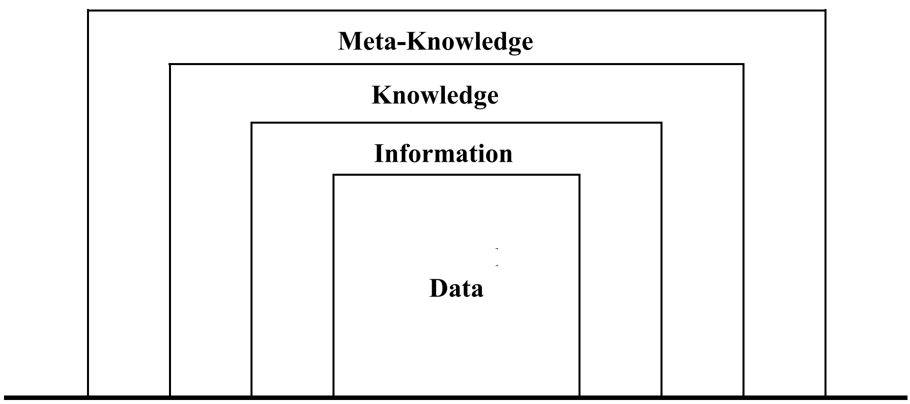

Fig. 1 Knowledge Levels

Information and data are not to be confused with knowledge itself, but they are strongly relevant to the application of the knowledge. For instance, a diagnostic system needs expert knowledge and the data concerning the problem to be diagnosed.

In some knowledge-based systems, we make distinctions between metalevel and object-level knowledge. Object-level knowledge is the knowledge for solving the problem in the defined domain. Metalevel knowledge is the knowledge which controls the use of object-level knowledge. The employment of metalevel knowledge is intended to provide a better control of object-level knowledge. However, metalevel knowledge is not the same as the control knowledge housed in the inference engine. As a matter of fact, metalevel knowledge is also controlled by the inference engine. In a metalevel reasoning system, metalevel knowledge is invoked first, which then selects appropriate objectlevel knowledge to make inference.

Meta-knowledge, however, is knowledge about knowledge, i.e. knowledge about what we know. Practically, it is the knowledge common to a variety of similar domains, from which specific domain knowledge can be generated.

One exceptional type of knowledge which is gathered mainly by experience is heuristic knowledge. It is the collection of all the skills, tricks or strategies that we might have accomplished during our professional work. For instance, an experienced physician can frequently decide at the very first look, with a high probability rate, the diagnosis concerning his visiting patient.

Closely related to heuristic knowledge is the belief, a coherently defined expression which, when true, represents the knowledge. Belief, supported by some evidence, is a hypothesis which - in spite of the evidence - might still be false.

When storing the domain knowledge in a computer for its later use for reasoning, symbolic computation, or intelligent manipulation, appropriate tools have to be used like a formal language having a well defined syntax of permitted expressions, as well as well-defined semantics for the interpretation of the meaning of such expressions. By a formal language is not meant a programming language for writing programs as a sequence of instructions or statements, and for their storing, but rather a representation language for describing objects, ideas, concepts and their interrelations. The character of such a language will considerably depend on the epistemological nature of the knowledge to be represented, i.e. on whether it is a procedural or a declarative knowledge.

The inference engine governs the use of the knowledge stored in the knowledge base. While the design of the inference engine is full of variety, we identify a general knowledge-based algorithm as follows.

The Knowledge-Based (Rule-Based) Algorithm (A general view)

Given a problem (initial conditions and the goal)

- The inference engine selects a piece of knowledge from the knowledge base.
- The.inference engine executes the selected knowledge either to transform the goal or to generate a new fact.
- If the goal (original or transformed) is solved (or deduced), then exit and succeed. If a certain stopping condition is met such as the case when the knowledge available is exhausted but the goal is not solved yet, then exit and fail. Otherwise go to step 1.

In spite of the promise of knowledge-based systems (expert systems), it would be a mistake to overestimate the ability of this technology. Current deficiencies include:

- Difficulty in capturing "deep" knowledge of the problem domain.
- Lack of robustness and flexibility. If humans are presented with a problem instance that they cannot solve immediately, they can generally return to an examination of first principles and come up with some strategy for attacking the problem. Expert systems generally lack this ability.

- Inability to provide deep explanations. Because expert systems lack deep knowledge of their problem domains, their explanations are generally restricted to a description of the steps they took in finding a solution. They cannot tell "why" a certain approach was taken.
- Difficulties in verification. Though the correctness of any large computer system is difficult to prove, expert systems are particularly difficult to verify. This is a serious problem, as expert systems technology is being applied to critical applications (such as air traffic control, nuclear reactor operations, and weapons systems.)
- Little learning from experience. Current expert systems are handcrafted; once the system is completed, its performance will not improve without further attention form its programmers. This leads to severe doubts about the intelligence of such systems.

In spite of these limitations, expert systems are proving their value in a number of important applications.

4 CONCLUSIONS

Currently, the dominant approach to artificial intelligence involves the construction of representational formalisms and the corresponding search-based mechanisms. The guiding principle of this representational AI methodology is the physical symbol system hypothesis.

The symbolic approach which has long dominated the field of AI was challenged by the neural network approach. There have been speculations about whether one approach should substitute for another or whether the two approaches should coexist and combine. More evidence favors the integration alternative in which the low-level pattern recognition capability offered by the neural network approach and the high-level cognitive reasoning ability provided by the symbolic approach complement each other. The optimal architecture of future intelligent systems may well involve their integration in one way or another.

The presented paper is the result of the scientific grant projects solution KEGA No. 3/120103 and VEGA No. 1/2216/05.

REFERENCES

[1] NEWELL, A. (1981): *Physical symbol systems, in Norman.*

[2] NEWELL, A., SIMON, H. (1976): Computer science as empirical inquiry: symbols and search. *Communications of the ACM* 19(3), pp. 113-126.

[3] SALOKY, T. (1998): *Applications of Machine Learning Techniques*. ELFA Košice.

[4] SALOKY,T. (1992): Solution of Some Knowledge Representation Problems in the System SRS Expert. In *Proceedings of the Second International Symposium ISMCR '92*. November 1992, AIST Tsukuba Research Center, Japan. (pp.395-401).

[5] SALOKY, T. (1993): *Applications of Artificial Intelligence Techniques*. ELFA Košice, 1993.

[6] SIMON, H. A. (1991): *Models of My Life.* New York: Basic Books.

Reviewer: doc. Ing. Radim Farana, CSc., VŠB-Technical University of Ostrava