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ARTICLES

EXPERT SYSTEMS AS A NECESSITY*

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The notion "expert system" seems to have gradually penetrated into the consciousness of a large circle of people. We see that two groups have been created: a group of defenders of expert systems and a group of opponents. I will show one of the aspects of expert systems' existence, which the opponents will have to face. I will present my opinion that expert systems are our next step on the way towards technical civilization and not simply a technical curiosity whose acceptance or rejection of which will not influence our progress. The question raised today should not be: *expert systems* – yes or no? but: *future progress in technology* – yes or no? Here are my reasons.

1

The issues concerning *expert systems* have their roots in another, rather controversial area of today's scientific-technical efforts – the field of *artificial intelligence*. Some negative views may, in fact, simply be projections of negative attitudes toward artificial intelligence. These standpoints often stem from the distorted ideas of the goals, methods and achievements of the struggle of artificial intelligence. In order to gain deeper insight into efforts to develop expert systems and the character of some of the expectations that have emerged in connection with this, it will be useful to make a few remarks on artificial intelligence.

Let us think a little bit about the potential meanings of the adjective *artificial*. In the expression *artificial intelligence* does it mean an artificiality, as in the case of artificial light, the physical nature of which is identical to natural light? Such an aim would easily lead to biology and then straightforward to science fiction.

Many people think that the matter at hand is, in principle, nothing more than that encountered in the case of *artificial flowers*, i.e. it is only an imitation without any deeper connection to the original, there is merely an approximate, superficial resemblance. This resemblance is not a consequence of *understanding* but of *mimicry* and a lack of consistency in observing exterior features. A more detailed analysis has been the aim of some philosophers, but often without paying attention to the remaining meanings of the adjective *artificial*. Thus, sometimes it

* The text is based on a talk delivered on November 20, 1991 in Bratislava at the workshop of the Society for Biomedical Engineering and the Slovak Medical Society.

happens that some criticisms of artificial intelligence are, in fact, only criticisms of "paradigms" of an artificial flower. However, they are declared (and by professionals outside the field of artificial intelligence, also accepted) to be criticisms of all approaches applied in this area.¹

The meaning of the adjective *artificial*, which, as in *artificial kidney*, often remains unnoticed. Here it takes on a meaning attributing certain useful properties of the original to a particular object produced by man and due to these properties the artificial product becomes a *useful substitute* for the original in certain circumstances and within certain limits. Expert systems represent this category of systems. Their development is inseparable from the developmental path of artificial intelligence, which, instead of looking for answers to questions, that are not clearly stated (and thus not precisely answerable) rather delimits particular goals and tries to achieve them by means of available methodology and technology.

The last-mentioned direction of the development of artificial intelligence has, at present, a number of defenders in theoretical research, experimentation and design of new routinely applicable computer systems. The perception of artificial intelligence as a *scientific discipline* investigating the *representation of knowledge and methods of its application* through *symbols and symbol processing* predominates. The limits of the possibilities of such a representation are being investigated and within them the particular technical possibilities of creating particular symbolic structures and computational procedures.

Research is based on *theoretical* methods common in mathematics, theoretical computer science and in formal logic. *Experimental* activities are based on various techniques of computer programming. *Engineering* activities are characterized by efforts to implement some theoretically supported conceptions or experimentally tested ideas on methods of symbolic representation and processing knowledge on available computer technology.

Of course, such a classification is always a little schematic: theoretical, experimental and engineering activities are *de facto* intertwined and they affect one another. Experiments often start as reactions to concrete orders of certain applications, i.e. as requests for engineering activities. The solutions obtained are supported after the first experimental phase by a particular theory and the process continues. The final product seldom has the strict appearance of a completed development; it may only concern a functionally convenient experiment. It is just this intertwining of activities which is not methodologically very transparent that often sows the seeds of misunderstanding and doubt about research achievements

¹ I have in mind mainly the criticisms of H. DREYFUS as presented in "What Computers Can't Do" (Harper & Row, New York, 1972) and in "Mind over Machine" (Basil Blackwell, Oxford, 1986) with S.E. Dreyfus as co-author. A more comprehensive description of the philosophy of artificial intelligence is given in "The Philosophy of Artificial Intelligence" (Oxford University Press, Oxford, 1990) edited by M. BODEN.

in the field of artificial intelligence. The results of a programmer's experiments with hypotheses pertaining to artificial intelligence will readily fit into the context of another programmer's activities; theoretical results are always related to the discipline whose methodology they use. This often brings about that a result, interesting from the theoretical point of view, will appear in another discipline, but not in artificial intelligence, where according to its nature it belongs. We should, therefore, be cautious about the criticisms of artificial intelligence from the viewpoint of its application or theoretical fertility.

2

A comparison of the functions of computer program systems with those of the most widely used media preserving symbolically represented human knowledge, i.e. the functions of a *book* – facilitates orientation in making a decision whether or not the system of computer programs is associated with efforts in the field of artificial intelligence. From the point of view of its user, the book becomes a source of knowledge due to its two functional characteristics, viz. it can be *read* and *leafed through*.

The greatest problem the author of a book has to face is the means of applying knowledge and the means of communicating procedural knowledge. The role of artificial intelligence might be understood as an effort to get the book's style of knowledge closer to the needs of particular intellectual activities focused on *problem solving*. *Computer programs*, whose *utility of behaviour is comparable with that of human experts* should therefore be our goal.

Our concise definition of *expert systems* which is a paraphrase of P.H. Winston² has brought us to our main topic. We might proclaim that expert systems are on path of our cultural advancement simply necessary to overcome what is represented by books.³ Discussions are often led on the possibilities of such a *substitute*. I shall try to adopt a pragmatic attitude toward these doubts.

Classical definitions define expert systems as systems capable of the automatic performance of various activities which are usually done by a trained person and the performance of which also requires practical experience. Discussions about utilization and applicability of an expert system can, from a certain point of view, be considered as having been concluded in the early 1990s. Expert systems have shown market vitality since areas have been found where they replaced human

² P.H. WINSTON: *Artificial Intelligence – A Perspective*. In: *AI in the 1980s and Beyond* compiled by W.L. Grimson and R.S. Patil (M.I.T. Press, Cambridge, Mass., 1987).

³ The functional and structural characteristics of expert systems and basic information on artificial intelligence, which are associated with their design, were described in: M. POPPER, J. KELEMEN, *Expert Systems* (Bratislava, Alfa 1989, in Slovak).

experts with sufficient reliability. To illustrate this argument, we shall use several examples presented in the impressive study by K.M. Wiig.⁴

Since 1986, *General Motors* has been using the expert system *Charlie* in routine operations that diagnose and analyse the vibrations of automobile engines. Since the mid 1980s, the *AT & T* has employed an *ACE* expert system in its regional Bell Centres to disclose damage to telephone cables. Both systems are implemented with the current PC technique. Expert systems are run on mainframes used for the *Underwriting Advisor* and *XCON* expert systems. The former is applied in several insurance companies for consultation and insurance services. The latter is used by *Digital Equipment Corporation* for configuring computer systems according to the buyer's request and the parameters of the producer's equipment. As an aside, about thirty people are occupied by keeping the data with which the system *XCON* works, up-to-date.

A list of routinely-used expert systems might be longer but I will give only one additional example – the *G2* system developed and sold by the *Gensym Corporation*. It is, in principle, a programming environment⁵ proposed for expert systems programming. The *Gensym Corporation* creates expert systems together with its customers, conforming to their customer's requests. The domains in which the *G2* system has been applied so far, are diverse: from systematic control (and correction), through paper industry production⁶ and similar activities in the chemical and food industries, constant control of nuclear power stations, control of fully-automated sea water preparation plants⁷ and constant control of US space shuttles or regulation of the closed biosphere within the *Biosphere 2* project.⁸ It seems that doubts about the possibilities of an efficient application of expert systems occur only in those people who do not want to take those systems into account. However, possibility does not mean necessity.

3

The possibility of the partial replacement of human skills in some domains does not mean the necessity of substitution. We can start to talk about necessity when we succeed in revealing the utilization of expert systems in such a sphere of activities where the activities of expert systems cannot be substituted by human

⁴ K.M. WIIG: *Knowledge-based Systems and Issues of Integration – A Commercial Perspective*, *AI & Society* 2 (1988), pp. 209–233.

⁵ See R. MOORE et al.: *The G2 Real Time Expert System*. In: *ISA Proceedings* (1988), pp. 1625–1633.

⁶ See R. YEAGER: *Real-time Experts Come to the Paper Industry*. *PIMA Magazine*, April 1990, pp. 45–47.

⁷ See the article in *Yankee Conveyor* of May 1989, pp. 1–11.

⁸ Information about the last two applications was published in *The New York Times*, February 10, 1991.

activities. Do we encounter such ways of utilizing expert systems today? Are we at least able to imagine them?

An expert system assisting with space shuttle control was developed in the G2 system environment at NASA. The system runs on-line: various sensors are located in 38 places in a space shuttle and the G2 monitors and evaluates the 16,000 pieces of data about the status and functioning of the engines which are provided by the sensors every second. It is unimaginable that any well-trained team of a real size working in an aviation centre or a space shuttle crew would be capable of such performance. It is argued⁹ that the development of the whole system took only two months thanks to the well-prepared G2 environment and it was the work of only one man! (An earlier attempt to create a system by direct implementation in the C language allegedly took three years. It cost too much money and hard work and, moreover, it was not successful.)

I accept the previous example of the use of expert systems as proof of the fact that expert systems are applicable in areas inaccessible to people. In other words, this case has convinced me that expert systems may become, under certain circumstances, indispensable to man. It is not only that they can replace him completely but they even significantly surpass some of his proficiencies. It might seem that we have come at last to the point where it can be stated that expert systems are *necessary* for managing some tasks which man is able to give himself but their solution is beyond his (e.g. physical) skills. However, the question which remains is whether in such situations an expert system can serve as a *substitute* for man or whether we are faced with another situation.

Our limitation of the expression *expert system* shows that there should not be any obstacles to the understanding of expert systems as *substitutes* for human experts. From this point of view they can be regarded as a continuation of the development of classical regulation techniques which gradually displaced man in the fields of various (mainly technological) processes. This view of the classical theory and practice of regulation by human beings is determinable even in deeply human-looking statements about the *irreplaceableness* of man by technology. It is simply claimed that man is (so far?) an irreplaceable component of the regulation technique.

An expert system can be understood not only as a substitute for man but also as his 'partner' or 'assistant' in decision-making, the diagnosing technical, social or biological systems, process management, etc.¹⁰ Experiences from such appli-

⁹ The data are from *Research Highlights (Artificial Intelligence)* of July 16, 1990.

¹⁰ We tried to draw attention to this aspect and some other problems which might arise for the field of (engineering) psychology in the article J. KELEMEN – Z. RUISELOVÁ: *Expert Systems as a Colleague – Some New Problems for Psychology* published in *Human Affairs*, 2, 1992, 1, pp. 48–57.

cations¹¹ supporting these opinions are available today. It, therefore, makes sense to look for alternatives other than an understanding of expert systems as 'substitutes' for human experts.

4

The word *aid* can serve as an alternative to *substitute*. One group of arguments in favour of such an understanding is of a legal nature. Responsibility for possible failure rests with man, who must not give up his opportunity to interfere. If, in spite of this, accountability was successfully transferred through law to expert systems, it might easily become an improper impetus for their wider application in places where man would rather not have accountability. Expert systems should, therefore, be considered aids to people, who will still bear full responsibility.¹²

The second group of arguments in favour of understanding expert systems as aids starts from the fact that expert systems are *de facto* a kind of *simulation* of some human cognitive and decision-making capabilities. The organization of knowledge with which these systems work, procedures for the use of knowledge for problem solving, methods and contents of explanations with which users can be provided by expert systems, all these stem from appropriate analyses of human thinking on the basis of how man would be able to *verbalize* these activities, how he would be able to *communicate* them and not on the basis of how human beings would *act* in certain situations. In other words, reality for expert systems exists in the form in which man is able to *speak* about the reality. Such a form can, however, differ from that *seen* and *faced* by man during his activities.

Improvements in expert systems understood as aids may increasingly remind users (by their fachidiotism and maybe for other reasons) of their colleagues. Figuratively speaking, expert systems become members of teams solving a certain sphere of problems. Performance of their functions within such teams may be even more skilled than when fulfilled by people. Some of their capabilities probably dominate those of any man. As an example, the G2 system in connection with its use for space shuttle control.

Let us try to create a more general formulation. Imagine a system (e.g. a team) which is composed of other systems (members of the team) constituting its *components*. Let the activity of the integrated system be the resultant of the components' activities. We are interested in the effect of the whole as compared with the effect of components. The effect of the whole could be characterized

¹¹ The article by A. GIECI: *Expertné systémy v rozhodovacej činnosti operátora* (Expert Systems in Decision-making Processes of an Operator), *Informačné systémy* 19, 1990, pp.121-140 supports such an understanding and provides more bibliographic data.

¹² For more details on the legal aspects of expert system introduction see G.S. TUTHILL: *Legal Liabilities and Expert Systems*, *AI Expert* 6, 1991, pp. 45-51.

simply as a sum of the components' effects (a shop as an integrated system sells exactly the sum of the goods which is sold by the individual assistants per day). It may, however, happen that the quality of the effect of the whole will surpass that of the effect of individual components (the opportunity of writing this text on a particular computer using a particular text editor is a result of the collaboration of an enormous number of components: some produced the integrated circuits of the computer, others programmed the text editor, others ensured its sale, etc.).

The systems, whose functions qualitatively go beyond the functions of their components are usually called *complex systems*.¹³ These systems are, at present, becoming subjects of intensive theoretical research. The technological possibility of creating extensive computer networks promotes entirely new ways of communication (electronic mail, information databases, banking...). However, such computer technology applications require a theoretical base for their construction and guarantees as to the necessary level of their functional reliability.¹⁴ The area of *robotics* has recently become another source of theoretical and experimental investigations. We see that some of the activities so far considered as possibly based on the representation of the environment in the system could, in fact, be based on simple reactive activities of the system components and of other systems situated in this environment.¹⁵

The use of an expert system created in a *G2* environment can be understood as a suitable supplement of a team of specialists – through a technological system. From this point of view, expert systems are becoming a real necessity for our future technical advancement.

Technological products of man properly integrated into the structure of his activities had an *emergent* impact on the development of human civilization. The steam engine and its significance for the first industrial revolution, or electrotechnology and its influence on information and means of communication provide ample evidence. In his report for the *Club of Rome*, A. King argues that *the influence of integrated circuits is revolutionary. The first industrial revolution significantly multiplied negligible strength of human and animal muscles. The second will multiply the intellectual capabilities of man in an unforeseen measure.*¹⁶

¹³ This concerns an understanding of *complex systems* as reported by H.A. SIMON in his book *The Science of the Artificial*, 2nd edition (M.I.T. Press, Cambridge, Mass., 1982).

¹⁴ A group of special problems associated with such systems (so-called open systems) is presented by C. HEWITT in his contribution *Organizations Are Open Systems* published in: *Artificial Intelligence at MIT: Expanding Frontiers*, vol. 1, pp. 596–611 (M.I.T. Press, Cambridge, Mass., 1990), edited by P.H. Winston and S.A. Shellard.

¹⁵ This approach is described in more detail in a study by R.A. BROOKS: *A Robot That Walks: Emergent Behavior from a Carefully Evolved Network* in volume 2 of the publication mentioned in the preceding note (pp. 29–39).

¹⁶ See A. KING's contribution in the report *Microelectronics and Society* (Pergamon Press, New York, 1982) edited by G. Friedrichs and A. Schaff.

Finally, it seems to me that systems most closely resembling the so-called *expert systems* are a necessity for the future advancement of man in the field of technology. And future progress in technology is necessary to the same extent, as we honour and uphold moral and ethical rules which are probably the most constant attributes of our civilization. We should not forget that one of the most efficient driving forces of the development of this civilization has been and will remain the technical inventiveness of the human spirit. Without this force, without the freedom of dreams and their coming true, the concept of civilization loses its original meaning.