IMITATION OF EXPERT JUDGEMENT

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Contents

Summary

An expert is a person with outstanding ability to solve without errors difficult problems in a professional field. In spite of differences between professional fields (geology, engineering, chess, music, medicine, mathematics and so on) there are similar conditions of expert skill development and similar features of expert knowledge. The different methods of imitation of expert knowledge in computer are developed. There are two ways of utilization of expert knowledge presented by the computer model: the development of expert systems and the development of tutoring computer systems. New directions of the research are given.

1. Introduction

In many fields of human professional activity there are people demonstrating an excellent performance that is clearly overcome the average level. They are called as

experts. According to dictionary, an expert is “a person with great knowledge, skill, and experience in a particular field”. The outstanding ability of experts to solve difficult practical problems in geology, engineering, chess, music, medicine and so on, attracts the attention of researchers during last 30-40 years.

There are two research directions aimed to the study of expert knowledge and performance: cognitive psychology and artificial intelligence. The psychologists are trying to investigate the organization of an expert memory, expert behavior in problem’ solution, the structure of expert knowledge. The researchers in artificial intelligence are trying to create the computer systems to collect expert knowledge and to develop the so-called knowledge bases helping a novice in practical tasks. It may be said that one of the main goals of artificial intelligence consists in the development of artificial systems imitating expert reasoning. Some problems and tools are common for both these directions of the research.

It is interesting to systemize the available knowledge about the expert behavior and existing attempts to develop computer systems imitating the expert reasoning.

2. The Nature of Expertise

There are several different theoretical approaches to the nature of human expertise.

Historically, the first explanation of outstanding expert performance was connected with the *belief in innate abilities and capacities of experts.* For many years such explanation was very popular. Many books about genius, prodigies, and exceptional performers have been published. The typical features of such books were descriptions of early signs of outstanding abilities of a future genius. According to general belief, the talent is given to the geniuses as a gift. They need some exercises to support and develop the talent but the origin is from their birth.

There are psychological studies of expert abilities. First, it is necessary to mention the book of A. Luria “The mind of a mnemonist”(1987). The book is devoted to the analysis of exceptional performance of one “mnemonist”(a person who could remember and reproduce without errors huge amount of information). The mnemonist Sh. was known in 1920s in Russia and his performance appeared as really mysterious. The famous Russian psychologist A. Luria investigated this phenomenon, founded the special heuristics and tricks used by Sh. and uncovered to a great extent the roots of his performance. Luria demonstrated the special feature of inherited capacities of the person including positive and negative features of his information processing system.

In the book of H. Gardner the theory of multiple intelligence is proposed (1983). According to his point of view, outstanding expert abilities depend on the correspondence between intelligence profile and the requirements of a professional field. He selected seven areas of intelligences: linguistic, musical, spatial, logical-mathematical, bodily kinesthetic, interpersonal and intrapersonal. Each of them is independent and has special biological basis. Following this theory, it is necessary to investigate innate children ability to find the type of intelligence. For example, the ability of small children to differentiate musical tones is the sign of musical intelligence.

Quite a different approach to the study of expert performance is proposed by K. A. Ericsson and his colleagues (Ericsson K.A., Lehmann A.C.,1996). They try to use laboratory experiment to find reproducible results of expert performance. According to the their opinion, the analysis of different experimental data demonstrates the leading and surpassing role of extended training. Using many examples, K. Ericsson developed the perception of superior performance through everyday extensive training. The critical factors for new "talent" are early beginning of training, good supervision and hard work: not less than 4 hours everyday for musicians. It was found that for the musicians it is possible to calculate the number of practiced hours and, in accordance with it, to differentiate top-level players(best experts), average and low-level players(Ericsson, Charness,1994).

H. Simon and his school have different view of expertise (Richman et al., 1996). They do not deny the role of expert talent (in spite of the difficulty to evaluate its influence in the experimental condition). From the point of view of information processing methodology, the most important feature of an expert is the size and organization of knowledge base. To simulate the process of knowledge base construction and chunking, EPAM (elementary perception and memory) model have been developed. This model imitates for verbal learning experiment the ability of an expert to create a chunk, then save it in the long-term memory and to distinguish between new and old chunks. The memory of an expert is not only a collection of many chunks but an indexed encyclopedia with convenient (for the expert) way of fast utilization. In spite of differences in the nature of perception of the expertise there are many common observations of expert behavior.

3. The Main Features of the Expert Knowledge

It is possible to select the features of expert behavior accepted by big majority of researchers.

3.1. Forward Reasoning

The phenomena of enhanced recall and forward reasoning were shown to be typical for the experts (Patel, Groen, 1991). It means they have superior memory skills in recognizing the patterns in the domains of expertise and tend to work "forward " from the description of a problem to a decision. Novices are working backward from the set of possible decisions to the problem description trying to select a decision corresponding to the description.

3.2. Fast Reasoning

For experts fast solution of a problem in the domain of expertise is typical. Sometimes, they demonstrate instant solution of a problem saying that they solved it by intuition. The example of Grandmasters playing chess with several players simultaneously is widely known.

For medical experts the behavior is similar: they read the description of a patient and make diagnosis. They can not verbalize the intermediate steps in the reasoning simply

saying that there is enough information for such decision. Sometimes, physicians spend more time to check the initial guess. But in the big majority of cases expert decision is usually right.

3.3. The Performance in a Different Field

It is interesting that in a different domain of expertise experts demonstrate the same kind of behavior as novices. In the experiment (Patel, Groen, 1991) the physicians were given the tasks from different a medical field. They demonstrated the pattern of behavior typical for medical students.

The chess experts have outstanding ability to replace the chess pieces on a board that they have seen only for 3-5 seconds. But for random combinations of figures the performance of the experts and novices is the same (Chase, Simon, 1973).

3.4. Magical 10 years

It was found that approximately ten years of intensive training are needed even for the most talented people to become experts in their fields. For example, Mozart was composing at the age of 5 but his world class music was composed at the age of 17. The same number of years was found for famous chess players: Kasparov, Fisher and so on. Even in natural sciences like physics the same number of years was needed for Einstein before the publication of first high-level paper (Richman et al., 1996).

3.5. The Size of Expert Memory

The outstanding performance of experts could be explained by big size of knowledge base located in LTM. For example, for the chess experts, according to the evaluation, the number of chunks (familiar patterns of pieces) held in the memory lie in the range from 50,000 to 100,000 (Ericsson, Lehmann,1996). According to Simon, the memory of an expert could be represented as an indexed encyclopedia.

3.6. The Difference Between Novices and Experts in the Organization of Information

H.Boshuizen and H.Schmidt (1992) found that physicians come to use a progressively smaller number of generalized clinical signs as they acquire more experience. They, probably, arrive at such signs by trial and error.

For the cases where the experts and novices do not differ by the number of diagnostic signs, the difference is in how experts use the signs , that is, in the decision rules (Shanteau, 1992).

According to the ACT theory advanced by J.Anderson (1983), the expert rules may be regarded as a “compiled knowledge”. By reference to mathematical problems, Anderson has shown that complex productions are formed in the subjects as they master the material, and that they use the constructions as a single rule. This is, probably, how the experts form their decision rules (Shanteau, 1992).

It was found that in making diagnosis, the experts tend to use binary scales of diagnostic signs, that is, to take into account clearly distinguishable and opposite values(for example, skin is dry or moist, breath is pathological or normal, etc.).

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Bibliography

Anderson, J., R.(1983) *The architecture of cognition*. Cambridge, MA, Harvard University Press.[The main ideas of ACT theory of expert knowledge transfer are presented].

Boshuizen, H.P.A. and Schmidt, H.G.,(1992) "On the role of biomedical knowledge in clinical reasoning by Experts, Intermediates, and Novices," *Cognitive Science*, 16, 153-184. [The experiments demonstrating the differences in the behaviour of experts, novices and intermediates are presented].

Chase, W. G., Simon H.A., (1973) *Perception in chess*. Cognitive Psychology, 4.55-81.[The difference in the ability of experts and novices to remember meaningful patterns of chess pieces is demonstrated in experiments].

Clancey W. J., (1985) Heuristic Classification. *Artificial Intelligence*, 27 215-251 [The approach of learning expert skill from the cases presented in productions is given].

Ericsson K. A., Lehmann A. C., (1996) Expert and exceptional performance: evidence of maximal adaptation to task constraints, *Annual Psychological Review*, v.47, pp.273-305.[A survey of the existing results on the causes of expert performance].

Ericsson K.A., Charness N., (1994) Expert performance, its structure and acquisition., *American Psychologist*, V.49, N 8, 725-747.[The explanation of expert performance is given and role of deliberate practice is stressed].

Gardner H.,(1983) *Frames of minds: The theory of multiple intelligences*., New York, Basic Books. [The theory of expert performance is proposed].

Larichev O., Mechitov A., Morgoev V., Moshkovich H., Furems E.(1990), Exact duplicates of human judgements , in: K. Borcherding, O. Larichev, D. Messick (Eds), *Contemporary Issues in Decision Making*, North-Holland, pp.43-55.[A new method of the construction for the complete and non-contradictory knowledge bases is given].

Larichev O., Naryzhny Y., (1999) Computer-based Tutoring of Medical Procedural Knowledge , In: S. Lajoie, M. Vivet (Eds.*) Artificial Intelligence in Education*, JOS Press, Amsterdam. [A new approach to the transfer of medical procedural knowledge is proposed].

Luria A.,R.,(1987) *The mind of a mnemonist*. , Cambridge, Massachusets and London. [A unique description of the life and abilities of outstanding expert is given].

Patel, V., Groen, G.,(1991) "The general and specific nature of medical expertise: a critical look". ,in: K.A. Ericsson and J. Smith (Eds.) "*Toward a general theory of expertise* ".,Cambridge Univ.Press, Cambridge,

pp. 93-125.[The results of experiments demonstrating the difference in the behaviour of experts and novices inside and outside of professional field are given].

Reber A.S., (1989) Implicit learning and tacit knowledge, *Journal of Experimental Psychology: General,* 118, pp.219-235.[Main ideas of implicit learning are given]

Richman H.B., Gobet F., Staszewski J.J., Simon H.A.,(1996) Perceptual and memory processes in the acquisition of expert performance: the EPAM model., In: K.A. Ericsson (Ed.), *The road to excellence: the acquisition of expert performance in the arts and sciences, sports and games.* Mahwah, New York, Erlbaum Associates, pp. 167-186 [A survey of the existing knowledge about expert behaviour and EPAM model are presented].

Shanteau J.(1992) How much information does an expert use? Is it relevant? , *Acta Psychologica,* 81, 75-86. [The difference in the information utilisation by the experts and novices is discussed].

Wielinga B.J., Schreiber A.Th., Breuker J.A. (1992) KADDS: A modelling approach to knowledge engineering. *Knowledge Acquisition,* 4(1),pp. 5-53.[An approach to the development of toolbox for a knowledge engineer is described].

Biographical Sketch

Professor **Oleg I. Larichev** received his Candidat Degree in Optimal Control Theory in 1965 and his Doctor Degree in Decision Making in 1975 from Institute for Control and Management Problems, Moscow. His fields of interest are Decision Making, Artificial Intelligence, Multicriteria Mathematical Programming, and Psychological Problems of Decision Making. He is Professor of Moscow Institute for Physics and Technology (Technical University). He is Head of Department in the Institute for Systems Analysis, Russian Academy of Sciences. He published 8 books (two in English) and 180 papers. In the field of Decision Making, HE developed new methodology for the construction of decision methods and decision support systems having psychological and mathematical foundation-Verbal Decision Analysis. In the field of Artificial Intelligence, he proposed a new approach to the study and exact imitation of experts' knowledge and to the construction of Intelligent Tutoring Systems. In 1991 Prof. O. Larichev was elected as Corresponding Member of Russian Academy of Sciences and in 1997-as a Full Member of the Academy. He received the Gold Medal from the International Society on Multiple Criteria Decision Making.