Title: Bridging Mechanisms for Knowledge-Based Systems

Course:
Year: 1990
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Report No: P90034

Abstract: Understanding of intuition's part in decision making, problem solving, and everyday thought is the focus of recent studies, which largely missed it in their prior investigations. This report summarizes results of a survey of present knowledge of this critical element in human cognition and presents a set of findings, along with hypotheses for adding intuition-enhancing components to knowledge-based systems. It also describes the impact of such proposals on the operation of the knowledge-based system and possible areas of research which may prove useful for future studies

BRIDGING MECHANISMS FOR KNOWLEDGE-BASED SYSTEMS

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EMP - P9034

Introduction

Current knowledge-based systems include powerful inference capabilities, constantly improving user interfaces, increasingly more complete knowledge bases, and are built using ever more robust methods. This progress has not been duplicated for the less obvious elements of these knowledge management systems. Among such subtler system components are user cognitive processes, communication of knowledge between human and computer as well as between humans, knowledge representation schemes that are closer to those used by humans to encode, retrieve, and analyze their memory and thoughts, and many other still ambiguous areas.

Within the realm of user cognitive processes are a number of uniquely human abilities to use the information they store and process to develop understanding. One such ability is intuition. While many authors are content to use this term as representing vague or unconscious activity of the mind, others have sought to refine its meaning. What is important is that the underlying cognitive process, while largely hidden from direct observation, is more often being seen as having a critical impact on a diverse range of human activities. This attention has brought a level of enthusiasm for a possible understanding of intuition's part in decision-making, problem solving, and everyday thought to recent studies that was largely missing in prior investigations.

This study undertakes a survey of present knowledge of this critical element in human cognition and presents a set of findings and hypotheses for adding intuition-enhancing components to knowledge-based systems. It also describes the impact of such proposals on the operation of the knowledge-based system as well as what possible areas of research may prove most useful for following studies.

Definitions

Intuition has been defined in many ways, oftentimes the same author has found a number of useful meanings and settings where they are most appropriate. The difficult task is to find the definitions and applications that are most direct to the solution of present knowledge-based system limitations. The following represents a broadly based survey to begin the process of discovering which meanings may prove of greatest value.

A very limited number of authors have attempted to study this subject in systematic, largely academic, ways. For example, an early work of Westcott published in 1968, indicates how recent the more rigorous studies have been. The next substantial work on the subject did not appear until 1982, which represented an even more ambitious effort. (Bastick). This excludes the occasional work in areas not emphasized in this study, such as philosophy, the

theory of scientific investigation (although some material from this subject is included), and any of a number of personal expositions on the subject which includes such widely read authors as Buckminster Fuller. Other authors' work is difficult to classify, such as that of Jonas Salk (1983) or Rudolf Arnheim (1986), but these can generally be seen as philosophical investigations into more narrow subject areas. The importance of these author's works lies in the clarity with which they describe their thoughts, helping make their work relevant in a wider scope and to this study.

Much of the work seen in bibliographies (much of it also not readily available) concentrates on the role of intuition in the creative processes and, more generally, in educational settings as part of both instructional technique and learning. Some discussion of learning will be presented later in this study, primarily in the context of applying enhancements of present knowledge-based systems to problem solving and to the management of organizational retention of information and knowledge. Otherwise, most of the work intended for educational environments lacks specificity for inclusion in this analysis.

The survey of definitions begins with Malcolm Westcott's book, Toward a Contemporary Psychology of Intuition, published in 1968. As its subtitle suggests, this work is an historical, theoretical, and empirical inquiry into the nature of intuition. It is its empirical aspect that sets it apart from other publications. And although his conclusions are

not surprising, it is still important for its emphasis on objectivity.

After four chapters of exploring the nature of common intuitive behaviors, Westcott offers what he calls "the most general case of intuition" as follows, "reaching a conclusion on the basis of less explicit information than is ordinarily required to reach that conclusion" (1968, p. 98). He also recognizes that this definition allows for the multitude of ways that information can be insufficient, lacking a consensus, or needing later verfication. (p. 98)

Wescott concludes his study with the results of his experiments showing that individuals could be classified along two dimensions - one, the amount of information they required before attempting to solve problems, and two, the success they had in solving problems. (1968, p.147-8) These two dimensions produced four kinds of performance. Of these, only one met the definition of intuitive thinking and the others were more in contrast to that style. (p. 148)

Most of the difference in the performance was attributed to personality, whereas there was little difference in other comparisons such as in academic performance. (Westcott, 1968, p. 148) The subjects that scored highest on their ability to solve problems correctly with less than typical needs for information, redundancy, and explicitness were judged to be more intuitive. (p. 191) No measures of prior knowledge or other possible justifications for the success at problem solving were tested. Thus, Westcott's conclusions are limited

in their generalizability.

A number of articles were published on the subject between the time of Westcott's book and Bastick's Intuition. How We Think and Act, in 1982. They are not included in here primarily because of the level of detail provided by Bastick and since his work mostly subsumes their conclusions. He successfully avoids some of the largest obstacles in finding a suitable definition for intuition in two ways. First, he leaves intuition as a phenomenon and does not ascribe conditions beyond personality, environment, and experience as necessary. Second, he excludes the mystical, metaphysical, and spiritual from consideration except as related subjects and uses them only peripherally.

Bastick has made the critical observation that any particular definition given for intuition is not only the subjective assessment of the person giving it, but it is likely to be specific primarily to one specialty. (1982, p. 13) In order to develop a more general definition, he assembled a list of properties associated with intuition derived from definitions of the term not as an operational definition but in general or theoretical use. (p. 24) The list contains twenty properties, as follows (p.25):

1. Quick, immediate, sudden appearance
2. Emotional involvement
3. Preconscious process
4. Contrast with abstract reasoning, logic, or analytic thought

5. Influenced by experience
6. Understanding feeling - emotive not tactile
7. Associations with creativity
8. Associations with egocentricity
9. Intuition need not be correct
10. Subjective certainty of correctness
11. Recentring
12. Empathy, kinaesthetic or other
13. Innate, instinctive knowledge or ability
14. Preverbal concept
15. Global knowledge
16. Incomplete knowledge
17. Hypnogogic reverie
18. Sense of relations
19. Dependence on environment
20. Transfer and transposition

These properties are not exclusive, since Bastick explains them in groups, illustrating the scope of the definitions found in his research. (1968, chap. 1) A very complex interdependence between these properties is presented, and indicates that it is not possible to separate the attributes of one property from many others. (p. 49)

Bastick, like several others, emphasizes that the widespread separation of analytic, intuitive, and other modes of thought is not justified. (1982, p.51) He argues that all thought is "interwoven with our intuitive processes and cannot exist independently" (p. 51).

Another important definition of intuition is given by Jonas Salk, in his 1983 work, Anatomy of Reality. He says, "Intuition may be seen as a continuation or extension of 'natural' processes, like instinct, for example. Reason may be seen as that which man adds to explain his intuitive sense" (p. 79). He goes on to state, "This suggests the pattern of the way the mind works as feeling/thinking entity, as an entity with an intuition/reason system for guidance. This is a way to regard how the mind functions, as a self-organizing, self-developing system which possesses a means for feedback, and also for feedforward...This system must have emerged by chance and was then selected for its self-correcting and self-balancing as well as its self-selecting and self-organizing properties" (p. 80). For the purposes of this research, the key term in the above quote is guidance. The feedback/feedforward supports improved guidance, and those are the kind of enhancements that it is hoped that this study can identify.

Although some of these issues are to complex to address here, Salk's represents one of the most conceptually complete definitions to date. For subsequent research, these qualities can be examined in terms of complex systems, sometimes called the sciences of complexity, as well as the more recent simulation technologies, such as artificial life. These techniques emphasize development, organization, evolution, and adaptation as having critical importance on the behavior of systems of all kinds. It may be that the study of

intuition and its role in certain cognitive processes, especially within the limited domain of knowledge-based systems, will find greater expression in the foregoing research subjects. This might be even more likely considering that guidance itself is similar to these experimental ideas.

Psychologists use the words insight and intuition interchangably, as many others do. Common meanings of insight in psychology use the concepts of sudden, seemingly comprehensively recognized solution to problems. (Reber, 1985, p. 359-60) Intuition is characterized as occuring without conscious thought, either with or without the use of implicitly recognized external cues. (p. 374) As such, both terms represent a kind of rapid learning, with the goal being to solve a problem or to result in having a clearer understanding of a concept or meaning.

Arnheim (1986) describes intuition as being one of two branches of cognition, the other being intellect. (p. 13-14) He states, "Intuition and intellect are somewhat complexly related to perception and thinking", meaning in that respective order. (p. 14) This is a useful comparison, since it supports the notion that to improve intuition more than just improving thought processes is involved. It suggests that acquiring a knowledge of the broader aspect of the problem under study is as important as intellective specifics. This does not imply that minutiae need be accounted for.

Instead, it argues for a more complete human-computer interaction that can capitalize on the effect that broader problem knowledge can have on improving overall mental capability. How this can be done is discussed later.

The symbiotic nature of intuition and intellect are expressed most clearly in the discussion by Perkins in his The Mind's Best Work (1981). He elaborates on a concept he calls critical response, which depends on both intuitive and analytic thought. Such response is simply finding solutions to problems that are not based entirely on one process or the other. Somehow we have evolved a language that accounts for this dualist nature of thought. It allows us to use "critical terms [that] both report a judgement pro or con and give a reason for it. Such terms aren't merely conveniently compact; they mirror the fused nature of our evaluative reactions" (p. 107).

Perkins goes on to say that we can dispose of these two terms entirely, since they are most often used as a convenience for describing the percieved or attributed dominant mode of thought. (1981, p.109) He asserts that while intuition remains something of a mystery, "Deliberate analytical evaluation...depends on a strategy that might be called 'looking harder'. Looking harder involves two important tactics: 'looking at' particular parts of the thing to be assessed, and 'looking for' particular features or kinds of features" (p. 110).

He concludes with the proposition that, "In general and in creative activity, people maximize sensitivity and thoroughness in evaluation by 'looking harder' - directing attention systematically to the various parts and aspects of something" (p. 111). This has relevance to this study in how the proposed additions to knowledge-based systems will influence problem solving. At some point, hypotheses can be given as to how to improve intuitive processes by the relying on its interrelatedness with analytical thought. These will derive, in part, from the application of tools for improving "looking for" and "looking at". It would also be interesting to see how such forms of search include the intuitive part of the cognitive dichotomy.

Decision Making Applications of Intuition

How intuition can be used in the domain of knowledge-based systems is similar to the way it has more recently been applied in the decision-making and managerial research. A prime example of such usage is given by Agor in his The Logic of Intuitive Decision Making (1986). The rapid change, crisis events, and the limited usefullness of linear models of the environment they have brought about have created a climate in which executives must find new techniques to assist in their decision-making. (p. 3)

Agor makes a key assumption that should improve acceptance of stronger reliance on intuition in executive

decisions, and that is that just because it is not easily explained or observed does not mean that intuition is not logical. (1986, p.5) In a way, he says, we have constantly tested our limits of what reality is, using as an example how at one time the scientific thinkers saw the scope of what is real as limited by the human eye's field of vision. (p. 5) That is, nothing existed beyond what was seen by the human eye, and hence the notion that the earth was flat.

Carl Jung, the psychologist, found specific characteristics of managers who were skilled in their use of intuition. (Agor, 1986, p. 7) In general, such individuals were better able to find new alternatives, more likely to have vision sensing future possibilities, adept at producing new ideas, and were more able to deal with rapid change, crisis, and complex situations. (p. 7) If true, then searching for ways to improve intuitive processes could produce a similar effect to that described by Niwa. (1990) He describes a case where users who develop their own knowledge base and rely on their intuitive skills as part of both the maintenance and utilization of the system are not only happier with the results, but have a system that extends the capability of typical expert systems in highly productive ways.

Mintzberg discusses some of the results of major researches into the nature of problem solving and intuition. (1989, chap. 4) Reviewing the work of Herbert Simon, he

states that using the concept of analyses frozen into habit, as Simon does, to describe intuition and judgment is too restrictive. (1989, p.67) It is better, Mintzberg offers, to view the strengths and weaknesses of analytical and intuitive cognitive processes as being that which is most descriptive of their nature. (p. 69)

Five categories for comparing the differences are given: cost, error, ease, complexity, and creativity. (Mintzberg, 1989, p.70-71) Mintzberg notes that although the relative cost for using analysis is high, acquiring the capability to perform analysis is relatively low. (p. 70) Conversely, acquiring useful intuition has a high cost, as a kind of investment, but exercising intuition often involves little cost; it can be almost immediate. (p. 70) The error and ease categories for contrasting systematic, analytical thought and the instinctive, intuitive show how both modes of thinking are needed, since the results otherwise can be 'extinction by instinct' or 'paralysis by analysis'. (p. 71) Such dualistic comparisons can be applied equally as well to complexity and creativity. Most problems arise when commonsense, whatever that may be, fails to prompt the decision-maker to use the other mode of thought as a check on the dominant mode used in arriving at the decision.

Some significant inadequacies of analysis and of the human brain can influence how analytical and intuitive thought processes are brought to bear on a given problem.

These can be seen as informational, organizational, or human cognitive limitations. (Mintzberg, 1989, p.73-75)

Mintzberg lists problems with information as:

1. Formal information is often too limited.
2. Formal information, by aggregating data, is often too general for the manager.
3. Much formal information is too late.
4. Some formal information is unreliable.

These are coupled with the organizational problems of:

1. Rigid, dysfunctional objectives can encourage the use of inappropriate information.
2. Politics can cause the distortion of information.
3. The nature of managerial work introduces a bias in favor of oral channels of information at the expense of documented sources.

And, finally, the limitations of the human brain:

1. Cognitive limitations restrict the amount of information that people consider in a complex decision process.
2. The brain systematically filters information in line with its established patterns of experience.
3. Psychological failures and threats further impede the brain's openness to information.

These all serve to illustrate that any decision process is not only limited by decision-making abilities of the person or persons involved, but also the constraints that most individuals have. People have little or no control over these

constraints, but they act influentially in the process as well. A knowledge-based system that tries to improve intuitive processes might also find benefit in recognizing that these usually uncontrollable aspects of the problem will influence not only intuition, but all other aspects of the problem.

Another very useful examination of the importance of both kinds of thinking appears in Louis Pondy's discussion of "Union of Rationality and Intuition in Management Action". (1983, chap. 7) In this chapter, Pondy presents several other authors' models of how the dichotomous nature of thought can be considered in a more complimentary or integrated way. Quinn's logical incrementalism is described, which is a model of the way strategic decisions are made. (p. 181-186) Quinn postulates that strategic change is the result of 'unfolding rationality'. (p. 181) That is, a new vision for a firm develops incrementally, with its origins only slightly felt and recognized as anomalies in current assumptions. (p. 182)

What is most important about this model is that the anomalies are not only noticed, they are given names, often ill-defined phrases. (Pondy, 1983, p. 182) This adds a communication dimension, permitting them to be discussed and their character developed and also isolated. It is then amplified, finally resulting in seeing a pattern or structure. (p. 183) Such amplification starts in the small,

and further observation leads to incrementally more detail, more explictness, broader exposure and support and more formal justification. (p. 184)

These changes in the form of the anomaly also lead to partial solutions. (Pondy, 1983, p.184) As time progresses, partial solutions are developed that begin to limit the potential harm from these anomalies as understanding of them improves. Feedback is recieved from the results of partial solutions, and a cooperative system of new observations, new partial solutions, and new results shapes the eventual strategic understanding of these problems. This is a kind of learning, letting the system evolve in a progressive refinement of the firm's ability to find the meaning of the anomaly and how to deal with it.

This type of approach may find use in knowledge-based systems since it suggests several ways to deal with poorly understood phenomena, such as intution. Pondy lists four considerations to improve the union of rationality and intuition (1983, p.190):

1. must be incremental over time, taking place through action and performance in the first-hand experience of individuals
2. incorporate both explicity, concrete details and tacit schemata
3. feed off and emerge from the misfits, imperfections, and local nuances within an otherwise ordered structure

4. result from the individual's subjective encounter with his or her external world

(It should be noted that Pondy offers a variety of closely related terms for what he calls the "two modes of consciousness" (1983, p.172). For rational, he lists analytical, sequential, convergent, detailed, logical, scientific, objective, digital, and explicit. For intuitive, he gives synthetic, simultaneous, divergent, holistic, artistic, pattern-recognizing, subjective, analogue, and tacit. Relating these terms is a task beyond the scope of this study, but an important one for further research into how such features could be added to knowledge-based systems.)

The importance of these models in the role of intuition in decision making is twofold. First, a good understanding of how this cognitive process is viewed is essential for capitalilzing on it within the confines of a programmed system, such as a knowledge-based system. Second, important, although sometimes subtle, characterizations of the human thought process have been discussed. Viewing such processes in light of decision making help to highlight critical parts of their operation. Thus, a base of decision making research related to this study's focus has been reviewed and can subsequently be used to evaluate the possible improvements to knowledge-based systems to follow. It is also advantageous to note that most of the managerial research cited emphasized real-

world solutions to such problems, and their concepts were rooted as much in empirical observations as theoretical analysis. Relying on these types of researches improves the applicability of any workable cognitive/intuitive enhancements.

Current Knowledge-Based Systems

Many examples can be found in the literature of systems whose developers sought to improve such systems decision making abilities. More recently, system developers have sought to improve these systems by adding non-analytical enahancements, such as in human-computer cooperative systems (Niwa, 1990), conversational systems (Gregory, 1986), or any of a number which seek to add some form of heuristics to the system.

Even for systems that are designed for operation in a single, although broad, domain (accounting for the degree of unstructuredness to the domain remains uncertain - examples of such systems are medical diagnosis systems for a large segment of the field of internal medicine, and not just a diagnostic specialty) a number of techniques must be improved. Advanced systems in the next decade will be more capable across a spectrum of techniques, including reasoning with uncertainty, temporal reasoning, qualitative reasoning, compilation of causal knowledge, and case-based reasoning. (Patil, 1988, p. 375)

Systems that purport to provide some form of expert consultation suffer not only from limited domains. They also inspire fear among the user base of limited job security, earning potential, and over reliance on automated systems that reduce the importance of the expert in the decision cycle. (Patil, 1988, p.376) Systems that overcome these fears tend to be promoted more as an adjunct and emphasize problem-specific informational needs, aid in the evaluation of alternative solutions, or offer advice on the decision making process. (p. 376) These results can be expected to be found in the user base of any knowledge-based system where it enters into a domain where established and highly-trained professionals will comprise most of the users. Therefore, some consideration will need to be given to these concerns in any implementation.

The ill-structured problems that predominate the business decsion making environment have a number of characteristics that are poorly understood. Current systems have largely been unable to account for either the knowledge or the strategies required to solve such problems in the manner of human experts. Premkumar, in a study focusing on the cognitive aspects of business decision making, lists the following major characteristics of such problems (1989. p. 562):

1. the problems are not well-structured
2. the knowledge domain is not well-defined
3. evaluation of both qualitative and quantitative

information

4. incomplete and probabilistic information is used in the decision making process
5. decision making is based on a set of assumptions about the organization and its environment which varies with time
6. the acquisition of knowledge is evolutionary and is continuously modified and refined with experience to suit new circumstances
7. organizational decision making requires the integration of knowledge from multiple experts spread across differenct functions in the organization

Knowledge-based systems will not perform well in such environments unless the underlying basis of the above problems can be addressed either in knowledge representation or in algorithms. This study advocates a gradual, or incremental, adoption of cognitive enhancers, such as those that might improve intuitive processes. Attacking the ill-structured nature of business decisions in a head-on approach does not seem warranted at this time. Too many unanswered questions of human cognition in the aggregate and how to cope with highly complex decision situations remain.

Possible Improvements

Many of the limits of present knowledge-based systems

are a result of the limited understanding of human cognition. It is instructive to discuss some of the research in this area. For example, Kaplan and Simon describe how a shift in problem representation necessary to solve a particular problem is addressed in an experimental setting. (1990, p.374) The performance on such problems can be predicted, the researchers held, based on the availability of generators and constraints used in the search for the solution. They state that there are four sources of search constraint for such problems (p. 381):

1. features of the problem itself
2. hints from the experimenter
3. relevant domain knowledge
4. heuristics

They believe that heuristics are most important for insight problems. One such heuristic is the rule of attending to features of a problem that remain invariant. (p. 382) In fact, this is a kind of constraint. Adding this capability to a knowledge-based system would require pattern matching, some form of lexicon to check similar word meanings, and a learning capability to add new constraints as they are discovered.

All of the possibilities for search constraint depend on knowldge representation, reformulation, and associational qualities that can be generated by the problem solver. It might prove useful to have users select key aspects of their problem from checklists that support establishing relational

links between elements. In a way, a crude form of building cognitive schemata could be supported. This would not be too much different from users building their own conceptual clustering schemes. Much learning, as mentioned earlier, is thought to proceed from the human ability to develop relationships.

Metaphors represent another powerful, distincly human, construct that facilitates inference between often quite dissimilar things. As Campbell says, "Metaphors synthesize disparate ideas. They allude, match, compare. They include and integrate possibilities...Metaphors are divergent, not convergent. But metaphors not only place the familiar in a context of the strange. They also place the strange in a context of the familiar." (1982, p.250) He continues with the observation that metaphors (in a manner similar to analogy) are often used by teachers to "bridge between information which the students already possess...and new information which they are required to learn." (p. 250) It has been shown that children can absorb large amounts of new information quickly if there is a pattern of relations, or a structure. (p. 250) This would require that the enhancement for the system have some technique for relating the terms. Again, this depends on improving other facets of knowledge-based systems, such as representation schemes. It seems at least possible, if not entirely probable, that more flexible methods for relating disparate data need to be found.

Such a technique could not depend on any form of natural language understanding, but it could be effective if the user were questioned as to why the relationship given in the metaphor is important. This, of course, assumes that such questions could be developed. It is not unreasonable to suggest that finding the what, why, when, and where of such relationships might be a useful first step. The system could maintain a list of explanations, and be searching for connections in the background while the user answers such questions. This could well make such interaction tedious, and this is recognized as a factor limiting its use. But it is the experimental information that such a technique could provide that might provide meaningful subsequent enhancements.

A variety of concepts about concepts, which seem closest in their nature to the metaphorical techniques above, might prove useful to constrain the search of a knowledge-based system. For example, there are a differing definitions for classical, probabilistic, correlated attributes, exemplars, and prototypes. (Ford, 1987, p. 360) Furthermore, objects and events are defined by more than their attributes. (p. 361) They often include organizational aspects, as well. That is, how objects and events are put together into meaningful wholes. Such synthesis of abstractions may prove overly difficult with present technology and knowledge of such processes. The improvement of intution would result

from the refinement (hopefully in relatively limited time) of the user's goals, guesses, categorizations, and representation schemes, but it will take many revisions of a such a system before adequate knowledge would be accumulated to make it useful.

One very problematic area of decision making that often appears as much intuitive as analytical is the application of probability. Fox (1987) argues that common assumptions about uncertainty in decision making have helped to misguide efforts to classify the nature of such concepts. For example, mathematical interpretations of probability rely on degrees of uncertainty, most often with a zero lower bound and upper limit of unity. The probilists (those who seek to "reduce the number of concepts of uncertainty to a single, manageable numerical idea" (p. 208)) have dominated this discussion while alternative theories have been less in evidence.

Fox believes that a logically-based theory of distinctions to classify uncertainty would have greater benefit. (1987, p. 208) He says that "uncertainty, like any other concept, is a subject that we have knowledge about and which we might articulate" (p. 203). In analyzing other heuristic models, Fox suggests that uncertainty is treated as a side-effect of cognition, not explicitly formed in thought. (p. 202) Fox states that it is "obvious that at some level we represent uncertainty explicitly...the vocubulary of natural language is littered with specialized terms that describe it. Words like 'possibility' and

'plausibility', 'suspicion' and 'doubt'...seem to suggest that uncertainty is to some degree an explicit part of our representation of our world" (p. 202). He says, "we can make distinctions about uncertainty which emphasize different logical aspects rather than degrees of uncertainty" (p. 204). He states that while the quantitative meaning of these terms is ambiguous, their logical foundations are not. (p. 205)

It may be possible to provide some support for the user to make more appropriate distinctions between the terms possible, plausible, and probable than currently is common. These terms serve as the logical foundation of probability, before any subjective or quantitative measures can be properly applied. This function could help constrain the scope of the search mechanism, especially when certain domains might have great differences between the importance of finding a conclusion probable, plausible, or possible. It would be useful to look for how these terms commonly affect the nature of managerial decisions and apply that insight to the development of a probability assessment bridge.

Conclusion

Whether they evolve from present expert systems, neural networks, machine learning techniques such as induction and clustering, or from the experiments of cognitive psychologists makes little difference. What these ideas suggest is that it is entirely possible that many of the

logically-based (one might even say analytically-based in contrast to intuitively derived) techniques so prevalent now will have limited value in the long term. It is this author's view that the mind is full of flexible methods for arriving at conclusions that are not described by extant models, and that only by testing these assumptions will progress truly result.

The noted artificial intelligence scholar John McCarthy explained the importance of having features in a system that represent best efforts, but that are not necessarily fully functional. He says. "The philosopher might claim that the working systems are too trivial to be of interest...He would be wrong, because it turns out that the philosophical investigations of action have missed important phenomena that arise as soon as one tries to design systems that plan actions." (1988, p.308) This is probably the case with most of the enhancements discussed in this study. Their payoff will not be immediate, but they are possible steps toward valuable future enhancements.

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