PROCEEDINGS OF THE INTERNATIONAL CONFERENCE
ON FIFTH GENERATION COMPUTER SYSTEMS 1988,
edited by ICOT.

A NEXT-GENERATION KNOWLEDGE-BASE FROM THE VIEWPOINT OF EXTENDING LOGIC FRAMEWORK

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Dr. D. Lenat has showed his belief and his approach toward a next-generation knowledge-based system [Lenat 87]. His view is certainly based on his experience on AM and EURISKO [Lenat 82a, 82b, 83a, 83b], which are prominent systems indicating a direction of future AI systems. Heuristic knowledge plays an important role in AM and EURISKO to guide the inference process and to achieve excellent performance, i.e., discovery in these systems.

For breaking through the current level of AI systems, Lenat emphasizes three points [Lenat 87]; i.e., (1) the knowledge principle (knowledge is the main power for excellent intelligent behavior), (2) the breadth hypothesis (analogical and commonsense abilities are necessary for intelligent behavior particuraly in unexpected situations), and (3) AI as empirical inquiry. Based on his belief, he is carrying out CYC project at MCC. I was very impressed by hearing his invited talk at IJCAI-87, Milano.

While I mostly agree with his view, I would like to describe some comments from somewhat different viewpoint [Ishizuka 88].

As Lenat states, one major limitation of the current knowledge-base is its brittleness; that is, it rapidly looses the competence beyond the scope of registered knowledge. This is due to the property of deductive inference. The positive side of this inference is its safety; that is, the result of deduction is always correct as long as the knowledge in the knowledge-base is correct. In other words, the result is a transformation of the knowledge originally implied in the knowledge-base. No new knowledge is generated.

In order to broaden the power of current knowledge-base, we are required to add advanced AI functions, such as, recognition, analogy, induction, abduction, etc. Of cource, researches on these individual functions are important. However, we think that there is an underlying common fuction, which is particulary important from the viewpoint of building next-generation knowledge-base systems. The fuction we are considering is the handling of incomplete knowledge.

Generally speaking, the incomplete knowledge is the knowledge which is not always correct. It means here more specifically hypothotical knowledge, knowledge with exceptions, partially missing knowledge, knowledge with inconsistency, generalized knowledge, etc. We consider that the next-generation knowledge-base system includes the incomplete knowledge in addition to complete knowledge and manipulates them to achieve the advanced AI functions.

As a starting stage toward such knowledge-base systems, we have chosen a logical hypothesis-based reasoning system, which has been exemplified in [Pool 87]. The key feature of this reasoning system is the function of constructing a set of consistent knowledge which can deductively prove given observations or constraints. Even if the knowledge-base includes inconsistent knowledge, its consistent part of the knowledge is used selectively.

Several frameworks under the name of

non-monotonic reasoning are being explored to deal with incomplete knowledge. Recently, the relation among different frameworks is also being clarified. The reason why we choose the logical hypothesis-based reasoning system is its practical usefulness; that is, it is applicable for wide range of practical problems, such as recognition including diagnosis, design, etc.

Starting from the hypothesis-based reasoning system, we have set our approach as shown in Fig.1, to develop several stages of the future knowledge-based system. So far, we have done some work on the mechanisms of inductive learning, knowledge assimilation & management, and inference speed inprovement for the knowledge-base including incomplete knowledge [Matsuda 88a,b].

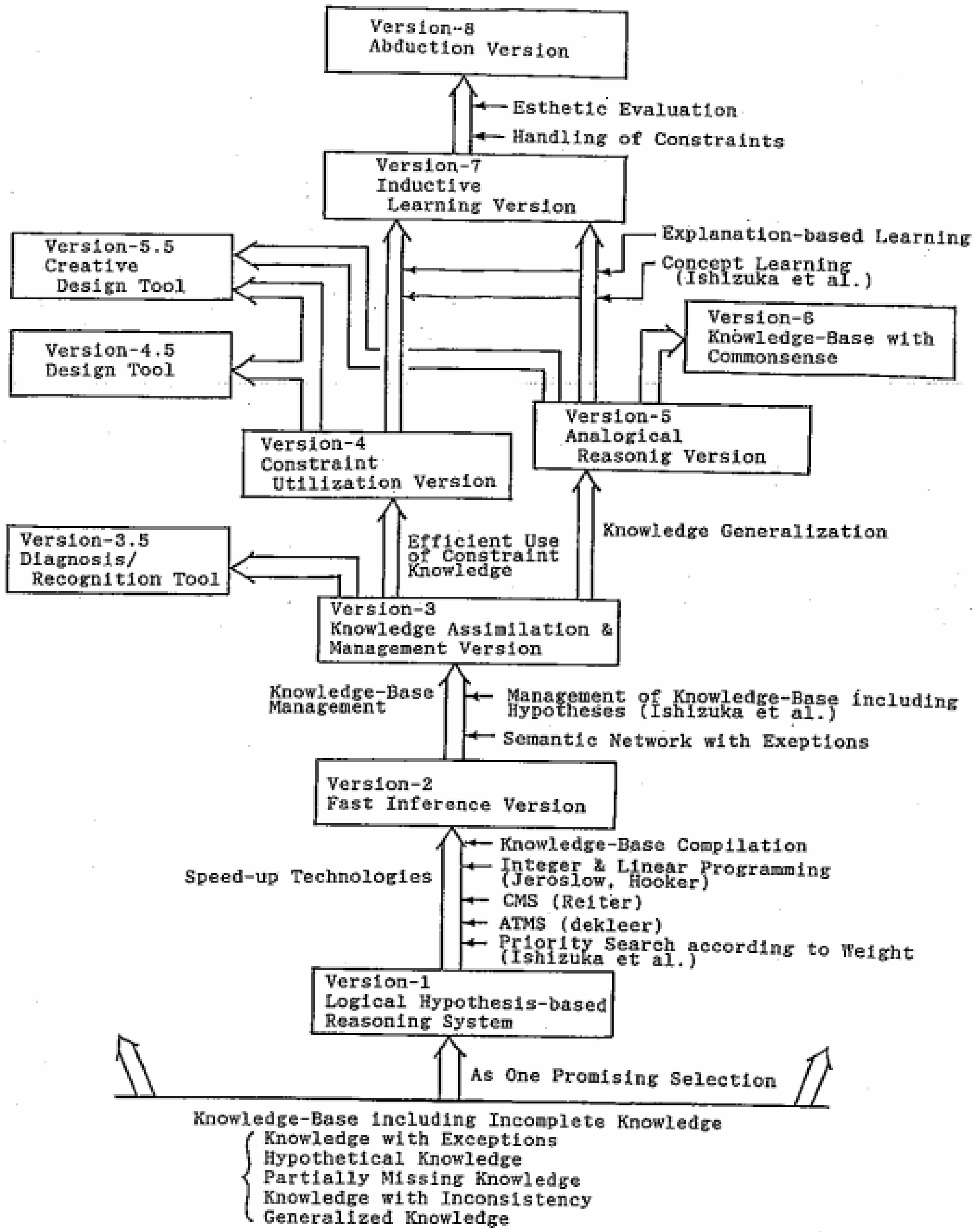

Fig.1 An approach toward next-generation knowledge-base systems.

Similar to the Lenat's view, we intend to realize the commonsense function based on analogical reasoning.

Our claim regarding this approach is that the advanced AI functions mentioned above are not isolated but has rather continuous spectrum on the function of handling incomplete knowledge.

The most crucial problem at present is the inference speed of the hypothesis-based reasoning system. While the advanced AI functions provide us braoder intelligence ability, they generally require more amount of inference. We have to solve this problem; otherwise, it cannot be practical. One effective way is to incorporate heuristic knowledge; however, it results in knowledge acquisition problem, since the heuristic knowledge is tend to be domain specific.

Of course, we should have the knowledge structure allowing the utilization of heuristic knowledge whenever it is available. On the other hand, we need some mechanisms which can effectively work even if the heuristic knowledge is not fully available. These mechanisms should be less dependent of domain knowledge. In some cases, we have to find some restricted knowledge representations which enable reasonable inference time. The use of weight assigned to knowledge is a relatively easy and practical way to control the priority of search process. The weight here is heuristic knowledge in a sense. (We have already implemented this method in our system.)

A more essential way is to explore a knowledge compilation technology for the knowledge-base including incomplete knowledge. Possible approaches toward this direction are suggested in [Reiter 87] and [Hooker 88], where the scope of knowledge representation is restricted to propositional logic at present. As indicated in [Hooker 88], it seems that the combination with integer and linear programming methods becomes important increasingly in order to attain the polynominal order of search time.

If speaking simply, the knowledge organization for problem solving in a computer and in a human brain has three levels as shown in Fig.2; i.e., skill, (heuristic) rule and basic knowledge levels. Lenat's view emphasizes the rule level, whereas our approach starts from the basic knowledge level. If the

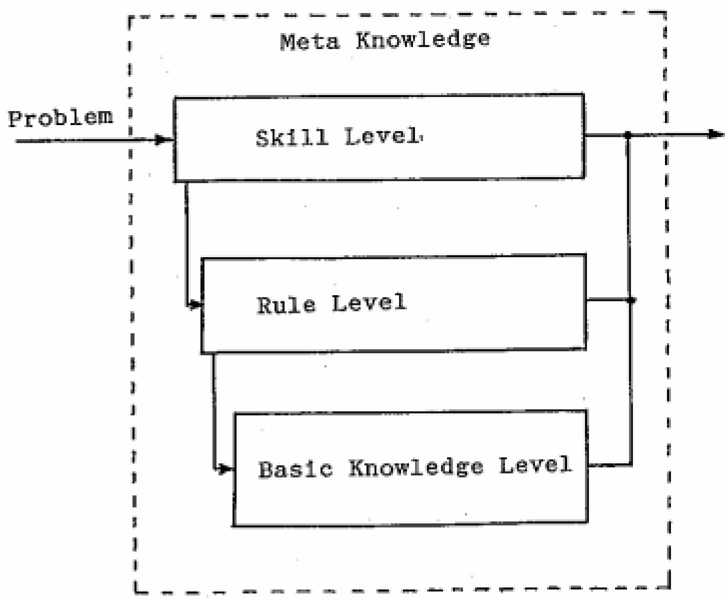

Fig.2 The levels of human/computer problem solving.

heuristic knowledge is available in each problem domain, the rule level can exhibit excellent performance. The knowledge acquisition problem, however, exists for the rule level. We are expecting that this problem will be lessen by the result of MCC's CYC research project.

I have pointed out here that technologies in the basic knowledge level are also required for the next-generation knowledge-base providing advanced AI functions. An automatic learning of the higher level knowledge by observing the behavior of its lower level is desirable. Some efforts toward this direction are being explored as seen in SOAR; however, their promise in practical sense is invisible. Thus it is necessary to develop efficent and tough technologies for each level. A meta-level structure which controls the hierachical or parallel behavior of the knowledge levels is also necessary.

REFERENCES

[Hooker 88] J.N. Hooker, "A Quantitative Approach to Logical Inference," Decision Support Systems, Vol.4, pp.45-69 (1988).

[Ishizuka 88] M. Ishizuka, "An Approach Toward Next-Generation Knowledge-Base System by Handling Incomplete Knowledge (in Japanese)," Jour. of Japanese Society for Arti. Intelli., Vol.3, No.5, pp.552-562 (1988).

[Lenat 82a] D. Lenat, "AM: Discovery in Mathematics as Heuristic Search," in Knowledge-based Systems in Artificial Intelligence (R. Davis and D. Lenat) McGraw-Hill (1982).

[Lenat 82b] D. Lenat, "The Nature of Heuristics," Arti. Intelli., Vol.19, No.2, pp.189-249 (1982).

[Lenat 83a] D. Lenat, "The Role of Heuristics in Learning by Discovery: Three case Studies," in Machine Learning (R. S. Michalski, J. G. Carbonell, T. M. Michell eds.) Springer-Verlag (1983).

[Lenat 83b] D. Lenat, "Theory Formation by Heuristic Search: The Nature of Heuristics II: Background and Examples," Arti. Intelli., Vol.21, No.1,2, pp.31-59 (1983).

[Lenat 86] D. Lenat, M. Shephrerd and M. Prakash, "CYC: Using Common Sense Knowledge to Overcome Brittleness and Knowledge Acquisition Bottlenecks," AI Magazine, Vol.6, No.4, pp.65-85 (Winter 1986).

[Lenat 87] D. Lenat and E. Feigenbaum, "On the Thresholds of Knowledge," 10th IJCAI, Milano, Italy (1987), also Int'l Workshop on AI for Industrial Applications, Hitachi, Japan (1988).

[Matsuda 88a] T. Matsuda and M. Ishizuka, "An Enhanced Knowledge Representation and Concept Learning Mechanism in Hypothesis-based Reasoning System," Jour. of Japanese Society for Arti. Intelli., Vol.3, No.1, pp.94-102 (1988).

[Matsuda 88b] T. Matsuda and M. Ishizuka, "Knowledge Acquisition and Management Mechanism for Frame Knowledge-base including Hypothesis Knowledge (in Japanese)," Trans. IEICE, Vol.J71-D, No.5, pp.902-908 (1988).

[Pool 87] D.L. Pool, A. Aleliunas and R. Gobel, "Theorist: A logical Reasoning System for Default and Diagnosis," in Knowledge Frontier -- Essays in the Representation of Knowledge (N.J. Cercone, G. McCalla eds.), Springer-Verlag, N.Y. (1987)

[Reiter 87] R. Reiter and J. deKleer, "Foundation of Assumption-based Truth Maintenance System: A Preliminary Report," AAAI-87, pp.183-188 (1987).