The Logic of Cognitive Action

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1 Cognition = Representation + Transformation

Human intelligence resides in our continually displayed cognitive skills, such as inference, learning, planning or searching, rather than in some static treasure house of accumulated knowledge. Hence, the logical structure of cognitive activities themselves is at least as important as that of their propositional or otherwise encoded products. This general epistemological view has a long philosophical pedigree dating back to the work of, amongst others, Wittgenstein, Popper and Toulmin, who have emphasized language games, learning strategies by trial and error, or juridical procedures as typical models for cognitive behaviour. Since the seventies, such dynamic views of cognition have found a more technical expression in philosophy and linguistics, witness various formal paradigms introduced by Hintikka, Stalnaker, Gardenfors, and the current "Dutch School" in dynamic logic. We shall discuss this movement, showing how both static and more dynamic aspects of cognition can be profitably studied from a logical point of view.

2 Logical Models for Cognitive Activity

There are at least three major formal models for bringing out the logical structure of cognitive activities. Perhaps the oldest proposal uses ideas of Game Theory, witness the work of Lorenzen and Hintikka, where winning strategies for logical games constitute the core of succesful inference or interpretation. Another important dynamic model is that of Proof Theory, especially in its "constructivist" guises, which has acquired explicit computational overtones in its recent development by authors like Martin-Lof, Girard and Gabbay. But the prevalent paradigm so far has been what may be called Programming Theory, drawing upon the ideas of program and process structure found in Dynamic Logic (Hoare, Pratt) or Process Algebra (Milner, Bergstra & Klop). What matters in all these approaches is the "software" , rather than the "hardware" of cognition which is often enshrined in the popular, but misleading emphasis on Turing Machines. These three paradigms share some broad logical features, but they also highlight different aspects of human intelligence, all of them crucial to the above project.

3 Key Issues in the Logic of Cognitive Action

In these various logical models of dynamics, several major issues may be identified. First, what is the logical structure of cognitive action? An answer would call for a fundamental set of operators creating complex procedures, whose possible universal status might give rise to an "intensional" version of Church's Thesis. Next, what are the basic varieties of inference (there are surely different styles of reasoning involved in different cognitive activities), with their logical properties,

and how do these relate to other cognitive skills (such as general problem solving or memory search)? Finally, what kind of "architecture" will integrate the various inferential components of the resulting logical systems, ensuring their meaningful cooperation, just as humans find it easy to switch their repertoire? Eventually, these individual concerns should be lifted to the many-agent case too, since a large part of human intelligence seems located in our social behaviour (for which games or distributed protocols may provide specific logical models).

4 Illustrations in Artificial Intelligence

We shall demonstrate the potential impact of these general considerations in some specific current issues in AI, viz. (1) non-monotonic logic, default reasoning and the dynamics of preference, (2) general proof theory of search procedures and problem solving, (3) planning with dynamic logic and process theory. These examples also suggest further links between Artificial Intelligence and more standard areas of Computer Science.

References

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