The Logic of Common Sense

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The Golden Age of logic came to an end in the sixties, with the solution of the remaining classical independence problems in set theory. It was the time for logicians to remember that logic is more than the study of mathematical proofs; it is the study of reasoning in general. For instance, proofs of program correctness are in the realm of logic also. Or, to put it differently, the theory of programming becomes a part of mathematics as soon as one has developed an axiomatic basis for it.

The theory of commonsense reasoning occupies a similar place in the history of logic. It provides an axiomatic basis for reasoning about the world inhabited by "agents" like us—by agents who have beliefs and goals, who perform actions in order to reach these goals and, by doing so, change the state of the world. It can be seen as a step towards the aim of rationalist philosophy, described by Descartes in *Discourse on Method*:

> Those long chains of reasoning, quite simple and easy, which geometricians use in order to achieve their most difficult demonstrations, had given me occasion to imagine that all things which can be known by man are mutually related in the same way.

The roots of today's research on commonsense reasoning are found in the 1959 paper by John McCarthy entitled *Programs with Common Sense* [6]. Considerable progress has been made since then. But much more work is required before we achieve the level of understanding of commonsense reasoning comparable to our current understanding of reasoning about sets or computer programs.

Default Reasoning

One of the features of commonsense reasoning that makes it different from traditional mathematical proofs is the use of defaults. A default is a proposition that is postulated to be true in the absence of information to the contrary. For instance, an agent may assume by default that his observation correctly reflects the state of the world, and be prepared to retract this assumption in the face of evidence that he is in error. Leibniz described this default in his essay *An Introduction to a Secret Encyclopedia*:

> There is given to us a natural propensity to trust the senses ... and also to believe all appearances unless there is a reason against this; for otherwise we would never do anything.

In this century, the important role of defaults was recognized by philosophers of law and ethics.

The AI researchers who realized, in the late seventies, how basic defaults are in commonsense reasoning, and tried to formalize them, found that the mathematical logic of that time was unprepared for this challenge. All systems of logic that had been discussed in the literature—classical, intuitionistic, modal, whichever—are *monotonic*: in these systems, adding a new axiom never results in the retraction of a conclusion derived without that axiom. Default reasoning is nonmonotonic, because the new axiom may represent an exception to one of the defaults included in the axiom set.

A 1980 issue of the journal *Artificial Intelligence* presented three theories of nonmonotonic reasoning that have had major impact on subsequent research on the logic of common sense [7, 8, 9]. Many modifications and alternative approaches have been proposed since then, but even in the original form the theories were quite sophisticated and mathematically elegant. (This is especially remarkable in view of the fact that the authors of these theories had not been trained as logicians.) The modern state of the field is described in [4]. More recent ideas on the use of one of the primary nonmonotonic formalisms, circumscription, are described in [5].

Years later, it became clear that some declarative languages of logic programming can be viewed as nonmonotonic formalisms and used, like circumscription, for expressing defaults. This interpretation of logic programming is stressed, for instance, in [2]. Defaults have been also integrated into terminological languages—computationally attractive subsets of first-order logic [1].

Commonsense Law of Inertia

One default has played a particularly important role in the study of commonsense reasoning—the default known now as the "commonsense law of inertia." It is stated by Leibniz in the essay quoted above as follows: "Everything is presumed to remain in the state in which it is." Any axiom describing the effect of an action on the state of the world represents an exception to this default.

Making the idea of inertia precise has been the subject of much work. Current research deals with such issues as the actions whose effects are indeterminate or are specified indirectly, or the actions that are performed simultaneously by several agents.

Logic and Computation

The research program outlined in [6] has two components: the formalization of commonsense reasoning and its automation. The former is sometimes referred to as the "epistemological" part of the program, and the latter as the "heuristic" part. The problem of formalizing default reasoning discussed above is, in this sense, epistemological.

In classical research on mathematical proofs, the problems of formalization and automation were treated separately, for a simple historical reason: logicians came up with satisfactory formalizations of mathematics many years before the advent of the modern digital computer. Some papers on commonsense reasoning, likewise, address one of the two problems; other contribute to both areas.

The possibility of expressing defaults in terminological languages and in languages of logic programming and deductive databases is important for the automation of default reasoning, because, for these languages, relatively efficient query evaluation procedures are known. Some of the relevant research on logic programming is described in [3]. In [10], reasoning about action is automated using the Boyer–Moore theorem prover.

Is the theory of commonsense reasoning a branch of logic, or does it belong to artificial intelligence? The answer is, it belongs to both. As Leibniz writes in the essay that has been already quoted twice,

> It does not make much difference how you divide the sciences,
> for they are one continuous body, like the ocean.

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