Historical Remarks on Nonmonotonic Reasoning, Especially Circumscription

John McCarthy
Computer Science Department
Stanford University
Stanford, CA 94305
jmc@cs.stanford.edu
http://www-formal.stanford.edu/jmc/

Abstract

Humans have always done nonmonotonic reasoning, but rigorous monotonic reasoning in reaching given conclusions has been deservedly more respected and admired. Euclid contains the first extended monotonically reasoned text available to a large public. I suspect that even Euclid did nonmonotonic reasoning in arguing for the postulates. It is unfortunate that the rigorous monotonic reasoning of Euclid has been deemphasized in education, because Euclid generates in people who are not mathematically minded a respect for rigor.

Conclusions derived by monotonic logical reasoning from precisely stated premises have always been the ideal. When people jump to conclusions, they are criticized for the gaps in their reasoning, because the conclusions are not guaranteed to follow from the premises. Worse yet, the premises are often unstated.

The inability to base all conclusions on logical reasoning from precise and agreed premises has been long noted. There are two main reactions. One is to try to develop other principles of reasoning, and the other is to abandon logic - a big mistake. In my 1977 paper, *Epistemological problems of artificial intelligence* (McCarthy 1976). I referred to people saying logic was inadequate. I may have been referring to Marvin Minsky's 1975 paper and not getting around to looking it up. I think he was the first to use the phrase "nonmonotonic reasoning".

Long before I wrote *Epistemological problems ...*, I knew deduction wouldn't suffice for AI. However, writing that summarizing paper obliged me to say something systematic about nonmonotonic reasoning and I introduced circumscription, perhaps with Occam's razor in mind. Here's how I summarized it.

> The intuitive idea of *circumscription* is as follows: We know some objects in a given class and we have some ways of generating more. We jump to the conclusion that this gives all the objects in the class. Thus we *circumscribe* the class to the objects we know how to generate.

In (McCarthy 1986) I summarized the proposed uses of circumscription as follows.

1. As a communication convention. Suppose A tells B about a situation involving a bird. If the bird cannot fly, and this is relevant, then A must say so. Whereas if the bird can fly, there is no requirement to mention the fact.

For example, if I hire you to build me a bird cage and you don't put a top on it, I can get out of paying for it even if you tell the judge that I never said my bird could fly. However, if I complain that you wasted money by putting a top on a cage I intended for a penguin, the judge will agree with you that if the bird couldn't fly I should have said so.

The proposed Common Business Communication Language (CBCL) (McCarthy 1982), similar to recent XML based systems but more general than most, must include nonmonotonic conventions about what may be inferred when a message leaves out such items as the method of delivery.

2. As a database or information storage convention. It may be a convention of a particular database that certain predicates have their minimal extension.

3. As a rule of conjecture. This use was emphasized in (McCarthy 1980). The circumscriptions may be regarded as expressions of some probabilistic notions such as "most birds can fly" or they may be expressions of standard cases.

4. As a representation of a policy. The example is Doyle's "The meeting will be on Wednesday unless another decision is explicitly made".

5. As a very streamlined expression of probabilistic information when numerical probabilities, especially conditional probabilities, are unobtainable but can be taken as infinitesimal or infinitesimally close to one.

6. Auto-epistemic reasoning. "If I had an elder brother, I'd know it". This has been studied by R. Moore.

7. Both common sense physics and common sense psychology use nonmonotonic rules. An object will continue in a straight line if nothing interferes with it. A person will eat when hungry unless something prevents it. Such rules are open ended about what might prevent the expected behavior, and this is required, because we are always encountering unexpected phenomena that modify the operation of our rules.

What of the future?

1. There are monotonic *solutions* of the frame problem such as those using *explanation closure* axioms. These

encode all admitted causes of change. The nonmonotonic reasoning is done by the human who wrote the axioms. Explanation closure is not *elaboration tolerant*; introducing new actions or new conditions for the success of actions requires surgery on the explanation closure axioms. This is ok as long as the scientific or practical objectives are sufficiently limited. Human-level AI or even reasonable elaboration tolerance will require the computer to do nonmonotonic reasoning.

2. In my opinion many variants of nonmonotonic reasoning that have been introduced, e.g. Vladimir Lifschitz's pointwise circumscription, have been insufficiently studied.

3. (McCarthy 1986) introduces *simple abnormality theories* in which a single predicate *ab* is minimized while all other predicates are varied. Lifchitz and McDermott respectively showed that particular simple abnormality theories for the blocks world and the Yale shooting problem suffered from unintended models. It remains possible that a simple abnormality theories with different predicate symbols and axioms could handle these problems. I conjecture that this won't work; certain so far unstated limitations apply to all simple abnormality theories.

4. I think minimization of predicates, i.e. circumscription, is here to stay, but this doesn't cover all possible future developments in nonmonotonic reasoning.

5. (McCarthy 1980) mentions such entities as "things wrong with the boat" and suggests minimizing them. No formulas are given, but I think such abstract entities will be needed even for a proper treatment of the missionaries and cannibals problem.

References

McCarthy, J. 1976. Epistemological Problems in Artificial Intelligence[1]. reprinted in (McCarthy 1990).

McCarthy, J. 1980. Circumscription—A Form of Non-Monotonic Reasoning[2]. *Artificial Intelligence* 13:27–39. Reprinted in (McCarthy 1990).

McCarthy, J. 1982. Common Business Communication Language[3]. In A. Endres and J. Reetz (Eds.), *Textverarbeitung und Bürosysteme*. R. Oldenbourg Verlag, Munich and Vienna.

McCarthy, J. 1986. Applications of Circumscription to Formalizing Common Sense Knowledge[4]. *Artificial Intelligence* 28:89–116. Reprinted in (McCarthy 1990).

McCarthy, J. 1990. *Formalizing Common Sense: Papers by John McCarthy*. Ablex Publishing Corporation.

[1] http://www-formal.stanford.edu/jmc/epistemological.html
[2] http://www-formal.stanford.edu/jmc/circumscription.html
[3] http://www-formal.stanford.edu/jmc/cbcl.html
[4] http://www-formal.stanford.edu/jmc/applications.html