

# REASONING WITH EXCEPTIONS FIRST

Marcelino C. Pequeno

Laboratório de Inteligência Artificial

Departamento de Estatística e Computação

Universidade Estadual do Ceará

Avenida Paranjana 1700

E-mail:marcel@ufc.br

**ABSTRACT.** This paper is concerned with a very basic question: "*What should we infer from a nonmonotonic knowledge base?*" We present three principles which we judge essential to correctly answer this question. The second principle *exceptions first* is the most important one. It sheds some light upon a very obscure issue in nonmonotonic reasoning: the rising of multiple extensions. It plays a very important role on the formalization of the frame problem. It implies that abnormalities for the frame axiom are calculated step by step instead of globally as all seminal nonmonotonic formalisms do.

**KEYWORDS:** Common sense reasoning, nonmonotonic logic.

## 1. INTRODUCTION

This paper is concerned with a very basic question which should be answered before any other consideration is carried out with respect to nonmonotonic reasoning:

"WHAT SHOULD BE THE *DEDUCTIVE* OUTCOME OF A NONMONOTONIC KNOWLEDGE BASE?"

We present three principles which we judge essential to correctly answer this question. The first two are logical principles. They are concerned with the design of a logic modeling common sense reasoning. The third principle is a methodological one. It is concerned with under which (pre)conditions we should use a nonmonotonic logic if we are to have any hope it will satisfactorily model the real life

situation under scrutiny. it is closely related to Carnap's requirement of total evidence [2], which is a methodological requirement for the use of inductive logic.

Undoubtedly the second principle which I call *exceptions first* is the most important one. It sheds some light upon a very obscure issue in nonmonotonic reasoning: the rising of multiple extensions, specially in situations where intuition seems to indicate a single alternative. We shall see that the pitfalls pointed out by Hank and McDermott [5] are just to be expected once the *exceptions-first* principle is neglected as it really is by all seminal nonmonotonic logics. *Exceptions first* principle is this sort of things that nobody notices it before, but once it is revealed it looks just too obvious!

The next section describes the first principle. Section 3 presents the second principle. First we enunciate it, then we show that the seminal nonmonotonic logics do not comply with it. The final section provides a brief discussion on the issues touched by this paper.

## 2. PRINCIPLE 1

*The general form of a nonmonotonic inference rule is the following:*

$$(1) \quad \frac{P ; U}{C}$$

*Where P represents the premises; U represents the 'exceptions' or undercutters; and C corresponds to the conclusion of the inference.*

The nonmonotonic inference rules distinguish from the deductive rules because the undercutters (U) are a sort of *negative* premisses, i.e., it is their absence rather than their presence which brings forth the conclusion.

We regard the undercutters (U) as an essential feature of nonmonotonic reasoning. Despite that, undercutters have usually

been neglected in AI. This is certainly true about the seminal papers on the special issue on nonmonotonic reasoning of the *Journal of Artificial Intelligence of 1980*.

Principle 2 next will regulate the interaction between the derivation of undercutters and the application of nonmonotonic rules.

### 3. PRINCIPLE 2 (EXCEPTIONS FIRST)

*Derivations of exceptions to nonmonotonic rules are privileged.*

Principle 2 states that considerations on the derivability of an exception to a nonmonotonic rule, should precede considerations on the applicability of the respective rule, i.e., if we have reasons to believe in an exception for a rule (even if only defeasible) in a given epistemic situation, then we should believe in it and consequently dismiss the respective rule.

Existing nonmonotonic logics do not comply with this requirement, consequently in some situations the use of a nonmonotonic rule may deter the derivation of its own exception. We believe this fact is entirely counter-intuitive. For example consider the following knowledge situation:

- (1) *Normally, birds fly unless they are penguins.*
- (2) *Normally, polar birds are penguins.*
- (3) *Penguins do not fly.*
- (4) *Polar birds are birds.*

Suppose now that we are concerned about the flyness of polar birds. What should be the outcome of this knowledge situation? Does a polar bird fly or not?

Intuitively, using (2), we conclude that he is a penguin since we have no ground to challenge this inference. Therefore since penguin is an exception to rule (1), rule (1) is

defeated, thus blocking the derivation that he flies. Moreover, by applying rule (3), we conclude that he does not fly after all.

However logics which do not comply with the *exceptions-first* principle (circumscription and default logic for instance) would infer that either a polar bird flies and he is not a penguin, or that he is a penguin and he does not fly (this because they would produce two extensions for this theory, one in which (1) is applied but not (2), and other in which (2) is applied but not (1). Observe that in the first extension we obtain the counter intuitive fact that a rule causes the non-derivation of its own exception).

The exceptions-first principle prescribes exactly that rule (2) should be applied once it leads to an exception (penguin) to rule (1).

### 3.1 NONMONOTONIC LOGICS DO NOT COMPLY WITH THE EXCEPTIONS-FIRST PRINCIPLE

None of the nonmonotonic logics proposed so far in AI complies with the *exceptions-first* principle. This is true for McCarthy's circumscription [8], Reiter's default logic [17], Moore's auto-epistemic logic [9], Poole's logic [15], etc. We substantiate this claim by presenting a symbolic example which according to the *exceptions-first* principle should lead to a single extension, but when formalized in any of those nonmonotonic logics would lead to multiple extensions or minimal models. Next we present the example and its corresponding formalizations in McCarthy's abnormality formalism, and Reiter's default logic. We chose these two logics to illustrate our point here because we regard them as the most popular nonmonotonic logics among the AI community, however this claim is equally valid to any nonmonotonic logic so far proposed in the literature.

In the following examples we represent a nonmonotonic rule in the form:

Where,

$$(1) \frac{P ; U}{C}$$

$P$  stands for the positive premises,  
 $U$  stands for undercutters or exceptions,  
 $C$  stands for the conclusion.

When the right hand side of the semicolon is empty, it means that there are no undercutters to the rule.

We shall represent rule (1) in the abnormality formalism by the axioms: (2)  $P \wedge \sim ab_1 \rightarrow C$

$$(3) U \rightarrow ab_1$$

In default logic, rule (1) will be represent as the multiple semi-normal default:

$$(4) \frac{P: MC, M\sim U}{C}$$

#### EXAMPLE I

$$(5) \frac{B ; P}{F}$$

$$(6) \frac{PB ;}{P}$$

$$(7) P \rightarrow \sim F$$

$$(8) PB \rightarrow B \quad (9) PB$$

The evidence for  $P$  in (6) is not challenged, thus according to the *exceptions-first* principle  $P$  should be inferred and (5) should be consequently defeated. Moreover  $\sim F$  (applying (7)) should also be derived.

Observe that our 'penguin example' fits exactly on this structure where  $B$  stands for *bird*,  $P$  for *penguin*,  $F$  for *flies* and  $PB$  for *polar-bird*.

Now let's see the formalization of this example in McCarthy's abnormality formalism (for details on the abnormality formalism see [8]).

EXAMPLE II

- (10)  $B \wedge \sim ab_1 \rightarrow F$       (11)  $P \rightarrow ab_1$       (12)  $PB \wedge \sim ab_2 \rightarrow P$   
 (13)  $P \rightarrow \sim F$       (14)  $PB \rightarrow B$       (15)  $PB$

This theory has two ab-minimal models one containing  $\{PB, PB \rightarrow B, P \rightarrow \sim F, B, P, \sim F, ab_1, \sim ab_2\}$ , and other containing  $\{PB, PB \rightarrow B, P \rightarrow \sim F, B, F, \sim P, \sim ab_1, ab_2\}$ . Thus circumscription only allow us to infer the disjunction  $(P \wedge \sim F) \vee (\sim P \wedge F)$ . So in this example circumscription has not complied with the *exceptions-first* principle.

Now let's see the formalization of this example in Reiter's default logic (for a more detailed presentation on Reiter's default logic see [17]).

EXAMPLE III

LET  $T = \langle W, D \rangle$ , Where  
 $W = \{(18), (19), (20)\}$   
 $D = \{(16), (17)\}$

- (16) 
$$\frac{B : MF, M\sim P}{F}$$
      (17) 
$$\frac{PB : MP}{P}$$
      (18)  $P \rightarrow \sim F$   
 (19)  $PB \rightarrow B$       (20)  $PB$

This theory has two extensions one containing  $\{PB, PB \rightarrow B, P \rightarrow \sim F, B, P, \sim F\}$ , and other containing  $\{PB, PB \rightarrow B, P \rightarrow \sim F, B, F, \sim P\}$ . Thus in this example default logic does not comply with the *exceptions-first* principle confirming our claim.

4. PRINCIPLE 3

*All relevant undercutters for a nonmonotonic rule within a given knowledge situation should be listed.*

Principle 3 is a methodological rather than a logical principle. It is concerned with the suitability of a nonmonotonic logic to represent a mundane situation. It guarantees that the logical formalization of a knowledge situation will in fact match reality.

Principle 3 may be regarded as the equivalent in nonmonotonic logic for the *requirement of total evidence* in inductive logic. This principle guarantees that a nonmonotonic rule is not applicable in a given knowledge situation unless the total available information in fact supports it.

Nevertheless, this principle is often neglected (even denied) by most of the AI logicians. A common mistake committed by them is to suppose that the use of a nonmonotonic logic would dispense with the necessity of representing exceptions for the nonmonotonic rules altogether.

It is important to point out here that early papers on nonmonotonic logic in AI recognize the importance of taking into account all relevant information available when using a nonmonotonic logic to formalizing a given knowledge situation.

## 5. CONCLUSIONS AND FURTHER WORK

In this work we presented three principles which we judge essential for the formalization of common sense reasoning. These principles are not complied with by any seminal nonmonotonic logic. We regard this fact as the reason for why these logics fail to formalize some knowledge situations as it has already been pointed out by some authors [5]. In another work [12] we present a nonmonotonic logic DLEF - *Defeasible Logic with Exceptions First* - which is designed according to these principles, and consequently it succeeds in those situations, specially it well formalizes the frame problem. At the moment we are developing a theorem prover for this logic [3, 4].

## 6.

## REFERENCES

1. Journal of Artificial Intelligence, 13, 1980. Special issue on nonmonotonic reasoning.
2. R. Carnap, *Logical Foundations of Probability*, 2nd ed. Chicago: University of Chicago Press, 1962. First Published in 1951.
3. Godel: Grupo de Estudos em Lógica do Ceará (in portuguese, it means Research Group on Logic from Ceará - Brazil), *Automatic Common Sense Reasoning*. Current CNPq project grant no. 500044/90-2.
4. Godel: Grupo de Estudos em Lógica do Ceará (in portuguese, it means Research Group on Logic from Ceará - Brazil), *Automatic Common Sense Reasoning*. Current CNPq project grant no. 500044/90-2.
5. S. Hanks, & D. McDermott, *Nonmonotonic Logic and Temporal Projection*, Artificial Intelligence 33, 1987.
6. R. Loui, *Response to Hanks and McDermott: Temporal Evolution of Beliefs and Beliefs about Temporal Evolution*, Cognitive Science, 11 1987
7. J. McCarthy, *Applications of Circumscription to Formalizing Common Sense Knowledge*, Proceedings of the American Association for Artificial Intelligence, 28, 1986.
8. J. McCarthy, *Applications of Circumscription to Formalizing Common Sense Knowledge*, Artificial Intelligence 28, 1986.
9. R. C. Moore, *Semantical Considerations on Nonmonotonic Logic*. Proceedings of the Eighth IJCAI, Karlsruhe, West Germany, August 1983.
10. M. C. Pequeno, *Normally Canaries Fly*, In: Anais of the VI Brazilian Symposium on Artificial Intelligence, Rio de Janeiro, November, 1989.
11. M. C. Pequeno, *Three Principles for the Formalization of Nonmonotonic Reasoning*. In: Anais of the VIII Brazilian Symposium on Artificial Intelligence, Brasília, November, 1991.
12. M. C. Pequeno, *Nonmonotonic Reasoning with Exceptions First*, submitted PhD thesis, Department of Computing, Imperial College, 1992.
13. T.H.C. Pequeno, *Inconsistent Default Logic*, Technical Reporter, Department of Computing, Imperial College, 1989.
14. T. H. C. Pequeno, and A. Buchsbaum, *The Logic of Epistemic Inconsistency*, Proceedings of the Second International Conference on Principles of Knowledge Representation and reasoning, Cambridge, Massachusetts, April 22-25, 1991.
15. D.L. Poole, *Default and Conjectures: Hypothetical Reasoning for Explanation and Prediction*, Research Report CS-87-54, University of Waterloo, Ontario, 1987.
16. R. Reiter, & G. Criscuolo, *Some Representational Issues in Default Reasoning*. Tech Rep. No. 80-7, Department of Computer Science, University of British Columbia, Vancouver, 1980.
17. R. Reiter, *A Logic for Default Reasoning*, Artificial Intelligence 13, 1980.