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Preface

This proceedings volume contains a selection of revised and extended papers presented at the Second International Workshop on Nonmonotonic and Inductive Logic, NIL'91, which took place at Reinhardsbrunn Castle, December 2-6, 1991. The first workshop was held at the University of Karlsruhe in December 1990. Its proceedings were published as Lecture Notes in Artificial Intelligence 543.

This series of workshops was made possible by financial support from Volkswagen Stiftung, Hannover. The application for funding was made within the framework of a special program of the Volkswagen Stiftung which promoted cooperation between the Federal Republic of Germany and what was then the German Democratic Republic. The dramatic events of the past years have had a major impact on this program. The workshops have turned into international meetings, though they still retain some emphasis on providing an opportunity for researchers from unified Germany to meet each other.

Besides the major funding by the Volkswagen Stiftung we also acknowledge support from IBM Deutschland GmbH and Siemens AG; their contributions helped give us a necessary flexibility in organising the workshop.

Besides the majority of papers belonging either to the area of nonmonotonic reasoning or to the field of inductive inference, both workshop programs included some papers integrating research from both areas. NIL'91, the second workshop in the series, was distinguished by two tutorials on the main topics of the workshop series held on the first day of the meeting in parallel sessions. R. Wiehagen presented the tutorial on inductive inference, whereas G. Brewka, J. Dix, and K. Konolige delivered the tutorial on nonmonotonic logic. This proceedings volume is introduced with an extended version of the tutorial on nonmonotonic logic by G. Brewka, J. Dix, and K. Konolige. The feedback we have received from the workshop participants suggests that they found it a stimulating five days in general, and two fruitful and instructive tutorials in particular. Who could ask for more?

We gratefully acknowledge the work by an international program committee including S. Arikawa, G. Brewka, K. P. Jantke, K. Konolige, D. Lehmann, D. Makinson, P. H. Schmitt, and R. Wiehagen. As always, behind the scenes, a number of people contributed to the success of the conference. We should like to thank the organising committee headed by S. Schönherr and including V. Gaida and E. Schneider.

November 1992

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A TUTORIAL ON NONMONOTONIC REASONING

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Abstract

Nonmonotonic reasoning, in its broadest sense, is reasoning to conclusions on the basis of incomplete information. Given more information, we are prepared to retract previously drawn inferences. To exhibit the classic example: if all we know about Tweety is that he is a bird, then we plausibly conclude that he can fly; on learning that Tweety is a penguin, we withdraw that conclusion. We call this reasoning nonmonotonic because the set of plausible conclusions does not grow monotonically with increasing information.

As Tweety shows, commonsense reasoning has a nonmonotonic component, and it has been argued that almost all commonsense inferences are of this sort. The attempt to formalize nonmonotonic reasoning so that computer programs could use it as part of their reasoning repertoire was begun by John McCarthy in the 1970's, and the early 1980's saw the development of the major nonmonotonic families: circumscription, default logic, and modal nonmonotonic logics. At the same time, proof methods that were clearly nonmonotonic were also being developed: the so-called Truth Maintenance Systems, and negation-as-failure in logic programming and deductive databases.

From the end of the 1980's to the present there has been an explosion in research in nonmonotonic reasoning. We now understand much better the properties of the major formalisms from a metatheoretic point of view, the relationships among the formalisms, and their connection to independently-developed proof methods. The goal of this monograph is to make this understanding more accessible. For those outside the area, the quantity and technical depth of the material can be a formidable barrier to understanding and applying nonmonotonic methods. For those actively pursuing research, it is often useful to have a concise guide to the major formalisms and their interrelationships. We intend this monograph to serve both purposes. We have tried to present the formalisms as simply and concisely as possible, stressing the connections among them and unresolved issues for future research.

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Chapter 1

Introduction

This monograph is the outgrowth of a tutorial given at the Nonmonotonic and Inductive Logic (NIL) conference held at Friedrichroda, Germany in December of 1991. Its purpose is to give a technical overview of the field of nonmonotonic reasoning. In the past few years this field has grown tremendously, and there is a need for a broad overview sketching the basic ideas, and also giving some of the technical background necessary for understanding them. Of course, it would be impossible to give detailed accounts of even the major formalisms and their application domains, so instead we will present short overviews of the most important concepts, point out their relationships, and recount the interesting issues that are the focus of current research. An extended version of this tutorial will be available as an CSLI report.

Nonmonotonic reasoning, as a form of reasoning, contrasts with standard deductive reasoning in the following way. Suppose we know that all men are mortal, and that Socrates is a man. Then it follows by simple syllogistic reasoning that Socrates is mortal. Further, nothing we can add to our knowledge will change that conclusion, given that we still hold the premises. Deductive reasoning within a theory is "local" in the sense that, having derived a conclusion from premises, we need not worry about any other sentences in the theory. To use the technical term, deductive reasoning is *monotonic*:

$$\text{If } A \vdash p, \text{ then } A, B \vdash p. \tag{1.1}$$

Obviously, nonmonotonic reasoning does not share this property. Why would we ever want a logic that is nonmonotonic? Historically, the need for nonmonotonic reasoning was identified in the course of trying to solve knowledge representation problems in several application areas of Artificial Intelligence.

Databases, puzzles

In developing a database of information, say about airline flights, we usually just put in the positive facts that exist, e.g., "there is a flight from Boston to NY on United at 10:20am, March 22, 1992." The unstated assumption is that the database contains all relevant facts, so that if a flight is not listed in the database, it does not exist. Obviously, it is impossible to put all the negative facts into the database: "There is no flight from Boston to NY at 10:21am, March 22, 1992," and so on. It

is also inconvenient to state the negative information using first-order axioms, since they must be changed every time the database is updated with new information. The solution, originated by Reiter [Rei78], is to formalize the assumption that the database contains all relevant facts: the Closed World Assumption, or CWA.

A second knowledge representation problem was noted by McCarthy [McC80] in formalizing various puzzles like the Missionaries and Cannibals problem:

> Three missionaries and three cannibals come to a river. A rowboat that seats two is available. If the cannibals ever outnumber the missionaries on either bank of the river, the missionaries will be eaten. How shall they cross the river?

As was the case with databases, it is easy to state positive facts, such as "the boat can carry at most two people at a time across the river," but more difficult to state negative assumptions that are implicit in the puzzle, such as "the only way across the river is by the boat." McCarthy proposed a formal solution called circumscription for dealing with this and other types of unstated assumptions limiting objects and relationships to those explicitly stated in the puzzle.

In fact the CWA and circumscription have much in common, since they both work on the principle of preferring interpretations (of the database, of the puzzle) in which positive facts are minimized. The idea of preferring certain interpretations of a theory (in the case of the CWA and circumscription, ones with minimal predicate extensions) leads to one general class of nonmonotonic formalisms, called *model preference logics*.

Defaults

Another type of representational problem occurs in commonsense reasoning. Usually we have just partial information about any given situation, and it helps to make assumptions about how things normally are, in order to carry out further reasoning. For example, if we learn that someone is a doctor, we usually assume that he (or, not to be too presumptive, she) is over 25 years old, makes a good salary, etc. Without such presumptions, it would be almost impossible to carry out the simplest commonsense reasoning tasks. Of course, defaults are presumptive precisely because they could be wrong, and if we learn of our doctor that he (to be specific) is Doogie Howser, an underage overachiever, we have to withdraw conclusion that he is over 25 years old. Reasoning with defaults is nonmonotonic because learning more information may force us to retract a conclusion previously drawn.

To draw on terms from the philosophical literature, a default is a *prima facie* justification for its conclusion. This justification is *defeasible*: an explicit fact that contradicts the conclusion will nullify the justification. Any proposition that, if believed, will nullify a default, is called a *defeater* of the default. Pollock [Pol75] has analyzed defaults from this perspective, and drawn attention to a basic difference between two kinds of defeaters, which he labels Type I and Type II. A Type I defeater outright contradicts a default. If we have access to our fictional doctor's salary records, and discover that he earns a low salary, then the presumption of a high salary is contradicted and defeated.