

## Chapter 15

# On the Use of Abduction as an Alternative to Decision Trees in Environmental Decision Support Systems

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### ABSTRACT

*Although decision trees are frequently used in environmental decision support systems, they have shortcomings. In the case of an available model, decision trees have to be constructed manually from the model. Moreover, not all knowledge is represented in the decision tree. To overcome this issue, the author proposes the use of abductive reasoning directly applied to the available cause-effect model. In particular the abduction problem the author introduces (i.e., the problem of finding a cause for observed effects), shows how this problem can be extended to allow distinguishing between competing explanations, and discusses the integration of testing and repair actions within the framework. The latter is especially important in case of environmental decision support systems.*

### INTRODUCTION

In the environmental domain knowledge-based systems for simulation, problem solving, and prediction are widely used. This holds especially in the case of environmental decision support systems. It is common to use either rule-based systems or decision trees for representing the knowledge used in such systems. In this paper we argue that neither decision trees nor rule-

based systems are very well suited for knowledge representation for decision support systems and in particular diagnostic systems. As an alternative we propose the use of abductive diagnosis, which allows for deriving root causes from effects where the underlying knowledge base represents cause effect relationships directly. Such models are usually available in the natural sciences. In order to show the use of abductive diagnosis in the environmental field, we use a model that was

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used for diagnosing a waste-water treatment plant (Comas et al., 2003).

We first start with a discussion about the characteristics of decision-tree-based systems. A decision tree comprises knowledge from effects to causes. In order to come up with a single solutions test vertices where the user is asked a question. Depending on the answer a certain branch is taken. Finally, a leaf vertex is reached that corresponds to the cause. Although, this kind of knowledge representation is very effective there are some drawbacks.

Usually available models of the real world describe the cause-effect relationships. Hence, extracting test vertices, which ask the state of effects, is a hard task and has to be done manually. The consequences are: (1) the decision tree is not very flexible. If other tests would be more effective the whole tree has to be generated again. (2) Not all knowledge is used and the focus is more on an effective computation of a result. (3) Model changes usually require lot of changes in the decision tree. (4) Manually extracted decision trees are likely to be error-prone and/or the risk for not accurately representing the model is high.

Although, the resulting decision tree allows for effective computing of a diagnosis, its use is limited. The coded knowledge can only be used for the purpose someone has in mind when constructing the decision tree. This is might be now direct drawback but consider the case where there are several different tasks to be fulfilled with a model. For each task a new decision tree has to be generated. Hence, decision trees represent knowledge more in a procedural fashion and not in a declarative one.

In order to overcome these drawbacks we suggest the use model-based techniques where a model is directly used for some purpose like diagnosis. In particular we focus on abductive diagnosis. In literature there are many applications of consistency-based diagnosis to the environmental domain reported. See for example the work by Heller and Struss (1996, 1997, 1998), and Struss

(1998). However, the use of abductive diagnosis for the same purpose has to our knowledge not been described. Since abductive diagnosis uses the fault behavior directly to extract root causes, it seems to be more appropriated in the domain of environmental decision support systems for plants in cases where the model can be formulated in terms of cause-effect relationships. Other examples of model-based reasoning applied to the environmental domain are articles written by Bredeweg and colleagues. In (Bredeweg et al., 2006; Salles et al., 2003a, 2003b) the authors introduced models for some environmental problems. In contrast to this paper and work by Struss and colleagues the focus was more on qualitative modeling and not on providing a methodology for diagnosis or reasoning in general. However, the used qualitative models also incorporate cause-effect relationships.

This paper is organized as follows. In the next section, we discuss problems regarding decision trees and rule-based systems in detail. Afterwards, we introduce a small running example that is based on a decision support system for a wastewater treatment plant. In the next section we use the running example for introducing the basic definitions of abductive diagnosis. Based on these definitions we discuss the use of abductive diagnosis and probing in the process of extracting appropriate repair actions. In a section on modeling for abductive and model-based reasoning we show how models should be organized in order to support re-use and maintenance activities. Finally, we conclude the paper.

## **Problems with Decision Trees**

The objective behind all different kind of decision support systems is to support a user in drawing conclusions from available knowledge in a particular situation and a given domain. The overall goal is to come up with a decision that is good enough and well elaborated. Another important issue is the explanatory capability of decision sup-

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