MODELS FOR REASONING UNDER UNCERTAINTY

ABSTRACT

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1. INTRODUCTION

Rule-based expert systems are those in which a certain number of IF-THEN rules are assumed to hold. Based on the verity of some assertions, the rules deduce as many new conclusions as possible.

In many cases, neither the rules nor the assertions are known with certainty. The system must then be able to obtain a measure of partial belief in the conclusion based upon measures of partial belief in the assertions and the rule.

The MYCIN system is a well known expert system which employs certainty factors as the measure of partial belief. A typical rule in the MYCIN system is the following:

RULE: IF THE ORGANISM GROWS IN CHAINS AND
THE ORGANISM GROWS IN PAIRS AND
THE ORGANISM GROWS IN CLUMPS
THEN THE ORGANISM IS STREPTOCOCCUS
WITH CERTAINTY .7.

The value .7 is a relative measure of the increased belief in the conclusion assuming the absolute verity of the assertions. This value is based on the assumption that +1 means the fule absolutely proves the conclusion, 0 means the rule has no effect on the belief in the conclusion, and -1 means the rule absolutely disproves the conclusion.

The following is a typical assertion in the MYCIN system:

ASSERTION: THE ORGANISM GROWS IN CHAINS
WITH CERTAINTY .6.

The value .6 is a measure of the relative belief in the assertion. The values again range between -1 and 1 where -1 means the assertion is definitely false and 1 means the assertion is definitely true.

There are three questions which MYCIN and any other model for reasoning under uncertainty must address: 1) How are the certainties in the assertion and the rule combined to give a certainty in the conclusion; 2) How is certainty in the conclusion determined when a rule requires two or more assertions to reach its conclusion; 3) How is certainty in a conclusion increased when two or more rules (items of evidence) argue for the same conclusion. The third question is the most difficult to contend with since certain assumptions concerning the independence of the two items of evidence is necessary before the certainties can be combined.

2. A MODEL BASED ON PROBABILITY THEORY

In the current paper, it is shown how the well known MYCIN model answers the above questions. The validity of the model is then proven based on the model's assumptions of independence of evidence. The assumptions are that the evidence must be independent in the whole space, in the space of the conclusion, and in the space of the complement of the conclusion, and even then the combinatoric method is valid only when combining certainties of the same sign. Independence of evidence for the above rules means that knowledge that it grows in chains does not change the certainty as to whether it grows in pairs or clumps. Independence in the space of conclusion means that, if it is known that the organism is streptococcus, then knowledge of one item of evidence does not affect the certainty in the others.

Next a probability-based model is described and compared to the MYCIN model. In this model, the certainties range in value between 0 and 1 with 0 meaning an assertion is definitely false (or, in the case of a rule, the rule absolutely disproves the assertion) and 1 meaning the assertion is definitely true. It is proven that the probabilistic assumptions for this model are weaker (independence is necessary only in the space of the conclusion and the space of the complement of conclusio), and therefore more appealing. An example is given to show how the added assumption in the MYCIN model is, in fact, the most restrictive assumption. It is also proven that, when two rules argue for the same conclusion, the combinatoric method in the probability-based model yields a higher combined certainty than that in the MYCIN model.

It is finally concluded that the probability-based model, in light of the comparison, is the better choice.