BOOK REVIEW

DESIGNING FUZZY EXPERT SYSTEMS

by Lawrence O. HALL and Abraham KANDEL
Series on Interdisciplinary Systems Research, n° 92,
Verlag TÜV Rheinland, Köln, 1986; 204 p.

Reviewed by Roger MARTIN-CLOUAIRE,
Lab. Lang. & Syst. Inf., Univ. Paul Sabatier, Toulouse, France.

What has motivated this book and the research work underlying it is the observation that the problem of dealing with uncertainty in expert systems has been either avoided or solved in an ad hoc and yet unsatisfactory manner by the well-known systems available in the early 80's. Basically, this book provides an introduction to expert systems in uncertain environments and attempts to lay out a methodology to build expert systems in this environment with some simple tools.

A fuzzy expert system has to be understood as an expert system having some approximate reasoning capabilities which are based on fuzzy set or possibility theory. The book consists of six chapters whose topical coverage begins with very general information about both fuzzy set theory and expert systems and gradually turns to the presentation of the specific realization of the expert system shell called FESS (Fuzzy Expert System Shell).

The first chapter of the book gives some background on this theory and a short overview of some of the most famous expert systems, among which few are equipped with approximate reasoning capabilities. A survey of the literature existing on fuzzy expert systems is also provided.

In the second chapter, the authors give a definition of expert systems and discuss in general terms how knowledge may be represented and used to infer some conclusions. An entire section is devoted to an original classification of existing expert systems (not shells). This interesting classification is based on their usability, that is, whether they are in common use solving everyday problems (like R1) or just advanced systems build for research purposes (like AM or HEARSAY) or somewhere in between. This undertaking puts in evidence the fondamental differences (e.g. size, presence or absence of uncertainty, etc...) between the domains of application and helps in identifying suitable and unsuitable problems. Another section focusses on the many possible sources of imprecision and uncertainty that may be encountered in building or using a knowledge-based system. It is then pointed out that systems like MYCIN or CASNET are dealing with uncertainty in an ad hoc manner and that fuzzy set theory and fuzzy logic can provide a viable theoretical means for dealing with uncertainty and imprecision (probabilistic approaches are not considered at all).

The third chapter entitled "Methodological and theoretical considerations for the development of a general fuzzy expert system" is mostly devoted to specific characteristics of FESS. However, a particular section deals with the problem of determination of a fuzzy set membership function. It seems that the above section has to be classified in the body of general information provided by the book since the remaining part of the book and, especially the examples, tends to show that fuzzy sets or possibility distributions are not used explicitly. FESS makes use of frames to represent knowledge. Unconditional pieces of knowledge (facts) and conditional ones (rules) are seen as fuzzy relations which are encoded in particular frames. A section is dedicated to the elicitation process that permits to break down the knowledge and puts it in frames. The problem of inference with uncertain rules (that is the problem of propagation of uncertainty from the antecedent part to the consequent part of a rule) is then addressed and the FESS inference mechanism is presented. The authors' approach is approximately stated in the following terms. Given a rule "if p then q" such that the relation between p and q holds with some strength or certainty denoted *cf* and given a fact p having a truth value a, we must find a value b of the truth value of the proposition q by solving the equation $cf = a \text{ -->}_i\, b$ where -->_i denotes an implication operator. For some reasons, that will be briefly discussed later, this multiple-valued logic approach is problematic in the situation where they intend to apply it. Due to the fact that the above equation does not always lead to a solution the authors are proposing an ad hoc solution which, in practice, turns out to have strong similarities with a functional approach studied by Trillas and Valverde. With the latter, one can always derive a lower bound of b and the no-solution situation of the multiple-valued approach corresponds to a lower bound equal to 0. The degree$b$ is also referred to as the value of the conclusion. Later on, in Chapter 4, the degree b is called a measure of belief of q and, thus, the reader may be puzzled by this inconsistensy in naming. Actually, this reflects the fact that these degrees strongly lack clear semantics. Indeed, the shift in naming hides a shift in meaning.

Next to the presentation of the inference method used in FESS the authors discuss the issue of chaining. Fess may operate in either a forward or a backward chaining mode depending on the user's choice. What is interesting is the tentative that has been made to exploit uncertainty in the strategy used to determine the next rule to consider among the candidates. An important feature of FESS is closing Chapter 3. It concerns the blackboard architecture of the system which enables it to emulate the activity of several cooperating experts.

Chapter 4, which is entitled " Building fuzzy expert sytems" begins with a presentation of the arguments that led the authors to the selection of MODULA-2 as the computer language in which

FESS is implemented. It is then explained how the knowledge is organized for ensuring efficiency of executions and also what is the technique used to match a fact against a proposition in the antecedent part of a rule. Here is the example given in the book. Assume the premise is "the temperature is cold" and the fact to be matched against it is "the temperature is almost cold" (which is supposed to be an absolutely certain fact). In this situation, the premise is said to have the value 0.9 where 0.9 is considered as a numerical translation of "almost". More precisely, 0.9 is the degree of matching "A" with respect to "almost A". Used in this way, the word "almost" represents a degree of certainty but not a modifier of the fuzzy concept "cold" (i.e. the fact tells that it is almost certain that the temperature is cold but it does not mean that the value of the attribute 'temperature' is the fuzzy interval 'almost cold'). Therefore stating that the above technique permits to "match an imprecise clause with another clause involving the same concept" is questionable. Since the content of the involved clauses is not taken into consideration imprecision is not dealt with. The proposition "the temperature is cold", as used in the above axample, is not more imprecise than the proposition "X is equal to 1".A matching taking imprecision into consideration would permit, for instance, to confront "the temperature is cold" with "the temperature is less than -10° C".

Let us come back to Chapter 4. A section is dedicated to combination of uncertainties in situations where several rules bring evidence for or against a given conclusion. The technique used by FESS is borrowed from MYCIN. A rather original feature of FESS is that it attempts to avoid the exhaustive exploration of the set of rules whose consequent part is relevant to the conclusion statement under consideration. The process associated to this feature involves the use of crisp thresholds. With such an approach the robustness of the system may be in danger however, that is, a slight variation in the different degrees used in facts and rules for representing uncertainty may lead to drastic changes in the results provided by the system. This issue is not considered.

Chapter 4 continues with the presentation of several facilities offered by FESS.These include capabilities for (1) seeking one of or all the possible conclusions, (2) generating explanation files, (3) using one or several knowledge sources that can communicate via the blackboard. A section discusses how a fuzzy expert system can be validated. It is concluded that the process is not very different than the one involved in the validation of a non-fuzzy system. The six pages constituting the last section of Chapter 4 provides a clear and concise methodology for building an expert system.

Chapter 5 discusses an application of FESS to the classification of trees and shrubs. The sample sessions shown in the appendix concern the same example and may be looked at at the same time. One may regret that the examples of use of FESS not be more enlighting with respect to the technique of approximate inference and the control of the reasoning process. The uncertainty degrees qualifying the rules are not shown (neither are the implication functions used to propagate uncertainty from the antecedent parts to the consequent parts of the rules).

The concluding chapter surveys the main results that have arised from the FESS project. Essentially, a new fuzzy expert system shell has been developed and the methodology of construction has been improved by the incorporation of some software engineering techniques. Also, MODULA-2 has proved to be a good tool for expert system development. Finally some open problems are pointed out. Most of them are relevant to expert systems in general, as for instance, knowledge acquisition, common sense or non monotonic logic. Combination of uncertainty and choice between implication functions are mentioned as subjects deserving more works for a better handling of uncertainty.

Among knowledge-based systems equipped with approximate reasoning capabilities a distinction has to be made between those mainly concerned with uncertainty and those dealing explicitly with vagueness or imprecision. As shown in the review of the fourth Chapter of this book, FESS is of the first kind (so is EMYCIN for instance). However, few second generation deduction systems, mainly developed in the last five years, embed sophisticated tools enabling them to manage imprecision also.

When a vague proposition as, for instance, "the temperature is cold" is evaluated with respect to a precise statement as "the temperature is -10°C" one can consider $\mu_{cold}(-10)$ (where μ_{cold} is the membership function associated to 'cold') as a genuine grade of truth of the first proposition given than the actual temperature is -10°C. If 'cold' is not considered as a vague predicate then $\mu_{cold}(-10)$ is either 0 or 1 and, thus, talking about intermediate (between 0 and 1) truth value in such a situation is semantically questionable. Now, given a situation in which a proposition can only be either true or false, one may not know whether it is one or the other. In this case, a measure of confidence (e.g. probability, possibility, credibility, necessity, etc...) can be used to express to what extent the truth (or falsity) of the proposition is supported. The measure of belief used in FESS or in MYCIN is just one such measure of confidence but it should not be confused with a degree of truth because the measures of confidence are not truth-functional (i.e. the confidence in the truth of a proposition does not enable us to determine the confidence in its falsity in general).

Of course a book cannot be all things to all people. This book is certainly not intended for an audience of researchers. Although more descriptive than prescriptive, "Designing Fuzzy Expert Systems" may be a valuable source of pragmatic information for those without background in artificial intelligence, that want to build an expert system (without necessarily starting from a shell) having basic approximate reasoning capabilities. The book provides a good step-by-step examination of the different phases one has to go through in the development of a simple expert system, emphasizing the main difficulties and problems that may be encountered. On the whole, the book does succeed in meeting its objective which was to provide an introduction to expert systems in uncertain environments.