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# APPLICATION OF FUZZY LOGIC IN DECISION MAKING SYSTEMS

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## ABSTRACT

*In this paper I explain the new ideas by means of a rating system for checking the credit solvency of small business firms. By means of a pilot software we are going to demonstrate that fuzzy decision support systems offer more information to the user than classical aggregation processes. Moreover, they provide a simple way for explaining the rating result.*

***Keywords***: Fuzzy Controller, Fuzzy Logic, Expert Systems, Human Reflection Process, Linguistic Variables, Membership Functions, Aggregation, DOF.

## INTRODUCTION

Decision Support systems are a specific class of Information Systems that support business and organizational decision-making activities. They are interactive software-based systems intended to help decision-makers to take decisions, to identify and solve problems, all that accomplished by compiling useful information from simple data, documents, personal knowledge, and/or business models..

Decisions and evaluations in economic and business problems are usually complex. A lot of variables and relations have to be specified. The expectations of the fifties and sixties of these centuries - that it would be possible to model all problems in form of adequate mathematical systems - could not be satisfied. Today we know this can only be achieved in case of relatively simple problem.

However, it has always been necessary to make decisions in complex situations. A circumstance which is still valid, no matter whether it concerns economic, business respectively jurisprudential problems or everyday situations for example, driving a car during rush hour. Based on qualifications and practical knowledge, individuals attempt to come to a satisfying solution. A person who obtains extraordinarily good results is called an "expert" in this field.

The motivation within the last 20 years was to model the decision process of experts instead of the decision situation. Expert knowledge does normally not consist of confirmed theories, it is rather composed of heuristic rules the expert obeys during h s own decision making. Expert rules are usually formulated by linguistic terms and therefore it is difficult to transform them into classical mathematical terms or to apply them to computer-aided processing.

By modeling linguistic variables in form of fuzzy sets, it is possible to transform expert rules into mathematical terms. Moreover the fuzzy set theory offers a great variety of operators which are able to aggregate and combine these rules. The advantages of fuzzy logic for controlling technical processes have become well-known, not only in Japan but during the last decade as well in America and Europe. Now the question arises, whether the procedures, used very successfully in fuzzy control, can also be applied to non-technical expert systems.

At the institute of Statistics and Mathematics of the University Frankfurt am Main we are working at the following Research projects using expert rules and fuzzy logic processing: -

- Checking the creditability of small business firms
- Checking the credit solvency of persons buying a car on installment plan
- Evaluating the capital structure, financial assets and revenue of firms in order to support the business of auditors
- Analytical procedures in the course of audits
- Portfolio management
- Evaluating suppliers

With the fuzzy logic based decision support system the following goals should be achieved:

- Construction of a transparent support system, which could be accepted by the users
- Reproduction of the behavior of experts concerning
  - subjective selection of attributes
  - classification of the attributes by evaluation classes stepwise and rule-based aggregation of the partial evaluations to an overall rating judgment
- Use of external data (branch of industry, country)
- Use of linguistic evaluations (poor, medium, good)
- Use of quantitative and qualitative information
- Processing of data measured on different scales (nominal, ordinal, cardinal)
- Softening of the crisp borders of evaluation classes
- Use of fuzzy inference
- Use of expert knowledge and of data banks
- Creating a rating judgment with accompanying commentary. Subsequent to the introduction, the paper is recognized in 6 chapters which are described with few comments

### Decision Making With Fuzzy Information

Decision making is a most important scientific, social, and economic endeavor. To be able to make consistent and correct choices is the essence of any decision process imbued with uncertainty. Most issues in life, as trivial as we might consider them, involve decision processes of one form or another. From the moment we wake in the morning to the time we place our bodies at rest at the day's conclusion we make many, many decisions. What should we wear for the day; should we take an umbrella; what should we eat for breakfast, for lunch, for dinner; should we stop by the gas station on the way to work; what route should we take to work; should we attend that seminar at work; should we write the memorandum to our colleagues before we make the reservations for our next trip out of town; should we go to the store on our way home; should we take the kids to that new museum before, or after, dinner; should we watch the evening news before retiring; and so on and so forth?

The problem in making decisions under uncertainty is that the bulk of the information we have about the possible outcomes, about the value of new information, about the way the conditions change with time (dynamic), about the utility of each outcome–action pair, and about our preferences for each action is typically vague, ambiguous, and otherwise fuzzy. In some situations the information may be robust enough so that we can characterize it with probability theory.

### Hierarchical Systems

In this system of attributes for the evaluation of material business creditability Complex and not directly measurable criteria, as for example the credit solvency of a business firm, may often be explained more transparently and more intelligibly by a hierarchical system of sub aspects. For evaluating the creditworthiness of a specific firm, at first the aspects on the bottom level have to be evaluated. Then those evaluations of the sub attributes need to be aggregated step by step until the top level of the hierarchical concept is reached.

Usually this aggregation process is accomplished by means of aggregation operators depending on parameters or weights which ask for further specification by the decision maker.

A disadvantage of these operators is that they portray the complex conjunction mechanism of the human mind only incompletely. In literature and practice there exist a lot of examples that the weights within an objective system depend not only on the objectives but often change with the obtained values. Therefore it is necessary to look for other ways of modeling the decision process of credit managers.

### Aggregation of Attributes by Expert Rules

In the artificial intelligence literature we can find many models in which the human decision process is described by means of rules formulated by experts. 1nthese rule-based models the evaluation of attributes is often described by the linguistic terms “poor", “medium” and “good". For every possible situation on the lower hierarchy level an aggregation rule is defined. Sometimes additional ratings (- and/or +) are allowed for the aggregation results.

Objections against those rules can be raised due to the fact that the rules are very inaccurate; the terms “good”, “medium”, “poor" allow a comparably large interpretation spectrum. To improve this situation we could try to enlarge the number of valuations for each criterion.

This however would result in an explosive increase of the number of rules as for n aspects with p possible valuations there exist $p^n$ rules. Therefore it is necessary to restrain the number of valuations for each aspect. Moreover if the rule map gets too large the expert team will not be able to guarantee a conscious distinction of each situation.

### Description of Expert Rules by Fuzzy Sets

Since intervals only allow Yes/No-statements and therefore different values of the same interval do not portray a linguistic term correspondingly, we propose to model the linguistic terms by fuzzy sets. The fuzzy set theory makes it possible to describe the different membership degrees according to the categories of "poor", "medium" or "good" credit solvency as precise as the credit expert can express it. These membership functions must be specified as carefully as possible, because they will decisively influence the valuation process. Nevertheless we will never obtain membership functions which are accurate in every detail, because a lot of data about similar firms and knowledge of the trade must be collected by the expert team. Therefore the form of membership functions in expert systems will be very simple and the same design will be used repeatedly. In practice it is sufficient to work with fuzzy numbers or fuzzy intervals of the LR-type.

Presenting fuzzy sets as categories of valuation provides the opportunity to precisely inform users of expert systems about their valuation basis. Moreover by comparing data of different branches of business this proceeding allows to resort to knowledge already stored in data bases. A way for a practical transformation has been analyzed in a pilot study at the Institute of Statistics and Mathematics of the University of Frankfurt am Main. The intention was to design membership functions in the course of an expert system for supporting the evaluation of the financial and operating position of business firms as part of the annual audit.

### Fuzzy Controller and Rule-Based Aggregation

In case of modeling the linguistic evaluation terms by fuzzy sets, the aggregation rules are only applied to those cases, in which the evaluations produce a membership degree 1 for all sub aspects. Then the corresponding rule of the rule map is applied and leads to a distinct evaluation of the upper-aspect with the membership degree 1, too. Therefore the use of fuzzy sets helps users to understand the basic principles of the expert knowledge more easily. This understanding is an essential factor for the acceptance of an expert system and related to that for its successful realization. For all the other cases, where at least one evaluation has a membership degree smaller than 1, no special rules have been stated by the experts. We assume that the given rules can be extended to situations in the vicinity. The rules are softened with the consequence that now many rules can be used simultaneously in a weakened manner. For a real situation we denote the degree of fulfillment (DOF) with the descriptions of state in the rule maps by DOF. According to the proceeding in *fuzzy* control, DOF is defined as the minimum of the membership degrees attached to the inputs of this rule. Having examined various operators regarding their ability to describe the human conjunction behavior in specific cases, we came to the conclusion that the minimum operator should be used. Besides others the minimum operator has the advantage that only few rules with positive DOFs exist, whereas by using compensatory operators almost all rules will show positive DOFs and we therefore have to expect intermediate evaluation. Now all rules with positive DOF contribute to the valuation of sales potential in proportion to their DOFs. In this context we want to remark that there is an essential difference between fuzzy control applications and non-technical evaluation and decision problems. Usually technical control processes are rapidly repeated. Therefore, it is sufficient when an approximately correct action is carried out, because the correction will follow immediately. On the contrary decision support systems require a definite decision for every section which evidently has to be correct. As a consequence the procedure in decision support systems has to be handled more carefully than in fuzzy control. Not only the linguistic evaluation terms have to be defined more carefully but also the calculation of the DOFs and the influence of the DOFs on the final result require an exact empirical examination. In fuzzy control the total result is calculated by applying the Maximum-operator for aggregating the evaluations of the rules with positive DOF. But in decision support systems corrections should be considered. On the other hand it seems absurd to add the DOFs if two or more rules turn up with the same output, because it would then be possible to get DOF-values greater than 1. We propose to adopt a middle course and suggest the use of the algebraic sum. In order to compress the data to a unique valuation, the well known defuzzification procedures can be applied. The best-known are the center of gravity method and the center of area method. But in hierarchical systems defuzzifying is not necessary, because it is better to use directly the fuzzy valuations as inputs for the next aggregation step.

## CONCLUSION

The application of linguistic variables and fuzzy conjunction methods offer an appropriate method to model the human reflection process. By doing so expert systems are constructed which actually deserve this name. This concept aims at the right direction. In the meantime, the first applications are used in practice.

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