FUZZY LOGIC-BASED PROCESSING OF EXPERT RULES USED FOR CHECKING THE CREDITABILITY OF SMALL BUSINESS FIRMS

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1. INTRODUCTION

Having in mind, that fuzzy controllers proved to be superior to traditional methods in many technical applications and that in Japan the term "fuzzy" stands for progressive technique, the question arises whether fuzzy control can also be applied to non-technical expert systems. Undoubtedly only few fuzzy control programmes can strictly speaking be considered expert systems. Especially self-organizing controllers in camcorders, telescopes, cameras etc. cannot be classified as expert systems. Other applications, however, as train control or the optimizing control of a Diesel engine, doubtless are expert systems because they satisfy more than one of the following four criterias which according to Schnupp / Nguyen Huu /10/ separate expert systems from traditional systems:

- the system possesses a knowledge base which means it accumulates not only facts (data base), but also rules (production rules)
- the system contains components which cultivate and extend the knowledge base (passive and active capability of learning)
- basing on the facts and rules stored in the knowledge base the system can produce new knowledge by using heuristics (processing techniques and search strategies)
- the system is able to explain the procedure chosen to solve a problem as well as name arguments in favour of the presented solution (explanatory component).

In technical control systems only the rule map contains unprecise information in general. This inaccuracy is usually caused by the expert who either does not know all the relevant cognitive processes, does not mention them at knowledge acquisition or does simply not express his knowledge explicitely enough. In expert systems for decision support of non-technical problems more uncertainties frequently become evident.

The following can be named:

- decision variables are unknown or are neglected due to the complexity of the problem
- the rule map often is incomplete in consequence of missing information (in comparison to that rules are consciously omitted in fuzzy control models in order to increase the control speed)
- data-basis is inaccurate, vague data
- information is not sufficient for specifying probabilities.

Considering the abundance of unprecise information it is clear that very early attempts were made to integrate fuzzy concepts into expert systems. Zimmermann /14/ quotes 24 expert systems by name which make use of fuzzy sets in various forms. During the past years additional systems took advantage of this technique. Fields of application are pattern recognition, medical diagnosis, treatment of Diabetes, chest pain diagnosis, mineral exploration, business planning, creditability check and many more.

Most of the fuzzy expert systems make use of several fuzzy concepts. Among the well known ones are:

- the use of linguistic variables in order to describe the terms of attributes (i.e. good, medium, poor), frequencies (i.e. never, rarely, normal, frequent, always), the actions (i.e. strong, medium, weak), truth qualification (i.e. true, false),
- the application of fuzzy numbers and fuzzy intervals in order to describe vague data and their conjunctions by means of extended operators, for example to define fuzzy expectation values or fuzzy expectation intervalls,
- the use of fuzzy logic concepts which replace the clear-cut terms "true" and "false" by corresponding linguistic variables in the sense of Zadeh and Baldwin,
- the employment of the possibility theory if there exists no sufficient information to define probabilities,
- the application of membership grades in order to evaluate objects in a hierarchic system, and the use of fuzzy operators to aggregate these valuations.

2. AGGREGATION OF CREDITABILITY

The concept last mentioned has been used by the Institut of Statistics and Mathematics, University of Frankfurt/Main to define the term "creditability of small business firms" more precisely and to contribute to the developement of an expert system to support creditability decisions, see Rommelfanger/Unterharnscheidt /6,7/.

The creditability aspects were evaluated by use of membership grades. On the basis of an extensive empirical study a lot of fuzzy operators were tested and as a result the compensatory arithmetic mean turned out to be most appropriate. Even the asymmetric operators which were developed early 1991 were not able to compete with the arithmetic mean, see Braun /2/. Those asymmetric operators offer the possibility that the weights of the particular aspects may depend on the obtained membership grade. This character qualifies them for strategic planning models and for models which intend to evaluate capital structure, financial assets and revenue of firms, see Paysen /4/ and Scheffel /8/.

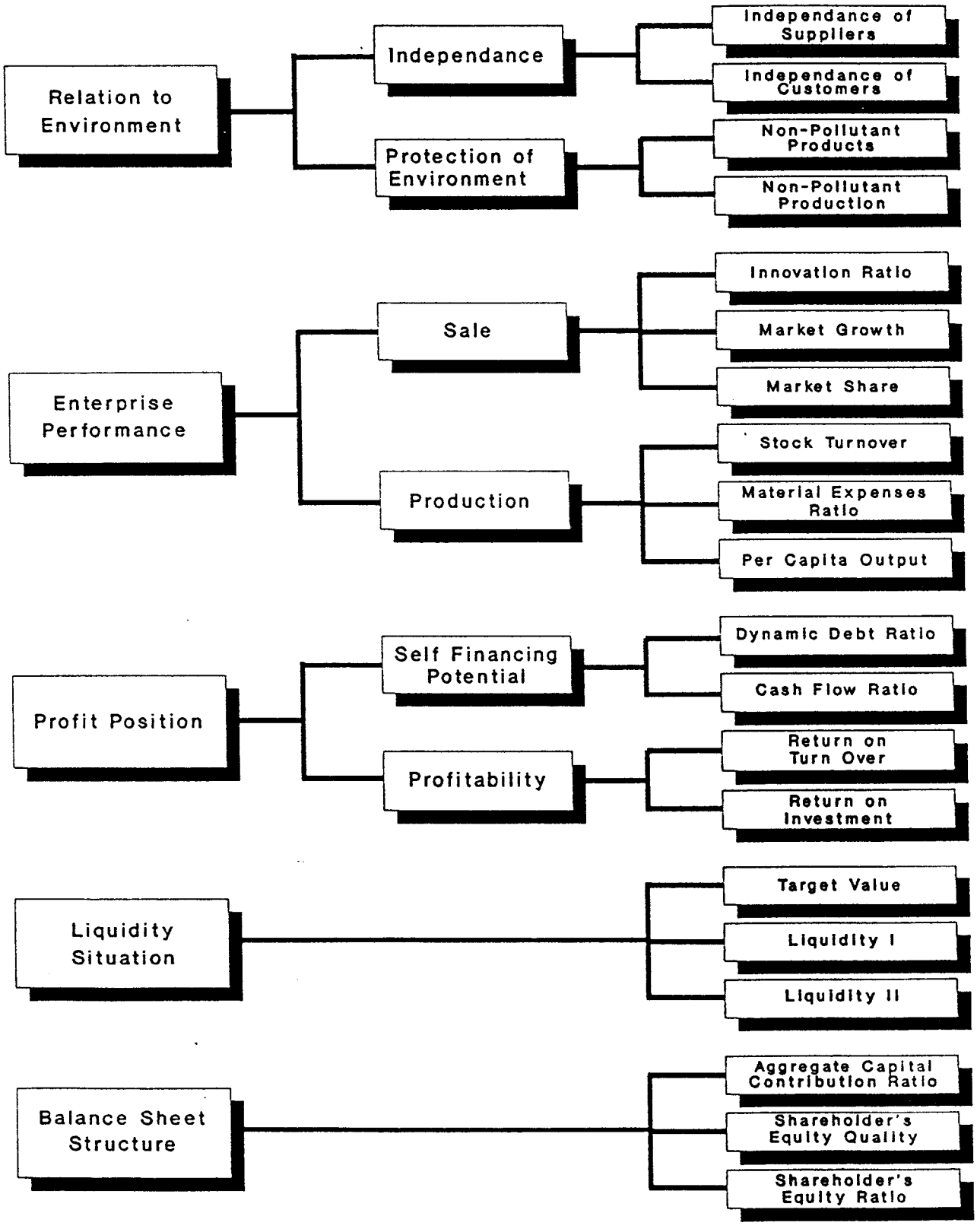

Fig. 1: Hierarchical System for Evaluating Material Business Creditability

All in all it became apparent that the application of parameterdependant operators reflect the complex conjunction mechanism of the human mind only incompletely. This is the reason for the attempt to establish in practice conjunction rules gained from expert teams. The following tables 1 and 4 present two of the rule map stated by the Commerzbank. They are part of a recently developed model for creditability checks. Figure 1 shows the hierarchical system of this model used to evaluate the material business creditability, see Bagus /1/.

Table 1: Aggregation Rules of Self Financing Potential

CF-Rate	Dyn. DR	Self Fin. Pot.
p	p	p-
p	m	p
p	g	m-
m	p	p
m	m	m
m	g	m
g	p	m
g	m	g
g	g	g+

Min(0,12; 0,28) = 0,12 DOF
Min(0,12; 0,62) = 0,12 DOF

Min (0,68; 0,28) = 0,28 DOF
Min (0,68; 0,62) = 0,62 DOF

Table 2: Valuation of Cash Flow-Rate

CF-Rate	Grade
< 0%	(6)
0% - 2%	6
2% - 4%	5
4% - 6%	4
6% - 8%	3
8% - 10%	2
> 10%	1

Table 3: Valuation of Dynamic Debt Ratio

Dyn. DR (Years)	Grade	
> 10	6	poor (great risk)
8 - 10	5	
6 - 8	4	medium (medium risk)
4 - 6	3	
2 - 4	2	good (small risk)
< 2	1	

At the chosen procedure an aggregation rule was formulated for every possible situation of the lower hierarchy level. To limit the number of rules in order to guarantee a conscious distinction of the given situation by the experts, not too many criteria values are to be distinguished. In this study only three values per criterion were selected, for the aggregation results , however, additional ratings (- and/or +) were accepted.

Objections against those rules can be raised: the rules are very inaccurate, as the terms "good", "medium", "poor" offer a comparably large interpretation spectrum, see the tables 2, 3, 5 and 6. A possible consequence could be that two companies are evaluated identically, although one of the companies performs in all inferior aspects poorer than the other. This can be the case if the inferior aspects of both companies fall in the same class, but the values of the first company are always found on the left, the second always on the right end side of the interval. Moreover the strong distinctions between the classes also give the impression of an arbitrary classification.

Table 4: Valuation of State of Liquidity

Liqu. I	Liqu. II	Target Value	State of Liquidity
p	p	p	p-
p	p	m	p-
p	p	g	p
p	m	p	p
p	m	m	m
p	m	g	m+
p	g	p	m
p	g	m	m+
p	g	g	g-
m	p	p	p
m	p	m	p
m	p	g	m-
m	m	p	m
m	m	m	m+
m	m	g	m+
m	g	p	m
m	g	m	g
m	g	g	g
g	p	p	p+
g	p	m	m
g	p	g	m+
g	m	p	m
g	m	m	g
g	m	g	g+
g	g	p	g-
g	g	m	g+
g	g	g	g+

Table 5: Valuation of Liquidity

Percentage of Deviation	Grade
< 50%	6
50% - 60%	5
60% - 70%	4
70% - 80%	3
80% - 100%	2
> 100%	1

Table 6: Valuation of Target Value

Percentage of Difference	Grade
> 30%	6
15% - 30%	5
0% - 15%	4
-15% - 0%	3
-30% - -15%	2
< -30%	1

3. DESCRIPTION OF EXPERT RULES BY FUZZY SETS

The preceding expert rules can be defined more precisely by means of linguistic variables which are described by fuzzy intervals or fuzzy numbers. This clearer transmission of the expert knowledge enables the user of the expert system to understand the basic principles. This "understanding" is an essential factor for the acceptance of an expert system and related with that its successful realization.

Figures 2, 3, 4 attempt to give a more detailed picture of the valuation of the cash flow rate, the dynamic debt ratio and the self financing potential for the rule map of table1.

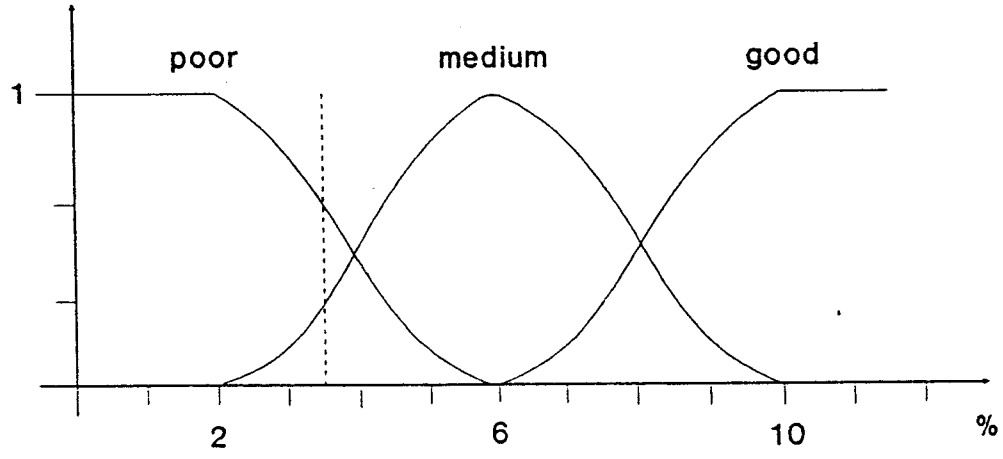

Fig. 2: Valuation of Cash Flow - Ratio

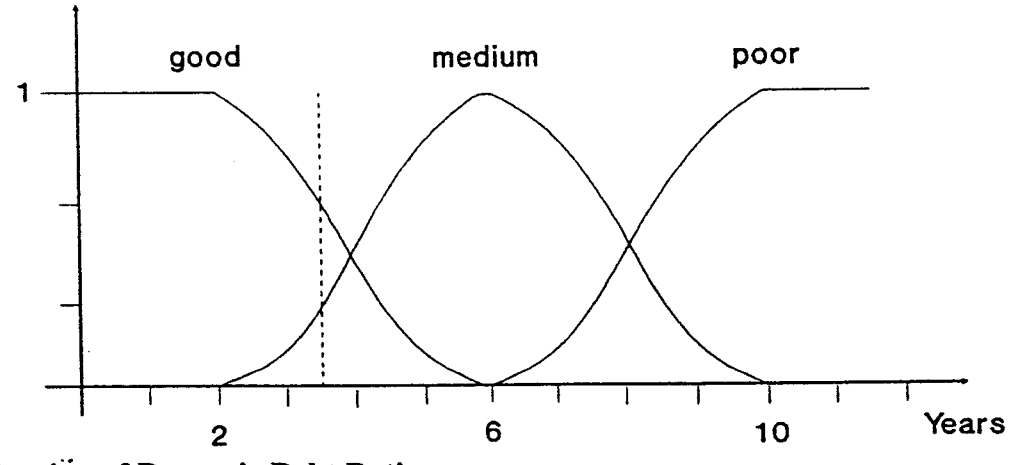

Fig. 3: Valuation of Dynamic Debt Ratio

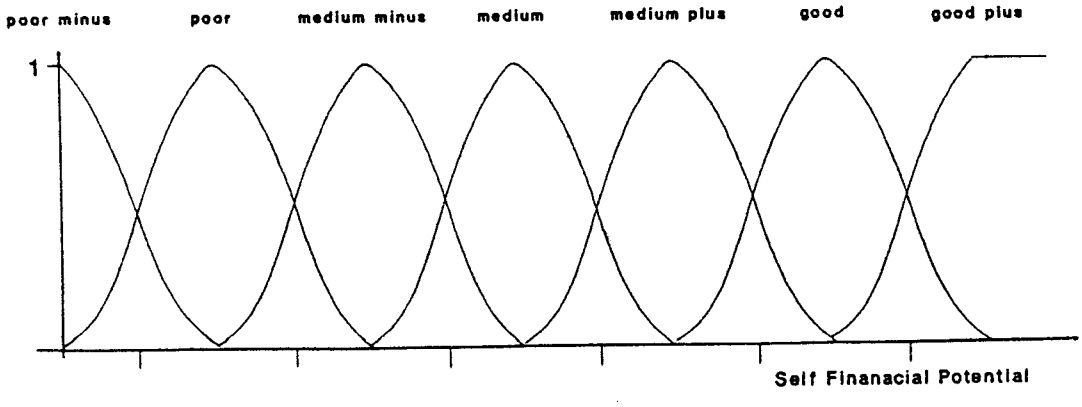

Fig. 4: Valuation of Self Financing Potential

4. VALUATION OF THE MAJOR OBJECTIVE BY RULE-BASED AGGREGATION

According to the proceeding with fuzzy control the rules must be provided with degrees of fulfilment (DOF), corresponding to the concrete situation.
In this context it obviously does not make sense to transfer the fuzzy control techniques directly to non-technical valuation and decision problems. An essential difference has to be taken into consideration. Technical control processes are rapidly repeated. Therefore it is sufficient when an approximately correct action is carried out, because the correction will follow immediately. Decision support systems require a definite decision for every section which evidently has to be correct. As a consequence the linguistic variables have to be defined very carefully. The calculation of the DOF of the consequences and the influence of the DOF on the final result need an exact empirical examination.

To illustrate the procedure we assume that the concrete situation is marked with little lines in the figures 2 and 3. Then only four rules show a positive DOF at the valuation of the self financing potential, if the the DOFs are calculated by means of the minimum operator, i.e.

$DOF_{SF} = \text{Min}\ (DOF_{CFR}, DOF_{DVG})$.

However, it has to be examined whether a compensatory operator would better describe the human conjunction behaviour in specific cases. The arithmetic mean could be an alternative, given the fact that all "situation variables" exceed a positive minimum membership grade.

All rules with a positive DOF_{SF} contribute to the valuation of the self financing potential. In "turning down" the valuations corresponding to the individual rules we recommend the use of the max-prod-inference which means that the membership values are fixed in proportion to the corresponding DOF, see figure 5.

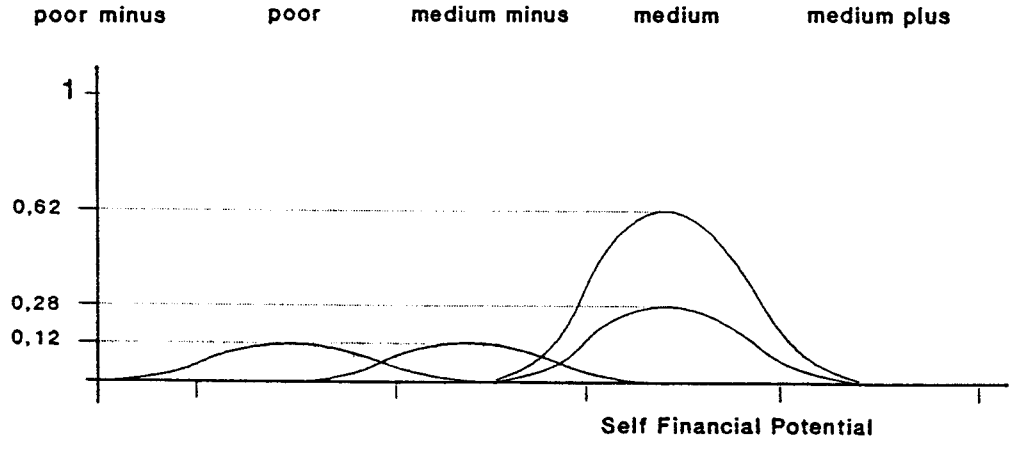

Fig. 5: Valuation of Self Financial Potential of Rules With Positiv DOF

We are convinced that the max-prod-inference is better than the max-min-inference because the elimination of membership values which go above the DOF implies that rules with low DOF obtain too heavy weights.

The total valuation - by application of the fuzzy control procedure - results from the fusion of the valuations of the relevant rules. Here corrections should also be considered. In our study the rating for the self financing potential "medium" can be found twice. On the one hand we do not consider it to be right that the rating "medium" only counts with a DOF Max(0,28, 0,62) = 0,62 which means that a rule with a positive DOF is completely neglected. On the other hand it seems absurd to add the DOF if they turn up with the same results. Therefore we suggest the use of the algebraic sum. We are convinced that in this example a consideration of "medium" with the DOF 0,28 + 0,62 - 0,28 * 0,62 = 0,72 presents a more balanced valuation.

Then the self financing potential is vaguely evaluated by means of the membership function shown in figure 6.

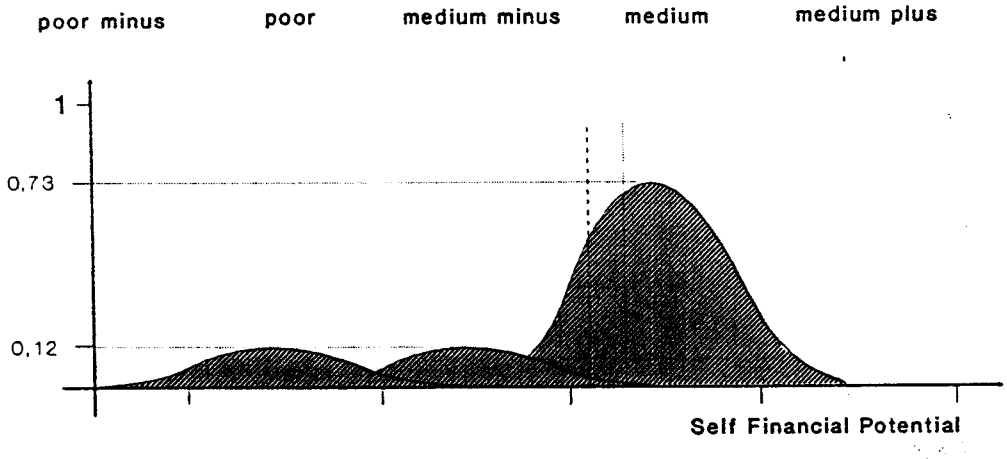

Fig. 6: Valuation of Self Financing Potential of Rules in a Special Case

If it is intended to "compress" the data to a unique valuation, the center of gravity method can be applied to calculate the values marked by little lines. Another alternative presents the plane bisection method which offers slightly better results marked by the pointed line. However, several other methods to select an accurate representative or a vague valuation set with a low "diffusion effect" can be imagined.

5. FINAL REMARKS

The application of linguistic variables and the employment of fuzzy conjunction methods offer an appropriate method to structure the human reflection process and by doing so to construct expert systems which actually deserve this name. There are still a lot of questions left to be answered, but I am convinced that this concept aims at the right direction.

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