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Fuzzy logic based loan evaluation system

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Abstract

Retail loans play a key role in the banking of many countries. At the same time loans to individuals are regarded as more risky than business loans. For these reasons, the efficiency of retail credit granting is important for the welfare of both households and of banking system.

In this paper a fuzzy logic model for retail loan evaluation is proposed. The fuzzy model consists of five input variables such as “income”, “credit history”, “employment”, “character”, and “collateral condition” and single output variable which indicates credit standing. Whether applicant’s credit standing shall be regarded as “low”, “medium” or “high” depends on the degree of membership for the linguistic terms of fuzzy output.

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1. Introduction

Banks play an important role in the economy since they support local communities with an adequate supply of credit to fund consumption and investment spending by individuals, businesses and government agencies. Bank loans satisfy the strong need of many individuals and businesses for immediate funds to cover expected future cash needs and to meet emergencies. For many individuals, taking out a loan may be the only way to afford a house, car, or other welfare. For many companies, bank lending supports the growth of new businesses and jobs and promotes economic vitality.

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Before approving or denying a particular retail loan, the credit division of a bank is evaluating the loan application. Loan evaluation is a field, in which different techniques to support automatic decisions have been utilized so far. Among most common models used is credit scoring models based on statistical methods such as discriminate analysis and logistic regression^{1,2}. In these models, decision making is based on statistical analysis of large numbers of historical data over many years of providing credit and decision variables are expressed in crisp values. However, because of incompleteness, imprecision and uncertainty of information such approaches cannot model the way human experts make their decisions about the creditworthiness of the applicant. These models make unrealistic statistical assumptions and have complete lack of communication with the decision makers. For example, the applicant's income level can be measured quantitatively but the other aspects such as applicant's character or saleability of collateral are usually valued according to loan officers' professional knowledge, experience and subjective judgments because it is often difficult to obtain exact economic assessment data. Linguistic values such as "very high", "adequate" and so on are usually used to express their estimations.

The topic of theory and application of application of fuzzy logic³ in marketing research is one of the topics increasing precision and reliability of portfolio analysis, customer segmentation, performance measurement, managerial decisions etc. and still being studied. In the books^{4,5,6} were considered applications of fuzzy logic in business, finance and management.

Rommelfanger⁷ investigated Fuzzy logic-based processing of expert rules used for checking the credibility of small business firms.

In⁸ was developed a fuzzy system for credit analysis in a German credit insurance system.

Decision making on credit-worthiness, using a fuzzy connectionist model was examined in⁹.

The aim of this paper is to develop a decision-making model for retail loans based on fuzzy logic concept that allows to handle uncertainty and imprecision of input data using human subjective judgment by linguistic terms.

2. Input information

Retail loan evaluation usually involves a detailed study of the following information about the applicant:

1. *Income level*. Loan officers want to be sure the borrower will have acceptable cash flow (usually net salary) to repay the loan.
2. *Credit History*. The loan decision can be negatively impacted if there is history of late loan repayments or bankruptcy gathered from credit bureau.
3. *Character*. Loan officers shall be certain about applicant's purpose of the loan and moral responsibility to repay a loan fully and on time.
4. *Employment*. Most lenders are not likely to grant a sizeable loan to someone who has held his or her present job for only a few months.
5. *Collateral*. Loan officers would like to be sure about the sale ability of collateralized asset.

3. Fuzzy logic based credit evaluation system

The fuzzy logic computation consists of three steps: fuzzification of inputs, fuzzy inference associated with the rule base and defuzzification.

Fig.1 shows the steps of fuzzy logic computation.

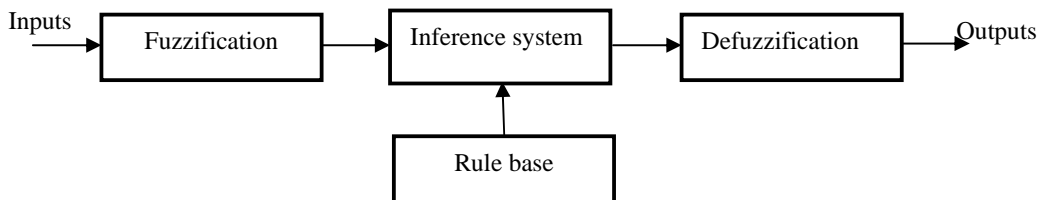


Fig 1. Steps of fuzzy logic computation

Fuzzification is the transformation of the input numerical values into membership functions represented by 3 linguistic terms, (Low/Medium/High, Bad/Average/Good or Short/Medium/Long) as shown in Table 1.

Table 1. Representation of inputs and output terms with linguistic variables.

Input variables	Linguistic terms	Min-max values Of variables
Character	Bad/Average/Good	0-1
Collateral condition	Bad/Average/Good	0-1
Credit History	Bad/Average/Good	0-1
Employment	Short/Medium/Long	0-25
Income Level	Low/Medium/High	0-3000
Output variable	Linguistic terms	
Credit Standing	low/Medium/High	0-1

For a more accurate evaluation, the number of linguistic terms can be increased subjectively (5 or 7).

As shown in Table 1 the input variables “character”, “collateral condition” and “credit history” take the values in the range 0 and 1. Input variable “employment” is expressed in years and takes values in the range 0 and 25 while variable “income level” is expressed in US dollars and takes values in the range 0 and 3,000. For input fuzzification we use triangular and trapezoidal membership functions

In Fig. 2, 3 and 4 are shown the results of fuzzifications of the variables using FuzzyTech Business software⁴.

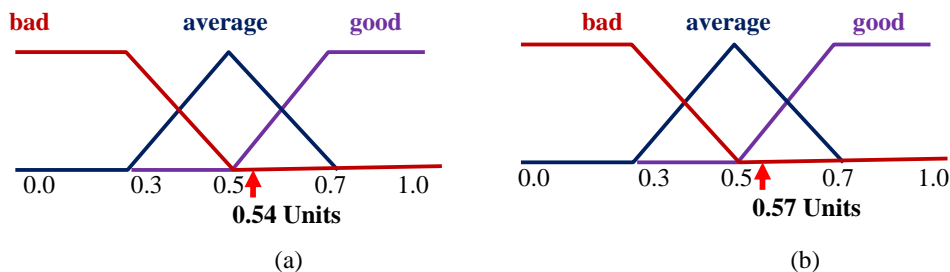


Fig. 2. Representation of "Character" (a) and „Collateral condition“ (b) with linguistics terms

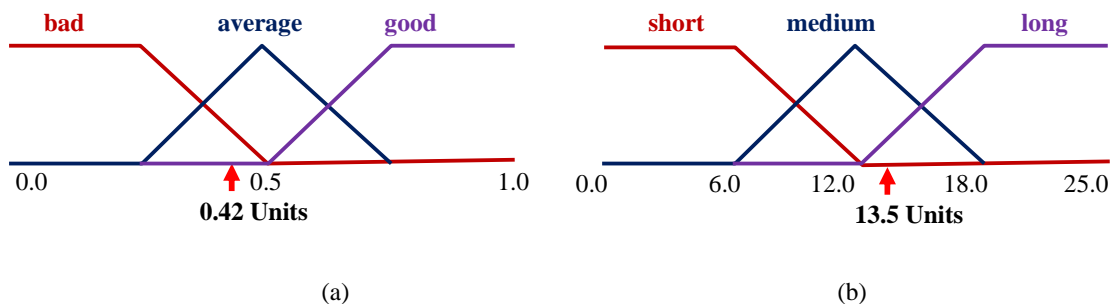


Fig. 3. Representation of " Credit history " (a) and „Employment“ (b) with linguistics terms

The fuzzy system generated by FuzzyTech for Business software⁹. System includes g input interfaces, rule blocks and output interfaces. The connecting lines symbolize the data flow

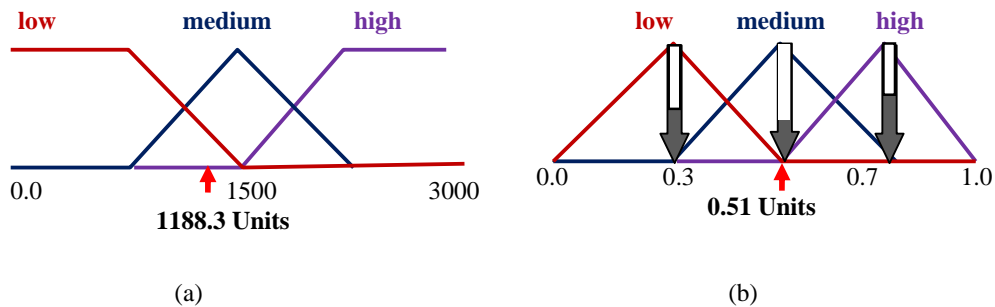


Fig. 4. Representation of " Income level " (a) and „Credit standing“ (b) with linguistics terms

The fuzzy inference step identifies the rule from the Rule base using current inputs, and computes the output fuzzy linguistic variables. There are 5 inputs and single output. Each input and output are represented with 3 linguistic terms, so the total number of possible rules is $3^5=729$.

The parameters of systems are follow:

Aggregation-Min/Max, Number of rules-729, Inputs-5, Output-1

The Fuzzy rules consist of two parts: an antecedent part (between IF and THEN) and consequent part (following THEN).

Example of rules:

- *If Character is “bad” and Collateral condition is “bad” and Credit history is “bad” and Employment period is “short” and Income level is “low”, Then Credit standing is “bad”.*
- *If Character is “good” and Collateral condition is “average” and Credit history is “good” and Employment period is “long” and Income level is “medium”, Then Credit standing is “average”.*
- *If Character is “good” and Collateral condition is “good” and Credit history is “good” and Employment period is “long” and Income level is “high”, Then Credit standing is “good”*

The next step involves aggregation which is used to combine the outputs of the several rules in order to produce single control output. Following Mamdani¹¹, it is natural to use for aggregation the operator OR.

In practical applications, two methods for aggregation are used to drive fuzzy output: maximum operation (MAX) and summation. The maximum method allows the strongest rule to be used for defuzzification. More detail on aggregation described in^{3,4,10}. In present study we apply commonly used fuzzy method – Mamdani type fuzzy inference¹¹. The minimum membership degree of the input variables in the antecedent part of each rule is computed and applied to the consequent part of the respective rule. Then, output fuzzy sets derived from the consequent part of the rules are aggregated .

Defuzzification is a process of translation of the linguistic variable presented as a fuzzy set into a numerical crisp value. For defuzzification in practice, Centre-of-Maximum (CoM), Centre of Area (CoA) and Centre-of-Gravitations (CoG) methods are used^{3,4,5,10}.

4. Results and Discussion

In order to explore alternative models that can aid loan officers during retail credit evaluation, we applied the fuzzy logic based credit evaluation system on retail loan data of one of the leading banks in Azerbaijan. The structure of system generated by FuzzyTech for Business software is shown in Figure We have used FuzzyTech for Business software in our research

To demonstrate how the fuzzy-based loan evaluation works, as an example we take one credit application for evaluation The inputs for this specific credit applicant are shown by the small arrows (↑) under the horizontal axis in

Fig. 2-4. For In other words, these arrows show how inputs are mapped into membership function of linguistic terms. For instance the input for “credit history”=0.42 intersects both the terms “bad” with degree 0.4 and “average” with degree 0.6.

Figure 4 (b) represents graphically the evaluation of retail credit standing, based on the information about the applicant. In this case credit standing is rated as “low” with a degree of $\mu=0.4$ as “medium” to a degree of $\mu=0.25$, and as “high” to a degree of $\mu=0.45$.

The small arrows under the horizontal axis denote the numerical input values. For Character this value is 0.54, for Collateral condition 0.57, for Credit history 0.42, Employer has been working 13.5 and his/her monthly income is 1188.3 For the given values of input variables, his/her credit standing is average with the membership degree:

Academic achievement = (Low=0.40, Medium =0.26, High=0.45).

Assuming that the fuzzy expert system provides an accurate evaluation of credit standing, according to subjective assessment, such a retail loan applicant must be regarded as potentially insolvent. In this respect, the term “low” for the linguistic symbol “credit standing” is being used as a primary fuzzy indicator of credit standing in terms of carefully evaluating borrowers, because identifying potentially insolvent loan applicants with a low credit standing is of primary importance in reviewing credit standing. All loan applicants in danger of insolvency should indicate a relatively high degree of membership for linguistic term “bad”. In other words, the higher this degree of membership, the greater the danger of an individual becoming unable to pay back a loan.

5. Conclusion

In this article, a fuzzy logic approach to evaluating retail loans that can be used to describe imprecise knowledge or human subjective judgment by linguistic terms is proposed. A fuzzy model has been created which is based on the information inputs mostly used by Azerbaijani banks when evaluating a retail loan. The fuzzy information inputs are the loan applicant’s income level, credit history, character, collateral and employment with linguistic terms such as “low”, “medium”, “high” and etc. The model’s knowledge base consists of rule block of 729 “IF.....Then...” rules.

The output of the constructed fuzzy model is credit standing which is also a fuzzy variable with linguistic terms. Whether applicant’s credit standing shall be regarded as “bad”, “average” or “good” depends on the degree of membership for these linguistic terms. The fuzzy loan evaluation model has been tested on the loan application data in one of the leading banks in Azerbaijan. A greater number of linguistic variables as well as more complex “IF...Then...” rules are recommended for more realistic results.

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