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Fuzzy Logic Application for Credit Risk Assessment

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Abstract. The paper presents the results of studies of risk assessment models by using fuzzy logic. The main criteria for assessing the borrower's creditworthiness are determined. An architectural model for assessing credit risk consisting of the following components: database; fuzzyfication; fuzzy inference; fuzzy production rule base; defuzzyfication is proposed. Fuzzy inference rules are formed and test data of the resulting model are presented in order to solve the problem. The proposed model for determining the creditworthiness of borrowers based on the Mamdani fuzzy inference algorithm allows to take into account the uncertainty of the initial information about borrowers, which is most effective in conditions of incompleteness and uncertainty of information, the presence of linguistic variables and qualitative criteria.

INTRODUCTION

Banking area faces various types of risks, which are constantly growing as banking products become more complex. A special place in this system of risks is taken by credit risks. Credit risk is a failure to meet contractual terms or other default by a borrower. Today consumer credit risk can be measured as the most risky type of credit risks. This type of lending has been intensively developing over the past two decades. Evaluation of the financial stability of the borrower, taking into account the possible risks of credit operations, allows the bank to objectively manage credit resources and make a profit. Creditworthiness is understood as borrower's estimated, potential ability to meet payments, the assessment of which should cover the expected period of using the loan. The goals and objectives of the analysis of creditworthiness are to determine: the ability of the borrower to repay the debt on the loan in a timely manner; degree of risk; the amount of credit that can be provided in the given circumstances and the conditions for its provision [1]. Thus, the assessment of credit risk is one of the most important issues in finance area.

In modern banking conditions there are a sufficient number of methods for assessing credit risk. These methods can be divided into the following main groups: statistical methods; rating models; neural networks; expert methods; fuzzy-multiple approach; scoring [2]. These methods of assessing credit risk can be conditionally classified into classical and "progressive". Classical methods are too formalized and do not accurately take into account the complex nature of credit risk. The classical approach is based on a standard assessment of the borrower's creditworthiness and assigning a credit rating to the borrower [3]. In "progressive" (neural networks, fuzzy-multiple approach) methods, complex mathematical models are applied that more accurately cover the specifics of credit risk.

The use of fuzzy-multiple approach provides a number of advantages, as it allows to: include qualitative variables in the analysis; operate with fuzzy input data; operate with linguistic criteria; quickly simulate complex dynamic systems and compare them with a given degree of accuracy; overcome the shortcomings and limitations of existing risk assessment methods [4].

Therefore, this paper considers the use of fuzzy logic in assessing borrowers' credit scores. To solve this problem, a set of fuzzy logic tools from the MATLAB program was used.

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APPLICATION OF FUZZY LOGIC IN ECONOMY

In paper [5] authors investigated, the most widely recognized base classifiers in credit scoring, such as logistic regressions, support vector machines, neural networks, gradient boosting decision trees and random forests. A new method of selecting classifiers using the Genetic Algorithm to consider the accuracy and variety of the ensemble was proposed [5]. In [6], the method for applying fuzzy logic to financial risk indicators in order to provide more accurate credit ratings was determined, and results show that the method provides very good solvency and a low level of risk. The paper [7] presents an assessment of external risk using the fuzzy logic method. This example is monitoring and risk assessment of the current activities of the enterprise. The solution of the task is carried out using fuzzy logic methods. The reliability of the life safety system and the consequences of chlorine leakage were considered as input variables of the fuzzy inference system. Thus, the proposed system allows using the developed tool for subsequent monitoring and risk control. The work [8] focuses on assessment of credit risk on the example of a commercial bank in Egypt. In the article, the researchers propose a fuzzy logic model that can be used to assist in determining and forecasting a bank's credit risk rating. The results showed that fuzzy logic is one of the most important machine learning methods that are used to predict the credit risk rating of commercial banks. The results showed that the fuzzy logic method is more scalable, reliable, stable and different from classical methods [8]. The work [9] proposes a model for forecasting the incapacity of commercial banks. The use of the suggested model will allow determining the level of financial failure in commercial banks and getting recommendations on how to eliminate bank financial problems. Application of the proposed fuzzy logic model showed it is scalable, reliable, stable and different from probability methods and based on natural language [9]. The paper [10] presents the application of fuzzy logic in credit scoring for microfinance organizations in Ghana. The main purpose of this study was to provide a fuzzy approach to credit scoring in order to reduce default on loans among microfinance institutions in order to ensure their continued existence. A wide range of applications of fuzzy logic in solving financial problems allows us to conclude its rationale for economic matters.

ARCHITECTURE OF THE CREDIT RISK ASSESSMENT MODEL

The main purpose of the proposed model is to assess the credit risk, which identifies borrower's potential ability to meet payments. As with modeling any Fuzzy Logic controller, it is necessary to formulate all the influencing factors and how they affect the output. Once the required set of inputs and outputs has been established, system modeling can be performed using any kind of fuzzy software. For this purpose, a set of fuzzy logic tools in MATLAB was used. The architectural model consists of the following five components: database; fuzzyfication; means of fuzzy inference; fuzzy production rule base; defuzzyfication.

The database is used to retain customer data. Basic client information, such as name, date of registration, amount of savings, etc. will be retained in the database. Since an important factor in assessing credit risk is the identification of the borrower's credit rating, we will determine the most important credit rating criteria. We will consider the most important factors as input for determining a credit rating in consumer credit. Those are the borrower's credit history; borrower's financial condition (income, type of employment, length of employment); borrower's demographic status (age, education, marital status, number of children) and ownership of real estate.

We will define the range for the listed variables. For example, the range for the *age* variable is from 18 to 65, which is the norm that most banks adhere to, the range of the *credit rating* variable is from 0 to 10 [11]. The range for the variable *income* and *real estate ownership* are shown in dollars. The following are range for variables to determine the credit rating [11]:

1) credit history of the borrower (0, 1);
2) financial condition of the borrower (Finance) (0, 10): income (100-3000); type of employment (0-2); length of employment (0-15);
3) demographic status (Demographics) (0, 10): age (18, 65); education (0, 3); marital status (0, 1); number of children (0, 5);
4) ownership of real estate (10000, 60000).

Fuzzyfication is understood not only as a separate stage of performing fuzzy inference, but also as the actual process or procedure for finding the values of membership functions of fuzzy sets based on conventional input data. Fuzzyfication is also called the introduction of fuzziness [12].

The most important two types of fuzzy inference method are Mamdani and Sugeno fuzzy inference methods. The model under consideration is based on the Mamdani inference method. The Mamdani-style fuzzy inference process is carried out in four steps: fuzzyfication of input variables; rule evaluation; aggregation of rule outputs; defuzzyfication. The role of the fuzzy inference arrangement is to match the fuzzy rules contained in the rule base with input values for indicator data stored in the database to determine which rules should be applied and govern the reasoning process [8].

Various shapes can be used to form membership functions such as Gaussian, Trapezoidal, Bell Curve, etc. The triangular membership function was used to create the model due to its simple formula and computational efficiency (Figure 1) [13÷14].

The rule base is designed to formally represent empirical knowledge or the knowledge of experts in a particular problem area. Creating a fuzzy If-Then rule base is necessary in order to determine how a variable affects the result. The following are some of the rules that were used to determine a candidate's financial score. If (Income - low) and (type of employment - service personnel) and (length of employment - short), then (Financial score - low). If (Income - average) and (type of employment - specialist) and (length of employment - average), then (Financial score - average). If (income - high) and (type of employment - director) and (length of employment - long), then (Financial score - high).

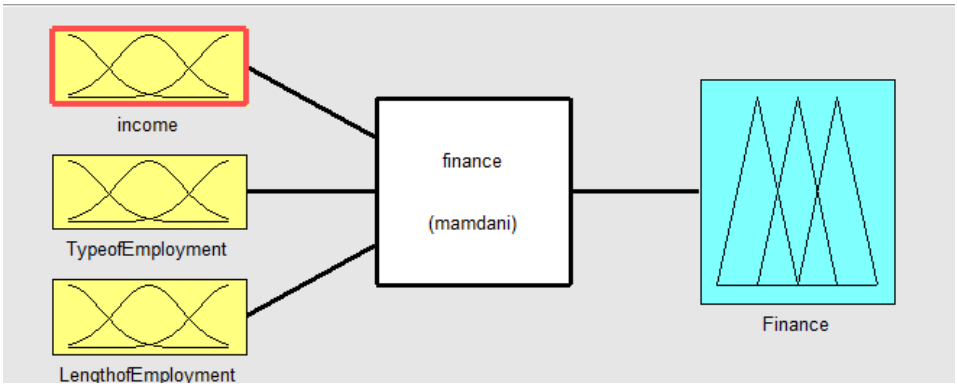

FIGURE 1. Mamdani Fuzzy Inference Method

Each element of this credit rating model has a detailed rule base covering 27 rules for assessing a borrower's financial condition. A rule base based on 51 conditions is applied to determine the demographic position of the borrower. When determining the final value of the borrower's credit rating, 72 rules were used, taking into account credit history, financial condition, demographic situation and the availability of real estate.

Defuzzyfication is a procedure or process of finding a common value for each of the output linguistic variables of the set $W=(w_1,w_2, \ldots w_s)$. The purpose of defuzzyfication is to obtain the usual quantitative value of each of the output variables, using the results of the accumulation of all output linguistic variables [12]. In this work, the center of gravity method is used as a defuzzyfication strategy.

Figure 2 shows the relationship between *income* and *length of employment* in assessing the financial condition of the borrower. According to the data obtained, an increase in income is considered to be favorable for the financial condition of the borrower, as it reflects a better ability to repay the loan. An increase in the duration of employment is also a favorable factor, since the increase in the length of employment may be due to financial stability.

Visualization of fuzzy inference is carried out using the Rule Viewer GUI module. This module allows you to illustrate the course of logical inference for each rule, obtaining the resulting fuzzy set and performing the defuzzyfication procedure [15]. Once the system has been fully developed, clear inputs can be entered to produce a credit score result. With income = 1000, type of employment = 1, and length of employment = 7 years, the fuzzy rule base generates a financial condition of the borrower in the amount of 7.68.

In this example, the centroid method was used for defuzzyfication, since this method is usually better than other methods in terms of consistency of results [16].

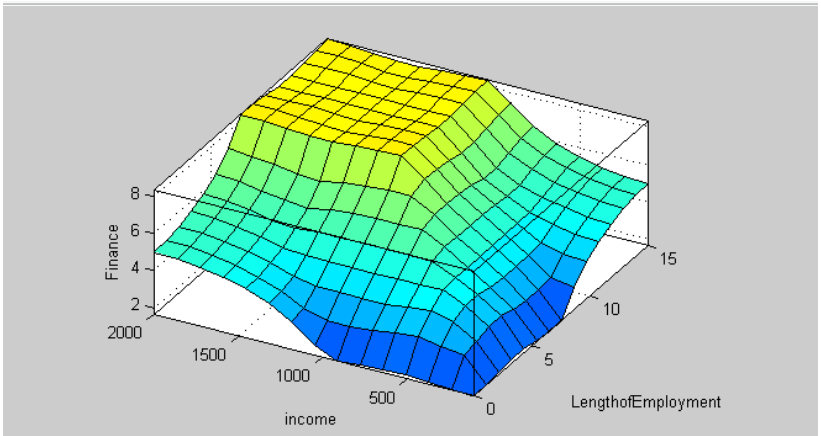

FIGURE 2. The ratio between income and length of employment in assessing the financial condition of the borrower

SYSTEM TESTING

In order to identify the borrower's credit rating, a list of sample data was submitted to the system, which makes it possible to consider the impact of certain parameters on the value of the credit rating. Table 1 presents the *financial condition* of the borrower (Finance) depending on three input values: income, length of employment and type of employment. Table 2 presents the indicator *Demographics of the borrower* (Demographics), which depends on the age, education, marital status and number of children of the borrower. Table 3 evaluates *Credit History, Financial Condition, Demographic Status and Real Estate Availability to determine the final Credit Rating of the borrower*.

TABLE 1. Borrower's financial condition variable (Finance)

Income	Type of employment	Length of employment	Borrower's Financial score
1000	1	7	7.68
1500	2	3	5.62
400	0.5	3	4.47
1760	0.5	11	6.15
1800	2	8	8.31

Thus, based on received data with the final value of the borrower's credit rating of 7.36, the positive credit history of the borrower (0.9) was considered, as well as the high indicators of the financial condition and demographic status of the client 8.31 and 8.26, respectively.

TABLE 2. Borrower's Demographics Variable

Age	Education	Marital status	Amount of children	Borrower's demographic score
23	1	1	2	3.7
37	1	0.5	0	5.78
45	1.8	0.7	1	5.61
38	3	1	0	8.35
24	3	0.83	0	8.26

TABLE 3. Borrower's credit rating variable

Credit history	Financial condition	Demographic condition	Availability of real estate	Credit rating
0	7.68	3.7	35000	4.47
1	5.62	5.78	50000	5.63
0.2	4.47	5.61	10000	4.17
1	6.15	8.35	60000	5.76
0.9	8.31	8.26	45600	7.36

CONCLUSION

The article is focused on study of fuzzy logic application for credit risk assessment. A set of financial indicators that are used in assessing the credit rating has been presented. These indicators were divided into four categories: credit history, financial condition, borrower demographics, and real estate ownership. Using the proposed model, bank employees can determine the credit rating by analyzing situations according to the "If-Then" scheme.

An architectural model for assessing credit risk based on fuzzy logic has been proposed, which includes the following components: database; fuzzyfication; means of fuzzy inference; fuzzy production rule base; defuzzyfication. The model for identifying the borrowers' creditworthiness, based on the Mamdani fuzzy inference algorithm, allows to consider the uncertainty of the initial information about borrowers, which is most effective in conditions of incompleteness and uncertainty of information, the presence of linguistic variables and qualitative criteria. Fuzzy inference rules for assessing borrower's the credit rating are formed and system testing data are presented in order to solve a task.

Thus, identifying the borrower's credit rating based on fuzzy logic makes it possible to more objectively draw intermediate and final conclusions, highlight the strengths and weaknesses of the client, and also make suggestions on the rational for loan issuance, which directly leads to credit risks reduction.

Fuzzy logic technique is one of the most important machine learning methods used for credit risk assessment. The application of fuzzy logic in the financial sector allows solving problems that are often influenced by many various and complex factors that cannot be labeled with a clear number or process. The formation of a rule base for a specific task is one of the most difficult stages in the application of fuzzy logic. Despite the complexity of creating a rule base, fuzzy logic models helps to efficiently solve complex problems in short period of time, which is not typical for traditional probabilistic mathematical models.

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