DEVELOPMENT OF FUZZY EXPERT DECISION SUPPORT SYSTEM FOR MORTGAGE ASSESSMENT

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ABSTRACT

One of the common problems that the financial institutions have to deal with is the assessment of risk posed by a borrower to a lender. Mortgage applications are not an exception. Probabilities models are often use when dealing with risks generally but this model may not be able to describe risks in a meaning way. The fuzzy logic rule base has a framework in which experts' constructive input and data can be used to assess the uncertainty involved and identify major issues, thereby making it easy to model risks. In this work, a mortgage application assessment model that utilises fuzzy logic was developed using MATLAB to serve as decision support for determining the credit worthiness or mortgage worthiness of applicants. The system was developed using MATLAB fuzzy logic tool, which was tested using mortgage application of ten individuals and the results were compiled.

Keywords: Assessment, Decision Support System, Expert System, Fuzzy Logic, Loan, Mortgage

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INTRODUCTION

According to Kagan (2019), a mortgage is a debt instrument, secured by the collateral of specified real estate property that the borrower is obliged to pay back with a predetermined set of payments. Mortgage finance is the cornerstone in housing construction. The relationship between the mortgagee (lender) and mortgager (borrower) has greatly contributed to the financial sector in developed countries (Yinusa *et.al,* 2017). A Mortgage application process begins with loan interview and ends with settlement which is rather a long and careful process as both the borrower and lender needs to consider all risk associated with mortgaging above and beyond financial services (Kagan, 2019). One of the common problems that the financial institutions have to deal with is the assessment of risk posed by a borrower to a lender. Consumers vying for a mortgage and the technicality needed in document sorting and reviewing, (this is a process known as underwriting where the lender formally evaluates the borrower ability to repay) seems to be another problem that could be solved with a well-designed supportive system. The inability to know the cause and effect makes it difficult to assess the degree of exposure associated with some types of risk using only basic probability models. Also, it is difficult to construct or know the analytic dependencies among the variables of a system. Enrique (2009) asserted that the growing internationalization, the globalization of financial markets and the introduction of complex products have increased the volatility and the number of risks in the business environment. A Decision Support System (DSS) is an information system that supports business or organizational decision-making activities. Korol (2012) asserted that one of the major thrusts of economic science is to describe the behaviour of individual units such as consumers, firms, government agencies and their interactions but a large number of economic or financial concepts are vague, or fuzzy in nature. Buckley et al. (2002) was of the opinion that fuzzy logic has the potential to be a very useful and powerful tool in financial analysis, if successful in supplanting mathematical methods. Fuzzy logic has been widely used in Engineering and other aspects of technology which require modelling and control systems (Herrera *et al.,*2014). In this work, MATLAB was used to develop a fuzzy logic-based decision support system using the fuzzy logic toolbox to create the Fuzzy Inference Systems for generating each of the outputs for mortgage loan assessment. The input variable comprises of consumer evaluation, market value of house, income and interest on loan.

Literature Review

A number called credit score was used by Sampath & Kalaichelvil (2014) to compared each consumer vying for a mortgage with each other. This credit score is generated by applying a mathematical algorithm to information in the applicant's credit report. The higher the credit score, the lower the risk posed by the candidate, and the better chance he has to be considered by the lender. The system is effective in detecting the risks associated with each borrower but it takes a considerable amount of energy to skim through data to determine the relationship between the different variables and formulate the rules.

Gupta &Celtelk (2001) used the approach of consulting human expert with experience and majorly on small business development which helps in choosing minimal criteria for determining loan grants. The limitation of the approach is that the system didn't consider new business owners or business owners without any credit or banking history. Also, the decision levels of lend/ do not lend are too affirmative (considering lending probably a lesser amount than the initial amount requested might be helpful in expansion or needs of the borrower).

Somayee*t al.* (2013) created and applied an expert system framework in granting credit facilities. It was a descriptive case study research that aimed at verifying relationship between credit risk and consumer credit. In their research, the scope of the study was not wide enough to use the information gathered and analysed to develop the knowledge base of a loan management system that can be used across the varying financial institutions indulged in. Also, there was no proposed developed architecture or proposed design for the application in granting credit facilities.

Mbam & Igboji (2013) designed a system using the Object Modelling Technique (OMT) to manage long and short-term loans in a cooperative society. The system intended to have a replacement of the manual method of computing member's records, with an electronic system that does this task efficiently, fast, reliable, and error free within the activities carried out in a cooperative society. Conditions for loan scheme were clearly stated which streamline the application to only eligible applicants.

Adewale *et al.* (2014) developed loan automation application that replaced paper works and methods of preparing, registering and granting of loan facilities. In this system, there is no requirements to be met by the client when requesting for loan because all decision have to be made by the administrator, which can make number of loan request higher than necessary. Also, the ability of the users to change passwords without security questions can lead to infringement to their accounts by hackers.

Shorouq *et al.* (2010) developed a lending decision model for the product of personal loans in commercial banks using a back-propagation multilayer feed-forward neural network. The quality of customer's service is enhanced by this approach because it **r**educed personal judgements and **distortion of decision that occ**urs through emotional intention but artificial neural networks generally do not tell the system users how it arrived at the results. Also, the system lacks a graphic user interface for effective and intuitive communication.

Yasaman *et al.* (2014) implemented an expert system for lending with certainty factor which assist banks in deciding, accepting or rejecting a particular loan request. The system built evaluates loan request based on questions answered by the client or user and the answer is given in a certainty term and in numerical basis. Minimum evaluation criteria were used in arriving at 4 final judgements (good, fair, poor, and excellent).The final result is expressed using a certainty factor, unlike previous works which rate requests as poor, average, or good.

Ryan (2015) implemented an expert system to ease the disbursement of home loans in a financial setting. The study however used two main approaches in acquiring this, which are; knowledge acquisition and software design. The knowledge acquisition includes document analysis and, knowledge elicited from the expert and also validating and verifying all these acquired facts before it is being integrated into the expert system. The systems proved secured by ensuring applicants with no account details have no permission to query the system further. The user interface of the system isn't a friendly one as it uses command prompt for querying the system.

Design Methodology

System Design

The system design is presented in figure 1. It comprises of four modules namely Fuzzification module, Knowledge Base, Fuzzy Inference Engine and Defuzzification Module.

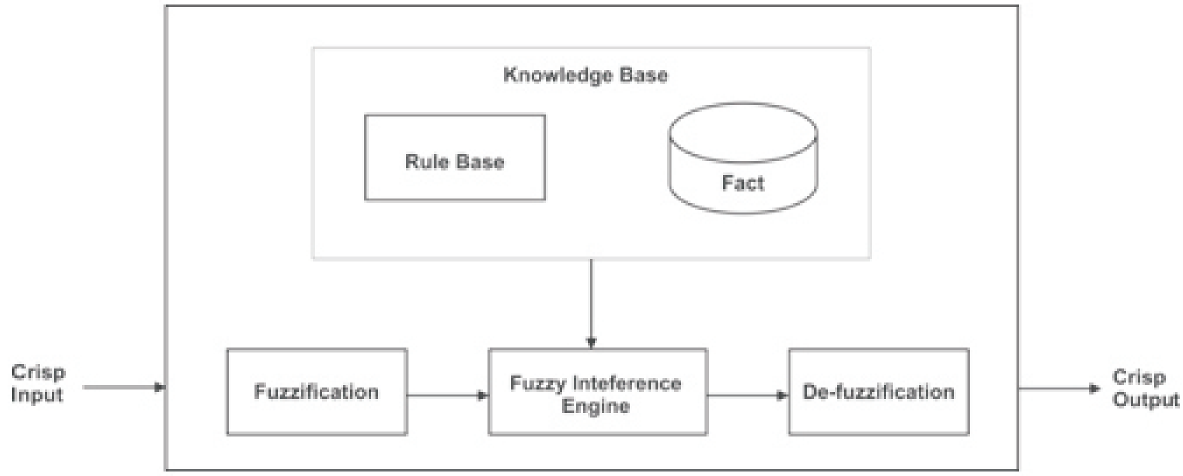


Figure 1: System Design

Component of the Architectural Design

(i) Fuzzification Module

It transforms the system inputs, which are crisp numbers; into fuzzy sets i.e. it converts the crisp quantities into fuzzy quantities. It splits the input signal into eight steps such as –

Very Low	Low	Medium	High	Very High	Bad	Fair	Excellent
VL	L	M	H	VH	B	F	E

(ii) Knowledge Base

The knowledge base of the system is that part of the system that contains facts and set of rules on the mortgage loan assessment, which was used to handle user loan requests**.** It stores IF-THEN rules provided by experts

(a) Facts

The following are the various facts in reference to mortgage loan assessment as provided by the expert: Market Value, Location, House, Asset, Income, Application, Interest and Credit.

(b) Rule

It contains fuzzy IF-THEN rules. Any rule consists of two parts: the IF part, called the antecedent (premise or condition) and the THEN part called the consequent (conclusion or action).

(iii) Inference Engine

It simulates the human reasoning process by making fuzzy inference on the inputs and IF-THEN rules.

(iv) Defuzzification Module

It transforms the fuzzy set obtained by the inference engine into a crisp value i.e. it converts the fuzzy quantities into crisp quantities.

Algorithm for the System

Step 1: Define linguistic Variables and terms
Step 2: Construct membership functions for

linguistic Variables
Step 3: Construct knowledge base of rules
Step 4: Encode the fuzzy sets, fuzzy rules and procedures to perform fuzzy inference into the expert system
Step 5: Convert output data.

Implementation and Results

The system was implemented using MATLAB (2007). In developing the fuzzy expert system, the following steps were incorporated:

Step 1 - Define linguistic variables and terms

Input and output variables which are in form of simple words or sentences are linguistic variables. For Market Value, Medium, High, Very High etc., are linguistic terms.

Market Value = {Medium, High, Very High}. The linguistic variables are shown in tables 1 to 8.

Step 2 - Construct membership functions for the linguistic variables

The fuzzy set for all linguistic variables such as market value variable, location, house, asset, income, applicant interest and credit used in this problem are represented.

Step 3 - Construct knowledge base rules

Fuzzy rules are represented in matrix form, that is, a two by one system (two input and one output)whichis depicted as M X N matrix of input variables. In this example, there are two input and one output variable. The matrix of location values versus market values that a home valuation is expected to provide, matrix of asset values versus income values that an applicant evaluation is expected to provide and matrix of income versus interest values and Applicant Versus house that a credit evaluation is expected to provide are shown in tables 9, 10 and 11 respectively.

Set of rules were built into the knowledge base in the form of IF-THEN-ELSE structures.

Rule Base 1: Home Evaluation

1. If (Market is Bad) then (House is low)
2. If(Location is Bad) then (House is low)
3. If (Location is Bad) and (Market value is low) then (House is very low)
4. If (Location is Bad) and (Market value is medium) then (House is Low)
5. If (Location is Bad) and (Market value is High) then (House is Medium)
6. If (Location is Bad) and (Market value is very High) then (House is High)
7. If (Location is fair) and (Market value is low) then (House is low)
8. If (Location is Fair) and (Market value is Medium) then (House is Medium)
9. If (Location is Fair) and (Market value is High) then (House is High)
10. If (Location is Fair) and (Market value is very High) then (House is Very High)
11. If (Location is Excellent) and (Market value is Low) then (House is Medium)
12. If (Location is Excellent) and (Market value is Medium) then (House is High)
13. If (Location is Excellent) and (Market value is High) then (House is very High)
14. If (Location is Excellent) then (Market value is very High) then (House is very High)

Rule Base 2: Applicant Evaluation

1. If (Asset is Low) and (Income is Low) then (Applicant is Low)
2. If (Asset is Low) and (Income is Medium) then (Applicant is Low)
3. If (Asset is Low) and (Income is High) then (Applicant is Medium)
4. If (Asset is Low) and (Income is very High) then (Applicant is High)
5. If (Asset is Medium) and (Income is Low) then (Applicant is Low)
6. If (Asset is Medium) and (Income is Medium) then (Applicant is Medium)
7. If (Asset is Medium) and (Income is High) then (Applicant is High)
8. If (Asset is Medium) and (Income is Very High) then (Applicant is High)
9. If (Asset is High) and (Income is Low) then (Applicant is Medium)
10. If (Asset is High) and (Income is Medium)

then (Applicant is Medium)
11. If (Asset is High) and (Income is High) then (Applicant is High)
12. If (Asset is High) and (Income is Very High)then (Applicant is High)

Rule Base 3: Credit Evaluation

1. If (Income is Low) and (Interest is Medium) then (credit is very low)
2. If (Income is Low) and (Interest is High) then (credit is very low)
3. If (Income is Medium) and (Interest is High) then (credit is low)
4. If (Applicant is Low) then (Credit is Low)
5. If (House is Low) then (Credit is Very Low)
6. If (Applicant is Medium) and (House is Very Low) then (Credit is Low)
7. If (Applicant is Medium) and (House is Low) then (Credit is Low)
8. If (Applicant is Medium) and (House is Medium) then (Credit is Medium)
9. If (Applicant is Medium) and (House is High) then (Credit is High)
10. If (Applicant is Medium) and (House is Very High) then (Credit is High)
11. If (Applicant is High) and (House is Very Low) then (Credit is Low)
12. If (Applicant is High) and (House is Low) then (Credit is Medium)
13. If (Applicant is High) and (House is Medium) then (Credit is High)
14. If (Applicant is High) and(House is High) then (Credit is High)
15. If (Applicant is High) and (House is Very High) then (Credit is Very High)

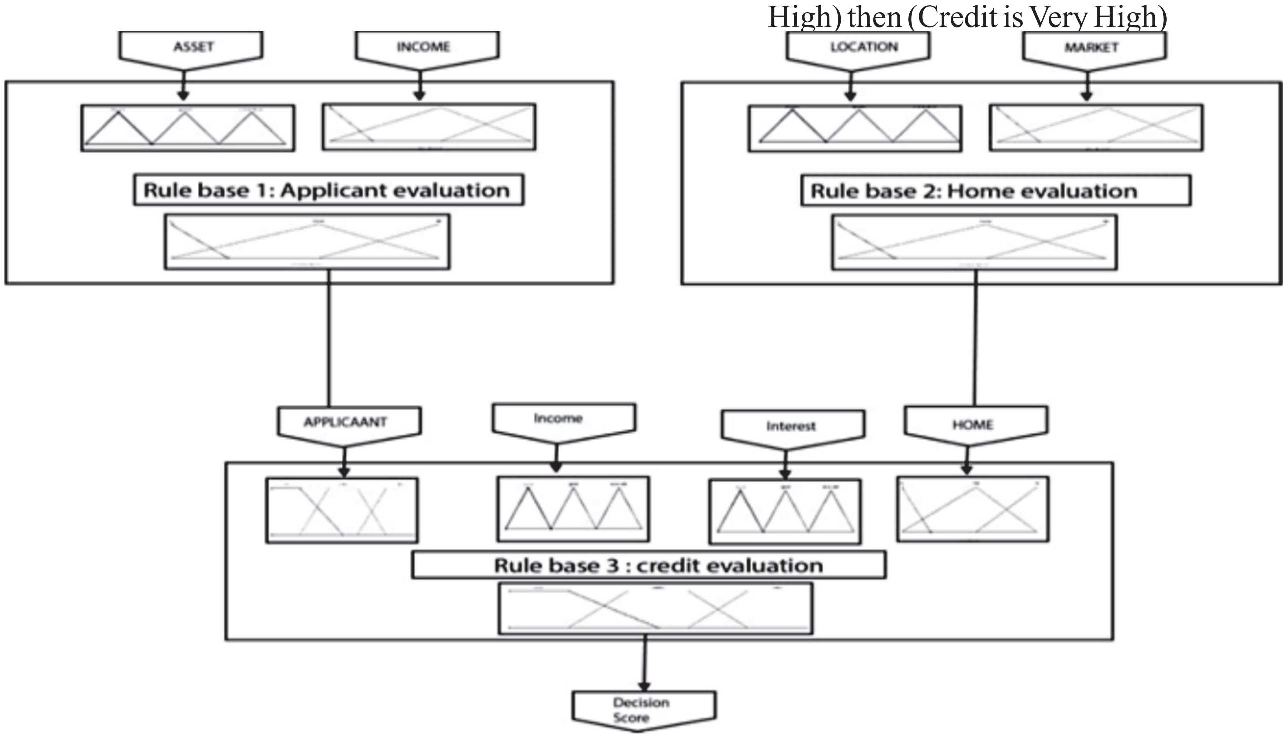


Figure 2: Hierarchical fuzzy model for mortgage loan assessment

Figure 2 shows the hierarchical structure of the complex relationships between all variables used in the fuzzy system

Step 4 - Obtain fuzzy value

After defining fuzzy sets and fuzzy rules, MATLAB Fuzzy Logic development tool was used to build a fuzzy expert system

Step 5 - Perform defuzzification

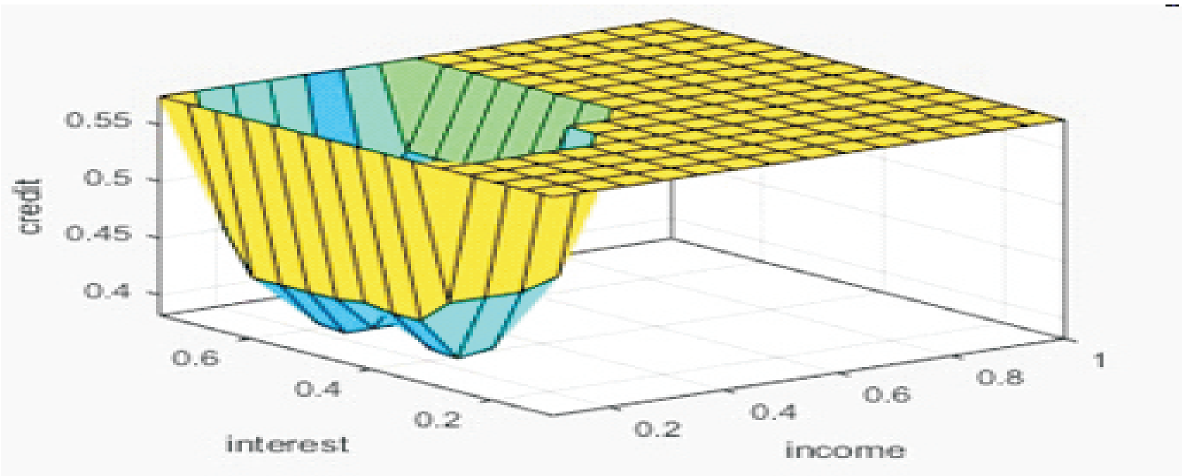
Defuzzification was performed according to membership function for output variable.

The output surface viewer provided by the fuzzy logic toolbox was used to evaluate and analyze the performance of the fuzzy system. The three-dimensional plots of the fuzzy system for mortgage loan assessment are represented in figures 3and 4.

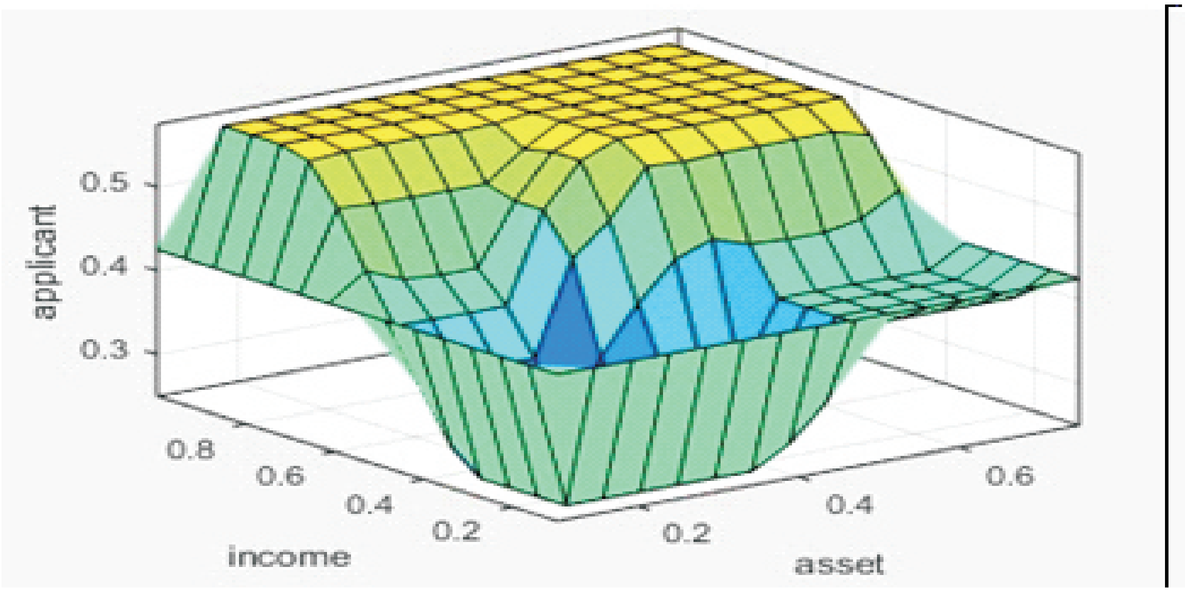
Conclusion

In this work a fuzzy decision support system for the assessment of mortgage was designed. It was designed not only to justify the chosen decision, but also to make recommendations to the process involved in mortgage loan grants. The system can help the human experts as well as applicants in explaining why a particular decision was made. It can evaluate the credit- worthiness of applicants, supply well informed and unbiased decision by providing recommendations enabling them to make decisions according to their preferences and convenience.

Appendix



(a)



(b)

Figure 3 (a & b): Three dimensional plots for Rule Base1 and Rule Base 2

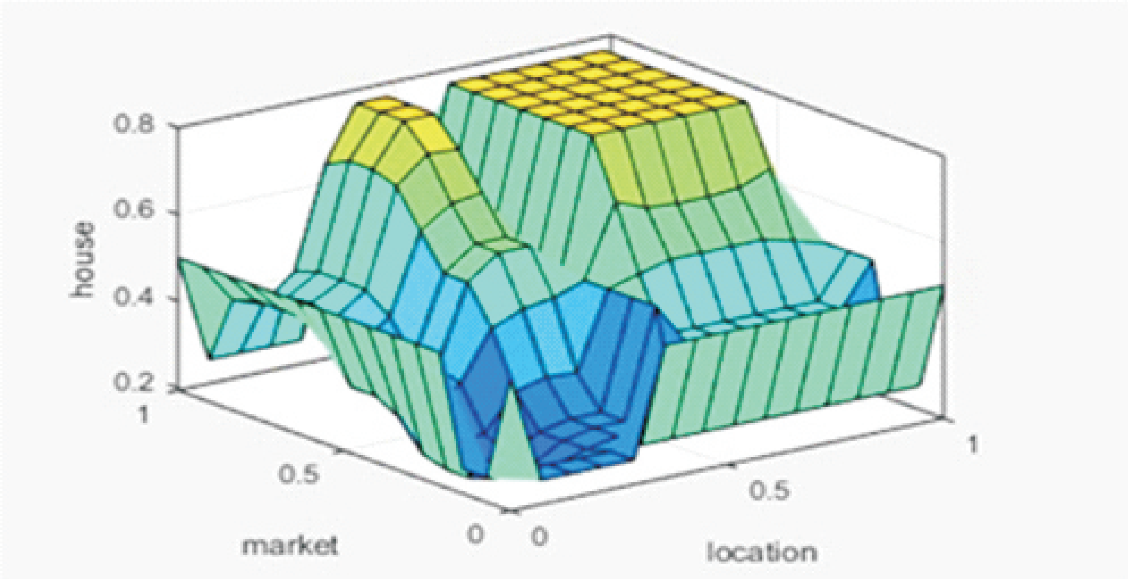


Figure 4: Three dimensional plots for Rule Base 3

Table 1: Linguistic Variable: (Market Value)

Linguistic Value	Notation	Numerical Range (Normalized)
Medium	M	[0, 0.5]
High	H	[0.4. 0.7]
Very High	VH	[0.6, 1]

Table 2: Linguistic Variable: (Location)

Linguistic Value	Notation	Numerical Range (Normalized)
Bad	B	[0, 0.3]
Fair	F	[0.2. 0.5]
Excellent	E	[0.6, 1]

Table 3: Linguistic Variable: (House)

Linguistic Value	Notation	Numerical Range (Normalized)
Very Low	VL	[0, 0.20]
Low	L	[0.1, 0.40]
Medium	M	[0.3, 0.5]
High	H	[0.4. 0.75]
Very High	VH	[0.6, 1]

Table 4: Linguistic Variable (Asset)

Linguistic Value	Notation	Numerical Range (Normalized)
Low	L	[0.1, 0.40]
Medium	M	[0.3, 0.5]
High	H	[0.4. 0.75]

Table 5: Linguistic Variable: (Income)

Linguistic Value	Notation	Numerical Range (Normalized)
Low	L	[0.1, 0.40]
Medium	M	[0.3, 0.5]
High	H	[0.4. 0.75]
Very High	VH	[0.6, 1]

Table 6: Linguistic Variable: (Applicant)

Linguistic Value	Notation	Numerical Range (Normalized)
Low	L	[0.1, 0.40]
Medium	M	[0.3, 0.5]
High	H	[0.4. 0.75]

Table 7: Linguistic Variable: (Interest)

Linguistic Value	Notation	Numerical Range (Normalized)
Low	L	[0.1, 0.40]
Medium	M	[0.3, 0.5]
High	H	[0.4. 0.75]

Table 8: Linguistic Variable: (Credit)

Linguistic Value	Notation	Numerical Range (Normalized)
Very Low	VL	[0, 0.20]
Low	L	[0.1, 0.40]
Medium	M	[0.3, 0.5]
High	H	[0.4. 0.75]
Very High	VH	[0.6, 1]

Table 9: Home Evaluation

Location/Market	B	F	E
L	L	L	M
M	L	M	H
H	M	H	VH
VH	H	VH	VH

Table 10: Applicant Evaluation

Asset/Income	L	M	H
L	L	L	M
M	L	M	M
H	M	H	H
VH	H	H	H

Table 11: Credit Evaluation

Income/Interest	L	M
L	L	
M		
H	L	L

Applicant/House	M	H
VL	L	L
L	L	M
M	M	H
H	H	H
VH	H	VH

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