Universidad Carlos III de Madrid

ARTIFICIAL INTELLIGENCE

Bachelor's Degree in Computer Science & Engineering

Mamdani Fuzzy Inference System (MFIS)

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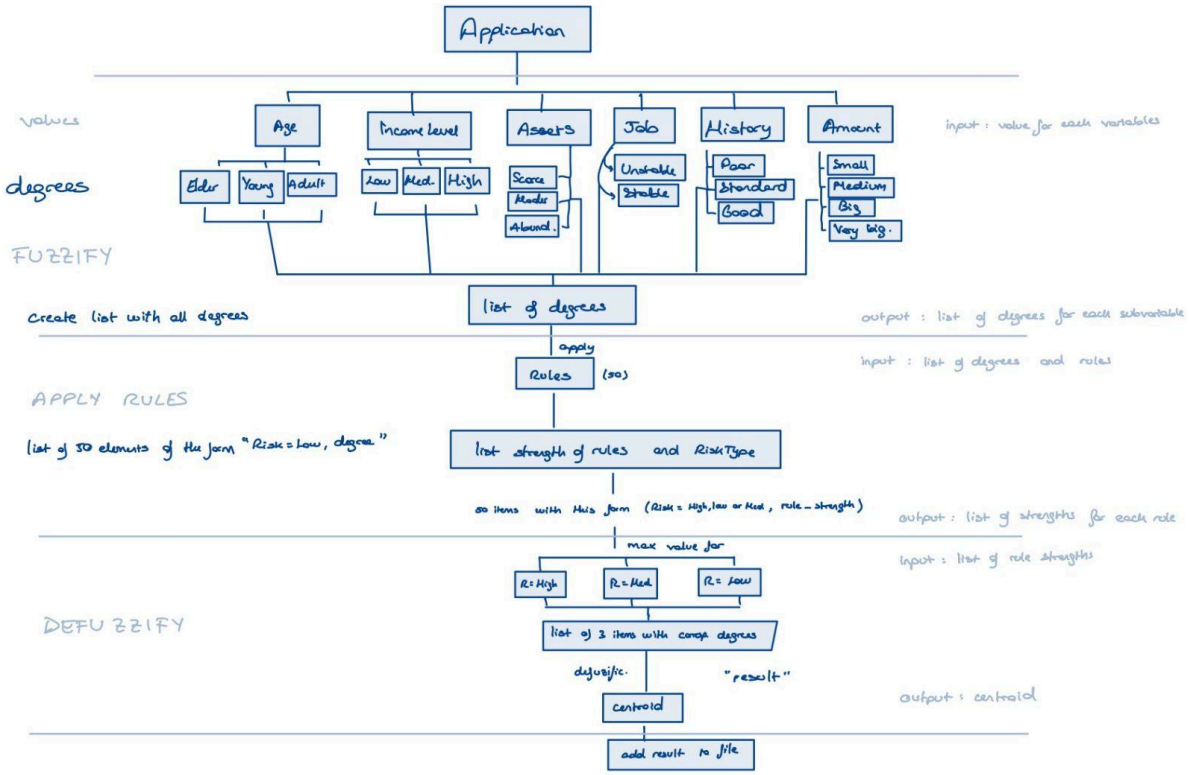
Executive summary

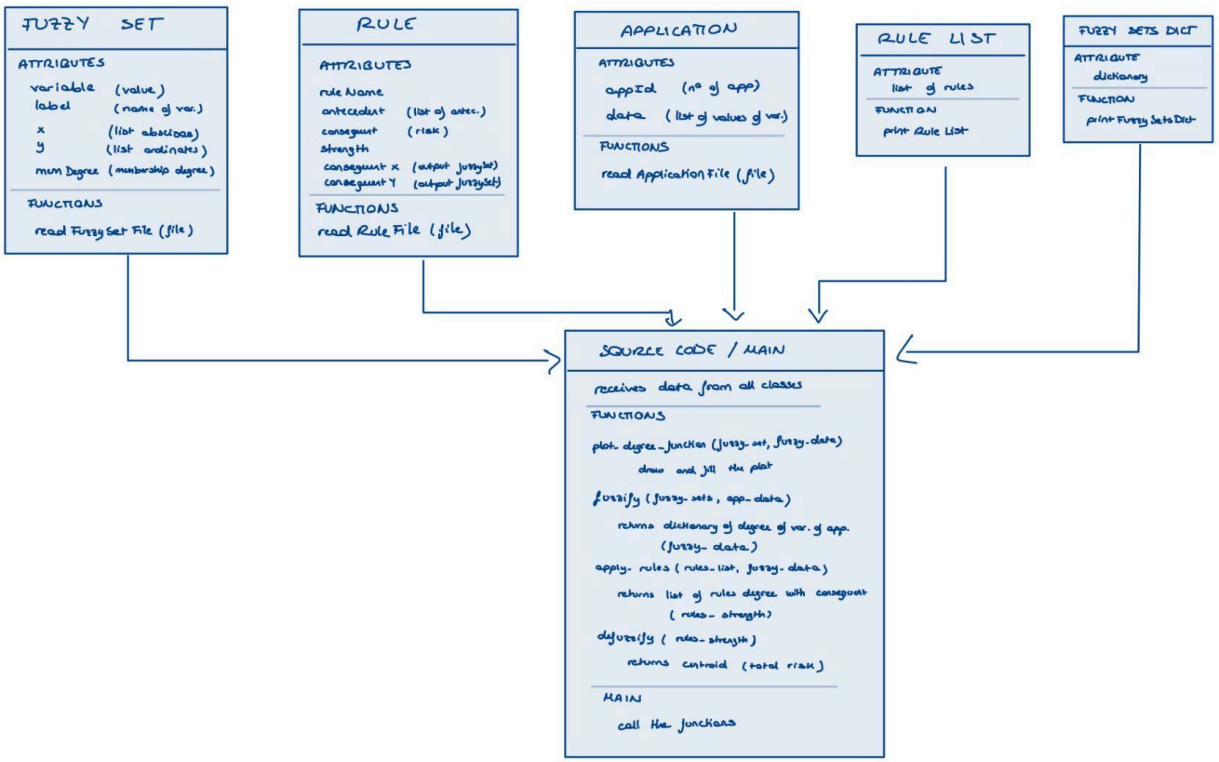
This report provides a detailed summary of the development of a decision support system designed specifically for Banco Pichin's personal loan approval process, led by C3L. The system uses a Mamdani fuzzy inference system (MFIS) to carefully evaluate loan applications and determine the corresponding risk levels. The central element of this advanced system is the MFIS framework, well-known for its effectiveness in managing complicated decision-making processes in uncertain situations. By examining elements like income, assets, job stability and loan performance, the MFIS skillfully manages the complexities of financial information, making it easier to conduct detailed risk evaluations.

One important aspect of the report is the detailed diagram illustrating the system's structure, clarifying the essential inputs and outputs needed for the loan approval process. This diagram provides a comprehensive understanding of how the MFIS combines different data sources to facilitate decision-making.

Here is a more logical view of how the system should work. For each application (50 in total) we receive the values of each of the 6 variables. By making the fuzzification we obtain a list with each sub variable and its corresponding degree. We apply each of the 50 rules to the list of degrees and we obtain another list with the rules' strength of all the rules. In this list we also have the type of the risk together with each degree (high, low or medium risk). Finally we take the maximum value for each risk (low, medium or high) in order to do the defuzzification and obtain the centroid.



In this technical diagram, a more detailed description of the code is provided. We have 5 different classes with their corresponding attributes. The functions of fuzzification, appliance of the rules and the defuzzification are developed in the source code that inherits the attributes and functions of all the classes. Finally, in the source code we also include the main, where we establish some variables that call the reading functions of the fuzzy set, the rules and the applications, and then we call the rest of the functions to make the operations and obtain the result.

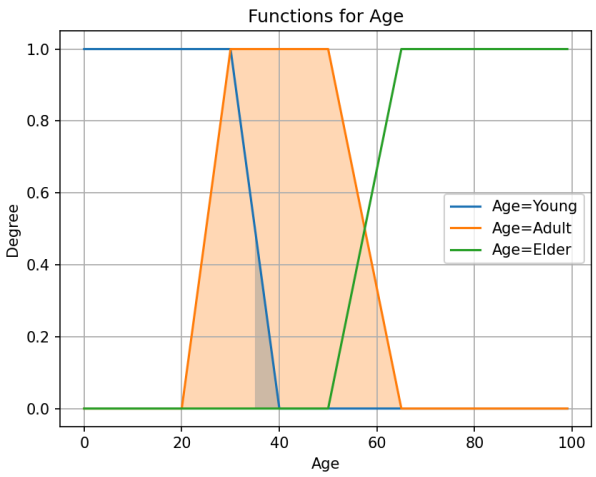


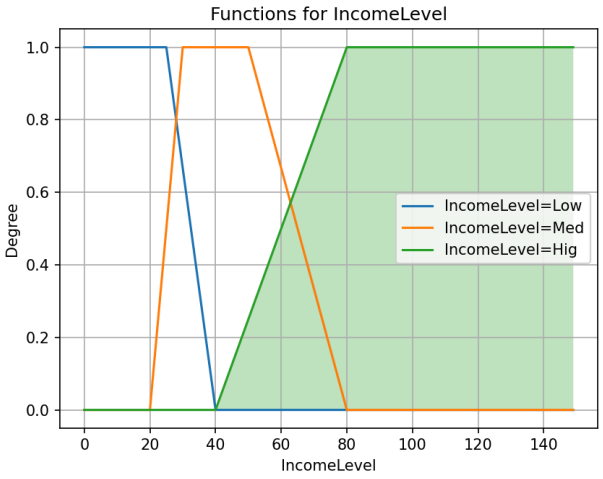
Description of the inference system

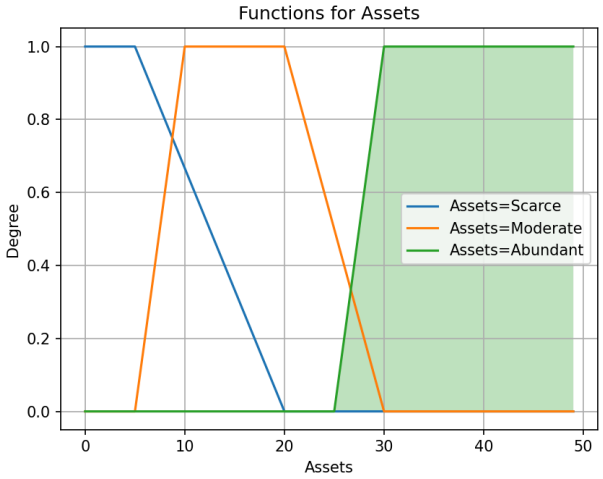
The inference system created by C3L for Banco Pichin is a complex tool designed to help in the decision-making process for approving personal loans. Similar to an experienced financial advisor, it carefully analyzes various aspects of loan applications to offer detailed risk evaluations. The system includes important metrics similar to those used by bankers. These metrics cover aspects like income, assets, job stability, loan in relation to income, payment history and age. It's worth mentioning that the system operates using fuzzy logic, recognizing the natural uncertainty and diversity in financial information.

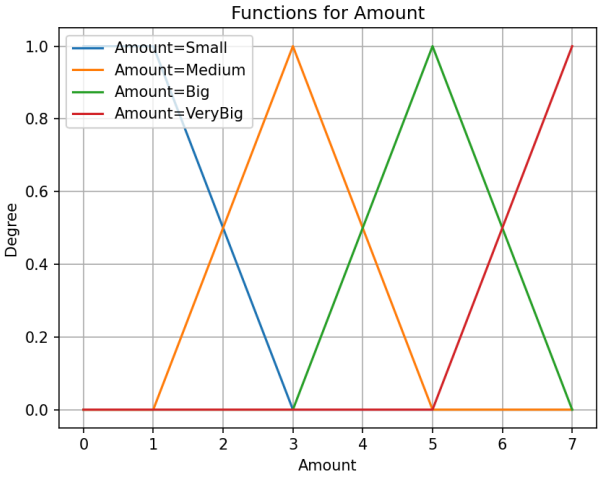
The system functions using a clear set of rules which, influenced by expert knowledge and industry standards, manage the inference process, allowing for personalized decision-making for each individual loan request. The system's significant capability is its skill in dealing with uncertainty. Just like an experienced banker's ability to make sound judgments with limited information, the system uses fuzzy logic to make strong

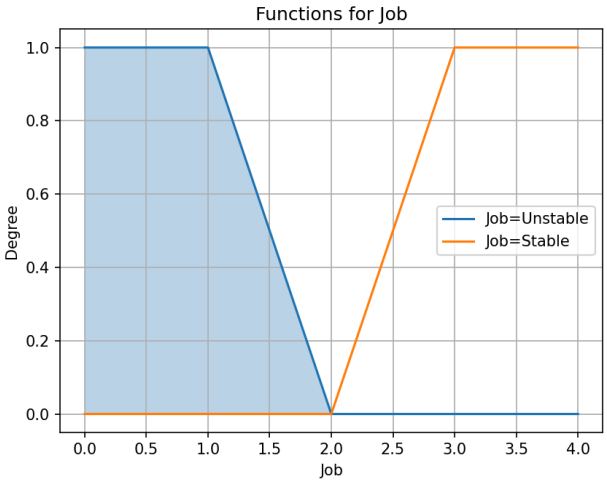
decisions in unclear situations. The system, despite being advanced, is designed with user-friendly features. This makes it easier for loan officers to understand and follow its suggestions, promoting trust and efficiency in the loan approval process. The inference system is a valuable tool for Banco Pichin, providing its decision-makers with valuable insights and assisting in responsible risk management for personal loans.











Methodology

In this part of the project, we will provide pictures of each step taking as an example the first application given in the Applications.txt file.

1. Definition of Variables: The first stage of the development process included a comprehensive analysis of the elements impacting the decision to approve a loan. This involved a detailed examination to find the main factors that influence loan approval decisions. Among the critical input variables were income, assets, job stability, loan amount in relation to income, loan and payment history and age. Fuzzy sets were designed and configured for each factor to capture the complexities and uncertainties present in financial information. These fuzzy sets, characterized by trapezoidal membership functions, accurately represent the range of potential values for each factor.

   For each application, we must get the input value provided and the correspondent variable in order to be able to do the operations needed to obtain the centroid:

```
Variable=Age, Value=35
Variable=IncomeLevel, Value=82
Variable=Assets, Value=38
Variable=Amount, Value=8
Variable=Job, Value=0
Variable=History, Value=1
```

2. Definition of the inference Rules: With the input variables established, the following stage included the formulation of principles regulating the decision-making process. A set of expert-derived rules was formulated, these rules embody the bank's decision-making logic, delineating the relationships between the input variables and the resulting risk assessments. Each rule represents a guideline for evaluating loan applications, specifying the conditions under which a particular risk level is assigned. The system, organized with clarity and precision, serves as the foundation upon which the inference system operates.

In the following picture, we can see the rules with their antecedents and the consequent (result):

```
Rule: Rule01, Antecedent: ['IncomeLevel=Hig', 'Assets=Abundant', 'Amount=Small'], Consequent: Risk=LowR
Rule: Rule02, Antecedent: ['IncomeLevel=Hig', 'Assets=Abundant', 'Amount=Medium'], Consequent: Risk=LowR
Rule: Rule03, Antecedent: ['IncomeLevel=Hig', 'Assets=Abundant', 'Amount=Big'], Consequent: Risk=MediumR
Rule: Rule04, Antecedent: ['IncomeLevel=Hig', 'Assets=Abundant', 'Amount=VeryBig', 'Job=Stable'], Consequent: Risk=MediumR
Rule: Rule05, Antecedent: ['Age=Young', 'Amount=Big'], Consequent: Risk=HighR
Rule: Rule06, Antecedent: ['Age=Elder', 'Amount=Big'], Consequent: Risk=HighR
Rule: Rule07, Antecedent: ['IncomeLevel=Low', 'Amount=VeryBig'], Consequent: Risk=HighR
Rule: Rule08, Antecedent: ['IncomeLevel=Med', 'Amount=VeryBig'], Consequent: Risk=HighR
Rule: Rule09, Antecedent: ['Amount=Medium', 'Job=Stable', 'History=Good'], Consequent: Risk=LowR
Rule: Rule10, Antecedent: ['Amount=Big', 'Job=Stable', 'History=Good'], Consequent: Risk=MediumR
Rule: Rule11, Antecedent: ['IncomeLevel=Low', 'Job=Unstable'], Consequent: Risk=HighR
Rule: Rule12, Antecedent: ['IncomeLevel=Med', 'Amount=Big', 'History=Poor'], Consequent: Risk=HighR
Rule: Rule13, Antecedent: ['IncomeLevel=Low', 'Amount=Big', 'History=Poor'], Consequent: Risk=HighR
Rule: Rule14, Antecedent: ['Assets=Scarce', 'Amount=Small', 'History=Good'], Consequent: Risk=LowR
Rule: Rule15, Antecedent: ['Assets=Scarce', 'Amount=Medium', 'History=Good'], Consequent: Risk=LowR
Rule: Rule16, Antecedent: ['Age=Adult', 'IncomeLevel=Hig', 'Amount=Medium'], Consequent: Risk=MediumR
Rule: Rule17, Antecedent: ['Age=Adult', 'Assets=Abundant', 'Amount=Medium'], Consequent: Risk=MediumR
Rule: Rule18, Antecedent: ['Assets=Moderate', 'Amount=Medium', 'Job=Stable'], Consequent: Risk=MediumR
Rule: Rule19, Antecedent: ['Age=Young', 'IncomeLevel=Low'], Consequent: Risk=MediumR
Rule: Rule20, Antecedent: ['Age=Young', 'IncomeLevel=Med'], Consequent: Risk=HighR
```

3. Implementation of MFIS: Once the variables and rules were defined, the focus moved to the improvement of the Mamdani Fluffy Inference System (MFIS) to ensure optimal performance. The MFIS was meticulously created to integrate defined variables and rules, guaranteeing consistent integration and effective decision-making. The implementation process includes a series of critical steps, beginning with the design and optimization of the fuzzy inference engine. Additionally, the integration of membership functions for each variable, and establishing the inference mechanism to generate risk assessments based on input data was an important aspect of the implementation process.

   Now we have to make the operations for the fuzzification process. First, we will get the degrees for each variable-label with the initial input value:

```
Fuzzify Age=Young: Value=35, Degree=0.5
Fuzzify Age=Adult: Value=35, Degree=1.0
Fuzzify Age=Elder: Value=35, Degree=0.0
Fuzzify IncomeLevel=Low: Value=82, Degree=0.0
Fuzzify IncomeLevel=Med: Value=82, Degree=0.0
Fuzzify IncomeLevel=Hig: Value=82, Degree=1.0
Fuzzify Assets=Scarce: Value=38, Degree=0.0
Fuzzify Assets=Moderate: Value=38, Degree=0.0
Fuzzify Assets=Abundant: Value=38, Degree=1.0
Fuzzify Amount=Small: Value=8, Degree=0.0
Fuzzify Amount=Medium: Value=8, Degree=0.0
Fuzzify Amount=Big: Value=8, Degree=0.0
Fuzzify Amount=VeryBig: Value=8, Degree=0.0
Fuzzify Job=Unstable: Value=0, Degree=1.0
Fuzzify Job=Stable: Value=0, Degree=0.0
Fuzzify History=Poor: Value=1, Degree=1.0
Fuzzify History=Standard: Value=1, Degree=0.0
Fuzzify History=Good: Value=1, Degree=0.0
```

   Then, we will apply the rules and get these results:

   The degree for each variable

```
Rule: Risk=LowR, Degree=0.0
Rule: Risk=LowR, Degree=0.0
Rule: Risk=MediumR, Degree=0.0
Rule: Risk=MediumR, Degree=0.0
Rule: Risk=HighR, Degree=0.0
Rule: Risk=HighR, Degree=0.0
Rule: Risk=HighR, Degree=0.0
Rule: Risk=HighR, Degree=0.0
Rule: Risk=LowR, Degree=0.0
Rule: Risk=MediumR, Degree=0.0
Rule: Risk=HighR, Degree=0.0
Rule: Risk=HighR, Degree=0.0
Rule: Risk=HighR, Degree=0.0
Rule: Risk=LowR, Degree=0.0
Rule: Risk=LowR, Degree=0.0
Rule: Risk=MediumR, Degree=0.0
Rule: Risk=MediumR, Degree=0.0
Rule: Risk=MediumR, Degree=0.0
Rule: Risk=MediumR, Degree=0.0
```

The degree for each rule

And finally we take the maximum value of each rule according to its consequent and calculate the centroid of this application.

```
Centroid: 63.6842105263158
```

In this case we obtained 63.68

4. Testing and Validation: Upon the completion of the implementation stage, testing and validation methods were carried out to ensure the precision and reliability of the MFIS. A wide range of test cases was created to evaluate system performance. Validation efforts were aimed towards confirming the system met Banco Pichin's loaning arrangements and regulatory requirements, guaranteeing compliance and reliability.

Budget

C3L proposes a budget of 100000€ to fund the costs related to finishing this project. The suggested pricing model is adjusted to represent the complexities of creating a customized Mamdani Fuzzy Inference System (MFIS) designed to fit the specific needs of Banco Pichin. Allocating resources involves thorough research, development and implementation phases to create a customized solution that fits perfectly with Banco Pichin's goals and operational structure.

Conclusion

In conclusion, we celebrate the culmination of our collaboration with Banco Pichin in developing a decision-support system for personal loan approvals. Our solution, which we have developed via careful planning, teamwork and creativity, promises to completely change how loan applications are evaluated and approved. This report's rigorous methodology, reliable inference system and extensive testing show how committed our team is to delivering solutions that meet the highest reliability and quality standards.

We are eager to see how this system may affect Banco Pichin's operations in the future. Our utilization of cutting-edge technologies and methodologies has established the groundwork for improved productivity, risk mitigation and client contentment. We stand ready to welcome Banco Pichin into this new era of decision support.