Experiment No. 4: To design and implement Fuzzy Inference System

Aim: To design and implement Fuzzy Inference System

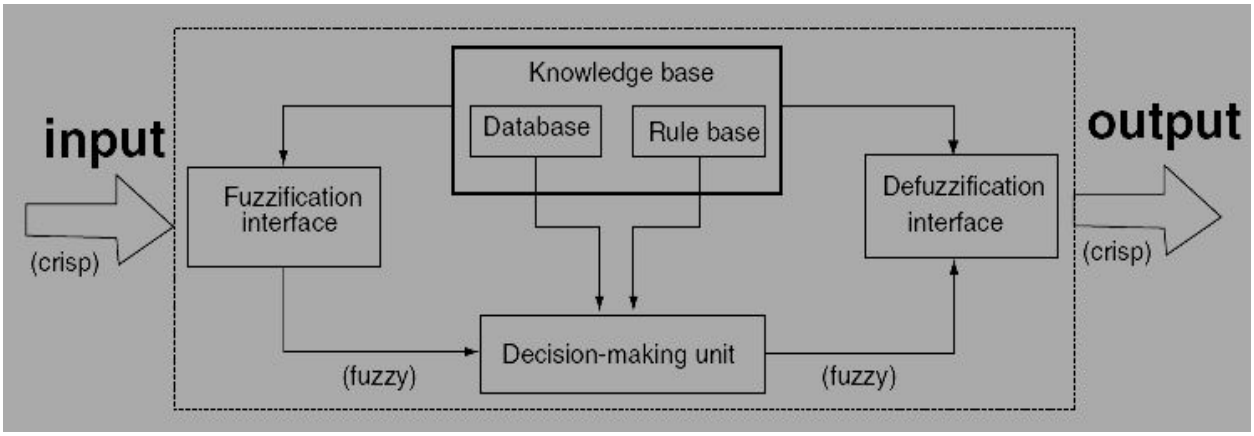
Theory:

Fuzzy Inference System (FIS)

A Fuzzy Inference System (FIS) is a way of mapping an input space to an output space using fuzzy logic.FIS uses a collection of fuzzy membership functions and rules, instead of Boolean logic, to reason about data.

FIS consists of four main components:

1. Fuzzification interface
2. Rule base,
3. Database,
4. Decision-making unit and Defuzzification interface.



Function of each block

1. Rule base : contains a number of fuzzy IF–THEN rules
2. Database : defines the membership functions of the fuzzy sets used in the fuzzy rules
3. Decision-making unit: performs the inference operations on the rules.
4. Fuzzification interface : transforms the crisp inputs into degrees of match with linguistic values; and
5. Defuzzification interface : transforms the fuzzy results of the inference into a crisp output

Firstly, a crisp set of input data are gathered and converted to a fuzzy set using fuzzy linguistic variables, fuzzy linguistic terms and membership functions. This step is known as fuzzification. Afterwards, an inference is made based on a set of rules. Lastly, the resulting fuzzy output is mapped to a crisp output using the membership functions, in the defuzzification step.

Steps in designing Fuzzy Inference Systems

1. Define the linguistic variables and terms (initialization)
2. Construct the membership functions (initialization)
3. Construct the rule base (initialization)
4. Fuzzification

5. Inference (Evaluate the rules in the rule base and combine the results of each rule)
6. Defuzzification

Problem Statement

Implement a Fuzzy Controller to determine the score of an essay. Assume the input is number of keywords and number of spelling mistakes in the essay. Use 3 descriptors for each input variable and 3 descriptors for output variable.

Steps in designing Fuzzy Inference Systems for Washing Machine Problem

1. Defining Linguistic Variables

Linguistic variables are the input or output variables of the system whose values are words or sentences from a natural language, instead of numerical values. A linguistic variable is generally decomposed into a set of linguistic terms.

Design:

Consider the TextGrading FIS.

Let Number of Spelling Mistakes (SM) is the linguistic variable which represents the Number of Spelling Mistakes. Then, the set of decompositions for the linguistic variable SM is SM(t) = {poor, average, good }.

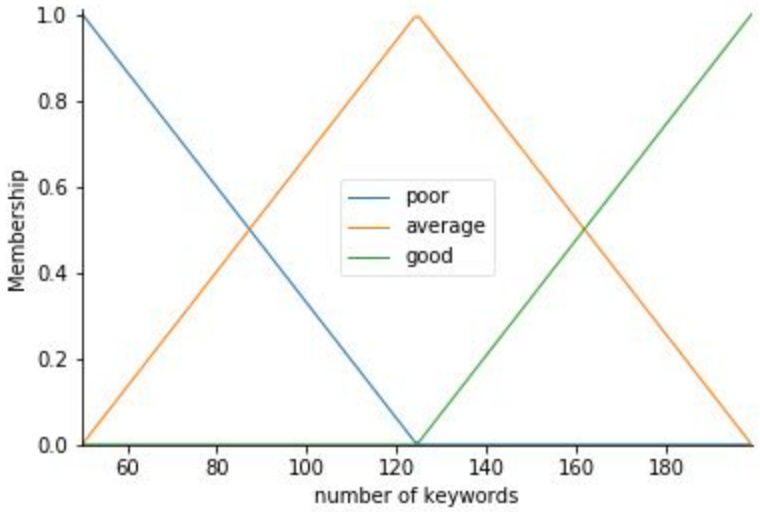
Let Number of Keywords (K) is the linguistic variable which represents the number of keywords in the essay. Then, the set of decompositions for the linguistic variable K is K(t) = {poor, average, good}.

Let Score (S) is the linguistic variable which represents the score of the essay. Then, the set of decompositions for the linguistic variable Score is S(t) = {poor, average, good}.

2. Construct the membership functions

Membership functions are used in the fuzzification and defuzzification steps of a FLS, to map the non-fuzzy input values to fuzzy linguistic terms and vice versa. A membership function is used to quantify a linguistic term.

Number of Keywords:



$\mu_{numberOfKeywords}(x)$:

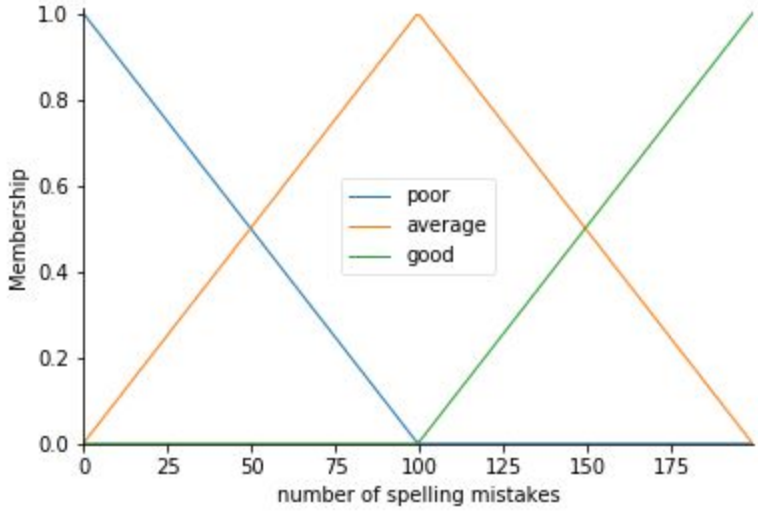
$$\mu_{poor}(x) = (125 - x) / x \qquad 0 \leq x \leq 125$$

$$\mu_{average}(x) = (x) / 125 \qquad 0 \leq x < 125$$

$$(200 - x) / 125 \qquad 125 \leq x \leq 200$$

$$\mu_{good}(x) = x / 75 - 5 / 3 \qquad 125 \leq x \leq 200$$

Number of Spelling Mistakes



$\mu_{NumberOfSpellingMistakes}(x)$:

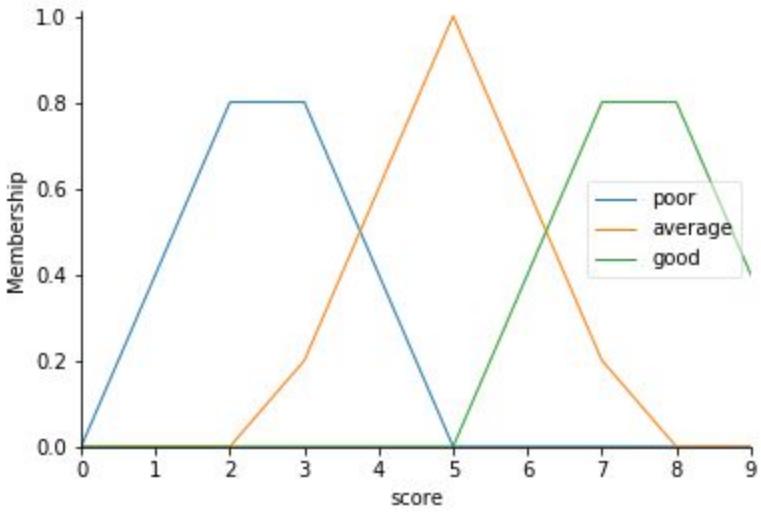
$$\mu_{poor}(x) = (100 - x) / x \qquad 0 \leq x \leq 100$$

$$\mu_{average}(x) = (x) / 100 \qquad 0 \leq x \leq 100$$

$$(200 - x) / 100 \qquad 100 \leq x \leq 200$$

$$\mu_{good}(x) = (x - 100) / 100 \qquad 100 \leq x \leq 200$$

SCORE



Score (z) :

$$\mu_{poor}(z) = \begin{cases} 2z/5 & 0 \le z \le 2.5 \\ 2 - 2z/5 & 2.5 \le z \le 5 \end{cases}$$

$$\mu_{average}(x) = \begin{cases} (x-2)/3 & 2 \le z \le 5 \\ (8-x)/3 & 5 \le z \le 8 \end{cases}$$

$$\mu_{good}(x) = \begin{cases} (x-5)/3 & 5 \le z \le 8 \\ (10-x)/2 & 8 \le z \le 9 \end{cases}$$

3. Construct the Fuzzy Rule Base

Number of Spelling Mistakes

	PSM	**ASM**	**GSM**
PK	**A**	**P**	**P**
AK	**A**	**A**	**P**
GK	**G**	**A**	**A**

4. Fuzzification

Converts the crisp input to a linguistic variable using the membership functions stored in the fuzzy knowledge base.

Example: Given Input 120 spelling mistakes and 200 Keywords,

$\mu_{ASM}(120) = (200 - 120)/100 = 4/5$

$\mu_{GSM}(120) = (120 - 100)/100 = 1/5$

$\mu_{AK}(200) = (200 - 200)/125 = 0$

$\mu_{GK}(200) = 200/75 - 5/3 = 1$

5. Inference

The evaluations of the fuzzy rules and the combination of the results of the individual rules are performed using fuzzy set operations. The mostly used operations are OR and AND operators

which are max and min, respectively. The results of individual rules can be combined in different ways.

1. Applying fuzzified inputs on rulebase

	0	**$\mu_{AK}(200)=0$**	**$\mu_{GK}(200)=1$**
0	**0**	**0**	**0**
$\mu_{ASM}(120)=4/5$	**0**	**$\mu_A(z)$**	**$\mu_A(z)$**
$\mu_{GSM}(120)=1/5$	**0**	**$\mu_P(z)$**	**$\mu_A(z)$**

Rules Fired:

- Rule 1:If x is ASM and y is AK then z is A
- Rule 2:If x is ASM and y is GK then z is A
- Rule 3:If x is GSM and y is AK then z is P
- Rule 4:If x is GSM and y is GK then Z is A

2. Appling Min Operation

	0	**$\mu_{AK}(200)=0$**	**$\mu_{gk}(200)=1$**
0	**0**	**0**	**0**
$\mu_{ASM}(120)=4/5$	**0**	**0**	**1**
$\mu_{GSM}(120)=1/5$	**0**	**1/5**	**1/5**

3. Applying Max Operation

The fuzzy set = {0, 1, ⅕, 1/5}. The max of the fuzzy set that is 1 which
Corresponds to $\mu_A(z)$.

6. Defuzzification

After the inference step, the overall result is a fuzzy value. This result should be defuzzified to obtain a final crisp output. This is the purpose of the defuzzifier component of a FLS. Defuzzification is performed according to the membership function of the output variable.

$$\mu_A(x) = \begin{cases} (x - 2)/3 & 2 \le z \le 5 \\ (8 - x)/3 & 5 \le z \le 8 \end{cases}$$

Substitute 1 in $\mu_A(z)$.
z1 = 5 and z2 = 5
Average = (5 + 5) /2 = 5.
Thus 5 is the score for 120 spelling mistakes and 200 keywords.

Steps 4, 5 and 6 are collectively called rule evaluation.

Algorithm

1. Identify a problem statement, where you can apply fuzzy logic.
2. Define Input and Output descriptors and linguistic variables for each input and output
3. Construct membership functions for input and output
4. Construct Rule Base.
5. Do rule evaluation for 3 cases : low , medium and high
6. Implement the Fuzzy Inference System in Python.

Conclusion: Thus the student will be able to design a fuzzy inference system for any given problem statement.