

Rainfall prediction using fuzzy logic

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Abstract

This paper presents occurrence of rainfall using principles of fuzzy logic applied in Matlab. The data are taken from raingouge station on the Vjosa River in Albania. In this application, the input variables were initially partitioned into five linguistic ranges Very high , High, Medium , Low, Very Low . The triangular membership functions is used.

Keywords: Fuzzy Logic, Rainfall, Rules, FIS, Membership functions

1. Introduction

Management of water resources are becoming more attractive topic due to growth in population and correspondingly increase in demand to water and energy. A river can be used as a source of water supply.

Water is essential for life and for most activities of human society. Both economic and social development and the maintenance of human health are completely dependent upon ready access to adequate water supplies. All societies require water both for basic survival and for economic development.

Fuzzy logic is an extension of classical logic. The main difference between fuzzy logic and classical logic is that fuzzy set using for membership of a variable.

Fuzzy logic has many advantages over classical logic in areas like artificial intelligence where a simple true/false statement is insufficient.

Humans are very good at recognizing by eye what they are looking at but computers are better at counting and measuring. Fuzzy Logic is very helpful in guiding computers to find the right thing to measure and calculate. Real-world attributes are known by human perceptions through quality and quantity appreciations linguistically or by measurements. Different questions may be asked about individual or joint behaviors of these attributes. Humans continue to acquire knowledge by perception, which is a never-ending process.

Fuzziness is a paramount characteristic of human perception that challenges humanity and propels the search for truth and understanding the secrets of reality. The fuzziness in human perception reveals ways of transcending it, and thus expanding the field of human inquiry. Fuzzy impressions and concepts are generated by the human mind, and it divides the seeable hydrological, environmental, or engineering reality into fragments and categories, which are fundamental ingredients in the classification, analysis, and deduction of conclusions after labeling each fragment with a word such as “name,” “noun,” or “adjective”.

Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multivalued logic and in a wider sense fuzzy logic is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects in which membership is a matter of degree. Even in its more narrow definition, fuzzy logic differs both in concept and substance from traditional multivalued logical systems.

2. Fuzzy Logic

Here is a list of general observations about fuzzy logic:

- Fuzzy logic is conceptually easy to understand.
- Fuzzy logic is a more intuitive
- Fuzzy logic is flexible.
- Fuzzy logic is tolerant of imprecise data

2.1 Fuzzy Logic theory

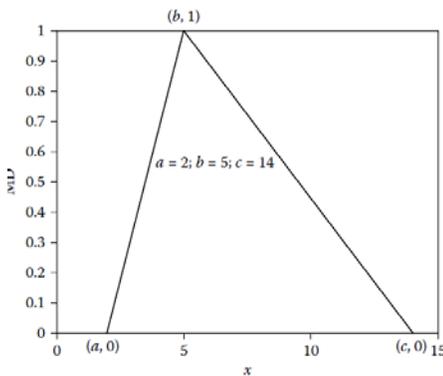
Definition (Zadeh, 1965) Let X be a nonempty set. A fuzzy set A in X is characterized by its membership function:

$\mu_A : X \rightarrow [0,1]$ $\mu(x)$ is interpreted as the degree of membership of elements in fuzzy set A for each $x \in X$.

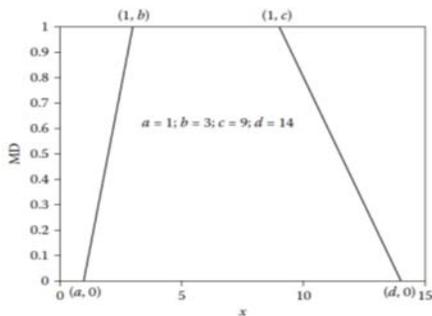
Let μ be a fuzzy subset of X ; the support of A , denoted $\text{supp}(A)$, is the crisp subset of X whose elements all have nonzero membership grades in A .

Membership functions are (show in Fig 1 a, b, c, d respectively)

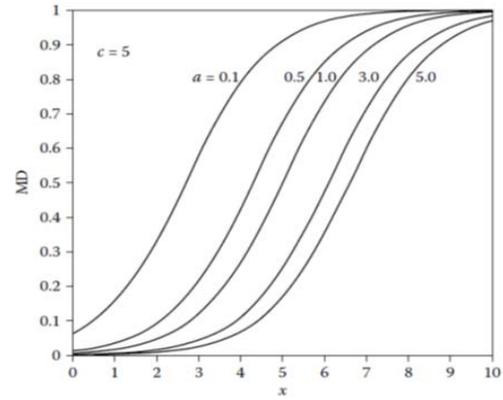
- Triangular
- Trapezoidal
- Sigmoid
- Gaussian



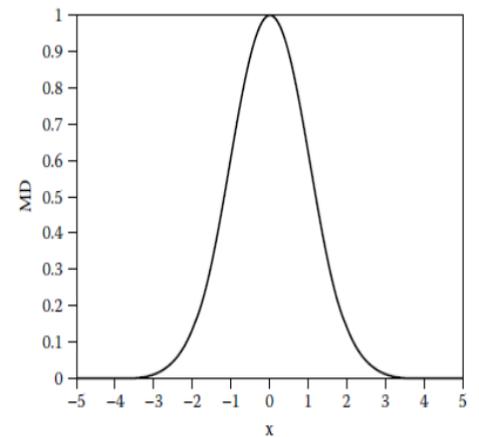
Triangular MF.



Trapezoidal MF.



Sigmoid MF.



More recently, fuzzy systems have gained attention.

First introduced by Zadeh [1965] fuzzy logic and fuzzy set theory are used in modeling the ambiguity and uncertainty in decision making. He introduced processing of the linguistic uncertainties by fuzzy logic and opened a wide spectrum of applications in many fields. The basic idea in fuzzy logic is rather simple according to which statements are not just “true” or “false” but they are partial true and practically acceptable

Fuzzy application areas include estimation, prediction, control, approximate reasoning, intelligent system design, machine learning, image processing, machine vision, pattern recognition, medical computing, robotics, optimization, civil, chemical and industrial engineering, but in hydrology and meteorology are new areas of fuzzy applications.

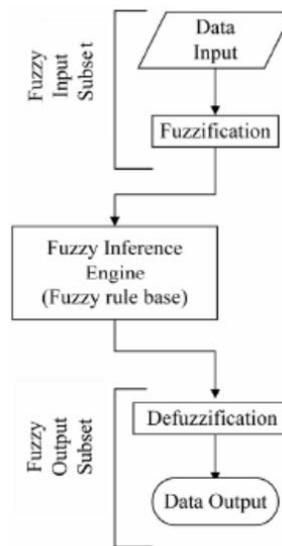
In this application, the input variables were initially partitioned into five linguistic ranges Very high , High, Medium , Low, Very Low . Triangular membership functions can be used. In general there could be m^n rules where n is the number of inputs and m is the number of partitions. However, as the number of rules increases, the complexity of the formulation also increases leading to what is referred to as the curse of dimensionality.

The fuzzy expert system consists of linguistic rules relating the membership functions of the input variables to the membership function of the output variable. A series of IF-THEN statements relates the input to the output variables. Operators such as AND can be used to relate the input variables to each other to define the result as a combination of the input variables. The AND operator is mathematically applied as an intersection by either the “minimum” or “product” function. Minimum is commonly used when the input data are independent of each other, and product is often applied if input variables are interdependent. In a rule-based model, the relationship between input variables and the results are easily understood by simply reading the rule. Rules are influential in selecting the number of variables and membership functions to be modeled because the model becomes exponentially more complex as the number of variables or membership functions increases. This is because a rule must be available for each possible combination of input variable membership functions and potential outcome membership functions.

Fuzzy Logic is present trend for decision making, classification and prediction where problem can be formulated by mapping input variable with output variable or where simple solution does not exists. There are three basic steps for fuzzy inference system such as Fuzzification, rule evaluation and Defuzzification.

Fuzzification means converting numeric value into linguistic value. Human intuition method is well accepted method for the membership function value assignment throughout the world. Fuzzy inference engine produce the result after rule evaluation also in terms of linguistic value.

Fuzzy inference is the process of mapping with a given set of input and output through a set of fuzzy rules. Figure 1 shows the general structure of a fuzzy system



Basic structure of a fuzzy inference model.

3. MATLAB fuzzy logic toolbox

- MATLAB fuzzy logic toolbox facilitates the development of fuzzy-logic systems using graphical user interface (GUI) tools command line functionalit The tool can be used for building Fuzzy Expert Systems Adaptive Neuro-Fuzzy Inference Systems (ANFIS)

3.1 Graphical User Interface (GUI) Tools

There are five primary GUI tools for building, editing, and observing fuzzy inference systems in the Fuzzy Logic Toolbox:

- Fuzzy Inference System (FIS) Editor
- Membership Function Editor
- Rule Editor
- Rule Viewer
- Surface Viewer

3.2 Fuzzy Inference system

- Two type of inference system
- Mamdani inference method
- Sugeno inference method

Mamdani's fuzzy inference method, the most common methodology

4. Application

Vjosa River is 272 km long, start from Mount Mavrovouni and stream into the Adriatic Sea.

Applied data are taken from a station on the River Vjosa. Some of the factors that influence the amount of rainfall are temperature and wind. For these factors we have reviewed the monthly and annual data (Tab1)

Tab 1

	Min	Max	Average
Vjosa Permet Wind Speed m/s	0.8	2.9	2.1
Rainfall, Vjosa Permet	0.3	9.3	3.6
Temp Vjosa Permet C	-6.2	40.2	13.9

Tab 2. Fuzzy variable

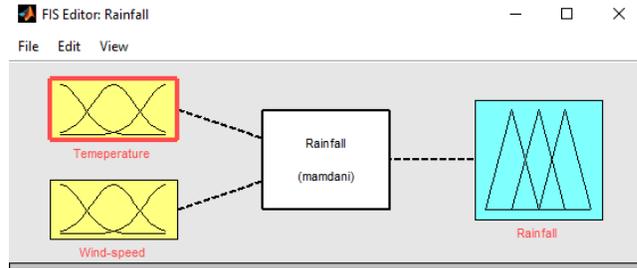
Fuzzy variables	Parameters	Linguistic Labels
1	Temperature, TP	Very high TP, High TP, Medium TP, Low TP, Very Low TP
2	Wind speed, WS	Very high WS, High WS, Medium WS, Low WS, Very low WS
3	Rainfall, RF	Very high RF, High RF, Medium RF, Low RF, Very low RF

Examples of production rules can be shown as follows:

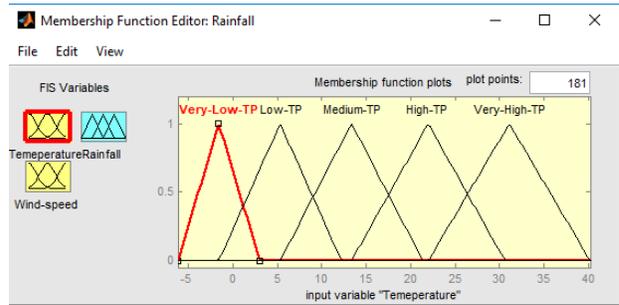
1. If (WS is VL) and (temp is VL) then (Rainfall is VL)
2. If (WS is L) and (temp is L) then (Rainfall is VL)
- ...
- ...
- ...
- ...
- ...
- ...
23. If (WS is very H) and (temp is H) then (Rainfall is H)
24. If (WS is VL) and (temp is very H) then (Rainfall is M)
25. If (WS is M) and (temp is very H) then (Rainfall is H)

The rainfall fuzzy number can be given as a triangular MF for input and output membership functions :

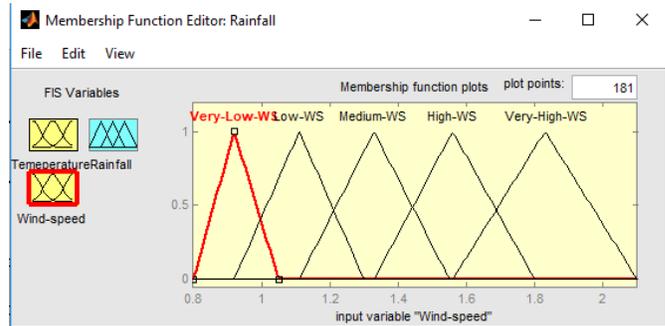
1. Fis editor



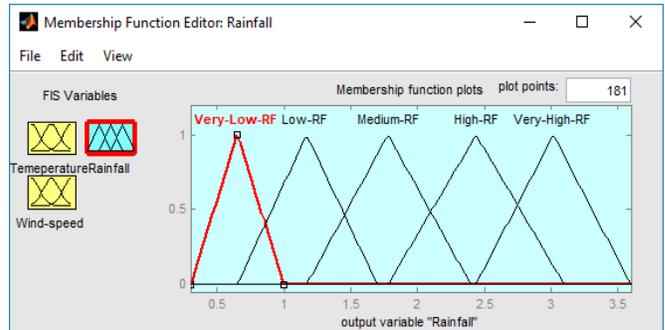
2. Membership Function Editor



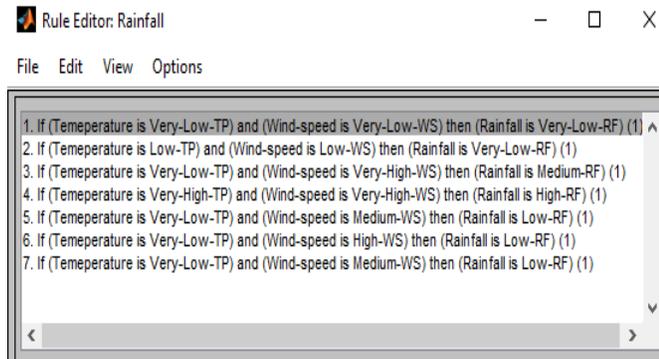
3. Input Membership Function



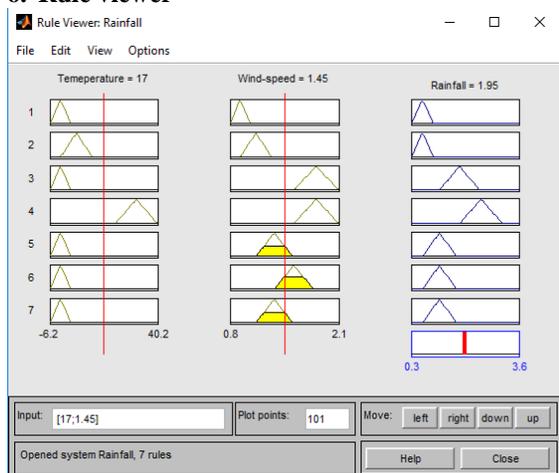
4. Output Membership Function



5. Rules editor



6. Rule viewer



5. Conclusions

Fuzzy inference system is the most important modeling tool based on fuzzy set theory. The FISs are built by domain experts and are used in automatic control, decision analysis, and various other expert systems. Fuzzy logic modeling for this modest application brings the advantage of controlling at any moment the situation as for x temperature and y wind speed predicts z amount of rainfalls.

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