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Modeling the Amount of Rainfall Using Fuzzy Logic

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Abstract
This material presents the construction of a fuzzy logic model for the amount of rainfall with Matlab. Fuzzy logic has the ability to express the amount of ambiguity in human thinking and subjectivity, including natural language, and hence words, adjectives, and sentences in a comparatively undistorted manner. Based on the problem, the following specific objectives are to explore the use of fuzzy logic and to develop a fuzzified model for rainfall amount

Keywords*: Fuzzy Logic, Rainfall, FIS, Membership Function*

1. Introduction

In recent years, the number and variety of applications of fuzzy logic have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection.
To understand why use of fuzzy logic has grown, you must first understand what is meant by fuzzy logic.
Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multivalued logic. However, 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.

- Why Use Fuzzy Logic?

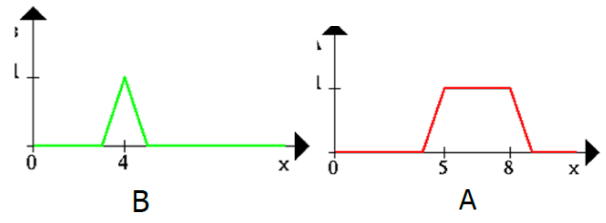
Here is a list of general observations about fuzzy logic:
• Fuzzy logic is conceptually easy to understand.
The mathematical concepts behind fuzzy reasoning are very simple. Fuzzy logic is a more intuitive approach without the far-reaching complexity.
• Fuzzy logic is exible.
With any given system, it is easy to layer on more functionality without starting again from scratch.
• Fuzzy logic is tolerant of imprecise data

Definition 1.1. (Zadeh, 1965) Let X be a nonempty set. A fuzzy set A in X is characterized by its membership function

$$\mu_A : X \to [0,1]$$

and μ(x) is interpreted as the degree of membership of elements in fuzzy set A for each x ϵ X.
Let μ be a fuzzy subset of X; the support of A, denoted supp(A), is the crisp subset of X whose elements all have nonzero membership grades in A.
Interpretations of basic operations(fig.1and fig 2):

- Union A ∪ B $\longrightarrow$ $\mu A \cup B(x) = \mu A(x) \vee \mu B(x) = max(\mu A(x), \mu B(x))$
- *Intersection* $A \cap B \longrightarrow \mu A \cap B(x) = \mu A(x) \wedge \mu B(x) = min(\mu A(x), \mu B(x))$



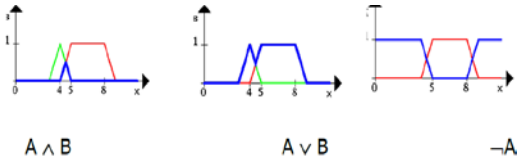


Fig 1

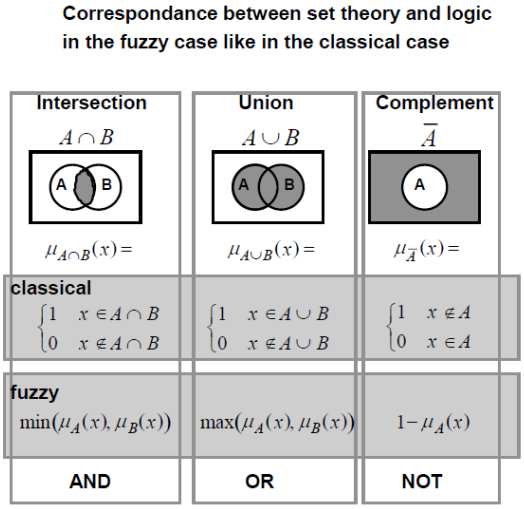


Fig 2

2. Fuzzy logic in hydrology

Hydrological sciences are full of ambiguous, vague, imprecise, and, in general, uncertain information sources that can be treated with the fuzzy logic concepts for clear ideas and solutions. The hydrological models are mathematically based on two Classical Logic alternatives as the Law of the Excluded Middle. Accordingly, mathematical equations, systematic algorithms, and formulations are the basis of the modeling for estimation, prediction, model identification, or filtering purposes. In probabilistic and stochastic modeling of hydrological processes, a set of assumptions is necessary, such as the stationarity, homogeneity, ergodicity, intrinsicity, etc. These assumptions complex hydrologic phenomena to manageable classical mathematical sizes and domains. Fuzziness is often confused with probability; whereas the former deals with deterministic plausibility, the latter concerns the likelihood of nondeterministic stochastic events. Fuzziness (vagueness) found in the definition of a concept or the meaning of a term such as *semi-pervious* aquifer, *long time*, or *moderate distance*. It conveys suspective human thinking, feeling, or language. However, the uncertainty of probability generally relates to the occurrence of phenomena as symbolized by the concept of randomness. For example, statements such as "It will rain tomorrow" and "There is a sandstone layer at 50 meter depth" have the uncertainty of random character.
From the modeling point of view, fuzzy models and probabilistic, statistical, or stochastic models possess different philosophical information. Fuzzy Logic has fuzzy sets and hence membership functions (MFs,) which represent similarities of objects to imprecisely defined properties, while probabilistic, statistical, and stochastic models convey information about relative frequencies that are based on crisp sets and on Classical Logic.

3. Example: Classification of rainfall in Tirana during one year

Climate in Tirana dominates a subtropical-Mediterranean climate with winter winters and average annual temperature in July + 24 ° Celsius and in January + 7 ° Celsius. In the year 1 189 mm rain falls.

The rainfall classification is:

1 - by intensity

- Rain drops when falling less than 1 mm per hour.
- Light rain 1-2mm per hour
- Average rain 2-6mm per hour
- Strong rain with more than 6 mm per hour.
- Storms more than 10 mm per hour
- Tempered rain more than 30 mm per hour

2- by the nature of the downfall

- Gentle rain is called when it consists of fine droplets of 0.5 mm diameter. These kinds of rainfall come from pebbled clouds. Not crashing for an hour can fall 0.5 mm

- The common rain is called one that does not consist of small droplets larger than 0.5 mm diameter. Measured with the total amount dropped in the unit of time.

- Rainfall is called gravel and lasts for a very short time, coming from cloudy clouds of rain. We always have variable intensity, occupy a small space, often called sunny rain. It can turn into ordinary storms when we have tropical currents

- rainfalls=[135 152 128 117 122 86 32 32 60 105 211 173]
- if rainfalls < 0.5 then is soft rain(SF),
- if rainfalls >0.5 and <10 then is common rain(CR);
- if rainfalls is >10 then is tempered rain(TR);

Tab 1

		Temp. Max. (°C)	***Temp. Min (°C)***	***Rainfall (mm)***
1	January	12	-8	135
2	February	12	-8	152
3	March	15	-4	128
4	April	18	-1	117
5	May	23	3	122
6	June	28	6	86
7	July	31	11	32
8	August	31	10	32
9	Sept	27	5	60
10	October	23	1	105
11	Nove	17	-3	211
12	Decem	14	-7	173

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4. 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 buildingFuzzy Expert Systems
Adaptive Neuro-Fuzzy Inference Systems (ANFIS)

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

In MATLAB: Fuzzy Logic Toolbox

Fuzzy Inference system

Two type of inference system

- Mamdani inference method
- Sugeno inference method

Mamdani's fuzzy inference method, the most common methodology

FIS Editor: Mamdani ‘s inference system

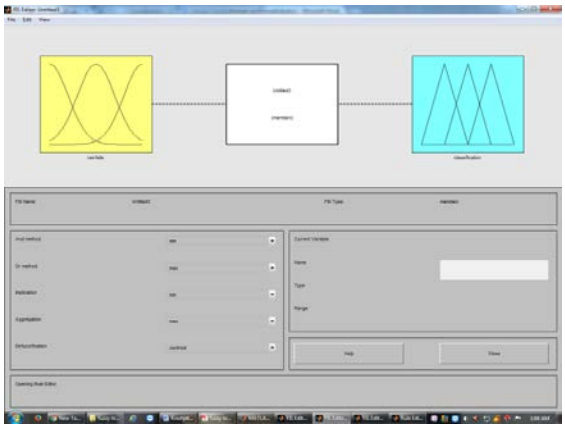

Fig 3

FIS Editor: Adding Input / Output

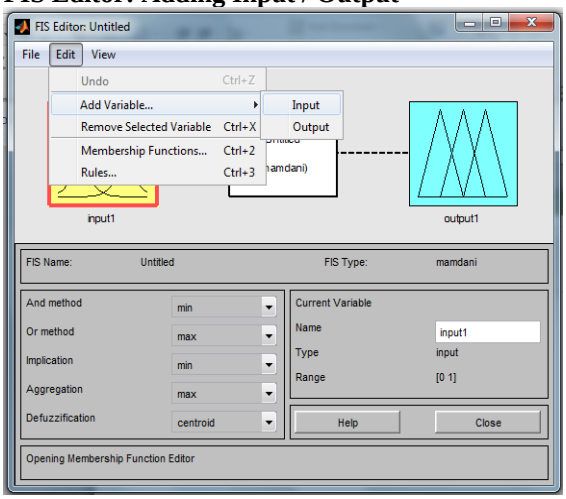

Fig 4

Membership Function Editor

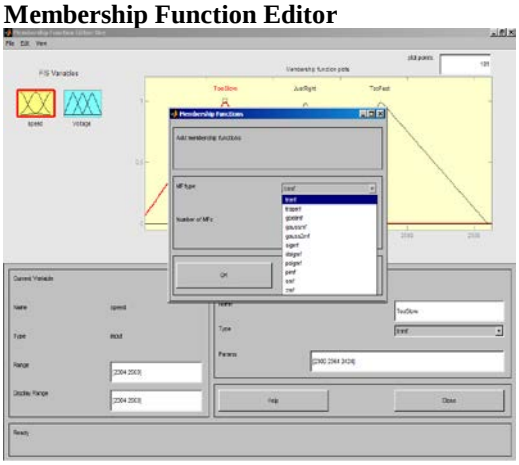

Fig 5**Input Membership Function**

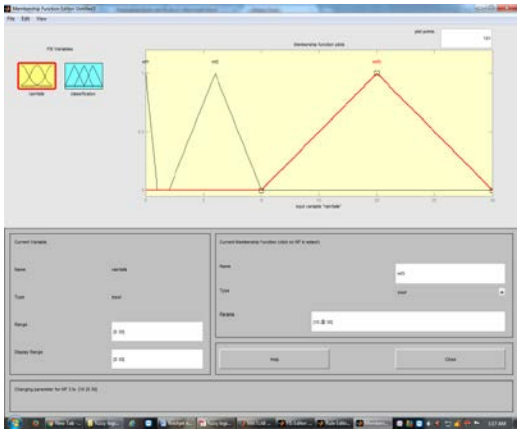

Fig 6

Output Membership Function

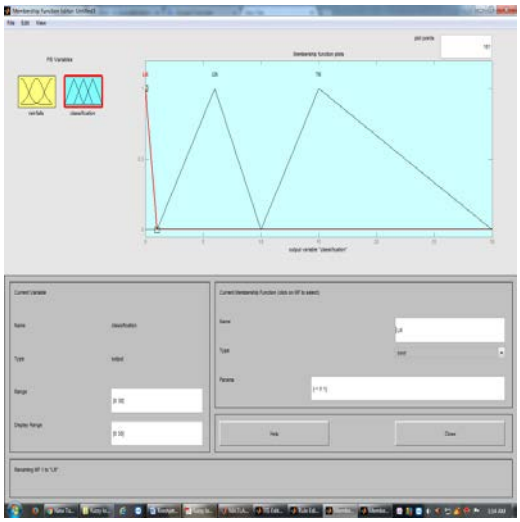

Fig 7

Sugeno-Type Fuzzy Inference

- Takagi-Sugeno-Kang, method of fuzzy inference similar to the Mamdani method in many respects. Fuzzifying the inputs and applying the fuzzy operator, are exactly the same.

The main difference between Mamdani and Sugeno is that the Sugeno output membership functions are either linear or constant.

FIS Editor: Sugeno inference system

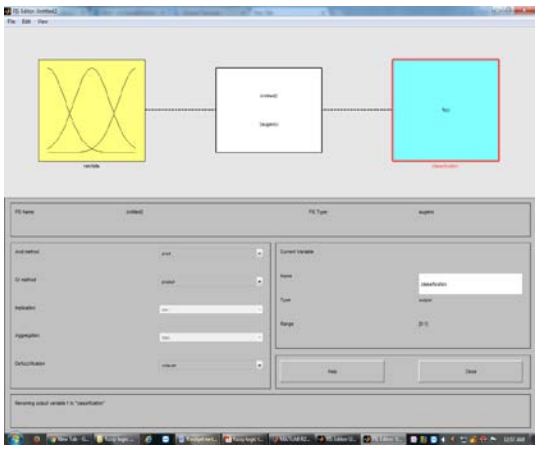

Fig 8

Advantages of the Sugeno Method

Sugenois a more compact and computationally efficient representation than a Mamdani system.

- It is computationally efficient.
- It works well with linear techniques (e.g., PID control).
- It works well with optimization and adaptive techniques.
- It has guaranteed continuity of the output surface.
- It is well suited to mathematical analysis.

Advantages of the Mamdani Method

- – It is intuitive.
- – It has widespread acceptance.
- – It is well suited to human input.

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.

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