

AN OVERVIEW OF FUZZINESS AND ITS APPLICATIONS

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Abstract: Fuzzy set (FS) has been comprehended substantial expansions across almost every branch of science, for its theoretical basis as well as widespread real-world applications in both scientific and everyday contexts. It has been acknowledged as a great tool for modelling human reasoning, and thus it has become a crucial method in several domains. This paper wishes to offer a brief outline to fuzzy logic, fuzzy graphs, and their applications. Based on outcomes from the study some examples demonstrating the application of fuzzy logic in home appliances are presented.

Keywords: fuzzy sets; fuzzy logic; fuzzy logic control; fuzzy graphs; applications.

1. Introduction:

It is often observed that classical or crisp set theory falls short when applied to real-world or empirical situations [1]. From a classical mathematical perspective, for example, categories like "the set of real numbers," "the set of intelligent students," or "the set of tall boys and girls" do not represent well-defined sets. However, these ill-defined classes are essential to human cognition, especially in domains like abstraction, information processing, and pattern recognition.

Lofti Zadeh [1965] proposed to the aforementioned issues by defining an FSt as an extension from classical set theory. The FS tries to address the issue of uncertainty, imprecision, and the vagueness inherent in many real world problems. A FS is defined as a collection of elements along their degree presence in the set [2]. Unlike traditional binary classifications, FSs permit the degrees of memberships of each member, giving a comprehensive nuanced and genuine depiction of uncertainty. This gradation makes FSs convenient for modeling the imprecise and uncertain nature of human mental processes [3]. Subsequently, FS is applied in many allied fields such as fuzzy logic and fuzzy graphs. These are applications were found to be useful in diverse domains such as pattern recognition, medical diagnosis, AI, computer science, and electrical engineering. Since 1965 FS entered into multiple areas of human knowledge. Japanese research teams started delving deeper into fuzzy set theory in the 1970s. Notably, in 1970, Ebrahim Mamdani developed the first fuzzy logic controller, marking a significant milestone in the field. Fuzzy logic started to be used in industrial settings in Europe and Japan by 1977. Its success in Japan during the early 1980s led to a renewed interest in fuzzy logic in the United States by the end of that decade [4].

In Section 2, definitions and applications of FS is widely covered. A brief discussion on fuzzy graphs and its applications will be found in Section-3. The conclusion is given in Section-4.

2. Some important Concepts related Fuzzy Sets and Applications:

2.1 Fuzzy Set and Fuzzy Logic:

The fuzzy set itself is known as the fuzzy logic and the fuzziness of any set is described by fuzzy logic. A fuzzy set F over U (universe of discourse) is characterized by $F = \{(u, \mu_F(u))\}$ where $\mu_F(u)$ is the membership or grade function of u in F that maps U to $[0,1]$. [1]

Example: Let $U = \{1,2,3,4,5,6,7, \dots \dots \dots, 10\}$ be a universe of discourse.

$F =$ "natural number close to 5"

$$\mu_F(u) = \{((5^2 - u^2) - 1)^{-1}\}$$

$$F = \{(1, 0.04), (2, 0.045), (3, 0.05), (4, 0.1), (5, 1), (6, 0.1), (7, 0.043), (8, 0.026), (9, 0.018), (10, 0.013)\}$$

2.2 Fuzzy Logic Control:

The operation of a fuzzy logic controller (FLC) comprises of the steps given below:

- Fuzzification: This first stage involves mapping crisp (precise) input values to suitable membership functions in order to transform them into fuzzy values.
- Inference: The above fuzzified inputs were gone through a series of IF-THEN rules process in stage 2. The fuzzy output is computed by aforementioned IF-THEN rules and the inference engine with logical reasoning.
- Defuzzification – Here, the output generated in the previous step is converted to a crisp value for practical implementations [5].

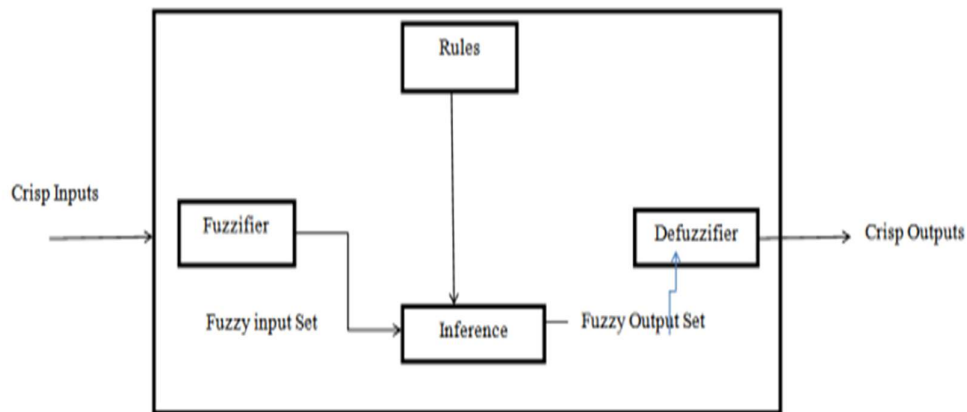


Fig 1: Fuzzy Logic System

2.3 Applications of Fuzzy Sets and Fuzzy Logic:

Fuzzy logic is an extensive and multipurpose notion that has established its usefulness in many allied domains of mathematics. This study surveys a couple of effective fuzzy logic implementations [6].

In the field of chemical science, Davidson and Hayward [7] presented numerous examples demonstrating the practical use of fuzzy logic. Almardy's study [7] employed a fuzzy control system to regulate the current supplied to a series of anodes, aiming to protect a long-buried pipeline while minimizing energy consumption.

Philomine Roseline T. and N. Ganesan [8] explored how the fuzzy logic can be applicable in field like pest management, seed management, weed management, etc. The various soil analysis and monitoring expert systems were proposed by [8].

Fuzzy logic is also employed in many home appliances and Washing machine and refrigerator are well-known examples. In washing machine, the input parameters like the dirt type and amount, sensitivity of fabric, and size of load are considered enable the machine to economical wash cycle efficiently [9].

In political science, fuzzy logic is applied to tasks such as candidate selection and election forecasting [6]. The fuzzy inference rules are used to determine the likelihood of a candidate's win an election. The MATLAB's Toolbox has included Sugeno and Mamdani. [10] inference systems.

2.4 Application of Fuzzy Logic on Washing Machine:

The fundamental function of a washing machine is to clean garments effectively without causing damage. To achieve this, careful consideration must be given to the output parameters of the fuzzy logic system related to the washing process. The elementary structure of a FLC model is given in Fig. 2.

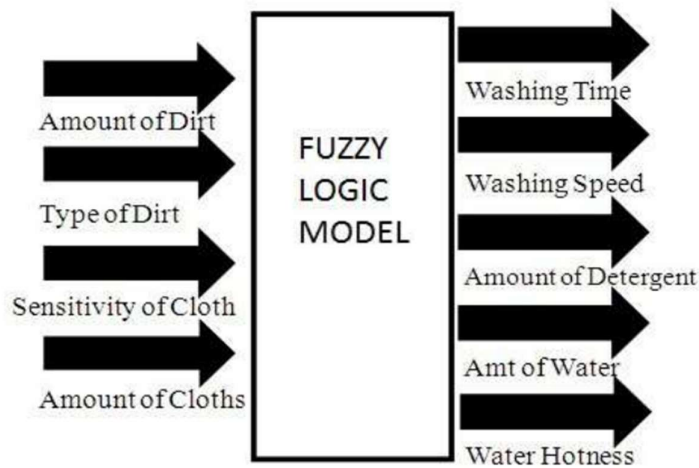


Fig 2: Inputs and outputs of the system

The membership functions for the input and output parameters—including their names, as well as upper and lower limits—are defined based on the specific problem. The membership functions of the input and output parameters, as well as the related upper and lower bounds, are shown in Figures 3 and 4, respectively.

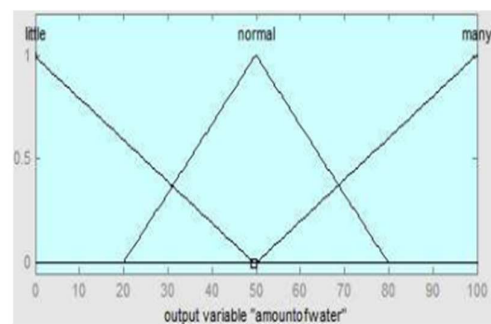
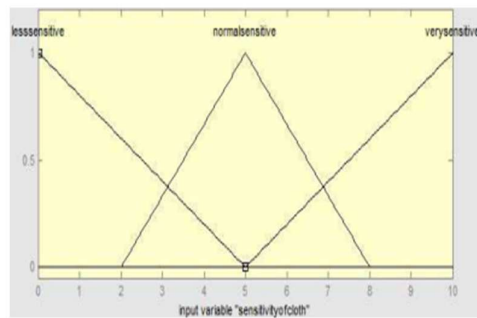
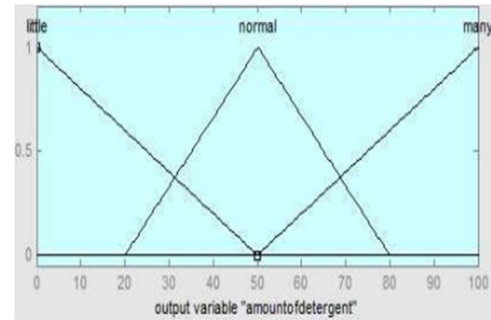
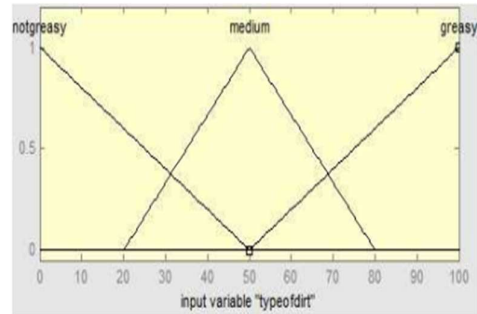
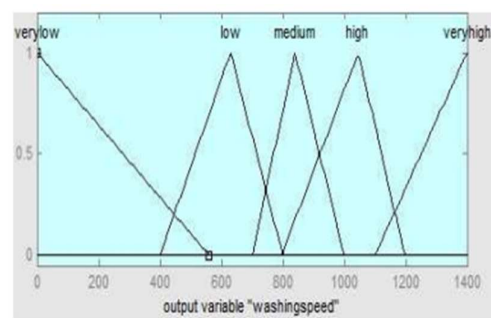
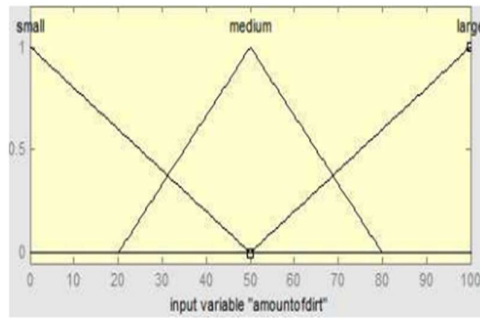


Fig 3: Fuzzy logic input membership functions

Fig 4: Fuzzy logic output membership functions

The washing machine's operation has been modeled using fuzzy rules. MATLAB fuzzy logic tool box was used to generate the complete system [9].

3. Some Important Concepts related Fuzzy Graphs and Applications:

3.1 Fuzzy Graph:

Approximately ten years after Zadeh published his seminal work "*Fuzzy Sets*," Rosenfeld introduced the concept of fuzzy graphs by extending the essential characteristics of graph-theoretic notions, such as bridges, pathways, cycles, trees, and connectedness.

Graphs, in which vertices represent items and edges reflect the connections between them, are widely acknowledged as useful tools for representing relationships. When there is uncertainty or ambiguity in the description of the objects, their relationships, or both, it becomes necessary to develop a *fuzzy graph model* to more accurately capture this imprecision [11].

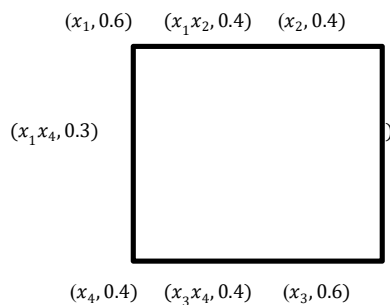
3.2 Definition: Let E be the (crisp) set of nodes. A fuzzy graph is then defined by

$$G(x_i, x_j) = \{((x_i, x_j), \mu(x_i, x_j)) | (x_i, x_j) \in E \times E\}$$

where $(x_i, \sigma(x_i))$ and $(x_j, \sigma(x_j))$ are called fuzzy points or fuzzy vertices and $(g, \mu(x_i, x_j))$ or $(g, \mu(g))$ are called the fuzzy lines or fuzzy edges of the fuzzy graph.

If $g = (x_i, x_j)$, then the fuzzy points $(x_i, \sigma(x_i))$ and $(x_j, \sigma(x_j))$ are called adjacent points and the fuzzy point $(x_i, \sigma(x_i))$ and the line $(g, \mu(x_i, x_j))$ are incident with each other. If two distinct fuzzy lines $(g_1, \mu(g_1))$ and $(g_2, \mu(g_2))$ are incident with a common fuzzy point, then they are called fuzzy adjacent lines. [1]

Example:



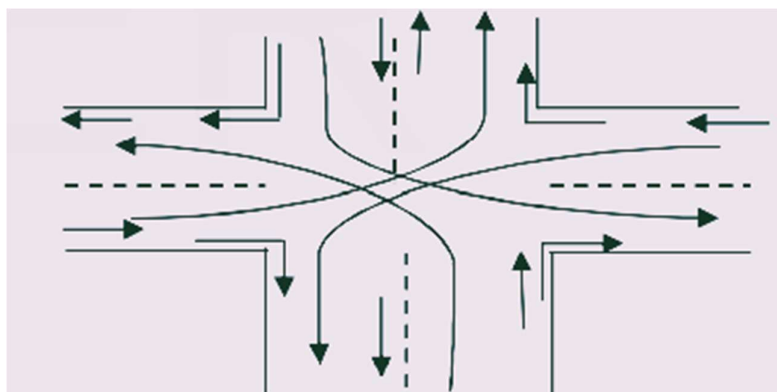
In the above figure,

- $(x_1, 0.6)$, $(x_2, 0.4)$, $(x_3, 0.6)$ and $(x_4, 0.4)$ are the fuzzy points.
- $(x_1x_2, 0.4)$, $(x_2x_3, 0.6)$, $(x_3x_4, 0.4)$ and $(x_1x_4, 0.3)$ are the fuzzy edges.
- $(x_1, 0.6)$ and $(x_2, 0.4)$ are fuzzy adjacent points.
- $(x_1x_2, 0.4)$ joins $(x_1, 0.6)$ with $(x_2, 0.4)$ hence $(x_1x_2, 0.4)$ is incident with $(x_1, 0.6)$ and $(x_2, 0.4)$.
- Since $(x_1x_2, 0.4)$ and $(x_2x_3, 0.6)$ are incident with $(x_2, 0.4)$ hence $(x_1x_2, 0.4)$ and $(x_2x_3, 0.6)$ are adjacent edges.

3.3 Application of Fuzzy Graphs:

In many real-world scenarios fuzzy graphs were used successfully. Traffic-signal control system is a well-known example. In the traffic-light problem, the purpose is to control the signal phases for safe and coordinated traffic flow. This problem can be addressed by using graph intersection, where each crossing point denotes a possible conflict zone for traffic flows from multiple directions. Graph-coloring are often used for modeling and analysing above issue for smooth traffic flow.

- Since the number of vehicles on different paths is not always equal, this variability is represented using fuzzy sets, where the membership value corresponds to the vehicle count. A higher number of vehicles on a path results in a higher membership value, while a lower number corresponds to a lower membership value [12].



TFN: A TELECOMMUNICATION NETWORK MODEL

The TFN is a social network. A fuzzy graph representation of the communications network has been suggested in this system. [12].

4. Conclusion:

The development of fuzzy mathematics has remodeled the modern mathematics and opened many avenues for different fields. Various real-life problems that were difficult to be handled Boolean or traditional logical systems could be successfully addressed with fuzzy approaches. This article summarized many real-world scenarios pertaining to fuzzy logic, especially within mechanical systems. It also discussed the increasing applications of fuzzy graphs in analysing traffic flow and determining high risk prone zone. It has been observed that fuzzy theory provides a powerful tool for addressing many complex scenarios where human judgement is prevalent. The examples emphasized its relevance and usefulness for future in-depth research in this evolving area.

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