

Fuzzy Logic

Intelligence, Control, and Information

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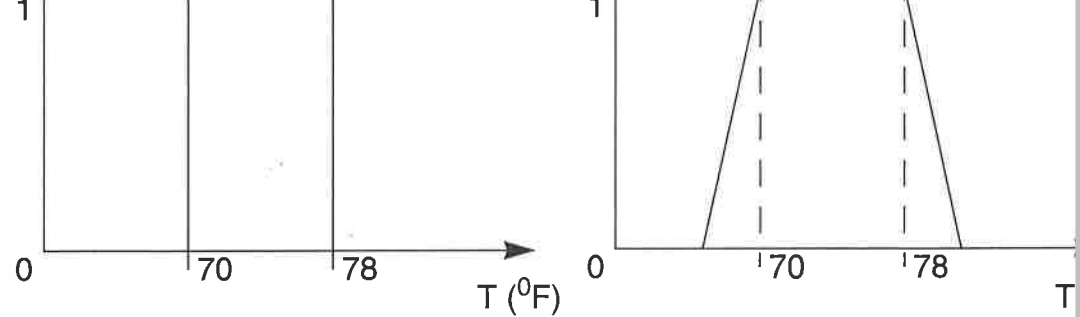
FUZZY LOGIC

After being mostly viewed as a controversial technology for two decades, fuzzy logic has finally been accepted as an emerging technology since the late 1980s. This is largely due to a wide array of successful applications ranging from consumer products, to industrial process control, to automotive applications. Before we engage in an in-depth discussion of technical issues concerning fuzzy logic, however, we must first place this paradigm in perspective. For this, we first clarify two meanings of the term “fuzzy logic” and present a brief history of the development of fuzzy logic technology and its applications. We will then discuss the insights that motivated the birth of this technology. This is followed by a clarification of some of the common misunderstandings about fuzzy logic.

1.1 What Is Fuzzy Logic?

The term fuzzy logic has been used in two different senses. It is thus important to clarify the distinctions between these two different usages of the term. In a narrow sense, fuzzy logic refers to a logical system that generalizes classical two-valued logic for reasoning under uncertainty. In a broad sense, fuzzy logic refers to all of the theories and technologies that employ fuzzy sets, which are classes with unsharp boundaries.

For instance, the concept of “warm room temperature” may be expressed as an interval (e.g., $[70^{\circ}\text{F}, 78^{\circ}\text{F}]$) in classical set theory. However, the concept does not have a well-defined natural boundary. A representation of the concept closer to human interpretation is to allow a gradual transition from “not warm” to “warm.” In order to achieve this, the notion of membership in a set needs to become a matter of degree. This is the essence of fuzzy sets. An example of a classical set and a fuzzy set is shown in Fig 1.1, where the vertical axis represents the degree of membership in a set.



The broad sense of fuzzy logic includes the narrow sense of fuzzy logic as a tool for solving real-world problems. Other areas include fuzzy control, fuzzy pattern recognition, fuzzy arithmetic, fuzzy mathematical programming, fuzzy probability theory, fuzzy decision analysis, fuzzy neural networks theory, and fuzzy topology, etc. In all these areas, a conventional black-and-white concept is generalized to a matter of degree. By doing this, one accomplishes two things: (1) ease of describing human knowledge involving vague concepts, and (2) enhance the ability to develop a cost-effective solution to real-world problems.

The term fuzzy logic in this book is most frequently used in the broad sense. However, if it is used in the narrow sense, we will explicitly state so.

1.2 The History of Fuzzy Logic

1.2.1 The Birth of Fuzzy Set Theory

The idea of fuzzy sets was born in July 1964. Lofti A. Zadeh is a well-respected professor in the department of electrical engineering and computer science at University of California, Berkeley. In the fifties, Professor Zadeh believed that all real-world problems could be solved with efficient, analytical methods and/or fast (and big) electronic computers. In that direction, he has made significant contributions in the development of system theory, the state variable approach to the solution of simultaneous differential equations, and computer science. In early 1960s, however, he began to feel that traditional systems analysis techniques were too precise for many complex real-world problems. In a paper published in 1961, he mentioned that a different kind of mathematics was needed:

We need a radically different kind of mathematics, the mathematics of fuzzy or cloudy quantities which are not described in terms of probability distributions. Indeed, the need for such mathematics is becoming increasingly apparent..., for in most practical cases the a priori data as well as the criteria by which the performance of a man-made system is judged are far from being precisely specified or having accurately known probability distributions.

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