Lotfi Zadeh: Fuzzy logic-Incoporating Real-World Vagueness

By Pragya Agarwal

Background

Fuzzy logic was first invented as a representation scheme and calculus for uncertain or vague notions. It is basically a multi-valued logic that allows more human-like interpretation and reasoning in machines by resolving intermediate categories between notations such as true/false, hot/cold etc used in Boolean logic. This was seen as an extension of the conventional Boolean Logic that was extended to handle the concept of partial truth or partial false rather than the absolute values and categories in Boolean logic.

Philosophers such as Plato had posited the *laws of thought* and one of these thoughts was the **Law of Excluded Middle**. Parminedes proposed the first version of this rule around 400 B.C. and stated amidst controversy that statements could be both true and not true at the same time. The Greek Philosopher Plato laid the foundations for the fuzzy logic by proposing a third region between true and false where the two notions tumbled together. In the early 1900s Lukasiewicz extended on to the conventional bi-valued logic of Aristotle and proposed a tri-valued logic in his paper in 1920 titled **On three-valued logic** where a new truth value was added to the truth logic 0 and false logic 1. This third value was termed possible with a logic value of �. The idea that logic ought to countenance more than two truth-values arose naturally in ancient and medieval discussions of determinism and was re-examined by C. S. Peirce, Hugh MacColl, and Nikolai Vasiliev in the first decade of this century. Explicit formulation and systematic investigation of many-valued logics began with writings of Jan Lukasiewicz and Emil Post in the 1920s and D. Bochvar, Jerzy Stupecki, and Stephen Kleene in the late 1930s. Lukasiewicz experimented with four and five valued logic and hypothesized the possibility of infinite-valued logic. Knuth proposed a three-valued logic similar to Lukasiewicz's, from which he speculated that mathematics would become even more elegant than in traditional bi-valued logic. His insight, apparently missed by Lukasiewicz, was to use the integral range [-1, 0 +1] rather than [0, 1, 2]. This,however, did not gain much prominence.

The fuzzy set theory was introduced by Professor Lotfi Zadeh in 1965 and can be seen as an infinite- valued logic. Lotfi Zadeh is currently serving as a director of BISC (Berkeley Initiative in Soft Computing). Prior to 1965 Zadeh's work had been centered on system theory and decision analysis. Since then, his research interests have shifted to the theory of fuzzy sets and its applications to artificial intelligence, linguistics, logic, decision analysis, control theory, expert systems and neural networks. Currently, his research is focused on fuzzy logic, soft computing, computing with words, and the newly developed computational theory of perceptions and natural language.

Innovation

Professor Zadeh's paper on fuzzy sets introduced the concept of a class with unsharp boundaries and marked the beginning of a new direction by providing a basis for a qualitative approach to the analysis of complex systems in which linguistic rather than numerical variables are employed to describe system behavior and performance. This approach centers on building better models of human reasoning and decision-making. His unorthodox ideas were initially met with some skepticism but they have since gained wide acceptance.

The basic principles are: 1. In fuzzy logic, exact reasoning is viewed as a limiting case of approximate reasoning. 2. In fuzzy logic everything is a matter of degree. 3. Any logical system can be fuzzified 4. In fuzzy logic, knowledge is interpreted as a collection of elastic or, equivalently , fuzzy constraint on a collection of variables 5. Inference is viewed as a process of propagation of elastic constraints. (Aziz, 1996). The basis of the theory lies in making the membership function lie over a range of real numbers from 0.0 to 1.0. The fuzzy set is characterized by (0.0,0,1.0). Real world is vague and assigning rigid values to linguistic variables means that some of the meaning and semantic value is invariably lost. Fuzzy logic operates on a concept of membership such as the statement Jane is old can be translated as Jane is a member of the set of old people and can be written symbolically as m(OLD), where m is the membership function that can return a value between 0.0 and 0.1 depending on the degree of membership. In Figure 1 the objective term "tall" has been assigned fuzzy values. At 150 cms and below, the person does not belong to fuzzy class while for above 180, the person certainly belongs to category "tall." However, between 150 and 180 the degree of membership for the class "tall" can be assigned from the curve varying linearly between 0 and 1. The fuzzy concept "tall ness" can be extended into "short," "medium," and "tall" as shown in Figure 2. This is different from the probability approach that gives the degree of probability of an occurrence of an event (Jane being old in this instance).

The fuzzy set theory attempts to follow more closely the vagueness that is inherent in most natural language and in decision-making processes. In a conventional logic approach, this inherent fuzziness of membership and categorization is not incorporated. Fuzzy logic has found many real-world applications that involve imitating or modeling human behavior for decision-making in the real world. Development of intelligent systems incorporating the basics of fuzzy set theory have helped advance techniques for handling imprecision in soft computing. The primary idea in soft computing is to mimic human reasoning through building models of natural language variables, human interpretation and reasoning and it has found numerous applications in business and finance sectors, mobile robotics and also in social and behavioral sciences. The dynamics and complexity of social systems are being explained and modeled through the use of fuzzy theory. In geography and environmental sciences, conventional cartographic representations for geographic phenomenon used definite boundaries for demarcation or differentiation in human and physical systems. Research in GIS and analysis of remotely sensed data has explored the use of fuzzy logic for representation of transition zones and imprecise categories. Again soft computing techniques have resulted in interesting developments in the field of geographic modelling, representation and analysis. The infinite-logic approach in fuzzy-set theory has also been one of the few attempts to respond to the "sorites paradox." The integration of fuzzy logic in relational database systems have also advanced conventional query techniques to incoporate linguistic variables and semantic concepts.

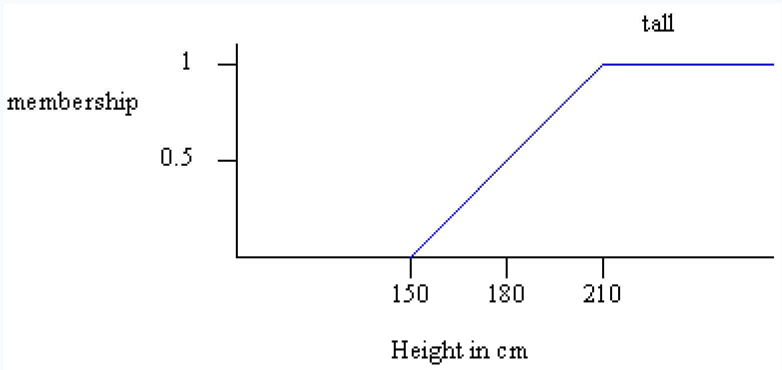

Figure 1. Graph showing membership functions for fuzzy set 'tall'

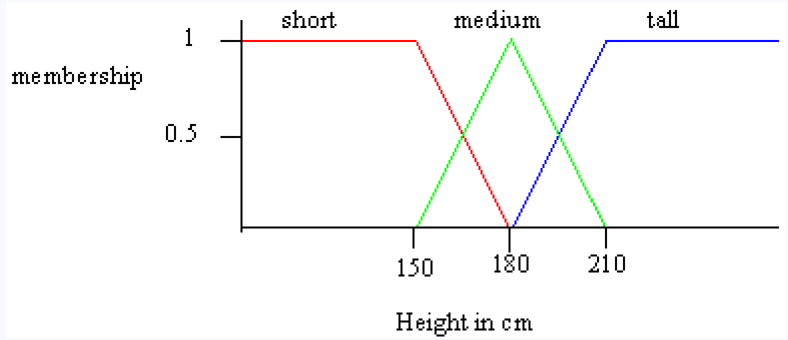

Figure 2. Graph showing membership functions for fuzzy sets 'short','medium' and 'tall'

Publications

Zadeh, L., Fuzzy sets, Information Control 8, 338–353, 1965

Zadeh, L., Probability measures of fuzzy events, *Jour. Math. Analysis and Appl. 23*, 421–427, 1968.

Zadeh, L., Knowledge representation in fuzzy logic, IEEE Trans. on *Knowledge and Data Engineering 1*:89–100, 1989.

Zadeh, L., A fuzzy-algorithmic approach to the definition of complex or imprecise concepts. *Int. Jour. Man-Machine Studies 8*:249–291, 1976

Related Works

J.F. Baldwin, Fuzzy logic and fuzzy reasoning, in *Fuzzy Reasoning and Its Applications* E.H. Mamdani and B. R. Gaines (eds.), London: Academic Press, 1981.

Smithson, M. J. Applications of fuzzy set concepts to behavioral sciences. *Journal of Mathematical Social Sciences, 2*:257–274. 1982.

Smithson, M. J. *Fuzzy Set Analysis for the Behavioral and Social Sciences*. New York: Springer-Verlag 1987, 327 pp.

Links

Example of systems based on fuzzy logic
Fuzzy logic applied to Thorstein Veblen's Evolutionary Thought Take the fuzzy shower challenge