Introduction to Fuzzy Logic and Fuzzy Linear Programming

Pandian Vasant
Universiti Teknologi Petronas, Malaysia

Hrishikesh S. Kale
K.K.Wagh Institute of Engineering Education & Research, India

FUZZY LOGIC

What is Fuzzy Logic?

Fuzzy logic (FL) is a mathematical technique for dealing with imprecise data and problems that have many solutions rather than one. Although it is implemented in digital computers which ultimately make only yes-no decisions, FL works with ranges of values, solving problems in a way that more resembles human logic.

FL is a multi-valued (as opposed to binary) logic developed to deal with imprecise or vague data. Classical logic holds that everything can be expressed in binary terms: 0 and 1, black and white, yes or no; in terms of Boolean algebra, everything is in one set or another but not in both. FL allows for partial membership in asset values between 0 and 1, shades of gray, and introduces the concept of the "fuzzy set." When the approximate reasoning of FL (Zadeh, 1965) is used with an expert system, logical inferences can be drawn from imprecise relationships. FL theory was developed by Lofti A. Zadeh at the University of California in the mid 1960s. However, it was not applied commercially until 1987 when the Matsushita Industrial Electric Co. used it to automatically optimize the wash cycle of a washing machine by sensing the load size, fabric mix, and quantity of detergent and has applications in the control of passenger elevators, household applications, and so forth.

FL has two different meanings. In a narrow sense, FL is a logical system, which is an extension of multi-valued logic. But in a wider sense, which is in predominant use today, FL is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects with un-sharp boundaries in which membership is a matter of degree. In this perspective, fuzzy logic in its narrow sense is a branch of FL. What is important to recognize is that, even in its narrow sense, the agenda of fuzzy logic is very different both in spirit and substance from the agendas of traditional multi-valued logical systems (Delgado, Verdegay, & Vila, 1989).

FL sometimes appears exotic to those unfamiliar with it, but once you become acquainted with it, it seems almost surprising that no one attempted it sooner. In this sense FL is both old and new because, although the modern and methodical science of FL is still young, the concepts of FL reach right down to our bones.

FL is a convenient way to map an input space to an output space. This is the starting point for everything else, and the great emphasis here is on the word "convenient."

What do we mean by mapping input space to output space? Here are a few examples: You tell me how good your service was at a restaurant, and I will tell you what the tip should be. You tell me how hot you want the water, and I will adjust the tap valve to the right setting. You tell me how far away the subject of your photograph is, and I will focus the lens for you. You tell me how fast the car is going and how hard the motor is working, and I will shift the gears for you.

Why Use Fuzzy Logic?

1. FL is conceptually easy to understand: The mathematical concepts behind fuzzy reasoning are very simple. What makes fuzzy nice is the "naturalness" of its approach and not its far-reaching complexity.
2. FL is flexible: With any given system, it is easy to massage it or layer more functionality on top of it without starting again from scratch.
3. FL is tolerant of imprecise data: Everything is imprecise if you look closely enough, but more than that, most things are imprecise even on

careful inspection. Fuzzy reasoning builds this understanding into the process rather than tacking it onto the end.

4. FL can be built on top of the experience of experts: In direct contrast to neural networks, which take training data and generate opaque, impenetrable models, FL lets you rely on the experience of people who already understand your system.
5. FL can be blended with conventional control techniques: Fuzzy systems do not necessarily replace conventional control methods. In many cases fuzzy systems increase the size of them and simplify their implementation.
6. FL is based on natural language: The basis for FL is the basis for human communication. Natural language, that which is used by ordinary people on a daily basis, has been shaped by thousands of years of human history to be convenient and efficient. Since FL is built atop the structures of qualitative description used in everyday language, FL is easy to use.

When Not to Use Fuzzy Logic?

FL is not a cure-all. When should you not use FL? The safest statement is the first one made in this introduction: FL is a convenient way to map an input space to an output space. If you find it is not convenient, try something else. If a simpler solution already exists, use it. FL is the codification of common sense—use common sense when you implement it and you will probably make the right decision. Many controllers, for example, do a fine job without using FL. However, if you take the time to become familiar with FL, you will see it can be a very powerful tool for dealing quickly and efficiently with imprecision and nonlinearity.

Fuzzy Sets

Fuzzy set was initiated by Zadeh at University of California in 1965 and subsequently several authors have discussed various aspects of the theory and applications of fuzzy sets. Since then, fuzzy set theory has been widely developed and various modifications and generalizations have also appeared. Recent applications to various scientific fields such as precision machinery, artificial intelligence, image processing, decision theory, military science, sociology, medical science, economics, psychology, biology, and linguistics have demonstrated that fuzzy set theory may not be a theory in search of applications, but indeed a useful tool for the expressions of professional judgments (Zimmermann, 1991).

FL starts with the concept of a fuzzy set. A fuzzy set is a set without a crisp, clearly defined boundary. It can contain elements with only a partial degree of membership.

To understand what a fuzzy set is, first consider what is meant by what we might call a classical set. A classical set (Figure 1) is a container that wholly includes or wholly excludes any given element. For example, the set of days of the week unquestionably includes Monday, Thursday, and Saturday.

We call this set a classical set because it has been around for such a long time. It was Aristotle who first formulated the Law of the Excluded Middle, which says X must either be in set A or in set not-A.

"Of any subject, one thing must be either asserted or denied."

Here is a restatement of the law: "Of any subject (say Monday), one thing (being a day of the week) must

Figure 1. Classical set

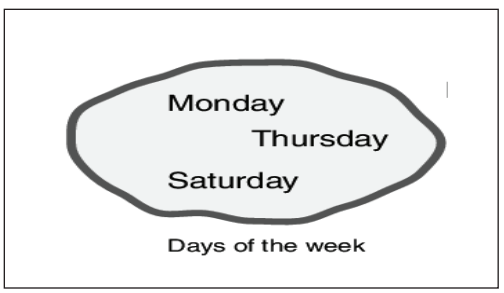

Figure 2. Fuzzy set