FUZZY LOGIC: ISSUES, CONTENTIONS AND PERSPECTIVES

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ABSTRACT

The past few years have witnessed a rapid growth in the number and variety of applications of fuzzy logic, ranging from consumer products, industrial process control and vision systems to medical instrumentation, information systems, signal processing and decision analysis. The foundations of fuzzy logic have become firmer and its impact within the basic sciences - and especially in mathematical and physical sciences - has become more visible and more substantive.

The other side of the picture is that the successes of fuzzy logic have also generated a skeptical and sometimes hostile reaction. The crux of the position of skeptics is that fuzzy logic is overrated or wrong and that anything that can be achieved through the use of fuzzy logic can also be achieved through the use of conventional techniques.

Most of the criticisms directed at fuzzy logic are rooted in a misunderstanding of what it is and/or a lack of familiarity with it. In many cases, what is not recognized is that the term fuzzy logic (FL) is actually used in two different senses. In a narrow sense, fuzzy logic (FLn) is a logical system which is an extension of multivalued logic and is intended to serve as a logic of approximate reasoning. But in a wider sense, fuzzy logic (FLw) is more or less synonymous with the theory of fuzzy sets (FST), that is, a theory of classes with unsharp boundaries. In this perspective, FL = FLw, and FLn is merely a branch of FL. What is important to recognize is that today the term fuzzy logic is used predominantly in its wider sense. It is in this sense that any field X can be fuzzified - and hence generalized - by replacing the concept of a crisp set in X by a fuzzy set. In application to basic fields such as arithmetic, topology, graph theory, probability theory and logic, fuzzification leads to fuzzy arithmetic, fuzzy topology, fuzzy graph theory, fuzzy probability theory and FLn. Similarly, in application to applied fields such as neural network theory, stability theory, pattern recognition and mathematical programming, fuzzification leads to fuzzy neural network theory, fuzzy stability theory, fuzzy pattern recognition and fuzzy mathematical programming. What is gained through fuzzification is greater generality, higher expressive power, an enhanced ability to model real-world phenomena and, most importantly, a methodology for exploiting the tolerance for imprecision - a methodology which serves to achieve tractability, robustness and lower solution cost. For these reasons, it is inevitable that eventually fuzzy logic will pervade most scientific theories and will have a particularly strong impact in the realms of artificial intelligence, systems analysis, intelligent control, signal processing, numerical analysis, optimization techniques, diagnostics, linguistics, information processing, decision analysis, cognitive science and related fields.

Although there has been a great deal of progress in our understanding of fuzzy logic and its potentialities, there are many issues that remain to be addressed. One such issue is that of the induction of fuzzy rules from observations. Although some successes have been achieved through the use of neural network techniques and genetic algorithms, there are many problems in this realm that remain to be solved. Other important issues relate to the problems of interpolation, commonsense knowledge representation, stability analysis, signal processing and data compression.

Today, most of the applications of fuzzy logic relate to control in the context of industrial systems and consumer products. This is the case because such applications are easy to make and result in systems and products with a higher level of MIQ (Machine Intelligence Quotient). What is discernible, however, is (a) the trend toward the use of fuzzy logic in task- oriented - rather than set-point-oriented - control; and (b) the incorporation of fuzzy logic and neural network techniques in the conception and design of complex systems in which control and expert system techniques are used in combination. Among the examples of such systems are power plants, cement kilns, elevator systems, air traffic control systems and, more generally, those systems in which there is an interaction between local control and higher level decision-making.

In the final analysis, fuzzy logic has succeeded where traditional approaches have failed because fuzzy logic does come to grips with the pervasive imprecision of the real world. In so doing, the role model for fuzzy logic is the human mind.

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