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FUZZY SETS AS A BASIS FOR INFORMATION ANALYSIS

FINAL REPORT

L. A. Zadeh

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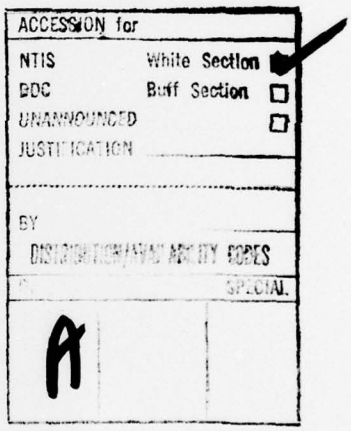

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Application of the theory of fuzzy sets to the processing of information which is imprecise, incomplete or not totally reliable. Linguistic approach to concept definition and systems analysis.

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The research supported by the U. S. Army Research Office has been aimed, in the main, at the development of computer-oriented techniques for the processing of information which is imprecise, incomplete or not totally reliable.

Among the significant accomplishments of this research are the following.

1. Development of the Linguistic Approach to System Analysis

   The novel feature of this approach is the systematic use of words rather than numbers to represent the values of variables as well as their interrelations. For example, the linguistic values of a variable X may be represented as small, very small, not very small, not very small and not very large, etc., where each linguistic value represents a fuzzy subset of the real line. A composite label such as not very small is assumed to be generated by a context-free grammar and its denotation is determined by a semantic rule. In this way, a concrete meaning may be assigned to a rule of the form "If X is small then Y is very large," and a collection of such rules may be employed to provide an approximate characterization of the dependence of Y on X.

   The linguistic approach has found important practical applications in the design of so-called fuzzy-logic controllers, which are currently in use in steel plants, cement kilns, heat exchangers, etc. A Fuzzy Logic Working Group has been set up at the Queen Mary College of the University of London and a number of papers on the applications of the linguistic approach have been presented at various workshops and conferences.

2. Application of Fuzzy Set Theory to Pattern Classification and Cluster Analysis

The conceptual framework of the theory of fuzzy sets provides a natural basis for the formulation and solution of problems in pattern classification and cluster analysis. A paper describing applications of fuzzy sets to pattern classification was presented at the Mathematics Research Center, University of Wisconsin, and was published in the proceedings of the symposium. A noteworthy consequence of the introduction of the concept of a fuzzy set into cluster analysis has been the development of the FUZZY ISODATA clustering algorithm by Dunn and Bezdek. In a recent paper presented by Dr. S. Gustafson at the Conference on Decision and Control (San Diego, 1979), this algorithm was shown to be superior to the conventional non-fuzzy algorithms for cluster analysis. A number of investigators both in the United States and abroad have become interested in exploring the applications of fuzzy sets to pattern recognition, and it is likely that fuzzy-set based techniques will become a standard part of pattern recognition methodology in the years to come.

3. Development of Algorithmic Techniques for Concept Definition and Diagnostic Procedures

A systematic technique based on the notion of a fuzzy relation has been developed for algorithmic characterization of complex or imprecise concepts. In this approach, the degree to which a concept is satisfied by an instantiated object is expressed as a function of linguistic answers to a collection of attributional and classificational questions. Then, a translation rule for fuzzy relations is employed to convert the relation with linguistic entries into one

with numerical values. And finally, the linguistic values of the attributes of the object are composed with the defining relation, yielding a linguistic value for the degree of fit.

This technique provides a basis for the construction of branching questionnaires for diagnostic purposes. Practical applications of the algorithmic technique have recently been described by investigators in France and Japan.

4. Development of Possibility Theory

A recent development in our research is the coalescence of various concepts and methods of dealing with nonstatistical uncertainties into what might be called possibility theory. A concept which plays a central role in this theory is that of a possibility distribution, which, informally, may be regarded as an elastic constraint on the values which may be assumed by a variable. By analogy with probability theory, one can define the concepts of conditional and marginal possibility distributions. In general, such distributions are induced by propositions of the form "X is small," or "If X is small then Y is large," and provide a basis for a nonstatistical analysis of inference processes and credibility assessment.

Possibility theory appears to be particularly relevant to knowledge representation, information analysis and problems relating to database security and performance evaluation.

In summary, the support provided by ARO played an important role in developing the theory of fuzzy sets and exploring its applications to

various problems in information processing. In many cases, the basic ideas developed in the course of our research have been picked-up by other investigators and eventually found their way into practical uses of the theory in process control, pattern classification, fault location, decision analysis and other application areas.

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