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RECENT CIVIL ENGINEERING APPLICATIONS OF FUZZY SETS

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INTRODUCTION

Since Brown *et al.* [1] reported on the state-of-the-art, much progress has been made. In this paper, an attempt will be made to summarize and discuss recent civil engineering applications of fuzzy sets.

CONCEPTS AND METHODS

Blockley [2] considered probability and fuzzy logic as special cases of the interval theory of possibilities. He explained Gaines' axioms, where the probabilistic logic is based on the law of the excluded middle, and the fuzzy logic is based on an assumption of total dependence without the law of excluded middle. In addition, he reviewed a fuzzy relational inference language (FRIL) and applied it to an example of risk and cost–benefit analysis for various treatment strategies for dealing with dangerous subsidence into ancient minings.

Lind [3] discussed the possible occurrence of unique loads and the representation of vague circumstances of loading in using design specifications. Here the probability of unique events may be interpreted as a fuzzy measure. He suggested that fuzzy sets may be appropriate in loading cases where the concepts in design codes are extremely vague. A numerical example involving the reduction of snow load when combined with wind was presented.

Elms [4] introduced the principle of consistent crudeness. He showed that the principle is useful in choosing appropriate levels of detail in both analysis and data acquisition. Several simple examples were given.

APPLICATIONS

Johnston [5] applied a diagnostic algorithm for an activated sludge wastewater treatment facility. In the same vein Jowitt [6] examined the application to river basin management including wastewater treatment and multireservoir operation.

In earthquake engineering applications, Brown *et al.* [7] made an extensive structural literature search and Chameau [8] reviewed related work on soil liquifaction and dam safety. Grivas and Souflis [9] applied a linguistic assessment method to establish the relationship between seismic load and resulting damage during the 1964 Alaska earthquake. Wong and Ross [10] found that the results obtained using fuzzy sets in treating uncertainties in structural dynamics were more consistent with intuition than those using stochastic processes.

Mullarkey and Fenves [11] applied fuzzy logic to a knowledge-based interpretation system in soil mechanics involving the use of core penetrometers. These field exploration devices are used to obtain information on soil stratigraphy. The resulting data are subject to interpretation by experts.

Shiraishi and Furuta [12] presented a method to use qualitative information for the assessment of structural durability. Both fuzzy multicriteria analysis and expert systems were used to evaluate structural deterioration of a concrete bridge deck. Yao and Furuta [13] enumerated several types of uncertainties encountered in civil engineering problems with the emphasis on probabilistic treatment of fuzzy events. In addition, several optimum criteria for decision-making under random and fuzzy conditions were compared, using as an example, the maintenance of bridge structures.

Recently, Hadipriono [14] applied fuzzy sets to assess the performance of falsework. He concluded that the method is a useful tool for quality control for falsework.

NSF WORKSHOP

The *Workshop on Civil Engineering Applications of Fuzzy Sets* was supported in part by the National Science Foundation and held at Purdue University, 17–19 September 1985. There were 53 registered participants and observers. It was dedicated to the memory of the late distinguished Professor King-Sun Fu of Purdue University.

The workshop was directed and conducted by a Steering Committee overseeing a Local Arrangement Committee and a Technical Program Committee. The *Workshop Proceedings* are being prepared by Brown *et al.* [7].

CONCLUDING REMARKS

The authors are encouraged by the intensive activities in the application of fuzzy sets to solve civil engineering problems. Plans are underway to organize a technical committee on civil engineering applications of fuzzy sets in the North American Fuzzy Information Processing Society (NAFIPS).

The applications suggest a sense of cohesion in problems where (a) interaction and communication, (b) experience-based opinions and (c) unique events exist. Then the use of fuzzy sets may be appropriate. Only Blockley [2] has moved towards a fundamental study of the correct conditions for the application of fuzzy set and of probability theories. Otherwise, the approaches have focused on the subjective features of the problem.

Other applications will undoubtedly arise. However, significant basic obstacles exist. Some of these are: (a) the reliable generation of membership functions; (b) the theoretical basis for combining objective and subjective uncertainties; (c) a complete extremum theory; and (d) the classification of problems for uncertainty analysis.

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