BULGARIAN ACADEMY OF SCIENCES

CYBERNETICS AND INFORMATION TECHNOLOGIES • Volume **9**, No 1

Sofia • 2009

Investigations in the Area of Soft Computing Targeted State of the Art Report

Vera Angelova

**Institute of Information Technologies, 1113 Sofia*
E-mail: vangelova@iit.bas.bg

Abstract*: The article attempts to give a projection of Soft computing in the investigations of the scientists from the Institute of information technologies of the Bulgarian academy of sciences. Areas of studied problems, as well as trends are mentioned.*

Keywords*: Soft computing, multicriteria decision making, theory of fuzzy sets.*

1. Introduction

In 1991 L. Z a d e h [37] introduces the idea of Soft computing as an example of a new kind of artificial intelligence. Soft computing is a fusion of methodologies, intended to solve real problems in complicated dynamical and undetermined systems with variable and uncertain parameters. Soft computing is a multidiscipline scientific area and it consists in computational instruments and techniques used in fuzzy logic, artificial neural networks, genetic algorithms and some aspects of the machine learning [5, 37]. The principal aim of Soft computing is to exploit the tolerance for imprecision and uncertainty to achieve tractability, robustness and low solution cost [37, 38], i.e. the general model for Soft computing is the human mind. The exploitation of the tolerance for imprecision and uncertainty underlies the remarkable human ability to make rational decisions in an environment of imprecision and uncertainty. The use of Soft computing and especially its basic element – fuzzy logic in the conception and design of intelligent systems increases MIQ (Machine Intelligence Quotient) of consumer products and industrial systems [37, 1]. The principal contribution of fuzzy logic is a methodology for computing with words. The words are less precise than numbers by their nature, but the use of words serves two main purposes: a) as a way of dealing with information which is not precise enough to justify the use of numbers; b) exploiting the tolerance for imprecision when precise information is available or can be obtained at a cost.

The term fuzzy logic [6] is used in two different senses. In a narrow sense, it is a logical system that aims at a formalization of approximate reasoning. In a broad sense, fuzzy logic is almost synonymous with fuzzy set theory. The growing tendency is to use the term fuzzy logic in its broad sense [37]. A concept that plays a central role in the applications of fuzzy logic is that of a linguistic variable [38]. One way to formalize the term linguistic variable is the usage of the term fuzzy variable [34]. The values of the fuzzy variable are the fuzzy numbers.

2. Soft computing in IIT – BAS

The scientific investigations in the Institute of Information Technologies (IIT) of the Bulgarian Academy of Sciences (BAS) connected with Soft computing are directed toward the multicriteria decision making, especially to the application of the fuzzy sets theory in multicriteria Decision Support Systems (DSS). The fuzzy decision making system is modelled on the base of given system behaviour established in advance but the fuzzy system has to be in condition to bear resemblance to its conduct. The fuzzy modelling has the following characteristics:

– the fuzzy modelling has to use as much as possible the expert and decision-maker's knowledge in the investigated area;

– if the input and output data are known, the application of standard techniques for the system identification is possible.

The models based on the fuzzy logic use the following advantages:

– the fuzzy logic is easy for interpretation – the used mathematical conceptions are comparably easy;

– the fuzzy logic is flexible – new rules and functions can be added without constructing a new model;

– the fuzzy logic is tolerant to imprecision and uncertainty of the information – the results from inexact and vague data can be worked out;

– the fuzzy logic can model non-linear functions with arbitrary complexity;

– a fuzzy system can be constructed on the base of the experts experience;

– the fuzzy logic can be combined with standard control techniques – the fuzzy systems are not obligatory to substitute the standard control techniques, they simplify their fulfilment in many cases;

– the fuzzy logic is based on the natural language – it is based on the human communications.

The fuzzy decisions are intelligent tools [7] to assist decision makers in:

– to assess the consequences of decision made in an environment of imprecision, uncertainty and partial truth;

– to examine the set of alternatives very quickly and find the value of the inputs to achieve a desired level of output;

– to use with human interaction and feedback to achieve a capability to learn and adapt through time.

It is obvious that the decision making in real complex systems is very complicated, very vague and very inexact. That's why it is necessary to use fuzzy logic based techniques in decision making models.

The following projects are devoted to problems of this area:

– "Models with uncertain information in multicriteria DSS" with the National Science Fund of the Ministry of Education and Science, 2003-2006.

– "Investigations of models for decision making in fuzzy environment" with Bulgarian Academy of Sciences, 2006-2009;

– Several projects to the Bulgarian innovation fond.

The purpose of these projects is directed towards researching and developing of the models for decision making support in multicriteria problems under uncertainties from fuzzy type. The models simulate (approximate) human decision making by means of applying the fuzzy set theory. Multicriteria fuzzy decision making problems are considered in cases of fuzziness present in initial information and at the stages of the problem's solutions, as well. These projects are developed to the algorithms and programs.

The multicriteria decision making models are based on:

– a finite set of alternatives, among which a decision maker has to choose (choice problem) or to rank (ranking problem) or to part (cluster problem);

– a finite set of judges or criteria on the base of which the alternatives are evaluated;

– a criteria importance, i.e. weights of the criteria.

The alternatives in decision making problems are usually evaluated from different points of views that correspond to particular criteria. In real-life situations, evaluations are neither certain nor precise. There are three main sources of uncertainty [35]:

– imprecision, because of the difficulty of determining the scores of alternatives on particular criteria;

– interdetermination, since the method of evaluation results from a relatively arbitrary choice from several possible definitions;

– uncertainty, since the values involved vary in time.

The criteria can be quantitative and qualitative ones. Usually quantitative criteria are assessed by means of precise numerical values. The qualitative criteria are presented in qualitative terms by means of linguistic variables.

The weights of the criteria can be real or fuzzy.

The solution scheme of the multicriteria decision making problems basically consists of three phases [4, 17]: uniform, aggregation and exploitation phase.

A. An uniform phase. It is required to make the information uniform, if the criteria are in different scales. One basic approach to make this is to use fuzzy relations over the set of alternatives as the main element of uniform representation. Therefore, some transformation functions are needed to define the relations between the couple of alternatives by each criterion. It is more realistic to use fuzzy relations because they have more convenient and adequate form for representing the relationship between alternatives then crisp relations. The fuzzy relations may model situations, whenever interactions between the alternatives are not exactly determined. Besides that, they reflect the interests of the experts or the decision-maker. These transformation functions define relations with different properties, for example similar or preference relations. A transformation function for this purpose is suggested in [11, 9], which gives as a result a membership degree of a couple of alternatives to a fuzzy preference relation. This relation possesses some properties useful to decide the problems of alternatives' ordering. It is proved that the membership degrees vary small under small changes of the alternatives' estimations.

The qualitative criteria are presented in qualitative terms by means of linguistic variables [36], i.e. variables whose values are not numbers but words or sentences in a natural or artificial language. The linguistic variables are presented as fuzzy numbers in the first possibility. That's why, the problem is how to compare the fuzzy numbers to obtain the corresponding fuzzy relation. Different methods for comparing or ordering fuzzy numbers exist. Some of them use a ranking function and other ones compute a comparison index for each pair of them. A new index for comparison and ordering of fuzzy numbers is suggested in [11, 12]. This index is based on the geometrical properties of the fuzzy numbers. It is tested on a group of selected examples and compared with the other well-known indexes. A method for comparison of sequences of fuzzy numbers and an algorithm for comparison of subsets (clusters) of similar, closed vectors of fuzzy numbers are presented as well.

B. An aggregation phase of the performance values with respect to all criteria for obtaining a union performance value for the alternatives. A purposeful approach for uniting individual evaluations corresponding to an alternative is to use the aggregation procedures that realize the idea of compensation and compromise between conflicting criteria, when compensation is allowed. The aggregation operators may perform these procedures. There is a large range of operators, which can be advantageously used in the confluence of the criteria. The choice of an operator for specific application depends on various factors. Some choice has to be made according to, e.g.:

- the mathematical model of the operators;
- the properties of the operators for deciding problems of ranking or choice, or clustering of the alternatives' set;
- the sensitivity of the operators for small variations of their arguments.

The dependence between the properties of the aggregated relation and the properties of the individual relations by each criterion for some operators is investigated in [8, 9, 10, 12, 13, 14, 19]. These dependences for each operator are represented in a table, which contains implications of the kind: if the initial relations possess given properties, then the aggregated relation possesses proved properties. Some of the most often used operators are presented and their properties are proved and presented in this table. It is shown how the properties of the aggregated fuzzy relation assist to solve the problems of choice or ranking of the alternatives. The obtained results from different aggregation operators are compared with other well-known methods for multicriteria decision making. The sensitivity of the operators with respect to variations in their arguments is defined and computed in [16]. In [15] the aggregation of the sequences of fuzzy numbers, representing the alternatives, is done through aggregation operators in such a way that the aggregated evaluations are fuzzy numbers, as well. The model is tested on the real example and compared with the results obtained from other well-known methods for multicriteria decision making.

The other problem is connected with weighted aggregation which are very important in decision problems. Weighted transformations in aggregation operators are used for this purpose. The problems of preserving the fuzzy relations' properties in applying these transformations are considered. The usage of the criteria' weights in the cases when they are not presented in the aggregation operators' formula is investigated in [18, 20, 21]. The problems, when the weights are presented as a fuzzy relation between the criteria importance [22, 24, 28] or fuzzy numbers [26] are considered. The models connected with weighting functions as a criteria importance, depending on the membership degrees of the fuzzy relations are suggested in [27, 29, 30]. The results of the weighted aggregations considered above are summarized in [23, 25, 26, 28, 30, 31]. Illustrative examples are given for comparison of the suggested models.

C. An exploitation phase of the union performance value for obtaining a rank ordering, sorting or choosing the alternatives. The problems of choice of a subset from the "best" in some sense alternatives; ordering over the whole set of alternatives; partition the set of alternatives of the subsets from the similar, close ones, i.e. partition from clusters, have to be solved in this phase. The following results are obtained in this area.

A method for comparison of fuzzy clusters is proposed in [11]. It gives a possibility to compare clusters from fuzzy numbers and orders these subsets in this way. The proposed algorithm is based on the results obtained in [32], where it is proved that the comparison between two fuzzy sets can be made on the base of comparison of only fuzzy sets' scores without information lost. The proposed algorithm is tested on the example illustrating the decrease of the computations.

Applications of the fuzzy logic in multicriteria problems for assessing the quality of an asset and making an investment decision are proposed in [2, 3, 33].

3. Open problems

Some trends of investigations concerning the Soft computing in IIT – BAS are directed to: obtain fuzzy relations between the alternatives by the different criteria with defined properties; an adequate correspondence between linguistic variables and their mathematical values, i.e. the fuzzy numbers; a choice of adequate weighting coefficients of the criteria. It is important to investigate the properties of the fuzzy relations determining the adequate aggregation operator or the methods of the information fusion, besides methods supporting the decision-maker in determining the parameters of the aggregation operators. These investigations have to be connected with algorithms and programs for solving the problems of fuzzy multicriteria decision-making.

References

1. A l i e v, R. A., R. R. A l i e v. Soft Computing and its Applications. Singapure, World Scientific, 2001. ISBN 981-02-4700-1.
2. G e o r g i e v a, P. Application of Fuzzy Logic for Making Multicriteria Investment Decisions. – In: Proc. of Sci. Conf. "Contemporary Technologies'07, 5-6 July 2007, Burgas, 210-216 (in Bulgarian).
3. G e o r g i e v a, P. Discovery HS, HIS, BT, BB, TT, TB, RT, RB Regularities in Historical Data for Assets Prices Through Fuzzy Logic. – Annular of Burgas Free University, Vol. **XVII**, 2007, 395-402. ISBN-10: 954-9370-44-5, ISBN-13: 978-954-9370-44-7 (in Bulgarian).
4. H e r r e r a, F., E. H e r r e r a - V i e d m a. Linguistic Decision Analysis: Steps for Solving Decision Problems under Linguistic Information. – Fuzzy Sets and Systems, **115,** 2000, 67-82.
5. H o f f m a n n, F., M. K o p p e n, F. K l a w o n, R. R o y. Soft Computing: Methodologies and Applications. – Series: Advances in Soft Computing, **32**, 2005. ISBN 978-3-540-25726-4.
6. N g u y e n, H., E. W a l k e r. Fuzzy Logic (Chapman & Hall/CRC, 2000). ISBN 0-8493-1659-6.
7. N i k r a v e s h, M., B. A z v i n e. Fuzzy Queries, Search, and Decision Support System. – Soft Computing, **6**, 2002, 373-399.
8. P e n e v a, V. G., I. P o p c h e v. Fuzzy Relations in Decision Making. – In: Proc. of FUZZ-IEEE'96, Int. Conf. on Fuzzy Systems, New Orleans, LA, 8-11 September 1996, 336-341. ISBN 0-7803-3645-3.
9. P e n e v a, V. G., I. P o p c h e v. Fuzzy Ordering on the Base of Multicriteria Aggregation. – Cybernetics and Systems, **29,** 1998**,** No 6, 613-623.
10. P e n e v a, V., I. P o p c h e v. Aggregation of Fuzzy Relations. – Compt. Rend. Acad. Bulg. Sci., **51**, 1998**,** No 9-10, 41-44.
11. P e n e v a, V., I. P o p c h e v. Comparison of Cluster from Fuzzy Numbers. – Fuzzy Sets and Systems, **97**, 1998**,** No 1, 75-81.
12. P e n e v a, V., I. P o p c h e v. Decision Making with Fuzzy Relations. – In: Proc. of the XIV EMCSR'98 (R.Trappl, Ed.) , Vienna, Austria, 14-17 April 1998, 195-200.
13. P e n e v a, V. G., I. P o p c h e v. Fuzzy Logic Operators in Decision Making. – Cybernetics and Systems, **30**, 1999**,** No 8, 725-745.
14. P e n e v a, V., I. P o p c h e v. Aggregation of Fuzzy Relations in Multicriteria Decision Making. – Compt. Rend. Acad. Bulg. Sci., **54**, 2001**,** No 4, 47-52.
15. P e n e v a, V., I. P o p c h e v. Aggregation of Fuzzy Numbers in a Decision Making Situation. – Cybernetics and Systems, **32**, 2001, No 8, 821-835. ISSN: 0196-9722.
16. P e n e v a, V., I. P o p c h e v. Sensitivity of Fuzzy Logic Operators. – Compt. Rend. Acad. Bulg. Sci., **55**, 2002**,** No 3, 45-50.
17. P e n e v a, V., I. P o p c h e v. Fuzzy Multicriteria Decision Making. – Cybernetics and Information Technologies, **2**, 2002, No 1, 16-26.
18. P e n e v a, V., I. P o p c h e v. Weighted Aggregation of Fuzzy Relations. – Compt. Rend. Acad. Bulg. Sci., **56**, 2003**,** No 10, 29-35.
19. P e n e v a, V., I. P o p c h e v. Properties of the Aggregation Operators Related with Fuzzy Relations. – Fuzzy Sets and Systems, **139**, 2003, No 3, 615-633.
20. P e n e v a, V., I. P o p c h e v. Transformations by Parameterized T-Norms Preserving the Properties of Fuzzy Relations. – Compt. Rend. Acad. Bulg. Sci., **57**, 2004, No 10, 9-18.
21. P e n e v a, V., I. P o p c h e v. Weighted Transformation in Aggregation Operators Uniting Fuzzy Relations. – Advanced Studies in Contemporary Mathematics, **10**, 2005, No 1, 25-44.
22. P e n e v a, V., I. P o p c h e v. Aggregation of Fuzzy Preference Relations with Different Importance. – Compt. Rend. Acad. Bulg. Sci., **58**, 2005, No 5, 499-506.
23. P e n e v a, V., I. P o p c h e v. Models of Decision Making Support by Multicriteria Problems in Fuzzy Environment. – Advanced Studies in Contemporary Mathematics, **12**, 2006, No 2, 291-308.
24. P e n e v a, V., I. P o p c h e v. Aggregation of Fuzzy Preference Relations by Composition. – Compt. Rend. Acad. Bulg. Sci., **59**, 2006, No 4, 373-380.

25. P e n e v a, V., I. P o p c h e v. Models of Weighted Aggregation of Fuzzy Relations to Multicriteria Decision Making. – Cybernetics and Information Technologies, **6**, 2006, No 3, 3-18.
26. P e n e v a, V., I. P o p c h e v. Aggregation of Fuzzy Relations with Fuzzy Weighted Coefficients. – Advanced Studies in Contemporary Mathematics, **15**, 2007, No 1, 121-132.
27. P e n e v a, V., I. P o p c h e v. Aggregation of Fuzzy Relations Using Weighting Function. – Compt. Rend. Acad. Bulg. Sci., **60**, 2007, No 10, 1047-1052.
28. P e n e v a, V., I. P o p c h e v. Aggregation of Fuzzy Relations to Multicriteria Decision Making. – Fuzzy Optimization and Decision Making, **6**, December 2007, No 4, 351-365.
29. P e n e v a, V., I. P o p c h e v. Fuzzy Criteria Importance with Weighting Functions. – Compt. Rend. Acad. Bulg. Sci., **61**, 2008, No 3, 293-300.
30. P e n e v a, V., I. P o p c h e v. Fuzzy Criteria Importance Depending on the Membership Degrees of Fuzzy Relations. – Compt. Rend. Acad. Bulg. Sci., **61**, 2008, No 5, 579-584.
31. P e n e v a, V., I. P o p c h e v. Multicriteria Decision Making Based on Fuzzy Relations. – Cybernetics and Information Technologies, **8**, 2008, No 3, 3-12.
32. P o p c h e v, I., V. P e n e v a. An Algorithm for Comparison of Fuzzy Sets. – Fuzzy Sets and Systems, **60**, 1993, No 1, 59-66.
33. P o p c h e v, I., P. G e o r g i e v a. A Fuzzy Approach to Solving Multicriteria Investment Problems. Innovative Techniques in Instruction Technology, e-Learning, e-Assessment, and Education. M. Iskander (Ed.). Springer Science+Business Media B. V., 2008, 427-431.
34. R a o, M. B., A. R a s h e d. Some Comments of Fuzzy Variables. – Fuzzy Sets and Systems, **6**, 1981, No 3, 285-292.
35. R o y, B. Main Sources of Inaccurate Determination, Uncertainty and Imprecision in Decision Models. – Mathematical and Computer Modeling, **12**, 1989, No 10-11, 1245-1254.
36. Z a d e h, L. A. The Concept of a Linguistic Variable and its Application to Approximate Reasoning. Part I. – Inf. Sci., **8**, 1975, 199-249.
37. Z a d e h, L. A. Fuzzy Logic, Neural Networks, and Soft Computing. – Communications of the ACM, March 1994, **37**, 1994, No 3, 77-84.
38. Z a d e h, L. A. The Role of Fuzzy Logic and Soft Computing in the Conception, Design and Deployment of Intelligent Systems. BISC Seminar. **http://www.cs.barkeley.edu/~zadeh**