World Scientific Proceedings Series on
Computer Engineering and Information Science 1

Computational Intelligence in Decision and Control

Proceedings of the 8th International FLINS Conference

Da Ruan
Javier Montero
Jie Lu
Luis Martínez
Pierre D'hondt
Etienne E Kerre
editors

World Scientific

World Scientific Proceedings Series on Computer Engineering and Information Science contains proceedings from major, peer-reviewed computer science, engineering, information technology and social science conferences with up-to-date coverage of new developments, methodologies and applications of new computer information-processing methods such as artificial intelligence, soft computing, computational intelligence, as complementary to traditional mathematical and statistical methods in Computer Engineering and Information Science.

Computational Intelligence in Decision and Control

FLINS, originally an acronym for Fuzzy Logic and Intelligent Technologies in Nuclear Science, is now extended to Computational Intelligence for applied research. The contributions to the eighth edition in the series of FLINS conferences cover state-of-the-art research, development, and technology for computational intelligence systems in general, and for intelligent decision and control in particular.

World Scientific
www.worldscientific.com
6802 hc

9 789812 799463

World Scientific Proceedings Series on Computer Engineering and Information Science

Series Editor: Da Ruan *(Belgian Nuclear Research Centre (SCK•CEN) & Ghent University, Belgium*

Vol. 1: Computational Intelligence in Decision and Control
edited by Da Ruan, Javier Montero, Jie Lu, Luis Martínez, Pierre D'hondt and Etienne E. Kerre

World Scientific Proceedings Series on
Computer Engineering and Information Science 1

Computational Intelligence in Decision and Control

Proceedings of the 8th International FLINS Conference

Madrid, Spain 21 – 24 September 2008

editors

Da Ruan
Belgian Nuclear Research Centre (SCK•CEN) & Ghent University, Belgium

Javier Montero
Complutense University of Madrid, Spain

Jie Lu
University of Technology, Sydney, Australia

Luis Martínez
University of Jaén, Spain

Pierre D'hondt
Belgian Nuclear Research Centre (SCK•CEN), Belgium

Etienne E Kerre
Ghent University, Belgium

World Scientific

Published by

World Scientific Publishing Co. Pte. Ltd.
5 Toh Tuck Link, Singapore 596224
USA office: 27 Warren Street, Suite 401-402, Hackensack, NJ 07601
UK office: 57 Shelton Street, Covent Garden, London WC2H 9HE

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.

World Scientific Proceedings Series on Computer Engineering and Information Science — Vol. 1
COMPUTATIONAL INTELLIGENCE IN DECISION AND CONTROL
Proceedings of the 8th International FLINS Conference

ISBN-13 978-981-279-946-3
ISBN-10 981-279-946-X

Printed in Singapore by B & JO Enterprise

Foreword

FLINS, an acronym originally for **F**uzzy **L**ogic and **I**ntelligent Technologies in **N**uclear **S**cience (1994), has been launched in line with the Belgian Nuclear Research Centre (SCK•CEN)'s objective to give PhD and Postdoc researchers the opportunity to carry out future-orientated research. FLINS was initially built within one of the above-mentioned postdoc positions. Now fourteen years later FLINS has been extended to *Computational Intelligence in Decision and Control* (2008) to advance the theory and applications of decision making and control for complex systems related research in particular. FLINS'08 is the eighth in a series of conferences on computational intelligence systems. It follows the successful FLINS'94 in Mol, FLINS'96 in Mol, FLINS'98 in Antwerp, FLINS'00 in Bruges, FLINS'02 in Gent, FLINS'04 in Blankenberge, Belgium, and FLINS'06 in Genova, Italy. FLINS'08 in Madrid, Spain, once again aims at covering state-of-the-art research and development in all aspects related to *Computational Intelligence in Decision and Control*. The principal missions of FLINS are: (1) conducting research on computational intelligence systems for solving intricate problems pertaining to nuclear/power research and related complex systems; (2) bridging the gap between machine intelligence and complex systems via joint research with Belgian, European, and international research institutes and universities; and (3) encouraging interdisciplinary research and bringing multi-discipline researchers together via the international FLINS conferences on computational intelligence systems.

FLINS'08, organized by Complutense University, Madrid, Spain, co-sponsored by the Belgian Nuclear Research Centre (SCK•CEN), Ghent University (UGent) in Belgium, Complutense University, Technical University of Madrid and the Government of Spain, and co-supported by University of Alcalá de Henares, the Interdisciplinary Institute of Mathematics of Madrid (IMI), European Centre for Soft Computing in Spain and European Society for Fuzzy Logic and Technology (EUSFLAT), offers a unique international forum to present and discuss techniques that are new and promising for *Computational Intelligence in Decision and Control* and to launch international co-operations.

The FLINS'08 proceedings consist of a series of invited lectures by distinguished professors and individual presentations, in a total of 184 papers selected out of 292 regular submissions plus 6 invited plenary and semi-plenary papers from 35 countries. The 3 plenary lectures are: (a) *Soft computing applications in prognostics and health management* by Piero Bonissone (General Electric, USA), (b) *Knowledge sharing and collaboration in fuzzy* *processing* by Witold Pedrycz (University of Alberta, Canada), (c) *Why do fuzzy representations need a careful design* by Enric Trillas (European Centre for Soft Computing, Spain), and the 3 semi-plenary lectures are: (d) *SCK•CEN: The Belgian Nuclear Research Centre research towards a sustainable option* by Pierre D'hondt (SCK•CEN, Belgium), (e) *New information processing methods for control in magnetically confinement nuclear fusion* by Andrea Murari (Consorzio RFX/ENEA EURATOM, Spain), (f) *What is Soft Computing? Revisiting possible answers* by Luis Magdalena (European Institute for Soft Computing, Spain). Each of the 6 invited papers is embedded as the first paper in the 6 contributed parts, respectively, in the proceedings: (I) Data Analysis and Information Processing, (II) Knowledge Representation and Learning, (III) Classification, Clustering, and Aggregation Techniques, (IV) Decision Making and Risk Analysis, (V) Decision Support Systems and Web Intelligence, and (VI) Control and Industrial Applications.

We are pleased to announce the launch of a new international journal on *Computational Intelligence Systems* in line with FLINS activities by Atlantis Press in Paris. The journal will also publish selected and extended papers from FLINS'08 in the near future. At the same time, we are happy to embed the FLINS'08 proceedings into the World Scientific Proceedings Series on *Computer Engineering and Information Science.*

Thanks are due to all contributors, referees, regular and invited sessions' chairs, and program committee members of FLINS'08 for their kind co-operation and enthusiasm for FLINS'08; to Pierre D'hondt and Etienne Kerre for their roles as FLINS advisors and program chairs of FLINS'08; to Jie Lu and Luis Martínez for their co-working as program co-chairs of FLINS'08; to Javier Montero (the local organization chair of FLINS'08 in Madrid) for his great leadership and efforts to make FLINS'08 a success and to the whole team of the local organization, including L. Garmendia, V. López, J.A. Martín, S. Muñoz, T. Ortuño, M. Santos, G. Tirado, J. Yáñez, especially to D. Gómez and B. Vitoriano for both of their key roles that made the proceedings of FLINS'08 possible in a timely manner, and to Chelsea Chin (Editor, World Scientific) for her kind advice and help to publish this volume.

Da Ruan, FLINS'08 General Chair
Mol & Gent, May 2008

CONTENTS

A SELECTION PROCESS TO DEAL WITH INCOMPLETE FUZZY PREFERENCE RELATIONS IN A 2-TUPLE FUZZY LINGUISTIC APPROACH

F. J. CABRERIZO[†], S. ALONSO[*], E. HERRERA-VIEDMA[†] and F. HERRERA[†]

[*]*Department of Software Engineering*
[†]*Department of Computer Science and Artificial Intelligence*
University of Granada, 18071, Granada, Spain
E-mail: cabrerizo@decsai.ugr.es, zerjioi@ugr.es, {viedma,herrera}@decsai.ugr.es

F. CHICLANA

Centre for Computational Intelligence, School of Computing
De Montfort University, Leicester LE1 9BH, UK.
E-mail: chiclana@dmu.ac.uk

When we deal with group decision making (GDM) situations with incomplete preference relations, there exist cases in which the classical selection procedure (aggregation and exploitation) could not be applied satisfactorily. For example, we could find that some preference degrees of the collective preference relation cannot be computed in the aggregation phase and consequently, the ordering of some alternatives cannot be computed in the exploitation phase. To overcome this problem, we present a selection process for GDM with incomplete 2-tuple fuzzy linguistic preference relations that requires three phases: (1) estimation phase of missing values, (2) aggregation phase and (3) exploitation phase.

Keywords: fuzzy linguistic preference relations, group decision making, selection process, incomplete information, consistency

1. Introduction

In Group Decision-Making (GDM) problems there are a set of alternatives to solve a problem and a group of experts trying to achieve a common solution. Since each expert has his/her own experience concerning the problem being studied, there may be cases where an expert would not be able to express the preference degree between two or more of the available options. This may be due to an expert not possessing a precise or sufficient level of knowledge of the problem, or because that expert is unable to discriminate the degree to which some options are better than others.

The aim of this paper is to present a selection procedure to deal with incomplete fuzzy preference relations in a 2-tuple fuzzy linguistic approach[1] because it provides some advantages with respect to the ordinal fuzzy linguistic modelling.[2] To do so, we include a complete procedure to complete the fuzzy linguistic preference relations. It is based on the linguistic extension of Tanino's consistency principle and makes use of all the estimation possibilities that derive from it.

To do it, the paper is set out as follows. In Section 2, we present the preliminaries. Section 3 introduces the estimation procedure of missing values. In Section 4, the selection process is presented. Section 5 shows a practical example. Finally, in Section 6 we draw our conclusions.

2. Preliminaries

2.1. *Incomplete 2-tuple fuzzy linguistic preference relations*

The 2-tuple linguistic model[1] takes as a basis the symbolic representation model and in addition defines the concept of symbolic translation to represent the linguistic information by means of a pair of values called linguistic 2-tuple, (s, α), where s is a linguistic term and α is a numeric value representing the symbolic translation.

Definition 2.1. Let $\beta \in [0, g]$ be the result of an aggregation of the indexes of a set of labels assessed in a linguistic term set $S = \{s_0, s_1, \ldots, s_{g-1}, s_g\}$, i.e., the result of a symbolic aggregation operation. Let $i = round(\beta)$ and $\alpha = \beta - i$ be two values, such that, $i \in [0, g]$ and $\alpha \in [-0.5, 0.5)$, then α is called a symbolic translation.

Based on the symbolic translation concept, a linguistic representation model which represents the linguistic information by means of 2-tuples (s_i, α_i), $s_i \in S$ and $\alpha_i \in [-0.5, 0.5)$ was developed.[1] This model defines a set of transformation functions between numerical values and 2-tuples (Δ) and viceversa (Δ^{-1}) (see[1] for more details).

Definition 2.2. A 2-tuple fuzzy linguistic preference relation (FLPR) P on a set of alternatives X is a set of 2-tuples on the product set $X \times X$, i.e., it is characterized by a membership function $\mu_P\colon X \times X \longrightarrow S \times [-0.5, 0.5)$. If it is not possible to give the 2-tuples for every pair of alternatives we have an *incomplete 2-tuple FLPR*.

2.2. *Linguistic additive consistency*

In this paper, we assume that experts can provide inconsistent opinions. However, some properties about the preferences expressed by the experts are usually assumed desirable to avoid contradictions in their opinions, that is, to avoid inconsistent opinions. One of them is *additive transitivity*, which was defined for fuzzy preference relations[3,4] as:

$$(p_{ij} - 0.5) + (p_{jk} - 0.5) = (p_{ik} - 0.5) \quad \forall i, j, k \in \{1, \dots, n\} \tag{1}$$

This additive transitivity property can be rewritten for 2-tuple FLPR as:

$$\Delta[(\Delta^{-1}(p_{ij}) - \Delta^{-1}(s_{g/2}, 0)) + (\Delta^{-1}(p_{jk}) - \Delta^{-1}(s_{g/2}, 0))] = \Delta[(\Delta^{-1}(p_{ik}) - \Delta^{-1}(s_{g/2}, 0)] \tag{2}$$

3. Estimating missing values for incomplete 2-tuple FLPR

3.1. *Estimating linguistic values based on the linguistic additive consistency*

Expressions (1), (2) can be used to estimate a linguistic preference value p_{ik} $(i \neq k)$ using an intermediate alternative x_j in three different ways:

$$(cp_{ik})^{j1} = \Delta(\Delta^{-1}(p_{ij}) + \Delta^{-1}(p_{jk}) - \Delta^{-1}(s_{g/2}, 0)) \tag{3}$$

$$(cp_{ik})^{j2} = \Delta(\Delta^{-1}(p_{jk}) - \Delta^{-1}(p_{ji}) + \Delta^{-1}(s_{g/2}, 0)) \tag{4}$$

$$(cp_{ik})^{j3} = \Delta(\Delta^{-1}(p_{ij}) - \Delta^{-1}(p_{kj}) + \Delta^{-1}(s_{g/2}, 0)) \tag{5}$$

3.2. *An estimation procedure of missing values in 2-tuple FLPR*

To manage incomplete 2-tuple FLPR, we use the following sets:[5] $A = \{(i,j) \mid i, j \in \{1, \dots, n\} \wedge i \neq j\}$, $MV = \{(i,j) \in A \mid p_{ij} \textit{ is unknown}\}$ and $EV = A \setminus MV$. Expressions (3), (4) and (5) are used to define an iterative estimation procedure of missing values in an incomplete 2-tuple FLPR according to the following two steps:

A) Elements to be estimated in step h

$$EMV_h = \{(i,k) \in MV \setminus \textstyle\bigcup_{l=0}^{h-1} EMV_l \mid \exists j \in \{H_{ik}^{h1} \cup H_{ik}^{h2} \cup H_{ik}^{h3}\}\}$$

where

$$H_{ik}^{h1} = \{j \mid (i,j), (j,k) \in \{EV \textstyle\bigcup_{l=0}^{h-1} EMV_l\}\}$$
$$H_{ik}^{h2} = \{j \mid (j,i), (j,k) \in \{EV \textstyle\bigcup_{l=0}^{h-1} EMV_l\}\}$$
$$H_{ik}^{h3} = \{j \mid (i,j), (k,j) \in \{EV \textstyle\bigcup_{l=0}^{h-1} EMV_l\}\}$$

B) Expression to estimate a particular missing value

function estimate_p(i,k)

1) $cp_{ik}^1 = (s_0, 0)$, $cp_{ik}^2 = (s_0, 0), cp_{ik}^3 = (s_0, 0)$, $\mathcal{K} = 0$

2) $cp_{ik}^1 = \Delta\left(\dfrac{\sum_{j \in H_{ik}^{h1}} \Delta^{-1}(cp_{ik}^{j1})}{\#H_{ik}^{h1}}\right)$, $\mathcal{K}{+}{+}$ *if* $H_{ik}^{h1} \neq \emptyset$.

3) $cp_{ik}^2 = \Delta\left(\dfrac{\sum_{j \in H_{ik}^{h2}} \Delta^{-1}(cp_{ik}^{j2})}{\#H_{ik}^{h2}}\right)$, $\mathcal{K}{+}{+}$ *if* $H_{ik}^{h2} \neq \emptyset$.

4) $cp_{ik}^3 = \Delta\left(\dfrac{\sum_{j \in H_{ik}^{h3}} \Delta^{-1}(cp_{ik}^{j3})}{\#H_{ik}^{h3}}\right)$, $\mathcal{K}{+}{+}$ *if* $H_{ik}^{h3} \neq \emptyset$.

5) Calculate $cp_{ik} = \Delta\left(\frac{1}{\mathcal{K}}(\Delta^{-1}(cp_{ik}^1) + \Delta^{-1}(cp_{ik}^2) + \Delta^{-1}(cp_{ik}^3))\right)$

end function

4. A selection process to deal with incomplete fuzzy preference relations in a 2-tuple fuzzy linguistic approach

The goal of the selection process in GDM is to choose the best alternatives according to the opinions provided by the experts. A classical selection process consists of two different phases: *aggregation* and *exploitation*. However, there may be cases in which the above classical selection procedure could not be applied satisfactorily when we deal with GDM situations with incomplete preference relations. For instance, some preference degrees of the collective preference relation cannot be computed in the aggregation phase and consequently, the ordering of some alternatives cannot be computed in the exploitation phase. To overcome this problem, we present a selection process for GDM with incomplete 2-tuple FLPR that requires three phases:

1) *Estimation of missing information.* Each incomplete 2-tuple FLPR is completed using the estimation procedure presented in Section 3.

2) *Aggregation phase.* Once all the missing values in every incomplete 2-tuple FLPR have been estimated, we have to obtain the collective 2-tuple FLPR, $P^c = (p_{ik}^c)$, by means of an aggregation procedure. To do so, we define the following 2-tuple linguistic OWA operator:

Definition 4.1. A 2-tuple linguistic OWA operator of dimension n is a function $\phi : (S \times [-0.5, 0.5))^n \longrightarrow S \times [-0.5, 0.5)$, that has a weighting vector associated with it, $W = (w_1, \dots, w_n)$, with $w_i \in [0,1]$, $\sum_{i=1}^{n} w_i = 1$, and it is defined according to the following expression:

$$\phi_W(p_1, \dots, p_n) = \Delta(\sum_{i=1}^{n} w_i \cdot \Delta^{-1}(p_{\sigma(i)})) \tag{6}$$

where $p_i \in S \times [-0.5, 0.5)$ and being $\sigma : \{1, \dots, n\} \longrightarrow \{1, \dots, n\}$ a permutation defined on 2-tuple linguistic values, such that $p_{\sigma(i)} \geq p_{\sigma(i+1)}$, $\forall i = 1, \dots, n-1$, i.e., $p_{\sigma(i)}$ is the i-highest 2-tuple linguistic value in the set $\{p_1, \dots, p_n\}$, (see[1] for more details of the comparison of two 2-tuple linguistic values (s_k, α_1) and (s_l, α_2)).

A natural question in the definition of OWA operators is how to obtain W. In[6] it was defined an expression to obtain W that allows to represent the concept of fuzzy majority[7] by means of a fuzzy linguistic non-decreasing quantifier Q:[8] $w_i = Q(i/n) - Q((i-1)/n),\ \ i = 1, \dots, n$.

3) *Exploitation: Choosing the Solution Set.* In order to select the solution set of alternatives from the collective 2-tuple FLPR we use the quantifier guided dominance degree[9] $QGDD_i = \phi_Q(p^c_{i1}, \dots, p^c_{i(i-1)}, p^c_{i(i+1)}, \dots, p^c_{in})$.

5. Practical example

Let $X = \{x_1, x_2, x_3, x_4\}$ be a set of four alternatives and $S = \{N, MW, W, E, B, MB, T\}$ the set of linguistic labels. Suppose three experts $\{e_1, e_2, e_3\}$ provide the following incomplete 2–tuple FLPR:

$$P^1 = \begin{pmatrix} - & x & (W,0) & x \\ x & - & x & (MW,0) \\ (B,0) & x & - & (E,0) \\ x & (MB,0) & (E,0) & - \end{pmatrix}; P^2 = \begin{pmatrix} - & (MW,0) & (W,0) & (W,0) \\ (MB,0) & - & (MB,0) & (MB,0) \\ (E,0) & (MW,0) & - & (W,0) \\ (E,0) & (MW,0) & (E,0) & - \end{pmatrix}$$

$$P^3 = \begin{pmatrix} - & (MW,0) & x & x \\ (B,0) & - & (MB,0) & (MB,0) \\ (W,0) & x & - & (W,0) \\ (W,0) & (MW,0) & (B,0) & - \end{pmatrix}$$

(1) Estimation of missing information

$$P^1 = \begin{pmatrix} - & (B,0) & (W,0) & (W,0) \\ (W,0) & - & (MW,0) & (MW,0) \\ (B,0) & (MB,0) & - & (E,0) \\ (B,0) & (MB,0) & (E,0) & - \end{pmatrix}; P^3 = \begin{pmatrix} - & (MW,0) & (B,0) & (E,0) \\ (B,0) & - & (MB,0) & (MB,0) \\ (W,0) & (N,0) & - & (W,0) \\ (W,0) & (MW,0) & (B,0) & - \end{pmatrix}$$

(2) Aggregation phase. We make use of the linguistic quantifier *most of* defined as $Q(r) = r^{1/2}$, which generates a weighting vector of three values $W = (0.58, 0.24, 0.18)$ to obtain each p^c_{ik}.

$$P^c = \begin{pmatrix} - & (E,-0.26) & (E,0.16) & (E,-0.42) \\ (B,0.22) & - & (B,0.28) & (B,0.28) \\ (E,0.40) & (E,0.14) & - & (E,-0.42) \\ (E,0.40) & (E,0.32) & (B,-0.42) & - \end{pmatrix}$$

(3) Exploitation phase. Using again the same fuzzy quantifier *most of* and the corresponding weighting vector W, the following QGDD is obtained, $(QGDD_1, QGDD_2, QGDD_3, QGDD_4) = \{(E,-0.05), (B,0.27), (E,0.19), (E,0.49)\}$ and the solution is the alternative $\{x_2\}$.

6. Conclusions

We have proposed a selection procedure to deal with incomplete 2-tuple FLPR in a 2-tuple fuzzy linguistic approach using an additive consistency based procedure to estimate missing values which is able to be applied in situations where other consistency based linguistic approaches are not.

Acknowledgments

This paper has been developed with the financing of SAINFOWEB project (00602) and FUZZYLING project (TIN2007-61079).

References

1. F. Herrera and L. Martínez. A 2-tuple fuzzy linguistic representation model for computing with words. *IEEE Trans. on Fuzzy Systems*, 8(6):746-752, 2000.
2. F. Herrera and L. Martínez. The 2-tuple linguistic computational model. Advantages of its linguistic description, accuracy and consistency. *Int. J. of Unc., Fuzz. Knowledge-Based Syst.*, 92:33-48, 2001.
3. E. Herrera-Viedma, F. Herrera, F. Chiclana and M. Luque. Some issues on consistency of fuzzy preference relations. *Eur. J. Oper. Res.*, 154:98–109, 2004.
4. T. Tanino. Fuzzy preference orderings in group decision making. *Fuzzy Sets and Systems*, 12:117-131, 1984.
5. E. Herrera-Viedma, F. Chiclana, F. Herrera and S. Alonso. A group decision-making model with incomplete fuzzy preferece relations based on additive consistency. *IEEE T. Sys., Man, and Cyb., Part B: Cyb.*, 37(1):176-189, 2007.
6. R.R. Yager: On ordered weighted averaging aggregation operators in multicriteria decision making. *IEEE Trans. on Sys., Man, Cyb. Part A: Systems and Humans* 18:183-190, 1988.
7. J. Kacprzyk: Group decision making with a fuzzy linguistic majority. *Fuzzy Sets and Systems* 18:105-118, 1986.
8. L.A. Zadeh: A computational approach to fuzzy quantifiers in natural languages. *Computers and Mathematics with Applications* 9:149-184, 1983.
9. F. Herrera and E. Herrera-Viedma. Choice functions and mechanisms for linguistic preference relations. *Eur. J. Oper. Res.*, 120:144-161, 2000.