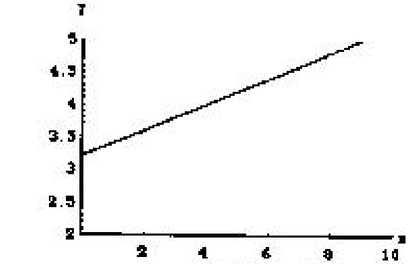
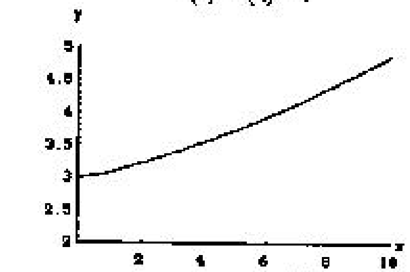
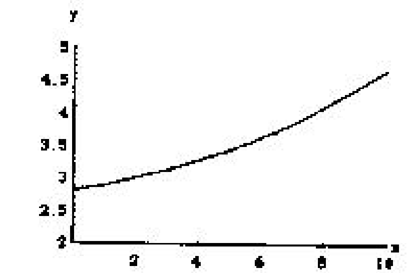


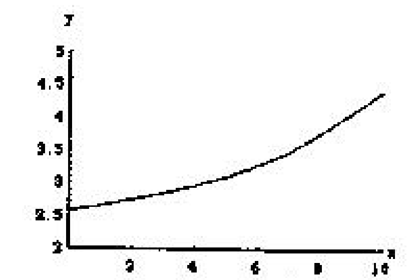
(a) : h(x) = 1



(b) : h(x) = ½ √x + ½



(c) h(x) = ½ x + ½



(d) : h(x) = ½ x² + ½

figure 3 : Aggregation of 5 data : σ(1,x,7,5,3) with different h functions and distinguished value : 10.

On these examples that correspond to optimistic cases, we see the influence of the h function. The more optimistic it is, that is to say the weight of high values is given more importance, the greater the result of the fusion is.

Conclusion

Our new class of aggregation operators allows to choose the most convenient aggregator with respect to the kind of reasoning to be adopted up to the context (economy, decision taking, ...)
It is different from the previous classes of aggregation operators because of the introduction of weights as function of the concerned variables (not fixed weight). Further investigations about these aggregation operators will be made in the near future.

References

[1] R. Yager - Connectives and quantifiers in fuzzy sets - Fuzzy Sets and Systems n°40 - 1991 - p. 39-75.

[2] D. Dubois, H. Prade - A review of fuzzy sets aggregation connectives - Inform. Sci. - n°36 - 1985 - p. 85-121.

[3] R. Yager - Aggregation operators and fuzzy systems modeling - Fuzzy Sets and Systems - n°67 - 1994 - p.129-145.

(90)

On the Computational Complexity of Computing Fuzzy Rationality Degrees.

Vincenzo CUTELLO
Department of Mathematics
University of Catania
Catania, Italy and Javier MONTERO
Faculty of Mathematics
Complutense University
Madrid, Spain and Giuseppe SORACE
Department of Mathematics
University of Catania
Catania, Italy

Abstract

An axiomatic basis for Fuzzy Rationality measures has already been introduced in [5,4,6], formalizing the fact that there exist degrees of consistency when preferences over a fixed set of alternatives are expressed in terms of fuzzy binary preference relations. Moreover, similarities and compositions of fuzzy rationality measures have been considered, showing natural ways of deriving new measures. In this paper we discuss upon a problem related with the fuzzy rationality measures and the feasibility of their use in real life applications. Indeed, some of the rationality measures proposed, though intuitively (and axiomatically) sound, appear to be quite complex from a computational point of view.

Keywords: aggregation rules, fuzzy preferences, decision making.

1 Introduction

This paper continues the scientific investigation started in [2,4,5,6]. Our main goal is to study the computational complexity of using fuzzy rationality measures. We recall that such measures represent criteria that can be used to evaluate the degree of rationality which can be associated to individuals expressing their opinions over arbitrary finite set of alternatives.

Given a set of alternatives X, we assume that the strength of preferences is modeled according to a fuzzy binary relation defined on X (see [28] and [7,11,12,20,30] for an extensive introduction). That is, a mapping $\mu : X \times X \to [0,1]$ where each value $\mu(x,y)$ means the intensity value to which alternative y is "not worse" than alternative x.

In particular, μ is understood as the *weak fuzzy preference*, with a *strict* and an *indifference part*. Reflexivity ($\mu(x,x) = 1$ for all x) is therefore implied. Moreover, we shall be assuming here that such a measure of intensity of preference μ is defined on an absolute scale.

This strict cardinal framework is indeed a strong assumption, but it has been justified in the past by some authors, within some particular context (see [29], for example).

Without such an assumption, many operations on preferences may not be meaningful at all. Addition and subtraction on intensities of preference need an interval scale at least, and multiplication requires that intensities are measured at least on a ratio scale (see [1,19,24] for an extensive discussion on measurement theoretic aspects of fuzzy sets).

Following [5] we shall assume that X is finite and that every μ is complete, in the sense that

$$\mu(x,y) + \mu(y,x) \geq 1, \forall x, y \in X$$

Notice that the above is not the only definition for completeness of a fuzzy binary relation that can be found in the literature (see, e.g [11]).

Let us denote by $\mathcal{P}(X)$ the family of all possible complete fuzzy binary relations on X. Obviously, $\mu \in \mathcal{P}(X)$ will be a crisp (complete) binary relation whenever $\mu(x,y) \in \{0,1\}, \forall x,y \in X$. In this case, an alternative x will be respectively strictly better (xBy), indifferent (xIy) or strictly worse (xWy) than alternative y when

- $\mu(x,y) = 1, \mu(y,x) = 0$;
- $\mu(x,y) = 1, \mu(y,x) = 1$;
- $\mu(x,y) = 0, \mu(y,x) = 1$.

Since μ is complete, the values

- $\mu_B(x,y) = 1 - \mu(y,x)$
- $\mu_I(x,y) = \mu(x,y) + \mu(y,x) - 1$
- $\mu_W(x,y) = 1 - \mu(x,y)$

can respectively be understood as the degrees to which xBy, xIy and xWy.

Hence,

$$\mu_B(x,y) + \mu_I(x,y) + \mu_W(x,y) = 1$$

holds for all $x,y \in X$ (see [14,15,16]; see also [10] for an axiomatic justification within a more general context, and [18] in order to check alternative conditions generating the above particular solution). The total strength of preference is in this way consistently splitted into both strict preferences and indifference.

An axiomatic characterization for the general notion of *rationality* measure has been given in [2,5]. Moreover, in [4,6] the concept of equivalence among rationality measures was introduced along with closure results under classical aggregation operators such as T-norms, T-conorms and Yager's OWA operators and conditions under which logical aggregation operators generate new fuzzy rationality measures.

2 Fuzzy rationality measures

Many measures for individual rationality have been proposed in the past. In the case in which the relations are crisp, i.e. $\mu(x,y) \in \{0,1\}$ for all $x,y \in X$, rationality has sometimes been considered equivalent to the idea of linear order (i.e., preferences over a fixed set of alternatives are consistent if and only they define a complete reflexive and transitive crisp binary relation); alternatively, rationality has also been characterized with the absence of strict cycles (see [21,23]). In the context of fuzzy binary preference relations, a standard assumption to characterise rationality is max-min transitivity [28].

Under this hypothesis if x is better than y with intensity $\mu(x,y)$ and y is better than z with intensity $\mu(y,z)$ then the degree to which x is better than z, i.e. $\mu(x,z)$, can never be lower than both values $\mu(x,y)$ and $\mu(y,z)$. However, the property of being max-min transitive is crisp, that is each relation either is or is not max-min transitive. Therefore, assuming max-min transitivity as key property for rationality does not allow a fuzzy classification.

This fuzzy classification of individuals is obtained if one uses the rationality measure given in [14,15,16]. Such a measure was initially introduced in order to formalize the problem of *rational* aggregation rules in group decision making (see [3] for a characterization of such *rational* aggregation rules).

In [5] rationality measures are formally characterized as maps of type $\rho : \mathcal{P} \to [0,1]$ where

$$\mathcal{P} = \bigcup_{X \text{ finite}} \mathcal{P}(X)$$

and a set of conditions that any fuzzy rationality measure must satisfy is introduced. Such conditions are the following ones:

(R1) $\rho(\mu) = 1$ for any μ defining a crisp strict chain on X (i.e., there are no two distinct indifferent alternatives, and transitivity holds for crisp strict preference relation B).

(R2) Given $\mu \in \mathcal{P}$ and a permutation $\pi : X \to X$ then

$$\rho(\mu^\pi) = \rho(\mu)$$

where $\mu^\pi(x,y) = \mu(\pi(x),\pi(y))$ for all $x,y \in X$.

(R3) For all $\mu \in \mathcal{P}$, $\rho(\neg\mu) = \rho(\mu)$, where $\neg\mu(x,y) = \mu(y,x)$ for all $x,y \in X$.

(R4) Let Y be a non-empty finite set of alternatives and let z be an extra alternative not belonging to Y. Let us consider a fuzzy preference $\mu : Y \times Y \to [0,1]$ such that $\mu(y,z) = 1, \mu(z,y) = 0, \forall y \in Y_1, \forall z \in Y_2$ for some Y_1, Y_2 partition of Y, and an extension μ' such that

$$\mu'(y,x) = \mu(y,x), \forall y,x \in Y$$
$$\mu'(y,z) = 1, \mu'(z,y) = 0, \forall y \in Y_1$$
$$\mu'(z,x) = 1, \mu'(x,z) = 0, \forall x \in Y_2$$
$$\mu'(z,z) = 1$$

Then it must be $\rho(\mu') \geq \rho(\mu)$.

(R5) Let $\mu \in \mathcal{P}(X)$ be fixed. Given an arbitrary ordered pair of alternatives $(\bar{x},\bar{y})$, an arbitrary point $(\bar{a},\bar{b}) \in [0,1] \times [0,1]$, and real numbers γ and λ such that $0 \leq \bar{a} + \lambda\cos\gamma \leq 1$, $0 \leq \bar{b} + \lambda\sin\gamma \leq 1$ and $\bar{a} + \bar{b} + \lambda(\sin\gamma + \cos\gamma) \geq 1$, we denote by $\Gamma^*(\lambda) \equiv \Gamma_\mu((\bar{x},\bar{y}),(\bar{a},\bar{b}),\gamma,\lambda)$ the fuzzy preference relation defined as

$$\Gamma^*(\lambda)(x,y) = \begin{cases} \bar{a} + \lambda\cos\gamma & \text{if } (x,y) = (\bar{x},\bar{y}) \\ \bar{b} + \lambda\sin\gamma & \text{if } (x,y) = (\bar{y},\bar{x}) \\ \mu(x,y) & \text{otherwise} \end{cases}.$$

Then, one of the following three properties must be verified by ρ.

(R5.1) $\rho(\Gamma^*(\lambda))$ is monotone, i.e. either

$$\rho(\Gamma^*(\lambda)) \leq \rho(\Gamma^*(\lambda'))$$

for any $\lambda \leq \lambda'$ or

$$\rho(\Gamma^*(\lambda)) \geq \rho(\Gamma^*(\lambda'))$$

for any $\lambda \leq \lambda'$.

(R5.2) there is no value λ such that

$$\begin{aligned} \rho(\Gamma^*(\lambda_1)) &> \rho(\Gamma^*(\lambda)) \\ \rho(\Gamma^*(\lambda)) &< \rho(\Gamma^*(\lambda_2)) \end{aligned}$$

for some λ_1, λ_2 such that $\lambda_1 < \lambda < \lambda_2$.

(R5.3) There is no value λ such that

$$\begin{aligned} \rho(\Gamma^*(\lambda_1)) &< \rho(\Gamma^*(\lambda)) \\ \rho(\Gamma^*(\lambda)) &> \rho(\Gamma^*(\lambda_2)) \end{aligned}$$

for some λ_1, λ_2 such that $\lambda_1 < \lambda < \lambda_2$.

See [5,6] for more comments on the above given conditions.

We then have the following definition.

DEFINITION 2.1 *Any mapping*

$$\rho : \mathcal{P} \to [0,1]$$

is a

1. normal fuzzy rationality measure *if it verifies conditions (R1)-(R5.1);*
2. pessimistic fuzzy rationality measure *if it verifies conditions (R1)-(R5.2),*
3. optimistic fuzzy rationality measure *if it verifies conditions (R1)-(R5.3).*

□

Obviously, a fuzzy rationality measure is normal if and only if it is simultaneously pessimistic and optimistic.

We will now give some examples of fuzzy rationality measures and study their computational complexities. See [5] for complementary examples.

2.1 A binary fuzzy rationality measure

In this case just two types of fuzzy binary preference relations are allowed: absolutely consistent and absolutely non consistent. As a consequence, *rationality* turns out to be a crisp concept applied to fuzzy objects (i.e., *preferences*). It is perhaps surprising, but most of the *consistency* criteria for fuzzy preferences that can be found in the literature are crisp in this sense. They do not allow a fuzzy classification and therefore small measurement errors may cause extreme changes in the qualification relative to rationality. As a consequence these binary rationality measures are basically unacceptable for real applications. In some cases (see, e.g., [17]) it is proposed a search for some alternative *consistent* fuzzy binary preference relation. The idea would be to capture measurement errors of the decision maker, in such a way that alterations on value assignments are small and the decision maker accepts such a new preference relation as *close enough* to his/her initial preference relation.

The standard binary rationality measure is *max-min transitivity*: a fuzzy binary preference relation $\mu : X \times X \to [0,1]$ is max-min transitive if and only if $\mu(x,z) \geq \min(\mu(x,y),\mu(y,z)), \forall x,y,z \in X$. That is, a fuzzy preference relation μ is max-min transitive if whenever x is better than y with intensity $\mu(x,y)$ and y is better than z with intensity $\mu(y,z)$, then the degree to which x is better than z, i.e. $\mu(x,z)$, can never be lower than both values $\mu(x,y)$ and $\mu(y,z)$. In our context, max-min transitivity leads to the following fuzzy rationality measure.

$$\rho_{mm}(\mu) = \begin{cases} 1 & \text{if } \mu \text{ is max-min transitive} \\ 0 & \text{otherwise} \end{cases}$$

Such a mapping ρ_{mm} was proven to be a *pessimistic* fuzzy rationality measure (see [5]).

Though semantically such a rationality measure is quite unsatisfactory, from a computational point of view is instead a good example. Indeed, as it can easily be seen, the value of $\rho_{mm}(\mu)$ can be computed in time $O(|X|^3)$.

2.2 A discrete fuzzy rationality measure

The example that follows is based upon Orlovsky's choice set of unfuzzy nondominated alternatives. For any arbitrary non-empty subset Y of alternatives we define

$$Y^\mu_{UND} = \{x \in Y | \mu(x,y) \geq \mu(y,x), \forall y \in Y\}$$

for any given fuzzy preference $\mu : X \times X \to [0,1]$. Then the following map is an optimistic fuzzy rationality measure (see also [5]):

$$\begin{aligned} \rho_N(\mu) &= 0 \text{ if } \exists Y^\mu_{UND} = \emptyset, \text{ for some } Y \neq \emptyset \\ &= \min\{\frac{1}{|Y^\mu_{UND}|} / Y^\mu_{UND} \neq \emptyset\} \text{ otherwise} \end{aligned}$$

The problem of computing such a rationality measures can be rewritten in a graph-theoretical manner. Given μ and X we can build a graph G_μ whose vertices are the elements of X and such that there exists an edge from x to y if and only if $\mu(x,y) > \mu(y,x)$. We then have

PROPOSITION 2.1 $\rho_N(\mu) = 0$ *if and only if there exists a cycle in* G_μ. ■

As a consequence, it is relatively easy to check whether μ is absolutely irrational. However, once we know that there are no cycles in G_μ, computing the value of $\rho_N(\mu)$ becomes a computationally hard problem. Indeed, the following holds

PROPOSITION 2.2 *Lets K be a given a positive integer. Then*

$$\rho_N(\mu) \leq \frac{1}{K}$$

if and only if G_μ has an independent set of size K or more. ■

We recall that an independent set is a subset of vertices such that no two vertices in it are connected by an edge. Moreover, it is well known that the problem of deciding whether a graph has an independent set of size K or more belongs to the class of NP-complete problems. If we introduce the following definition

DEFINITION 2.2 *We shall say that a fuzzy rationality measure is computationally hard if given any $0 \leq r \leq 1$ and fuzzy preference relation μ the problem of deciding whether $\rho(\mu) \geq r$ is NP-hard.* □

then we have that ρ_N is computationally hard.

2.3 Polynomial Constructability

We end this section by remarking a property of the fuzzy rationality measure ρ_N which will be used later on. Given any positive integer K it is possible in polynomial time to produce a fuzzy preference relation μ such that $\rho_N(\mu) = \frac{1}{K}$. By using the graph G_μ, we build a graph on X with a maximum indipendent set of size K as follows:

- choose randomly a set Y of K vertices;
- add an edge from each vertex of Y to each vertex not in Y;
- if $K \geq \frac{|X|}{3}$ then stop, else recursively, build a graph on $X \setminus Y$ with an indipendent set of size K.

DEFINITION 2.3 *A fuzzy rationality measure ρ is (polynomially) constructible if there exists a (polynomial) algorithm which given any number $0 \leq r \leq 1$ decides whether there exists μ such that $\rho(\mu) = 1$ and it outputs an example.* □

Obviously, ρ_N is polynomially constructible.

3 Similarities

In practice, two fuzzy rationality measures can be considered equivalent if they always agree when comparing individual rationalities, from a qualitative point of view. In this case, it can sometimes be considered that discrepance between both rationality measures is just due to different underlying scales. We can therefore introduce the following definition:

DEFINITION 3.1 *Given two fuzzy rationality measures ρ_1 and ρ_2 we will say that ρ_1 and ρ_2 are equivalent if and only if for any pair of individuals μ_1 and μ_2, $\rho_1(\mu_1) \geq \rho_1(\mu_2)$ if and only if $\rho_2(\mu_1) \geq \rho_2(\mu_2)$.* □

It is easy to see that the above definition is indeed an equivalence relation. Moreover, any two equivalent fuzzy rationality measures are based on the same idea of rationality as expressed by condition (R1). Indeed, the following theorem holds.

THEOREM 3.1 *If ρ_1 and ρ_2 are equivalent then $\rho_1(\mu) = 1$ if and only if $\rho_2(\mu) = 1$.*

Obviously, the converse of the above theorem does not hold in general.

An immediate characterization of equivalence among fuzzy rationality measures is given by the following theorem.

THEOREM 3.2 *Let $\rho_1 : \mathcal{P} \rightarrow [0,1]$ be a fuzzy rationality measure. Then $\rho_2 : \mathcal{P} \rightarrow [0,1]$ is an equivalent fuzzy rationality measure if and only if there exists a strictly increasing function $f : [0,1] \rightarrow [0,1]$ such that*

- $f(1) = 1$;
- $\rho_2 \equiv f \circ \rho_1$, *i.e. for all μ, $\rho_2(\mu) = f(\rho_1(\mu))$.*

From the above result we have

COROLLARY 3.1 *Let ρ_1, ρ_2 be two equivalent fuzzy rationality measures. Then they are either pessimistic or optimistic (or both).*

In an attempt to bypass the hardness problem such as the one above seen, one may think to find a rationality measure, equivalent to a given computationally hard one but that instead can be computed easily. In fact, this approach is in general doomed to failure. Indeed the following hold

THEOREM 3.3 *Let ρ be a computationally hard fuzzy rationality measure. Suppose that ρ is polynomially constructible. Then, if ρ' is equivalent to ρ, is computationally hard as well.*

4 Final Remarks

Some basic results relative to the computational problem of computing the values of fuzzy rationality measures of fuzzy preferences have been developed in this paper. Future research should start from these results and on one hand try to generalize and complete them, while on the other hand use the results on good approximation algorithms for $\mathcal{NP}$-complete problems in order to produce results which can be used in practice.

Acknowledgements: This research has been partially supported by Dirección General de Investigación Científica y Técnica of Spain.

References

[1] T. Bilgi and I.B. Turksen. Measurement-theoretic justification of connectives in fuzzy set theory. Technical report.

[2] V. Cutello and J. Montero. An axiomatic approach to fuzzy rationality. In: K.C. Min, Ed., *IFSA'93* (Korea Fuzzy Mathematics and Systems Society, Seoul,1993), 634-636.

[3] V. Cutello and J. Montero. A characterization of rational amalgamation operations. *International Journal of Approximate Reasoning* 8:325-344 (1993).

[4] V. Cutello and J. Montero. Equivalence of Fuzzy Rationality Measures. In: H.J. Zimmermann, Ed., *EUFIT'93* (Elite Foundation, Aachen, 1993), vol. 1, 344-350.

[5] V. Cutello and J. Montero. Fuzzy rationality measures. *Fuzzy sets and Systems* 62:39-54 (1994).

[6] V. Cutello and J. Montero. Equivalence and Composition of Fuzzy rationality measures. *Fuzzy sets and Systems*, 1995. To Appear.

[7] D. Dubois and H. Prade. *Fuzzy Sets and Systems: Theory and Applications.* Academic Press, New York, 1980.

[8] P.C. Fishburn. *Interval Orders and Interval Graphs.* Wiley, New York, 1985.

[9] J.C. Fodor and M. Roubens. Preference modelling and aggregation procedures with valued binary relations. In: R. Lowen and M. Roubens, Eds., *Fuzzy Logic* (Kluwer Academic Press, Amsterdam, 1993), 29-38.

[10] J.C. Fodor and M. Roubens. Valued preference structures. *European Journal of Operational Research* 79:277-286 (1994).

[11] J.C. Fodor and M. Roubens. *Fuzzy Preference Modelling and Multicriteria Decision Support.* Kluwer Academic Pub., Dordrecht, 1994.

[12] L. Kitainik. *Fuzzy Decision Procedures with Binary Relations.* Kluwer Academic Pub., Boston, 1993.

[13] G.J. Klir and T.A. Folger. *Fuzzy sets, Uncertainty and Information.* Prentice Hall, Englewood Cliffs, NJ, 1988.

[14] J. Montero. Arrow's theorem under fuzzy rationality. *Behavioral Science*, 32:267-273 (1987).

[15] J. Montero. Social welfare functions in a fuzzy environment. *Kybernetes*, 16:241-245 (1987).

[16] J. Montero. Rational aggregation rules. *Fuzzy Sets and Systems* 62:267-276 (1994).

[17] J. Montero and J. Tejada. Some problems on the definition of fuzzy preference relations. *Fuzzy Sets and Systems*, 20:45-53 (1986).

[18] J. Montero, J. Tejada and V. Cutello. A general model for deriving preference strucutres from data. *European Journal of Operational Research*, to appear.

[19] A.M. Norwich and I.B. Turksen. A model for the measurement of membership and the consequences of its empirical implementation. *Fuzzy Sets and Systems*, 12:1-25 (1984).

[20] S.E. Orlovski. *Calculus of Decomposable Properties, Fuzzy Sets and Decisions.* Allerton Press, New York, 1994.

[21] P.K. Pattanaik. *Voting and collective choice.* Cambridge Univ. Press, Cambridge, 1971.

[22] F.S. Roberts. *Measurement Theory.* Addison-Wesley, Reading, MA., 1979.

[23] A.K. Sen. *Collective choice and social welfare.* Cambridge Univ. Press, Cambridge, 1971.

[24] I.B. Turksen. Measurement of membership functions and their acquisition. *Fuzzy sets and Systems*, 40:5-38 (1991).

[25] R.R. Yager. Connectives and quantifiers in fuzzy sets. *Fuzzy sets and Systems*, 40:39-75 (1991).

[26] R.R. Yager. On ordered weighted averaging aggregation operators in multi-criteria decision making. *IEEE Transactions on Systems, Man and Cybernetics*, 18:183-190 (1988).

[27] R.R. Yager. Families of owa operators. *Fuzzy sets and Systems*, 59:125-148 (1993).

[28] L.A. Zadeh. Similarity relations and fuzzy orderings. *Information Science*, 3:177-200 (1971).

[29] U. Thole, H.J. Zimmermann and P. Zysno. On the suitability of minimum and product operators for the intersection of fuzzy sets. *Fuzzy sets and Systems*, 2:167-180 (1979).

[30] H.J. Zimmerman. *Fuzzy Sets Theory and its Applications.* Kluwer-Nijhoff, Boston, 1985.

PROCEEDINGS

volume I

SIXTH INTERNATIONAL CONFERENCE

IPMU

INFORMATION PROCESSING
AND MANAGEMENT OF UNCERTAINTY
IN KNOWLEDGE-BASED SYSTEMS

Granada, July, 1 - 5 , 1996

I.S.B.N. Tomo: 84-8254-077-7
I.S.B.N. Obra Completa: 84-8254-076-9
D. Legal: GR-655/96
Impresión: Proyecto Sur de Ediciones

CHAIRPERSONS

Bernardette BOUCHON-MEUNIER (CNRS, France)
Miguel DELGADO (University of Granada, Spain)
José Luis VERDEGAY (University of Granada, Spain)
María Amparo VILA (University of Granada, Spain)
Ronald R. YAGER (Iona College, NY, USA)

HONORARY PRESIDENT

Lotfi A. ZADEH (University of California, Berkeley, USA)

INTERNATIONAL PROGRAM COMMITTEE

J. Aczel (Canada)
J. Aguilar-Martín (France)
J. Baldwin (UK)
S. Barro (Spain)
A. Blanco (Spain)
H. Berenji (USA)
J. Bezdek(USA)
P. Bonissone (USA)
P. Bosc (France)
J.L. Castro(Spain)
D. Dubois (France)
F. Esteva (Spain)
M. Fedrizzi (Italy)
M.A. Gil (Spain)
A. González (Spain)
S. Guiasu (Canada)
J. Gutiérrez (Spain)
F. Herrera (Spain)
K. Hirota(Japan)
J. Jacas (Spain)
J.Y. Jaffray (France)
J. Kacprzyk (Poland)
A. Kandel (USA)
E.P. Klement (Austria)
G. Klir (USA)
R. Kruse (Germany)
M.T. Lamata (Spain)
H.L. Larsen (Denmark)
S.L. Lauritzen (Denmark)
R. López de Mántaras (Spain)
R. Marín (Spain)
J. Montero (Spain)
S. Moral (Spain)
H. Nguyen (USA)
S. Ovchinnikov(USA)
J. Pearl (USA)
H. Prade(France)
I. Requena (Spain)
A. Rocha (Brazil)
E. Ruspini (USA)
A. Sage (USA)
E. Sanchez (France)
G. Shafer (USA)
P. Shenoy (USA)
P. Smets (Belgium)
M. Sugeno (Japan)
S. Termini (Italy)
A. Titli (France)
E. Trillas (Spain)
I.B. Turksen (Canada)
R. Valle (France)
L. Valverde (Spain)
T. Yamakawa (Japan)
H.J. Zimmermann (Germany)

ORGANIZING COMMITTEE

S. Moral (President)

A. Blanco
J.L. Castro
J.C. Cubero
A. González
F. Herrera
M.T. Lamata
J.M. Medina
O. Pons
I. Requena
J.M. Zurita