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Majority or Majorities?

by

Thierry Marchant
(thierry.marchant@ugent.be)
Ghent University

1. Introduction

It is common to read sentences like “*x* is better than *y* on a majority of criteria” or “a majority of voters prefer *x* to *y*”. What do such sentences precisely mean? Although the concept of majority, in everyday life, seems unproblematic and well understood by most people, some difficulties arise when we want to use it formally in MCDA, like in ELECTRE (Roy and Bouyssou, 1993), Melchior (Leclercq, 1984), PROCFTN (Belacel and Boulassel, 2004), TACTIC (Vansnick, 1986), VIKOR (Opricovic and Tzeng, 2004) or VIP-G (Dias and Climaco, 2005). The reason of these difficulties is mainly that it is not clear what the statement “*x* is better than *y*” means when, for some criteria, indifference is allowed. Suppose indeed that we have the following situation: *x* strictly better than *y* on three criteria, *y* strictly better than *x* on two criteria and *x* and *y* indifferent on two criteria. If we look only at strict preferences, then *x* is better than *y* on a majority of criteria (3 out of 5) but, if we look at all criteria, then *x* is better than *y* on a minority of criteria (3 out of 7). The problem is even more complex when qualified majorities, i.e. majorities with a threshold, are used. So, depending on the threshold that we use and on the way we take indifferences into account, there is not one majority but many : simple majority, absolute majority, weak majority, ... The aim of this paper is to present and compare some of them.

In section 2, we will introduce some notation and present some majorities that will be analyzed subsequently. We will limit our analysis to non-weighted majorities because our current understanding of weighted majorities is still limited and does not allow us to analyze all weighted majorities in a unified framework. Yet, we hope that a sound analysis of non-weighted majorities can help to enhance our understanding of the corresponding weighted majorities. We will also limit our analysis to neutral majorities. Non-neutral majorities are very common in committees and parliaments, where a proposition is often opposed to the status quo; If the proposition has the support of a majority (e.g. at least 60% of the deputees attending vote for the proposition), then the proposition passes. Otherwise, it is rejected (i.e. the status quo passes). With such a procedure, the two alternatives (the proposition and the status quo) are not treated equally: the status quo can pass with less than 60% of support. We say that such a procedure is not neutral. In multicriteria decision aiding, very often, we want to treat all alternatives equally. That is why we restrict our attention to neutral majorities. The reader interested in non-neutral majorities will have a look at (Fishburn,1973).

Section 3 will be devoted to the analysis of the majorities presented in section 2. We will show what they have in common but also what makes them different, what are their salient characteristics. With this information at hand, we hope that analysts or people designing new decision aiding techniques will be able to choose a majority that is adequate for their problem (if they want to use a majority at all). Section 4 will conclude.

The present paper is based on a more technical one (Marchant, 2005). The interested reader will also have a look at the abundant literature on voting theory. A good starter for this might be (Bouyssou et al., 2000, ch. 2) and (Bouyssou et al., 2006, ch. 5). Not to miss on simple majority: May, 1952.

2. An overview of the main majority rules

Suppose we have a decision problem for which we think n criteria are relevant. We represent these criteria by n natural numbers: 1, 2, …, n. And the set of criteria is denoted by N. In this paper, we consider problems in which, for each criterion, we have a preference relation, denoted by $\geq_i$, on the set of alternatives (finite and denoted by X). These preference relations can be directly expressed by the decision-maker or can be derived from a performance table using some preferential information or … but this is not the focus of this paper and we will assume that the preference relations are given. The statement "$x \geq_i y$" means "x is at least as good as y on criterion i". If $x \geq_i y$ and NOT $y \geq_i x$, then x is strictly better than y and we write $x >_i y$. If $x \geq_i y$ and $y \geq_i x$, then x is indifferent to y and we write $x =_i y$. The n-uple $(\geq_i)_{i\in N}$ is called a profile and denoted by $\geq_N$. It is used to represent the preferences of a decision-maker according to n criteria.

Given a profile $\geq_N$, one may try to construct a global preference relation. This we do by means of an aggregation procedure (denoted by $\geq$), i.e. a function mapping each profile $\geq_N$ on a global preference relation denoted by $\geq(\geq_N)$. When there is a strict preference (resp. an indifference), we will use the symbol > (resp. ~) We can think of many different aggregation procedures. For instance, the plurality rule. It ranks the alternatives according to the number of criteria for which they are ranked first.

Example 1. Suppose $X=\{w, x, y, z\}$ and $N=\{1, 2, 3\}$. Suppose also that the preferences of the decision-maker are the following weak order[1]: $x >_1 y =_1 w >_1 z$, $x >_2 z >_2 w >_2 y$, $y >_2 w >_3 z =_3 x$. Alternative x (resp. y) is ranked first on criteria 1 and 2 (resp. 3). According to the plurality rule, the global preference relation is this weak order: $x >(\geq_N) y >(\geq_N) w \sim(\geq_N) z$. When only one profile is under consideration and no confusion is possible, we just write $x > y > w \sim z$.

We can also use the anti-plurality: It ranks the alternatives in decreasing order of the number of criteria for which they are ranked last. Using the profile of Example 1, we obtain the following weak order: $w > x \sim y > z$. Note that it is different from the plurality ranking. There are many other rules: the Borda rule, dictatorial rules, Kemeny rule, … and, of course, the majority rules that we now present. Let $P(x,y,\geq_N)$ be the number of criteria in N for which $x >_i y$ and $I(x,y,=_N)$ be the number of criteria in N for which $x =_i y$. Of course, $P(x,y,\geq_N) + I(x,y,=_N) + P(y,x,\geq_N) = n$. We are now ready to present some important majority rules.

Weak Majority. With this rule, x is globally at least as good as y iff x is at least as good as y on half the number of criteria. Since n can be odd, we need to be careful in the formal definition of the rule: $x \geq(\geq_N) y$ iff $P(x,y,\geq_N) + I(x,y,=_N) \geq \lceil n/2 \rceil$, where $\lceil t \rceil$ is the smallest integer not smaller than t (upwards rounding). If we apply this rule to the profile of Example 1, we obtain yet another weak order: $x > y \sim w > z$.

Qualified Weak Majority. This rule is similar to the previous one but uses a threshold possibly smaller than $\lceil n/2 \rceil$: $x \geq(\geq_N) y$ iff $P(x,y,\geq_N) + I(x,y,=_N) \geq \delta$, whith δ integer and $0 < \delta \leq \lceil n/2 \rceil$. It is of course possible to choose δ non-integer but several values of δ then lead to the same aggregation procedure (e.g. 2.1, 2.3 and 2.9). If we apply this rule to the profile of Example 1 with $\delta = 1$, we obtain yet another weak order: $x \sim y \sim w \sim z$; all alternatives are indifferent. Actually, qualified weak majority is not a single aggregation procedure, but a family of procedures, depending on the parameter δ. This family includes weak majority.

ELECTRE I Majority. This rule is similar to the previous one but uses a threshold possibly larger than $\lceil n/2 \rceil$: $x \geq(\geq_N) y$ iff $P(x,y,\geq_N) + I(x,y,=_N) \geq \delta$, whith δ integer and $\lceil n/2 \rceil \leq \delta \leq n$. If we apply this rule to the profile of Example 1 with $\delta = 3$, we find that all alternatives are incomparable. This is the aggregation procedure used in ELECTRE I to construct the concordance relation, eventually with weights. ELECTRE I is also a family of procedures, including weak majority.

Remark that qualified weak majority and ELECTRE I majority can be seen as special cases of a larger family where the threshold can vary in $]0,n]$. We suggest to call this family generalized qualified weak majority.

Simple Majority. This rule is quite different from the previous ones. Instead of comparing the weak support of x (i.e. $P(x,y,\geq_N) + I(x,y,=_N)$) with a threshold, it compares the weak support of x with the weak support of y (i.e. $P(y,x,\geq_N) + I(x,y,=_N)$). Formally, $x \geq(\geq_N) y$ iff $P(x,y,\geq_N) + I(x,y,=_N) \geq P(x,y,\geq_N) + I(x,y,=_N)$. Note that $I(x,y,=_N)$ cancels out on both sides of the equation but we keep it to make clear the link with a rule that we will introduce later. If we apply this rule to the profile of Example 1, we find the same weak order as with the weak majority.

a-Qualified Simple Majority. The rules in this family are similar to the previous one. They also compare the weak supports of x and y, but use an additive threshold. Formally, $x \geq(\geq_N) y$ iff $P(x,y,\geq_N) + I(x,y,=_N) \geq P(x,y,\geq_N) + I(x,y,=_N) + \delta$, with δ integer and $-n < \delta \leq n$. If we apply this rule to the profile of Example 1 with $\delta = 1$, we find a relation that is not complete: $x > y > z$, $x > w > z$ and $x > z$ but w and y are incomparable. Simple majority is of course a special case of a-qualified simple majority.

m-Qualified Simple Majority. This family, contrary to the previous one, uses a multiplicative

[1] A weak order is a complete and transitive relation. It is a complete ranking, possibly with ties.

threshold. Formally, $x \geq(\geq_N)\ y$ iff $P(x,y,\geq_N) + I(x,y,=_N) \geq \delta\ [\ P(x,y,\geq_N) + I(x,y,=_N)\ ]$, with $0 < \delta \leq n$ and $k\delta$ in N for some k in N. If we apply this rule to the profile of Example 1 with $\delta = 1.5$, we find again a relation that is not complete: all alternatives are incomparable except that $x > z$. Simple majority is of course a special case of m-qualified simple majority.

Tactic Majority. This family, like the previous one, uses a multiplicative threshold but it is based on the strict support (i.e. $P(x,y,\geq_N)$) and not on the weak one. Formally, $x >(\geq_N)\ y$ iff $P(x,y,\geq_N) > \delta\ P(x,y,\geq_N)$, with $1 \leq \delta < n$ and $k\delta$ in N for some k in N; otherwise, x and y are incomparable. If we apply this rule to the profile of Example 1 with $\delta = 2$, we find the same relation as with the ***a-Qualified Simple*** *Majority* with $\delta = 1$.

Note that the many families we introduced are distinct only if the single-criterion preferences contain some indifferences. Otherwise, the following three families are equivalent: generalized qualified weak majority, a-qualified simple majority and m-qualified simple majority. TACTIC majority is almost equivalent to these families; the only difference being that any indifference in the global preference relation becomes an incomparability with TACTIC.

3. Analysis of the main majority rules.

The many different majorities that we have presented in section 2 are distinct aggregation procedures: they sometimes lead to different global preference relations. Before using one or the other, it is therefore important to know what makes them different, what the distinctive properties of each one is. Only then is it possible to choose with the full knowledge of the facts. Nevertheless, these procedures also have a lot in common. So, before presenting the distinctive properties, we will show what these procedures share.

With all majority rules of Section 2, the rule used to determine the preference (>,< or ~) between two alternatives is the same for (x,y), (x,z), (y,z), (w,z), etc. All aternatives are treated in the same way. This is called *neutrality*.

With all majority rules of Section 2, all criteria play exactly the same role. Indeed, the global preference relation depends only on the numbers of criteria for which $x >_i y$, $x <_i y$ or $x =_i y$, but not on the criteria themselves. This property is called *anonymity*.

It is also clear that, with all majority rules of section 2, the global preference relation between x and y depends only on $P(x,y,\geq_N)$ and $I(x,y,=_N)$. We do not need to know anything about z or w for determining the global preference between x and y. This is called *independence of irrelevant alternatives*. Note that it is not satisfied by the plurality rule.

The following two conditions are monotonicity conditions and are satisfied by all majority rules of section 2. Suppose that, using the aggregation procedure $\geq$ with the profile $\geq_N$, we find $x \geq(\geq_N)\ y$. Suppose now that alternative x (say an investment plan) is improved relatively to y, in some way, on criterion i. On the other criteria nothing changes. Since x was globally as good as x before the improvement, it should still be as good as x after the improvement (and eventually better than x). An aggregation procedure respecting this principle is said to satisfy *weak non-negative responsiveness*. Since we did not define what an improvement is, weak non-negative responsiveness is not yet well-defined. We consider two kinds of improvements: going from $y >_i x$ to $x >_i y$ and from $x =_i y$ to $x >_i y$. The first one corresponds to *weak non-negative responsiveness 1*; the second one to *weak non-negative responsiveness 2*.

The last property that all majority rules of section 2 share is *unanimity*: when x is strictly better than y on all criteria, then x is globally strictly better than y. Note that it is not satisfied by the plurality rule.

Since it is hard to conceive a majority rule that would not satisfy independence of irrelevant alternatives, non-negative responsiveness 1 and 2 or unanimity, we propose the following definition for a majority rule: an aggregation procedure is a majority rule if and only if it satisfies independence of irrelevant alternatives, non-negative responsiveness 1 and 2 and unanimity. If, in addition, it satisfies neutrality and anonymity, we then say that it is a symmetric majority rule.

So, if we find the above-mentioned properties compelling, in a particular decision problem, then, we should probably use a symmetric majority. But, which one? We try to answer this question by providing, for each symmetric majority rule (or family of symmetric majority rules) of section 2, one or two properties that only that rule satisfies.

Generalized qualified weak majority.

A distinctinctive property of generalize qualified weak majority is *limited influence of indifference*. It is the same property as weak non-negative responsiveness 2 except that it is stated for a deterioration instead of an improvement. More precisely, suppose that, using the aggregation procedure $\geq$ with the profile $\geq_N$, we find $x \geq(\geq_N)\, y$. Suppose now that alternative *x* (say an investment plan) is deteriorated relatively to *y*, going from $x >_i y$ to $x =_i y$, on criterion *i*. On the other criteria nothing changes. Since *x* was globally weakly preferred to *y* before the deterioration and since the weak support of *x* against *y* does not change, it should still be weakly better than *y* after the deterioration[2]. An aggregation procedure respecting this principle is said to satisfy limited influence of indifference. All generalized qualified weak majority rules satisfy limited influence of indifference and no other symmetric majority rule satisfies it. So, if we find the common properties (neutrality, anonymity, independence of irrelevant alternatives, weak non-negative responsiveness 1 and 2, unanimity) compelling and if we think limited influence of indifference is also an important property, then we must use one of the generalized qualified weak majority rules.

If, in addition, we think that incomparability should be allowed, then we must use an ELECTRE I majority rule. If, on the contrary, we want that the global preference relation be complete (i.e. without incomparabilities), then we must use a weak qualified majority rule. Finally, if we want a complete relation but, with as few indifferences as possible, then we must use the weak majority rule.

a-Qualified simple majority.

A distinctive property of the a-qualified simple majority is *pairwise cancellation*. Suppose that, using the aggregation procedure $\geq$ with the profile $\geq_N$, we find $x \geq(\geq_N)\, y$. Suppose now that alternative *x* is deteriorated relatively to *y*, going from $x >_i y$ to $x =_i y$, on criterion *i*. Suppose also that alternative *y* is deteriorated relatively to *x*, going from $y >_j x$ to $x =_j y$, on criterion *j*. On the other criteria nothing changes. One can argue that the deterioration of *x* on criterion *i* exactly compensates the deterioration of *y* on criterion *j*. The two deteriorations cancel out each other. Hence, since *x* was globally weakly preferred to *y* before the changes, it should stilll be so after the changes. A similar argument can be used when *x* is improved relatively to *y*, going from $x =_i y$ to $x >_i y$, on criterion *i* and *y* is improved relatively to *x*, going from $y =_j x$ to $y >_j x$, on criterion *j*. An aggregation procedure respecting this principle is said to satisfy pairwise cancellation. All a-qualified majority rules satisfy pairwise cancellation and no other symmetric majority rule satisfies it.

If, in addition, we think that incomparability should be allowed, then we must use an a-qualified simple majority rule with a positive threshold. If, on the contrary, we want that the global preference relation be complete (i.e. without incomparabilities), then we must use a non-positive threshold. Finally, if we want a complete relation but, with as few indifferences as possible, then we must use the simple majority rule.

Note that, depending on the sign of the threshold, an a-qualified simple majority will always yield global preference relations possibly containing indifferences ($\delta \leq 0$) or incomparabilities ($\delta > 0$) but never both (contrary to ELECTRE I majority).

Tactic majority.

A distinctive property of the TACTIC majority rule is ***P-invariance***. Suppose we have two profiles $\geq_N$ and $\geq'_N$ such that

One can argue that, since the ratio of the strict supports is the same in both profiles, the outcome should also be the same; i.e. $x \geq(\geq_N)\, y$ iff $x \geq(\geq'_N)\, y$. An aggregation procedure respecting this principle is said to satisfy P-invariance. Another distinctive property is ***asymmetry***: there are no indifferences. All TACTIC majority rules satisfy P-invariance and asymmetry and no other symmetric majority rule satisfies both properties.

m-Qualified simple majority.

A distinctive property of the a-qualified simple majority is *PI-invariance*. It is similar to P-invariance except that it is based on weak supports instead of strict ones. Formally, suppose

$$\frac{P(x,y,\geq_N) + I(x,y,\geq_N)}{P(y,x,\geq_N) + I(y,x,\geq_N)} = \frac{P(x,y,\geq'_N) - I(x,y,\geq'_N)}{P(y,x,\geq'_N) - I(y,x,\geq'_N)}$$

One can argue that, since the ratio of the weak supports is the same in both profiles, the outcome should also be the same; i.e. $x \geq(\geq_N)\, y$ iff $x \geq(\geq'_N)\, y$. An aggregation procedure respecting this principle is said to satisfy PI-invariance. All m-qualified simple majority rules satisfy it and no other symmetric majority rule satisfies it.

4. Discussion.

We have seen that each family of symmetric majority rules can be distinguished from the others by using a single property: limited influence of indifference, pairwise cancellation, P-invariance or

[2] Note that, if $x > (\geq_N)\, y$ before the deterioration, then limited influence of indifference does not exclude that $x \sim (\geq_N)\, y$. So, indifference can have an influence on the result of the aggregation but it is limited.

PI-invariance. Each of these properties has a similar structure: it starts with a profile $\geq_N$ then considers a second profile $\geq'_N$, similar to the first one but where the relative position of *x* and *y* has been modified in a specific way. The property finally imposes that the global preference relation between *x* and *y* should be the same because the two profiles are very similar. Suppose an analyst wants to use a symmetric majority rule but is wondering which one to use. Since each family corresponds to one specific property, the analyst may well concentrate on these distinctive properties and forget the rest. If he thinks that one of these properties makes more sense than another one, in his decision context, then he automatically knows which aggregation procedure to use.

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L'utilisation de l'intégrale de Choquet en aide multicritère à la décision

Michel GRABISCH
Université Paris I - Panthéon-Sorbonne
Michel.Grabisch@lip6.fr

1. Introduction

Si l'intégrale de Choquet est une notion qui est apparue en 1953 (et même bien avant : en 1925, Vitali avait déjà proposé cette notion), il faut attendre les années 90 pour voir les premières applications en aide multicritère à la décision (MCDA), essentiellement faites au Japon (voir [1] pour une brève description de celles-ci). Depuis, la théorie s'est étoffée de nouveaux concepts pour l'aide multicritère, comme la notion d'interaction, et une méthodologie s'est développée, ainsi que des outils informatiques, si bien que maintenant il est tout à fait possible d'utiliser l'intégrale de Choquet dans des applications pratiques. Ce bref article a pour but d'introduire à cette méthodologie, et ne nous permet pas de donner une exposition technique complète ni une bibliographie détaillée. Le lecteur intéressé pourra consulter en particulier [2, 6] pour plus de détails.

2. Insuffisance de la somme pondérée et naissance de l'intégrale de Choquet

Bien que la plupart des méthodes existantes en MCDA se basent sur la somme pondérée, et ce pour des raisons évidentes de simplicité, il est bien connu que celle-ci présente des défauts fondamentaux qu'il n'est pas possible d'éliminer. Nous illustrons ceci par un exemple.

Example 1 : Considérons un problème MCDA à 2 critères, et 3 objets *a, b, c*, dont les scores sur les critères sont:

$$u_1(a) = 0.4 \quad u_1(b) = 0 \quad u_1(c) = 1$$
$$u_2(a) = 0.4 \quad u_2(b) = 1 \quad u_2(c) = 0$$

en supposant que les scores sont donnés sur une échelle de 0 à 1. Le décideur a comme préférence $a \; \boldsymbol{f} \; b \sim c$. Cherchons w_1, w_2 tels que ce choix soit représenté par la somme pondérée. On obtient :

$$b \sim c \; \& \; \hat{U} \; w_1 = w_2$$
$$a \; \boldsymbol{f} \; b \; \& \; \hat{U} \; 0.4\,(w_1 + w_2) > w_2$$

équivalent à $0.8\, w_2 > w_2$, ce qui est impossible. □

Comment expliquer cette contradiction ? Pour cela, il faut comprendre la signification des poids w_1, w_2. Il est bien connu qu'un poids sur un critère n'a pas de sens en soi, mais seulement dans un modèle donné. Pour la somme pondérée, w_1 est en fait le score global d'un objet ayant un score totalement satisfaisant (1) sur le premier critère, et inacceptable (0) sur les autres. Cependant, notre décideur est plus satisfait par un objet jugé de façon égale sur les deux critères, même si ce jugement reste moyen, que par un objet présentant une évidente faiblesse sur un des deux critères.

Il serait possible de tenir compte de cette préférence bien naturelle en considérant non pas que des poids sur les critères pris individuellement, mais aussi des poids définis pour des groupes de critères. Dans notre cas très simple à deux critères, cela revient à introduire un poids w_{12} sur les deux critères considérés ensemble, et nous gardons comme interprétation que w_{12} est le score global attribué à un objet étant totalement satisfaisant sur les deux critères.

Cet objet étant par conséquent le plus satisfaisant possible (car seulement 2 critères), il convient de lui donner le score maximal, soit 1. Afin de modéliser le fait que le décideur considère un objet ne satisfaisant qu'un des 2 critères comme peu acceptable, nous pourrions donner à w_1, w_2 une même valeur assez faible, 0.3 par exemple. Essayons maintenant de réinventer la somme pondérée en tenant compte du nouveau poids w_{12}. En s'en tenant à l'interprétation des poids ci-dessus, il est facile de calculer les scores globaux de *a, b, c* :

- ***a*** a ses scores égaux sur les deux critères, cela correspond donc à la situation représentée par w_{12}, au facteur 0.4 près. En supposant la propriété d'homogénéité du modèle, on pose donc comme score global $u(a) = 0.4\, w_{12} = 0.4$.
- *b, c* correspondent respectivement aux situations décrites par w_2, w_1. On pose donc $u(b) = w_2 = 0.3$, $u(c) = w_1 = 0{,}3$.

Les préférences du décideur sont modélisées. On voit que pour w_2, w_1 il aurait suffit de prendre n'importe quel chiffre entre 0 et 0.4 exclus. On voit aussi qu'il serait facile de modéliser n'importe quelle préférence entre *a, b, c* avec cette méthode.

Le lecteur peut cependant arguer que ce cas était extrêmement simple, car les scores correspondaient exactement aux situations décrites par les poids. Prenons alors un exemple plus compliqué : considérons un objet ***d*** dont les scores sont 0.2 et 0.8 respectivement (on peut supposer que notre décideur préférera ***d*** à ***b*** et *c*, mais sans doute préférera-t-il toujours ***a*** à ***d***). En fait, on peut considérer que notre objet ***d*** est la somme de deux objets fictifs *d*', *d*'' définis par les scores suivants :

$$u_1(d') = u_2(d') = 0.2$$
$$u_1(d'') = 0,\; u_2(d'') = 0.6.$$

En supposant notre modèle linéaire, le score global de ***d*** sera la somme de scores de *d*' et *d*''. Or nous pouvons calculer ces derniers car ils correspondent à des situations décrites par des poids. Ainsi nous obtenons :

$$u(d') = 0.2\, w_{12} = 0.2$$
$$u(d'') = 0.6\, w_2 = 0.18$$
$$u(d) = u(d') + u(d'') = 0.38.$$

Remarquons que nous obtenons l'ordre de préférence désiré : $a \; \boldsymbol{p} \; d \; \boldsymbol{p} \; b \sim c$.

Cette méthode pour calculer le score global n'est en fait rien d'autre que l'intégrale de Choquet, et les poids sur les groupes de critères définissent une *capacité* ou *mesure floue*. En généralisant le calcul ci-dessus à *n* critères, on arrive aisément aux définitions suivantes.

Définition 1 : *Soit $N = \{1,\ldots, n\}$ un ensemble de critères. Une capacité sur N est une fonction μ : $2^N \rightarrow [0,1]$ vérifiant $\mu(\emptyset)=0$, $\mu(N) = 1$, et $\mu(A)$ £ $\mu(B)$ si A Í B (monotonie).* □

La condition de monotonie provient du fait que l'importance d'un groupe de critères ne peut décroître si on ajoute un critère au groupe.

Définition 2 : *Soit μ une capacité sur N, et f : N→ Â une fonction représentant les scores d'un objet sur les n critères. L'* intégrale de Choquet *de f par rapport à μ (score global de l'objet) est donné par :*

$$C_m(f) = \sum_{i=1}^{n} [f(s(i)) - f(s(i-1))] m(A_i)$$

avec A_i := {σ(i),...,σ(n)}, f(σ(0))=0, et σ est une permutation sur N telle que f(σ(1)) £ f(σ(2)) £ ... £ f(σ(n)). □

3. Importance et interaction des critères

Supposons que nous ayons une capacité μ décrivant les poids sur les groupes de critères (nous verrons plus loin comment l'obtenir). Si l'interprétation des poids sur les critères d'une somme pondérée va de soi, il n'en est pas de même pour une capacité μ, car il y a 2^n coefficients ! Une première question naturelle est la suivante : dans un problème MCDA où l'on cherche à construire un modèle, il importe de savoir quels sont les critères importants et ceux qui sont négligeables. Par définition même d'une capacité, on pourrait penser qu'il suffit de regarder les valeurs de μ sur tous les singletons (critères pris individuellement). Que dire alors de l'exemple suivant avec 3 critères :

A	1	2	3
μ(A)	0	0.2	0.2
A	12	13	23
μ(A)	0.8	0.8	0.4

Puisque *μ(1) = 0*, on pourrait conclure que le critère 1 est inutile. Cependant, un examen des valeurs montre que chaque fois que le critère 1 est ajouté a un groupe de critère *A*, la *valeur ajoutée* par le critère 1 est considérable: 0.6 quand *A = 2* ou *3* ou *23*. Il semble donc que ce critère soit en fait très important. Comment définir un *indice d'importance* ϕ qui rende compte de cela ? Cet exemple suggère que cet indice devrait être une moyenne des quantités *μ(A È {1}) - μ(A)*, pour tous les groupes *A* possibles (y compris *A= ∅*). En imposant de plus que la somme des indices sur tous les critères fasse 1, Shapley a montré que la seule définition possible est la suivante :

$$f(i) = \sum_{A \subseteq N \setminus \{i\}} \frac{(n-a-1)!a!}{n!} \times$$
$$\times [m(A \cup \{i\}) - m(A)]$$

avec *a* = |*A*|, le cardinal de *A*. Appliqué à l'exemple ci-dessus, on trouve *f(1) = 0.4* et *f(2) = f (3)=0.3.*

Il est facile de voir que deux capacités différentes peuvent avoir les mêmes indices d'importance : pour l'exemple ci-dessus, il suffit de prendre *μ'(1) = 0.4, μ'(2) = μ'(3) = 0.3*, et ensuite $m'(A) = \sum_{i \in A} m(\{i\})$, comme le lecteur pourra le vérifier. En effet, une telle mesure est dite additive, et l'on a toujours *μ'(A È {i}) - μ'(A) = μ'({i})*. Une question naturelle vient alors à l'esprit : comment distinguer, par un indice approprié, deux capacités qui ont les mêmes indices d'importance ? C'est là qu'intervient la notion d'*interaction* entre critères. Reprenons l'exemple ci-dessus et considérons les critères 1 et 2. L'interprétation des valeurs de *μ(1)*, *μ(2)* et *μ(12)* suggère que les critères 1 et 2 pris individuellement ne sont pas importants (i.e., le décideur n'est pas satisfait par un objet étant bon sur seulement le critère 1 ou le critère 2), par contre la réunion des deux est importante (i.e., le décideur est satisfait pas un objet bon à la fois sur les critères 1 et 2).

Il y a donc un phénomène de *synergie* entre ces deux critères, on dira aussi de *complémentarité*. La quantité de synergie peut très bien être exprimée par *μ(12) - μ(1) - μ(2) = 0.6*. Remarquons que l'on pourrait imaginer la situation inverse, où cette quantité serait négative. Cela voudrait dire que les critères 1 et 2 seraient par eux-même importants, et que les deux réunis ne seraient pas beaucoup plus importants (i.e., le décideur ce serait pas beaucoup plus satisfait par un objet bon sur les critères 1 et 2 que par un objet bon sur seulement l'un des deux critères). On parlerait alors de critères *redondants* ou *substituables*. Enfin, il pourrait arriver que la quantité de synergie soit nulle~: c'est le cas des critères 2 et 3. On dira alors que les critères sont indépendants (la satisfaction du décideur est additive avec de tels critères). L'*indice d'interaction* entre les critères *i* et *j* est la moyenne de la quantité de synergie entre *i* et *j* en présence d'un groupe de critères *A*, pour tous les groupes *A* possibles (y compris *A=∅*) :

$$I_{ij} = \sum_{A \subseteq N \setminus \{i,j\}} \frac{(n-a-2)!a!}{(n-1)!} \times$$
$$\times [m(A \cup \{ij\}) - m(A \cup \{i\}) -$$
$$- m(A \cup \{j\}) + m(A)]$$

On pourra vérifier qu'avec l'exemple ci-dessus, on trouve $I_{12} = I_{13} = 0.3$ et $I_{23} = -0.3$, ce chiffre négatif provenant du fait que la quantité de synergie de 2 et 3 en présence de 1 est négative.

La même question nous revient à l'esprit : existe-t-il deux capacités différentes ayant les mêmes indices d'importance et les mêmes indices d'interaction ? Oui en général, mais il devient plus difficile d'en trouver. Pour notre exemple ci-dessus, on peut vérifier qu'il n'y en a pas, mais c'est un cas particulier. Par contre pour $n = 2$, il n'est pas possible de trouver deux capacités différentes ayant même indices d'importance et d'interaction, ceci parce que pour $n = 2$, le nombre de degrés de liberté pour définir μ est de 2, et si $f(1)$ et I_{12}} sont spécifiés, il ne reste plus de degrés de liberté. Si alors $n > 2$, par quel indice distinguer deux capacités ayant les mêmes indices ? La réponse est simple : on définit un indice d'interaction entre 3 critères d'une façon tout à fait similaire, en considérant la synergie entre 3 critères i, j, k : $\mu(ijk) - \mu(ij) - \mu(ik) - \mu(jk) + \mu(i) + \mu(j) + \mu(k)$. Il n'y aura alors pas deux capacités différentes possédant les mêmes indices d'importance et d'interaction pour 2 et 3 critères tant que *n £ 3*. On comprend alors le procédé général~: pour un problème à n critères, une capacité est déterminée de façon unique par ses indices d'importance et d'interaction entre 2, 3 et jusqu'a n critères.

4. Capacités *k*-additives

La souplesse de modélisation apportée par les capacités a un coût : pour n critères, le modèle comporte $2^n - 2$ paramètres libres, ce qui laisse présager une identification du modèle difficile. Il existe plusieurs moyens de remédier à cet inconvénient, en prenant des familles de capacités particulières demandant moins de coefficients : c'est le cas des capacités décomposables, qui satisfont la propriété *μ(A È B) = S(μ(A), μ(B))* pour A, B disjoints et S une t-conorme (pseudo-addition), des capacités p-symétriques, qui supposent que les critères peuvent être partitionnés en p groupes de critères indistinguables, et des capacités k-additives. Une capacité est dite ***k-additive*** si tous ses indices d'interaction sont nuls au-delà de k critères. Ainsi, une capacité *1*-additive a tous ses indices d'interaction nuls, c'est donc une capacité additive, et l'intégrale de Choquet correspondante est une simple somme pondérée. Une capacité 2-additive permet de représenter l'interaction entre 2 critères, mais pas davantage. Elle nécessite donc $n + \frac{n(n-1)}{2} - 1 = \frac{n(n+1)}{2} - 1$ coefficients pour être déterminée. C'est un excellent compromis entre souplesse de modélisation et complexité du modèle. Expérimentalement, on montre que l'on gagne peu en précision du modèle en passant d'une capacité *2*-additive à une capacité générale (*n*-additive), par contre on perd beaucoup en passant de 2-additif à 1-additif. D'autre part, il est difficile pour un décideur humain d'appréhender le sens des interactions à plus de 2 critères.

L'intégrale de Choquet peut s'exprimer très simplement en fonction des indices d'importance et d'interaction si la capacité est 2-additive :

$$C_\mu(f) = \sum_{i,j|I_{ij}>0} (f(i) \wedge f(j)) I_{ij} + \\ + \sum_{i,j|I_{ij}>0} (f(i) \vee f(j)) \, |I_{ij}| + \\ + \sum_{i \in N} f(i) \left[f(i) - \frac{1}{2} \sum_{j \neq i} |I_{ij}| \right]$$

Cet expression est formée de trois sommes. La première somme agrège les paires de critères dont l'interaction est positive par l'opérateur minimum ; c'est une agrégation conjonctive : pour que le résultat soit satisfaisant, il faut que les deux critères soient satisfaits. La seconde somme agrège les paires de critères dont l'interaction est négative par l'opérateur maximum ; il s'agit d'une agrégation disjonctive, il suffit donc qu'un des deux critères soit satisfait pour que le résultat soit satisfaisant. La troisième somme n'est autre qu'une somme pondérée, dont les poids sont les indices d'importance diminués de la somme des interactions se rapportant au critère en question.

On comprend alors bien le sens exact de l'interaction entre critères, et comment celle-ci intervient dans le calcul du score global. D'autre part, on peut montrer que l'expression ci-dessus est une somme convexe : tous les coefficients sont positifs et se somment à 1. Cela veut dire que l'on est capable de dire, pour une capacité 2-additive donnée, quel est le pourcentage de linéarité ou de conjonction ou de disjonction du modèle, ce pourcentage pouvant même être donné pour un critère ou une paire de critères particulier.

5. Identification du modèle

Il nous reste à aborder le problème pratique de la détermination de la capacité dans une application donnée (afin de ne pas alourdir la présentation, nous supposons ici que les fonctions d'utilité $u_1, \ldots, u_n$ des critères sont déjà obtenues, par exemple par la méthode MACBETH). L'idée générale est de combiner deux types d'information :

- une information sur les préférences révélées par le décideur : l'objet a est globalement meilleur (ou indifférent) que b, etc. Ces objets peuvent être des objets réels, ou des objets fictifs (prototypes) ;

- une information sur l'importance des critères et leurs interactions, limitées aux paires de critères. Par exemple, le décideur peut stipuler que le critère *i* est plus important que le critère *j*, que les critères *i* et *j* sont complémentaires, etc.

La proportion de ces informations varie en fonction du type de problème pratique rencontré. Le deuxième type d'information est plus directif, en ce sens que le décideur donne des indications sur la façon dont selon lui les critères doivent être agrégés.

Toutes ces informations peuvent se traduire sous la forme de contraintes linéaires en fonction des $2^n - 2$ (ou moins si une capacité *k*-additive est utilisée) coefficients de la capacité μ :

$$C_\mu(u_1(a_1),\ldots,u_n(a_n)) - C_\mu(u_1(b_1),\ldots,u_n(b_n)) \geq \delta$$
$$\phi(i) - \phi(j) \geq \delta'$$
$$I_{ij} \geq \delta''$$

et ainsi de suite, δ, δ', δ'' étant des seuils d'indifférence fixés. Afin d'assurer que μ soit une capacité, il faut de plus imposer des contraintes de monotonie :

$\mu(A) - \mu(A \setminus i) \geq 0,$ " A Í N, " i Î A.

Il se peut que l'ensemble des contraintes exprimées définisse un domaine vide. En ce cas, les préférences et diverses informations données par le décideur sont soit contradictoires, au sens d'axiomes couramment admis en décision multicritère (par exemple la dominance, la non transitivité de la préférence stricte), soit que l'intégrale de Choquet n'est pas un modèle suffisamment puissant pour représenter les préférences du décideur. Dans le premier cas, il incombe au décideur de réviser ses préférences, dans le second cas, il faut envisager d'autres modèles (voir ci-après).

Il reste à spécifier une fonction objectif afin d'obtenir μ comme solution optimale d'un problème d'optimisation. Il existe tout un éventail de possibilités (voir [3]) : par exemple, on peut minimiser une distance entre μ et une capacité pré-spécifiée, ou minimiser un critère de dispersion (variance, entropie, etc.). Ces fonctions objectif sont par essence non linéaires, quadratiques dans le meilleur des cas. Un exemple simple de programme linéaire est le suivant~: maximiser ε sous les contraintes définies ci-dessus, mais en remplaçant δ par $\delta + \varepsilon$. Ainsi le programme donnera comme solution une capacité qui maximisera les écarts entre les scores globaux.

6. Vers d'autres modèles

On considère en général que les scores sont des quantités positives. Cependant, des études en psychologie ont montré que la décision humaine est basée sur l'*affect*, et que celui-ci a un caractère bipolaire. Cela signifie que l'échelle des scores traduisant la satisfaction du décideur comporte en général un niveau neutre qui est la frontière entre les scores ressentis comme satisfaisant et ceux ressentis comme mauvais.

Par exemple, dans le système français de notation des étudiants, l'échelle va de 0 à 20. La note 10 est le plus souvent considéré comme le niveau neutre, qui marque la frontière entre ceux qui ont réussi l'examen et ceux qui ne l'ont pas réussi. Des expériences ont clairement montré que l'attitude de décision dépend de la position des scores par rapport à ce niveau neutre : un décideur ayant une attitude disjonctive (tolérante) pour le calcul du score global peut devenir conjonctif (intolérant) suivant la position des scores par rapport au niveau neutre. Une solution simple pour modéliser la bipolarité est de construire deux capacités, l'une dévolue aux scores au-dessus du niveau neutre, l'autre étant pour les scores en-dessous de ce niveau.

Un modèle plus général est celui des bicapacités. Une *bicapacité* est une fonction *v* à deux arguments *A, B*, ceux-ci étant des groupes disjoints de critères, tel que *v(A,B)* représente le score global attribué à un objet dont tous les critères appartenant à *A* seraient totalement satisfaits, tous les critères appartenant à *B* seraient totalement insatisfaisants, et tous les autres seraient au niveau neutre. Il est possible alors de définir une intégrale de Choquet par rapport à une bicapacité afin de calculer un score global, ainsi que des indices d'importance et d'interaction (voir [4 ,5]). L'inconvénient de ce modèle très puissant est sa complexité, puisqu'il nécessite $3^n - 3$ coefficients, mais là également il est possible de définir des modèles *k*-additifs, ainsi que des modèles hybrides entre capacités et bi-capacités.

7. Software

A notre connaissance, il existe encore très peu de logiciels implantant les méthodologies autour de l'intégrale de Choquet. Le package Kappalab, conçu sur la plate-forme R de statistiques, est un logiciel libre téléchargeable depuis http://www.polytech.univ-nantes.fr/kappalab ou http://cran.r-project.org. Celui-ci n'est pas dédié à la décision multicritère, mais est une boîte à outil générale permettant de manier dans un langage du type Matlab toutes les notions autour des capacités, et qui contient aussi des méthodes d'identification de capacités à partir de données (voir [3] pour une illustration). Le logiciel Myriad développé par Christophe Labreuche à Thales Research and Technology est par contre dédié à a décision multicritère, mais n'est pas un logiciel libre.

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Multicriteria modeling and result analysis

by

Maria Franca Norese

mariafranca.norese@polito.it

The ELECTRE method can be successfully used in structured decision problems where a complete set of actions is defined and a consistent family of criteria can easily be elaborated. Many sources of uncertainty, imprecision and ignorance are present (Roy, 1989) and induce difficulties in the definition of the multicriteria (MC) model parameters, which are related above all to the performances of each alternative on each criterion and to the importance of the criteria. An application of ELECTRE is also possible when the decision problem is only partially structured, but in this case there is also uncertainty in relation to the aspects that have to be considered meaningful and several knowledge elements should be acquired to reduce uncertainty. A different methodological approach and some tools are proposed in literature (see for instance Rosenhead, 1989) to deal with unstructured or ill-structured problems.

Some years ago ELECTRE III was tentatively used to support the structuring of a valid model in relation to some technical problems that were presented as particularly complex and not well structured (Balestra et al., 2001; Cavallo and Norese, 2001). In both these situations, the problems were connected to specific research fields rather than to decision contexts.

The request to support model building for a new and not sufficiently known problem situation was first considered unusual, but at the same time challenging. ELECTRE, which was well known because it had already been applied to resolve a structured decision problem in the same technical context (muscle fatigue evaluation), was specifically requested to test the modelling hypotheses and the proposal was accepted because data already existed, in terms of different possible measures of the muscle fatigue electrical manifestations that were not numerically adequate for a statistical data analysis approach, and the fact that the data had been directly acquired by the research group was considered as a guarantee of good knowledge of their meaning.

In a second case, the situation was similar: a research context, with a large number of data to be analysed to identify the main reasons for slope instability and erosion phenomena, and a subset of more detailed data, which was interesting but numerically inadequate for a statistical data analysis. ELECTRE was only used in this case for the subset while Multivariate analysis was instead used for the other data, to create more possibilities of validating each conclusion.

The result of the first ELECTRE III application to both problems was considered unacceptable. The two distillation procedures produced totally different results and, more critically, results without any correlation to the few certainties present in the research field. In one case, there were many analysed actions[3] and the rankings showed classes of 20 ex equo actions, at the same level, and therefore also a very limited discriminating capability of the model. In the other case, there were few analysed actions (a variable number of actions, from six to eighteen, in relation to the twenty-two situations that required the ELECTRE III application) and there was a distance of six classes between their positions in the two distillations in several cases.

The modelling hypotheses were reanalysed and the structure of the model changed but the result was again meaningless. At this point, the possible reasons for these disastrous results were searched for in the model and analysed and each of them tested, changing one element of the model at a time (in this case the role of each specific criterion in the model structure rather than its importance). A cyclic learning process developed, other experts in the research field were involved in the analysis of both the modelling hypotheses and their evident global unacceptability. New modelling hypotheses were defined and the results of each ELECTRE application became more reasonable. At this point, a tuning action on the parameters allowed the global MC model to be considered enough 'robust' and to be accepted in the research field.

These experiences using ELECTRE III with models developed in relation to not well-structured problems were useful in the formative process to transfer knowledge to the students on the use of the ELECTRE method in decision aiding situations.

The description of some MC models is interesting for the students, but not sufficient for them to acquire the capacities necessary to structure a good model in real situations. A consequence is often the use of 'an old model in a new decision problem', but this natural attitude can become critical in the training process. The concept that the specific decision situations, in a general decision context, can be at least partially different and can require different models is not easily accepted. The idea that each decision aiding intervention requires some problem and decision context analysis and model structuring steps, before the definition of all the model parameters, is automatically accepted but not often made operational. Each suggestion of combining modelling and validation activities obtains almost the same results. The request of analysing the results after each implementation of the method results in a very limited activity, which is often not consistent with the nature of the results and not sufficient to produce a valid conclusion.

In order to limit the criticality of this situation, where a new proposed problem is often perceived as complex and not well structured, I started elaborating simple result analysis exercises to stress the ideas that a result may present critical elements and that obtaining a result should not considered automatically the end of an application. I then proposed sensitivity analysis exercises, where the parameters that contribute more to the variance of the outputs have to be identified, and robustness analysis exercises where, after some oriented tests, a final conclusion has to be produced. The different perspectives of these exercises underline the fact that the relationship between outputs and model parameter setting should always be analysed.

A growing complexity in the proposed exercises produced a first result, in terms of better comprehension, at least for some students, and was considered above all as a preparatory step to pass to the real learning process: an MC decision aid laboratory. In this laboratory real, or at least realistic, decision situations are proposed to the students. The problems are quite simple, but are perceived as complicated and unstructured decision situations by the students, because of their inexperience. When, for the first time in the laboratory, the students face a decision problem, they are in a situation that can be described as complex, because they develop an ELECTRE application for a decision problem that they perceived as unstructured, even though it is structured or at least partially structured.

The large number of students in this kind of laboratory (more than 2000 over the last seven years) allowed an interesting observation to be made on how a new practitioner reads decision aiding problems and how he/she can acquire an acceptable expertise in using MC methods. The laboratory was initially only oriented to the use of ELECTRE III. A new decision problem was proposed each time, with some possible actions and an available database to extract elements for structuring and detailing an MC model. The demo version of ELECTRE III that can be unloaded from the LAMSADE site was used, with

[3] In (Cavallo and Norese, 2001) the data were related to two situations, the first required a model with 80 actions and the second a model with 300 actions.

its limits[4], to stress the idea that "data are not criteria" and that a good model includes only the (few) significant elements of the problem, but has to be complete and not redundant. Only at a second stage, do the students pass to the normal version of ELECTRE III. The ELECTRE TRI method was proposed in the laboratory only in the two last years.

While assisting in the laboratory, we realized that the students easily understand the meaning of the various ELECTRE model parameters analysing the results of each application of the method to a model and changing the model parameters step by step. But the connection between "good" results and attention to the structuring of the model, in terms of problem definition and identification and development of adequate criteria, is more difficult to transfer. The general idea is that "my criteria are obviously good, but the weights and the thresholds may be changed to improve results that are not acceptable".

Four years ago, in order to improve their approach to the problem, the organization in the laboratory was changed. A database that is useful for a decision context was also proposed in this case, but the students were required to formulate a specific decision problem in the proposed context and to support a real (or realistic) decision maker. If, for instance, the decision context is the location of an industrial facility in a district area, a problem formulation may be the location of a production plant in the leather sector, in the automotive or in other different sectors but also the decentralization of some production processes in a new plant, or the location of a new warehouse for the distribution of perishable goods. If the decision context is a personal selection, a problem formulation may be related to a multinational company that needs managers and assistants who have to move to the different plants, but may also refer to a small company that needs salesmen for its different markets, in Italy, in Europe and elsewhere.

The students, who work in couples, generally identify their tutor of a previous stage in an enterprise, a relative or an acquaintance who has or can have a specific problem in relation to the proposed general decision context as their decision maker. When they do not know a possible decision maker they can choose an assistant or myself as their decision maker. In this case, we must avoid any support or suggestion but we become the "problem owners". In this laboratory, the students find the same difficulties that are described in (Balestra et al., 2001; Cavallo and Norese, 2001) but, after a first disastrous result, it is simple for us to suggest (and demonstrate) that a richer and detailed problem formulation can reduce their difficulties in model building and the first model is partially changed or globally reorganized.

The presence of several incomparabilities in the results, that are evident in the ELECTRE III partial graph or in the assignment to non adjacent categories by the two ELECTRE TRI logics, is now more easily interpreted as a possible consequence of an incomplete model or a superficial structuring of the strategic dimensions of the problem and/or a non consistent definition of the relevance of each strategic aspect in the problem. Sometimes, the non-operational definition of the actions (i.e. a generic plant location in a site, without any indication of the plant characteristics and/or the location motivations) is the cause of the problem and the real reason is always the problem formulation that is not correctly or not sufficiently made explicit. When these possible reasons are analysed and eliminated step by step the number of incomparabilities is always reduced and can easily be related to a structural problem of some specific actions that present conflictuality in the evaluations.

ELECTRE TRI Assistant (ETA), which is included in Version 2.0 of the ELECTRE TRI SW tool proved useful. The presence in the SW of a tool that supports the model definition reinforces the idea that a good model is not a normal starting point but one of the main results of a decision aiding intervention. The inclusion of ETA in the SW system is often perceived as an answer to the difficulties of the decision aiding process, and to be more concrete and more acceptable than the explanation of what a constructive approach to the problem is. Other SW systems, such as IRIS, will be tested in the laboratory over the next few years.

One limit of the available ELECTRE SW tools is the absence of a section dedicated to result analysis with, at least, the possibility of comparatively visualizing the results that were produced in connection to different modelling scenarios, when the problem structure is defined step by step and the results significantly change, or in a robustness analysis, where the results of a set of acceptable model versions have to be compared to define a robust conclusion. A good tool is, for

[4] The demo of the ELECTRE III/IV SW accepts only six actions and five criteria.

instance, the SURMESURE diagram (see figure 1) that was proposed in (Simos, 1990) and is described in (Rogers et al., 2000).

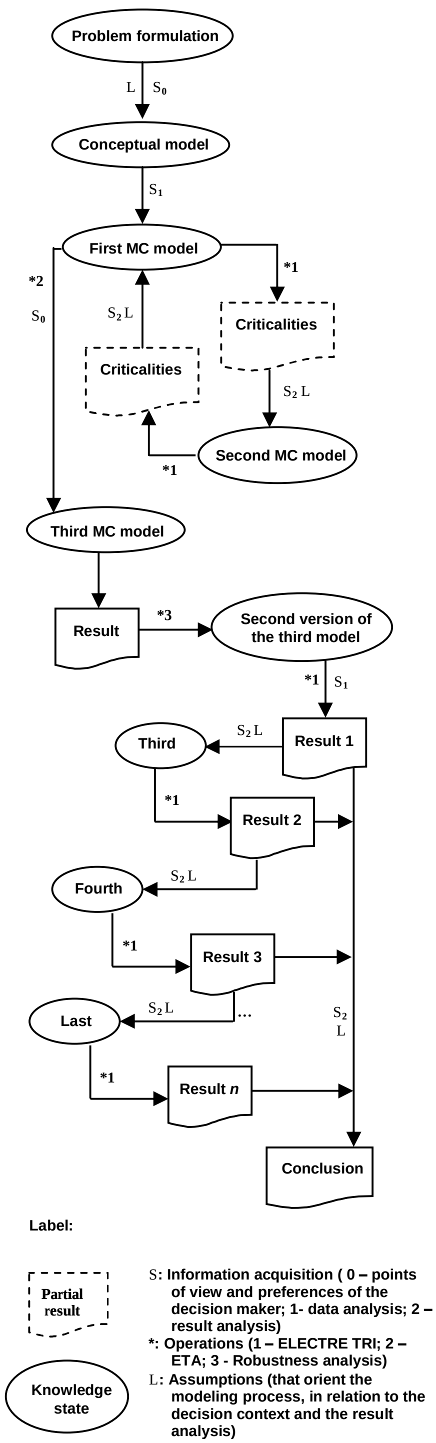

Figure 2 – Map of a modeling process

Another useful support could be a map of the main steps of model structuring, detailing and tuning, of the feedback cycles to marginally or globally redefine the model (and sometimes the problem formulation) and the elements of knowledge that can be acquired from the analysis of a previous result. I found the most useful to be the map (see figure 2) that is described in (Lendaris, 1980).

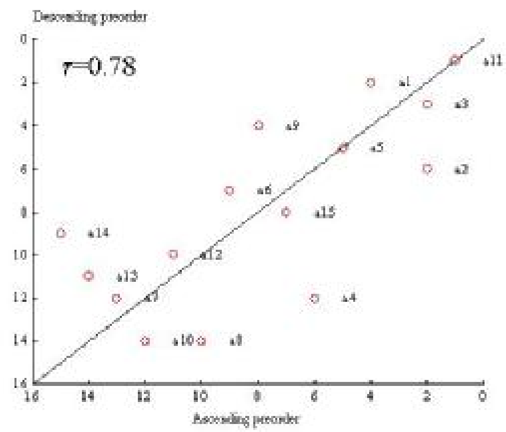

Figure 1 - SURMESURE diagram of the first modeling hypothesis results

Some tools, which are directly proposed to support the structuring of problems and models, are explicitly oriented to an MC approach to the problem[5]. When the students use one of these tools in the laboratory, to structure a specific "unstructured but not so complex" problem, they acquire skills in modelling that they successfully use to adequately apply an ELECTRE method to face more structured MC decision aiding problems. The integration of "structuring assistants" to stimulate structuring skills in the users can be essential for MC decision aid.

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MCDA Research Groups

Industrial Engineering Department, Middle East Technical University

by
Murat Köksalan
IE Department, ODTÜ
06531 Ankara
Turkey

The Industrial Engineering (IE) Department (http://www.ie.metu.edu.tr/) of Middle East Technical University (METU) has approximately 20 full-time faculty members, 600 undergraduate students, 200 M.S. students, and 15 Ph. D. students. Faculty members and students conduct research in a wide spectrum, covering many areas of IE. The research constitutes methodological developments as well as application projects for the public and private sectors. Every year, teams of senior-level students undertake some 20-25 Systems Design projects for different organizations under the supervision of faculty members. Additionally, faculty and graduate students are regularly involved in projects and consulting funded by various organizations.

I will briefly review the Multiple Criteria Decision Making (MCDM) – related research we have been conducting in recent years. Some of this research is in the form of developing approaches for the general MCDM area. Some address MCDM issues in different functional areas. Some research consider multiple criteria explicitly in real life applications and some provide decision makers (DMs) an indirect support on potentially interesting solutions.

The 15th International Conference on MCDM was organized at METU in 2000 and Murat Köksalan chaired the organizing committee. Many presented research papers were submitted after the conference and those that survived a thorough review process were collected in the Proceedings of the conference.[29]

I will summarize our recent research efforts under several headings.

Multiobjective Combinatorial Optimization (MOCO)

MOCO is an exciting research area that has been steadily growing in recent years. The problems in this area are computationally difficult and modern heuristic search have been widely used. Evolutionary methods have been particularly useful. We have been involved in MOCO research. The literature is flooded with approaches that try to generate the efficient frontier for bi-criteria problems. While we also develop approaches for approximating the efficient frontier of a general MOCO problem[38], we find it important to converge towards the most preferred solution of the DM through an interactive approach[36,37] or to generate the efficient solutions in the preferred regions of the solution space.[23]

Many scheduling problems fall under the category of MOCO. We have been studying scheduling problems extensively. Many of these are bicriteria problems. Some studies try to generate the efficient frontier while others try to converge the most preferred solution under certain assumptions.[1,2,3,4,13,22,33,39] Facility location problems are another class of MOCO problems we address.[30]

Ranking and Sorting

Ranking of alternatives based on multiple criteria has many applications in real life. We developed several approaches in this area and applied some of them.[10,12,27] A closely related problem is the so called sorting problem where alternatives are categorized into a number of preference-ordered classes. We have been doing research in this area as well. In addition to recent publications[7,20,28,40], we have several ongoing projects. Performance evaluation is another closely related problem we have considered.[34]

General MCDM

We have been studying interactive approaches for a long time. We may cite two recent approaches for finding the most preferred solutions of DMs for continuous solution spaces[21] and for discrete alternative sets.[26] Searching the discrete alternative set is computationally easier. We developed an approach that tries to obtain a discrete set of alternatives that represents the underlying continuous solution space well.[14]

We also worked on outranking-based models and behavioral aspects of MCDM.[15,16,31,32]

We have two overview papers intended as introductory material to those who want to get acquainted with MCDM.[11,18]

Applications

In many of our work with the industry we consider multiple criteria. In some, we explicitly evaluate the criteria and in others we explore the solution space in such a way to facilitate DMs to consider other criteria before making the final decision.[5,6,8,9,17,35] We regularly prepare teaching material based on our practical experiences from the application projects. These also incorporate multiple criteria either directly or indirectly. Two case studies we prepared won the first prizes in the 2002 and 2006 INFORMS Case Competitions.[19,25]

An important application area for MCDM is product and process design. Values of design parameters affect various performance measures and the relations are highly nonlinear. In the literature various aggregation functions have been used to determine the values of design parameters. We proposed an interactive approach that progressively incorporates the DM’s preferences into the solution process of determining the design parameters.[24] Our approach conveys the past developments in the MCDM area into product and process design.

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Forum

(Robustness Analysis)

Robustness Analysis: An Information-Based Perspective

Daniel E. Salazar A.[1] (anielsalazaraponte@gmail.com), **Claudio M. Rocco S**.[2] (crocco@reacciun.ve), **Blas J. Galván G**.[1] (bgalvan@step.es)

1. *Institute of Intelligent Systems and Numerical Applications in Engineering (IUSIANI). University of Las Palmas de Gran Canaria. Spain.*

2. *Central University of Venezuela. Caracas, Venezuela.*

1. Introduction

Decision-making problems are –*not only but essentially*- information problems. Such information tells us about levels of aspiration or satisfaction, goals, criteria, among others. If all the right information is available at the right moment and the desired alternative is reachable, there is no decision to make. Otherwise the decision-making process comprises discovering, investigating, interpreting and adapting knowledge from what is envisaged until the moment when the right alternative to choose comes along.

Likewise, robustness problems are decision-making problems and therefore information problems. Searching for robustness implies coping with ignorance. Sometimes such ignorance could be reduced, sometimes not. It is important to notice that, even in those cases where the ignorance could be reduced, on occasions the high price of the additional knowledge could not justify the gain in information. Thus, the natural option is to deal with ignorance instead of reducing it.

For instance, in robust design we search a system configuration or setting that is able to resist variation in its input without a significant loss of quality –like a major deviation from a target value- in its output. Why do we search such a design? Clearly because we consider that the resulting loss of quality entails regrettable consequences; otherwise we could change our minds and accept the output's variability. In other words, Decision-Makers (DM) are supposed to define when the output is undesirable or moreover unacceptable.

Independently of the DM's criteria and no matter what the system is (a method, a decision, an optimal solution, a physical system –see Vincke 2003 for a discussion-); we always can find situations when the usefulness of a system could be sensitively affected due to input's uncertainty. For example, a decision could be no longer appropriate if the scenarios where the decision is based on change. The same thing might occur with, e.g., an optimal alternative. Once implemented, this alternative could experiment a considerable loss of optimality in the presence of uncertain values of its decision variable. This diversity of systems and situations explains why the concept of robustness meets so many realizations as those presented in earlier issues of the present forum as well as in a large number of publications in the field (see e.g. Sayin, 2005).

A natural question that derives from this wide horizon of robustness formulations is what concept should an analyst use and why? The answer to this question logically depends on the information available and naturally on the kind of system into consideration. The labour of the analysts is, in consequence, a two-stage task. First the particular formulation of robustness should be drawn from the most generic idea of robustness; then the analyst has to decide how to solve the problem.

As the authors have a special interest in optimisation and particularly in evolutionary optimisation, the following discussion is focused on robust solutions.

2. Information-Based Robustness Analysis

2.1. A Generic Robustness Formulation

Perhaps the most common and very general formulation of robustness states that a system is robust when its output is insensitive to small variation of its input (Sayin, 2005). In optimisation it is said that a solution is robust when the value of the objective function does not change significantly when the decision vector are slightly shifted inside its neighbourhood. However, none of the above concepts define how "small" an input's variation should be or what "insensitive" means. Since the size of these qualifiers depends on DM's criteria, we argue that any analyst should investigate what information the DM may provide, among other factors, before defining the particular formulation of robustness that is applicable to the problem under consideration.

Let us consider a general optimisation problem:

$$\begin{aligned} &\text{Opt } F(x) \\ &\text{s.t.:} \\ &\quad G_j(x) \leq b_j \text{ , } j = 1,2,\ldots,m. \\ &\quad x \in X \end{aligned} \tag{1}$$

Within an uncertain environment, it is commonly assumed that the decision vector x is exposed to a source of variability that could be represented as $x+\delta_i$, where the vector δ_i is a particular realization of uncertainty phenomenon δ. Nevertheless this assumption could be invalid in some discrete domains that only allow being represented by means of scenarios. Another concern often presented in robustness analysis is the constraint satisfaction.

For the sake of simplicity, let us focus now on those problems that might be represented by considering δ. Evidently, the DM will be interested in assessing the effect of the uncertainty on the output; thus the objective is transformed in some robustness indicator that has x,δ as an argument. Besides we know that despite the size of the variation, δ may be bounded yielding $\delta_{min} \leq \delta \leq \delta_{max}$. A vector of uncertain independent variables or parameters $p_{min} \leq p \leq p_{max}$ can be defined as well. Consequently we must define the new objective considering these additional elements and their ranges of variation.

The aforementioned elements can be integrated to yield a general robustness formulation as:

$$\begin{aligned} &\text{Opt } R(F, x, \delta, p, \gamma) \\ &\text{s.t.:} \\ &\quad G_j(x, \delta, p) \leq b_j \ (j= 1,2,\ldots,J) \\ &\quad x \in X \qquad\qquad (2) \\ &\quad F_{min} \leq F(x, \delta, p) \leq F_{max} \\ &\quad \delta_{min} \leq \delta \leq \delta_{max} \\ &\quad p_{min} \leq p \leq p_{max} \end{aligned}$$

where the new objective function R is the robustness measure, which is function of the value of F in the presence of uncertainty (δ,p) and in accordance with DM's criteria. The extra parameter γ is necessary for some formulation as will be explained later on. The bounds F_{min} and F_{min} are related to the maximal and minimal value that the original function F(x) reaches over x, δ. Such bounds could serve to state goals or levels of attainment as well as to control the size of the output's variability.

2.2. Deriving Robustness Formulations: a two-stage Information-based perspective

1st Stage: Robustness Definition

The previous formulation has the intention of being as generic as possible in order to unify diverse concepts present in the literature. Hence, according to this perspective the first stage is a conceptual stage: how can we define robustness in terms of the given information?

The analyst should precisely define what is known and what is unknown in order to find which definition of robustness may be employed. Some questions that could be posed to help the analyst task are:

- Domain: What is known about the domain and what can be assumed?
  - o Discrete or continuous domain?
  - o It is possible to define a variable neighbourhood?
  - o Are there constraints? Should they be strictly satisfied?
- Uncertainty: What is the uncertainty source?
  - o Should the uncertainty be represented by scenarios, by a probability law, intervals…?
  - o It is possible to describe δ with a probability distribution function (PDF)? What PDF? What are the parameters? Other forms?
- Robustness criteria: What is the functional expression of R(F, x, δ, p, γ)?
  - o Are there target values? ($\gamma = f_{target}$)
  - o What is the DM's attitude? (risk-lover, risk-adverse)
  - o It is possible to define constraint and/or goals over the output?

With the answers to these questions the analyst defines the particular robustness problem to be solved. This constitutes the first stage. Then the analyst must decide the proper method to solve it, completing the second stage.

Now let us derive some robustness problems from the generic formulation in (2). For the sake of simplicity the only source of uncertainty considered from now on is δ. Nonetheless the analysis could be extended to consider vector p.

The following table summarizes some of the different cases an analyst could find.

INFORMATION	**KNOWN** $d_{min} \leq d \leq d_{max}$	**UNKNOWN** $d_{min} \leq d \leq d_{max}$
KNOWN $F_{min} \leq F(x, d, p) \leq F_{max}$	Case 1	Case 3
UNKNOWN $F_{min} \leq F(x, d, p) \leq F_{max}$	Case 2	Case 4

Approach 1: uncertainty propagation

Cases 1 and 2 correspond to those approaches based on uncertainty propagation. Here a description of δ is necessary. Usually δ is described by means of a PDF with mean zero and σ the standard deviation. Depending on the type of PDF, δ_{min}, δ_{max} takes different values; e.g. $\delta_{min}=-\infty$, $\delta_{max}=\infty$ for a normal law or δ_{min}=-a, δ_{max}=a where a is a vector of finite scalars, for a uniform law.

Some typical criteria employed in these cases are:

- *Optimization of the expected value* E(x)*:* if no preference is expressed about the output (case 2) the first stage is completed making R(x,δ) = E(x,δ), and the second stage consists in determining how the uncertainty will be propagated (Sampling *-Monte Carlo, Latin Hypercube, Importance sampling* (Du & Chen, 1999); Interval Arithmetic (Kolev, 1994), Probability Bounds Analysis (Ferson & Hajagos, 2004)). Notice that a typical subproblem that could arise at this stage is the comparison among intervals.

  A pretty common example of case 2 is the so called Effective Function (Tsutsui & Gosh, 1997; Sörensen, 2003; Sevaux & Sörensen, 2004):

$$R(x,\delta) = F_{eff}(x) = \tfrac{1}{n}\sum_{i=1}^{n} F(x+\delta_i)$$

  Taguchi's robust design principle also belongs to case 2. Here the DM establish a target value around which the deviation should be minimized, yielding:

$$R(x,\delta,\gamma=f_{target}) = \max\{dist(F_{min},f_{target}), dist(F_{max},f_{target})\}$$

  Case 2 comprises as well the multiple objective formulation R(x,δ) = (E(x,δ), Var[F(x, δ, p)]), where the expected value is optimized while the variance is minimized. This is probably the most frequent approach adopted by analysts.

  When the DM are able to express some criteria about the output (case 1), it is possible define more specific problems. For instance, the variance does not necessarily have to be minimized but simply bounded inside a threshold of acceptance. Other constraints are possible. One example of this in evolutionary computation is constituted by Deb's multiple objective robust definitions 2 and 4 (Deb & Gupta, 2005), where the percentage of deviation between the single and expected values of F(x) is constrained a priori.

- *Optimization of the worst case:* this is a less common but still valid criterion used in case 2, and corresponds to min-max or max-min problems. Sometimes it is considered as a conservative criterion, but its usefulness depends on the problem. This criterion is often employed in combinatorial problems. A well-known group of robustness criteria that consider worst-case (*in discrete domain*) are Kouvelis and Yu's (1997) metrics.

Approach 2: effective domain assessment

When it is not possible to retrieve neither information nor suitable assumptions about δ, analysts may try to assess what is the effective domain within which the system remains valid. In robust design, the constraint satisfaction problem is a typical example of what we are talking about.

Now consider case 3 where the DM can state some goals or constraints on F(x). If F_{min} and F_{max} can be identify, then a valid approach consists of identifying that value of x that allows the maximal deviation without missing the requirements $G_j(x,\delta,p) \le b_j$ and $F_{min} \le F(x,\delta,p) \le F_{max}$. Therefore robustness criterion to be maximized is $R(x,\delta) = dist(\delta_{min},\delta_{max})$. Such distance could be defined in different ways (Milanese et al., 1996). For example in (Rocco et al., 2003; Rocco, 2005; Salazar & Rocco) the authors use the Maximal volumen Inner Box (MIB) distance formulated as:

$$dist(\delta_{min},\delta_{max}) = \prod|\delta_{min,i} - \delta_{max,i}|$$

where $\delta_{*,i}$ is the i*th* component of vector δ_*, and is applied to single and multiple objective robustness problems. Then, stage 2 is carried out with Interval Arithmetic and Evolutionary Computation.

Approach 3: minimal information approach

Case 4 is the hardest situation that an analyst could cope with. It is characterized by an inability of describing δ plus ignorance about the range of function F(x). The consequence is that the preceding approaches cannot be employed successfully. To our best knowledge this kind of situations has not been studied before, perhaps because, even when this circumstance might arise -and in fact it does- in real problems, it is far away from being frequent. Nonetheless, a methodology based on the minimal information that the DM can articulate was introduced by Salazar et al. (2006), when dealing with a particular flow-shop scheduling problem.

The idea is to assume plausible values of δ_{min}, δ_{max} and a uniform PDF, in order to apply the uncertainty propagation approach just to figure out the zone of optimality in the objective space, in such a way that the DM can have a better panorama of the behaviour of F(x), as well as obtaining some optimal solutions. Afterwards, since there's no reliable information to suitably describe the uncertainty, the original assumption about δ is discarded and approach 2 is applied, fixing F_{min} and F_{max} in accordance with DM’s preferences. Given that an increment in the range of δ could reduce the level of optimality of the previously found solutions, the condition to be imposed is to allow any displacement interval considered indifferent by the DM. The solution with the MIB is the chosen one.

2nd Stage: solving the problem

Finally, once the robustness criteria are correctly identified, the 2nd stage consists in determining a suitable methodology to find the solution. This is actually an open field characterized by recent innovations and contributions [Jin] [Paenke] [Ong]. However, it is important to remark that all the contributions in this area are subject to a particular concept from those mentioned earlier on. If the concept is no longer applicable in a particular problem, the strategies developed to accomplish the 2nd stage must be tailored in the best case. Thus we have two areas of research, the conceptual one and the implementation one.

3. Final comments

Even when the classification of the different concepts of robustness is in any case not a new idea (see e.g. the *two families* of approaches in Aloulou et al., 2005), we believe that the perspective presented here is useful to clarify where and how the different contributions made in this area fit and relate to each other. Likewise it allows identifying the difficulties and the actual limitations for solving the 2nd stage. Moreover, the generic formulation proposed is useful to understand why there are so many variants of the same concept and, at the same time, it’s a nice way of joining all them together. As we mentioned in the introduction, this information-based perspective must be extended to consider other sort of systems and their derived problems.

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Consultancy Companies

Intertox Inc.

www.intertox.com

1. Introduction

Intertox Inc (www.intertox.com) is a scientific consulting and research firm whose mission is to achieve long-term solutions to enhance public health and manage risk. Headquartered in Seattle, Washington, **Intertox** is comprised of scientists with expertise in risk assessment, decision analysis, toxicology, epidemiology, industrial hygiene, occupational medicine, ecology, and regulatory policy who work with local, national, and international clients.

Intertox strives to develop sound *science* strategies that clients use to protect health, minimize risks associated with products that they use or produce and ultimately improve product manufacturing process efficiency. The firm has national and international experience in situations where scientific data are limited or non-existent and where regulatory policy is pressing – both highly relevant to emerging threats. Work products and scientific opinions developed by Intertox are used by the National Academy of Sciences, U.S. EPA and U.S. DOD to develop regulatory standards and to establish policy directions in several EHS areas, including nanotechnology.

Risk assessment and decision analysis go hand-in-hand in Intertox’s offerings. Intertox is one of a few companies who is combining the best of the two disciplines to support client’s needs. Details about our unique approach and projects are provided below

2. Areas of Specialization

2.1. Integration of Risk Assessment and Decision Analysis

Multi Criteria Decision Analysis (MCDA) and risk assessment are often used to support decision making. Nevertheless, the decisions are often made with an arbitrary process that may or may not be based on risk analysis. Risk analysis (RA) may be just one factor to consider, in addition to stakeholder input, costs, etc., but no guidance exists on how to integrate these. In the process of risk analysis, people do make decisions, but these are often not explicitly documented. While each discipline operates within its own set of methods and tools, some decisions may benefit from the fusion of the two disciplines. Decision makers operating in a risk analysis setting may benefit from the structure provided by decision analysis (DA) when, for example, tradeoffs must be made between risks, alternatives need to be clarified and selected, and when there is some dynamic possibility of resolving uncertainty. A combined RA/DA differs from pure decision analysis because much of risk analysis is mandated, certain information is present that may not be obtained in standard DA, and there is generally a high budget for analysis. Risk analysis may have explicit requirements about who must be involved, what must be modeled and how, as well as rules about what must be done given the findings of the risk analysis study. T he way the budget is determined for risk-analysis based decisions is different from a standalone decision analysis. In this situation, various stakeholders' preferences for tradeoffs of money vs. mitigation depend on whose money is involved. All this could make DA fail. Intertox scientists have successfully integrated DA techniques as effective tools to augment the formal RA process, and furthermore help accommodating these approaches in order to allow federal agencies to make better decisions.

2.2. Risk Communication and Training

Risk communication is a critical part of overall risk management. While risk assessment produces estimates of potential risks, risk communication puts the risks into perspective, including making complex scientific principles understandable to lay audiences. When used effectively, risk communication provides a basis for discussing the relative importance of risk assessment information, encourages positive community and government involvement, and involves all parties in solving problems in a constructive manner.

In large organizations, business development leaders, managers, and scientists are likely to be involved in operations in which they must be interdependent with the cultures of organizational units, including scientists of different disciplines, governmental agencies, industrial partners, and customers. Exposure of personnel to different groups and units within the organization may be limited. Today's competitive business environment requires cognitive skills from managers who must deal with social, cultural, and technological challenges. Interox's projects frequently include front-end analysis to determine the components of shared mental models of organization members' understanding of cultural differences among the organizational units and professional disciplines, as well as operational capabilities and situations where these issues are especially important. Based on this analysis, Intertox is developing a computer-mediated training tool that can rapidly enhance the cognitive leadership skills required for personnel to be effective in a wide range of research and development activities.

2.3 Environmental Risk Assessment

Risk assessment is an important tool used to quantitatively estimate the potential for adverse health effects from chemical or microbial exposures. Intertox specializes in preparing risk assessments for a variety of situations where chemical or microbial exposure is a concern, including industrial activities, accidental releases, and consumer exposures. The primary objective of the risk assessment process is to develop a clear understanding of potential risks, including identifying chemicals of interest, characterizing potential routes of exposure, and identifying potentially sensitive population groups in order to support informed decision-making. Risk assessments provide valuable information that may be used to respond to citizen action groups concerned over potential impacts to the community, quantify the risks associated with site development or proposed action (such as a contaminated site cleanup), or develop adequate protective standards for human health and ecological impacts.

2.4 Litigation Support

Intertox has an established practice providing toxicological and risk assessment expertise for clients involved in litigation. The firm has provided expert witness services, toxicological data review, and independent toxicological research for both plaintiff and defense attorneys in a wide variety of cases. The firm's toxic tort experience includes large-scale class action cases as well as small cases involving individual health claims due to chemical and biological exposures. Intertox works closely with attorneys and other technical experts retained by the client to develop strategies for managing the scientific aspects of each case. The firm is particularly skilled at critically evaluating opponent's scientific information and developing scientifically sound support for clients. The scientists advise on the technical merit of lawsuits or threatened lawsuits and testify on behalf of clients when necessary. Intertox's multi-disciplinary team is skilled at uncovering the factual scientific basis of complex issues, which are sometimes contrary to public perception. The firm's team approach supports the uncovering of new information that can aid the legal process, allowing clients to examine their case from different angles. Intertox scientists have conducted a full range of research and risk assessments required to gain a thorough understanding of whether the suspected chemical or biological agents of concern have or can cause the alleged health effect. Intertox and its associates have testified as experts in depositions, arbitration matters, and trials. Intertox scientists adhere to objective examination of the evidence, and rely upon sound science to deliver this service.

3. Principal Scientists

Intertox is comprised of a multidisciplinary team of risk assessors, toxicologists, industrial hygienists, and regulatory policy experts working together to solve complex human health and environmental issues with innovative, cost-effective, and resourceful approaches based on sound scientific methodology.

3.1 Igor Linkov – Risk Assessor and Decision Analyst

Dr. Igor Linkov is a Managing Scientist with Intertox Inc. in Brookline, MA, and Adjunct Professor of Engineering and Public Policy at Carnegie Mellon University in Pittsburgh, PA. Dr. Linkov's skills include decision analysis, environmental security, risk assessment for emerging threats, multiple criteria toxicology, radiation health and safety, guidance development, risk communication, policy analysis, and biostatistics.

Dr. Linkov’s research in the area of emergency response, portfolio management and homeland security has been supported by the North Atlantic Treaty Organization as well as the US Department of Defense. One focus of his current research is integrating risk assessment and multi-criteria decision analysis tools in military and environmental management. He is currently developing decision support tools to prioritize resource allocation and technology gaps in several military programs as well as in other areas (such as algal bloom management and nanotechnology). He managed the radiation safety program for the US Army Soldiers’ Systems Command and helped in developing the Army Risk Assessment Modeling System (ARAMS). He is developing cognitive leadership training materials for the US Army Research Institute.

Dr. Linkov has organized more than a dozen national and international conferences and continuing education workshops on risk assessment, decision analysis, risk communication and modeling and participated in organizing many others. For NATO, he organized several international workshops including: Role of Risk Assessment in Addressing Environmental Security Needs (2004); Integrating Human Effectiveness and Risk Characterization of Non-Lethal Weapons into Antiterrorism Civil Science Programs (2003); Environmental Security in Harbors and Coastal Areas (2005); and Ports Security and Critical infrastructure (2006). As a Member of the Organizing Committee for the 2003, 2004, 2005 and 2006 annual meetings of the Society for Risk Analysis (SRA), Dr. Linkov was responsible for the military and terrorism-related track, and he organized several symposia and special sessions on military applications and emergency response. He has also organized SRA continuing education workshops on Risk Communication: Application and Case Studies in Military and Emergency Settings, and he is currently organizing one on the Use of Risk Assessment and Decision Analysis in Military Applications. Dr. Linkov has published widely on policy, environmental modeling, and risk analysis, including eight books and over 80 peer-reviewed papers and book chapters.

Dr. Linkov serves as a Scientific Advisor to the Toxic Use Reduction Institute, a position that requires nomination by the Governor of Massachusetts. Dr. Linkov is the Founding Chair of the SRA Decision Analysis and Risk Specialty Group and is Past President for the Society for Risk Analysis-New England. He is also Past Chair of the SRA Ecological Risk Assessment Specialty Group and participates in several SRA and Society of Environmental Toxicology and Chemistry (SETAC) Committees. Dr. Linkov is the recipient of the 2005 SRA Chauncey Starr Award for exceptional contribution to Risk Analysis.

3.2 Richard Pleus – Risk Communicator and Toxicologist

Dr. Pleus, Intertox Director, is a toxicologist with over 25 years experience assessing the risk to humans exposed to chemical and biological agents via food, consumer products, therapeutic agents, and the environment. He is an expert in neurological and reproductive toxicology. He has a proven ability to communicate risks of toxicants to a variety of audiences, skillfully facilitating both public forums and industry meetings, in litigation support, on expert panels, and as an expert witness. His clients include companies from the pulp and paper, utility, cement manufacturing, mining, building material, and chemical industries; law firms; citizen groups; and governmental agencies both national and international. He continues to be involved in research, publications, and education.

Dr. Pleus’ research focuses on human health risk, including mode-of-action studies aimed at quantifying exposure to critical organ systems, with particular interest in human and laboratory animal nervous system development. In association with these activities, he has conducted a variety of human health risk evaluations of exposures to chemical and biological agents in air, water, food, and soil, as well as risk evaluations relating to consumer products and therapeutic agents. His work is focused on the application of academic research results to protect human health and resolve public health issues. He has presented the results of his research at national and international meetings in Australia, France, South Africa, and the Czech Republic.

Dr. Pleus was an instructor for 10 years at the University of Minnesota where he taught human science classes for both lower and upper level undergraduate students. In addition, he taught courses in physiological psychology and psychopharmacology for Metropolitan State University. He periodically serves as a graduate level guest lecturer in toxicology at the School of Public Health at the University of Washington. He is an adjunct Associate Professor in the Department of Pharmacology at the University of Nebraska Medical Center, as well as a faculty member of the Center for Environmental Toxicology at the University of Nebraska. He is an elected member of the Delta Omega Honorary Society in Public Health.

Dr. Pleus’ credentials include a B.S. with Honors from Michigan State University, an M.S. in Environmental Health, a Ph.D. in Environmental Toxicology from the University of Minnesota, and postdoctoral research in neuropharmacology at the University of Nebraska Medical Center.

4. Case Studies

Our highly trained and experienced scientists provide expert project support customized to our client’s needs. We take pride in the opportunity to be called upon to evaluate some of the most challenging issues in the world. Our project experience exemplifies our valuable relationships with clients in our local community, foreign governments, and with some of the most successful companies in the world.

4.1 Human Health Risk Assessment for Large Watershed

Overview: Intertox participated in a water quality and quantity monitoring and modeling project focused on a large watershed in Washington State. This project was initiated to support a variety of potential water resource decisions for the majority of the watershed. The primary purpose was to assist wastewater capital planning, habitat conservation planning, salmon recovery, and watershed planning efforts by collecting information, developing a set of scientific tools to better understand the watershed, and use these same approaches to explore resource management options. One of the primary tools for use in these planning efforts was the assessment of potential current and future human health risks resulting from human alteration of the watershed. The risk assessment consisted of three sequential tiers of increasing refinement. Intertox completed the human health component of Tier 1, a general risk screening of all existing water, sediment, and tissue chemical data, and designed the methodology for Tier 2. Tier 1 used conservative assumptions to identify and screen out chemicals posing negligible human health risk from further evaluation. Chemicals not screened out through the Tier 1 process were retained for further evaluation in the Tier 2 evaluation. Client benefit: The screening level risk assessment allowed the client increased efficiency for the remainder of the risk assessment by being able to focus on dominant contaminants and routes of exposure.

Chemicals of concern: Contaminants of potential concern in the Tier 1 evaluation included chemical constituents such as metals and organic compounds, including polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and pesticides, as well as conventional stressors that may be of potential concern to human health (e.g., phosphates, nitrates). The biological indicators E. coli and fecal coliforms were also evaluated in Tier 1.

Approach: The chemical screening approach used in Tier 1 was based on technical guidance for selecting exposure routes and contaminants of concern by risk-based screening developed by USEPA Region III. The screening approach involved four steps: (1) data quality evaluation; (2)

reducing the data set using risk-based concentration screening; (3) considering re-including eliminated chemicals and routes; and (4) makeing further specific reductions in the data set (optional). All chemicals for which water, fish tissue, and/or sediment data from the study area were available were evaluated in Tier 1 using the risk-based screening approach described above. Chemicals that did not exceed screening criteria in any one of the three environmental media (water, sediment, or fish tissue) were eliminated from further consideration.

4.2 Environmental Health Impacts from a Proposed Wastewater Treatment Facility

Overview: Intertox provided an evaluation of potential environmental health impacts from the construction and operation of a proposed wastewater treatment plant to workers at a neighboring food production facility and its customers. Specifically, Intertox determined whether these potential impacts had been adequately and consistently evaluated in an Environmental Impact Statement for the plant and if recommended mitigations were appropriate and set in a consistent manner. Sources of potential impacts included soil contaminants, hazardous constituents of buildings, raw and treated sewage, biosolids, disease vectors (e.g., birds, rodents, insects), and treatment chemicals. Because it produces food for public consumption, the potentially impacted facility presented unique business concerns that not only included health risks, but the perception of risks by customers due to potential odors from the proposed plant or the mere proximity of its presence.

Client Benefit: With our findings, the client was able to negotiate a favorable settlement in the matter.

Chemicals of Concern: Biological agents; volatile organic compounds; metals

Approach: Intertox performed a variety of investigations to support its findings. These included: evaluating the adequacy of the Environmental Impact Statement for the proposed plant; reviewing environmental site assessments for the parcels composing the site to determine historical releases to soil and hazardous building constituents; and performing literature reviews of chemical and biological agents in wastewater and biosolids and their potential releases.

4.3 Nanotechnology EHS Risk

Nanotechnology is likely to produce revolutionary materials for industry, consumers, and medicine. Companies worldwide are looking to take advantage of nanotechnology to help them improve products and gain competitive advantages. However, much work needs to be done to understand the environmental health and safety (EHS) risks of nanomaterials. In response to this need, Intertox has developed a nanotechnology team to help firms assess and minimize their exposure to nanotechnology EHS risks and promote good public health practices. Intertox promotes the use of multi-criteria decision analysis and risk assessment for nanomaterials management.

Software

An Open Source MCDM Macro for OpenOffice.org

by

Jutta Geldermann

Implemented algorithms

This text is about a free Multiple Criteria Decision Making tool written as a Java macro for OpenOffice.org. For any decision problem entered, the classical multi attribute decision-making approaches Simple Additive Ranking (SAR) and Simple Additive Weighting (SAW) are offered, as well as the outranking approaches PROMETHEE I and PROMETHEE II.

The first two decision methods are very basic concepts, which may also be implemented using a template spreadsheet for standard office software. However, the tool described here can be used for any given decision problem without changing the calculation scheme and offers additional sensitivity analyses for each criterion.

The outranking approach PROMETHEE (as described by (Brans et al., 1986),(Brans, Mareschal, 2005)) is based on pairwise comparisons of alternatives with regard to each regarded criterion by several value functions, which makes quick analyses by hand (i.e. without using specialized software) more cumbersome. In order to value the deviation between the evaluations of two alternatives on a particular alternative, several vale functions are proposed by (Brans et al., 1986).

PROMETHEE I results in a partial ranking, which declares alternatives with contradictory information about their comparative strengths and weaknesses as incomparable and leaves the decision on ranking them to the decision maker.

In order to determine how sensitive the results of each decision method are to changes in the weighting between the criteria, sensitivity analyses are used. This allows the user to assess how robust the results are to the subjective weighting of the criteria.

Open Source for implementing the tool

The reason for choosing an office suite as the underlying software is to provide an easy to use tool for standard software that people are familiar with. The input of the evaluation table as one spreadsheet is a very comprehensible user interface and the output as one spreadsheet for each method allows a facile subsequent treatment or presentation. Whereas Microsoft Office is the most diffused office suite, the alternative OpenOffice.org was chosen for several reasons: Firstly, this office suite is Open Source, meaning it can be downloaded without license fees. This is especially of advantage for academic use, as it allows all students to work with the same version of the office suite, and can thus contribute to the diffusion of tools designed for this office software. Thus this tool was developed within the EDUKALIBRE project which aimed at promoting the use of Open Source Software in academic teaching (see (Gonzalez-Barahona et al., 2005)). Secondly, OpenOffice.org allows programming macros in high-level languages, which allows utilizing and reusing complex class libraries.

The MADM-tool was realized as an Open Source Java macro for OpenOffice. Open Source Software is software available without charge and for which the underlying programming code is available to the users so that they may read it and make changes to it. The aim is to allow anyone with programming experience to revise and change the programming code to suit their individual needs and to share improved versions. There are many types of Open Source Software, mainly differing in the licensing term under which (altered) copies of the source code may be redistributed. This tool is subject to the GNU Lesser General Public License (LGPL). This means, that individual classes used in the program can be employed in any way (including commercially) but an improved version of the whole program is to remain under this license, i.e. Open Source. For more details about this license see http://www.gnu.org/copyleft/lesser.html. As we are hoping to trace the spread of the tool and to establish contact to other researchers, the complete source code will be sent on request by email, whereas the tool can directly be downloaded for the convenience of end users.

Implementation

The MADM tool was written as a Java macro for OpenOffice using Netbeans IDE 3.6. The use of common functions is eased by a collection of classes and libraries provided in the Application Program Interface (API) of OpenOffice.org. As a Java macro can define its own data types and classes can inherit properties, it can be designed in a very structured modular way. Whereas the compiled tool comes as one single file, about 20 classes are employed for programming the data input and output, the calculations and graphics. This modular composition allows future enhancements and the reuse of single classes for other purposes. The source code contains numerous comments, as well as a packet and class description according to the Javadoc specification.

The tool can be downloaded from the following website:

http://wwwiip.wiwi.unikarlsruhe.de/forschung/technik_html/forschungsgebiete/tool/index.htm

It requires the free office suite OpenOffice.org and Java to be installed beforehand, which both are available for several operating systems. Once installed, the tool can be easily started using its own button in the OpenOffice.org menu bar.

The basic data of any multi-criteria problem is contained in the evaluation table, which is required as the input for the MADM-tool. A template for this table is provided, which shows the structure of the data expected by the program. The number of alternatives and criteria is only limited by the hardware (and programming language) restrictions. The weights assigned to each criterion have to be inserted as numbers and are automatically normalized (their sum being one) when the tool is run.

For each criterion, the user has to specify if a minimum or maximum value is aspired, for use in PROMETHEE maximum and minimum values can be entered optionally. This outranking approach also requires the selection of a weighing function (the six functions proposed by (Brans, Mareschal, 2005) can be chosen) and the input of values for the parameters used by these value functions.

Once the data is inserted and the tool (macro) started, new spreadsheets are created for displaying the results of the implemented methods (Simple Additive Ranking, Simple Additive Weighting, PROMETHEE I and II). These spreadsheets include tables for intermediate steps, final results and sensitivity analyses for each criterion. The partial ranking resulting from PROMETHEE I and the total ranking resulting from PROMETHEE II are graphically displayed in a separate spreadsheet.

Screenshots:

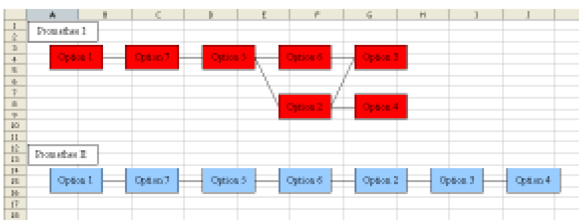


Figure 1: PROMETHEE Rankings

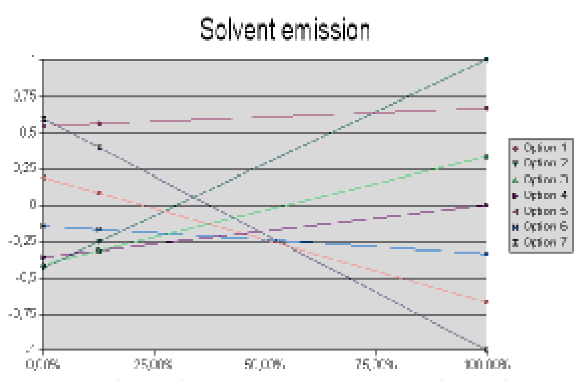


Figure 2: Sensitivity Analysis

References:

Brans, J-P, Mareschal, B (2005) PROMETHEE Methods. In: Figueira, J, Greco, S, Ehrgott, M (Eds.), Multiple Criteria Decision Analysis - State of the Art Surveys, Springer, New York, pp. 163-195.

Brans, J-P, Vincke, Ph, Mareschal, B (1986) How to select and how to rank projects: The PROMETHEE method, European Journal of Operational Research 24, pp. 228-238.

Gonzalez-Barahona, J, Tebb, C, Dimitrova, V, Chaparro, D, Romera, T (2005) Transfering Libre Software Development Practices to the Production of Educational Ressources: the Edukalibre Project, Proceedings of the 1st International Conference on Open Source Systems, July 11-15 2005, Genova.

Persons and Facts

International Society on MCDM – Members Elected for the Executive Committee: Salvatore Greco, Jacinto Gonzalez-Pachon, Daniel Vanderpooten, Luis Vargas.

About the 64th Meeting

by

George Samaras,
Pandelis Ipsilandis, and
Nickolaos Matsatsinis

The 64th meeting of the European Working Group "Multiple Criteria Decision Aiding,, was held in Larissa, Greece, in 28-30 September 2006, at the Technological Education Institute of Larissa (Departments of Project Management). George Samaras, Pandelis Ipsilandis and Nickolaos Matsatsinis were the organisers, with the support of Ntina Tzavella and Joanne Ipsilandis. The organisation was supported by HELORS (Hellenic Operational Research Society) and the Technical University of Crete, while financial support was provided by the Piraeus Bank, and the Municipality of Larissa. EURO supported the participation of some PhD students. The meeting was attended by almost 47 participants from 10 different countries, around the main theme of Multicriteria

Decision Support Systems, but with a large diversity of contributions from different areas, as reported in the programme (see below). The participants received a bag with the conference logo containing conference related material (programme, abstracts etc.) plus a booklet and CD with tourist information and a bottle of local spirit (ouzo) kindly offered by a local producer.

Scientific programme
The scientific programme included seven (7) sessions which besides the main theme of the conference on multicriteria decision support systems included papers on theoretical aspects, modelling techniques and applications of multicriteria analysis. A total of 40 papers included in the programme, 23 of them for presentation and the rest 17 for discussion. Submitted papers will undergo a two-fold blind review to be selected for publication in a special issue of ORIJ - “Operation Research: An International Journal” published by HELORS (Hellenic Operational Research Society).

Social programme
The social programme included a visit to the site of Meteora where conference participants had a chance to visit monasteries that were built during the Byzantine era (10th – 14th century ac.) on step and tall rocks. Participants were guided by a local guide and had a chance to see small chapels with frescos and icons form those years handicrafts, old scripts and the organization of monastic life. The visit ended with lunch at the footsteps of the rocks with a magnificent view of the scenery.

PROGRAMME SCIENTIFIQUE / SCIENTIFIC PROGRAM

64^{e} Journées du Groupe de Travail Européen
“AIDE MULTICRITERE A LA DECISION”
(28-30 Septembre, 2006)

64th Meeting of the European Working Group
"MULTIPLE CRITERIA DECISION AIDING"
(September 28-30, 2006)

Larissa-Greece

***Jeudi 28 Septembre* / Thursday, September 28**

10:30-11:15 *Inscription* / **Registration**

11:15-11:30 *Session d’ ouverture* / **Opening session**

11:30-13:00 Session 1 : ***Aspects Théoriques* / Theoretical Aspects**

Président / Chairman: José Rui Figueira

- Bernard Roy, “A propos de la signifiance des dépendances entre critères : Quelle place et quels modes de prise en compte pour l’aide à la décision ?” (présentation type A)
- José Figueira, Salvatore Greco, Bernard Roy, “ Methodes Electre Avec Interaction Entre Criteres: Une Generelisation De L’ Indice De Concordance”

Papiers Soumis à Discussion / Papers Submitted for Discussion

- Vassilios N. Pagounis, George Stavridis, "Operational Research for Engineering Applications. Optimization methods for logistics design of GPS network design"
- Roman Słowinski, Salvatore Greco, "Necessary and possible ranking constructed using a set of utility functions or a set of decision rules compatible with holistic preference information"
- Willem Karel M. Brauers, "A Critical Analysis of Goal Programming for a Wellbeing Economy"
- Evangelos Grigoroudis, Yoannis Siskos, Yoannis Politis, "Self assessment for measuring business excellence: A multistage multicriteria approach"
- A. Benamar & M. Benbouziane, "Nonlinearity and Long Memory Process: A Joint Hypothesis for the Purchasing Power Parity in MENA Countries"
- Pavlos Delias, Nikolaos F. Matsatsinis, "Assigning Work Items in a Workflow Management System Using a Multiple Criteria Methodology"

13:00-14:00 *Déjeuner* / **Lunch**

14:00-16:00 Session 2 : ***Systèmes d’ Aide à la Décision* / Decision Support Systems**

Président / Chairman: Maria Franca Norese

- Juan Carlos Leyva Lopez, Lizbeth Dautt Sánchez, Miguel Angel Aguilera Contreras, "A Multicriteria Decision Support System with an Evolutionary Algorithm for Deriving Final Ranking from a Fuzzy Outranking Relation"
- Maria Franca Norese, Simona Borrelli, “An MC System to support Monitoring in the public administration”
- Nabil Belgasmi, Lamjed Ben Saïd, Khaled Ghédira, “Spatial Decision Support Systems for localizing landfills”
- Serre D., Peyras L., Maurel P., Diab Y., "Multicriteria decision model integrated in a GIS to optimize inspection, maintenance and reparation operations of river levees"

Papiers Soumis à Discussion / Papers Submitted for Discussion

- Ivan Blecic, Arnaldo Cecchini, Clara Pusceddu, "Constructing Strategies in Strategic Planning: A Decision Support Evaluation Model"
- Nikos F. Matsatsinis, Konstantinios-Dimitrios Tzoannopoulos, "Multiple Criteria Group Decision Support through the Usage of Argumentation-Based Multi-Agent Systems: An Overview."

16:00-16:30 *Pause café* / Coffee break

16:30-18:00 Session 3 : *Questions Environnementales et Soustenabilité* / Enviromental and Sustainability Issues

Président / Chairman: George Mavrotas

• Fotios Thomaidis, Popi Konidari, "Ranking of the Energy Community countries' prospects for integration into a regional competitive gas market"

• Cedomir Beljic, Zoran Gligoric, "Multiple Criteria Decision Making as Support to Opening (development) Underground Mine of Gold"

• Patrizia Lombardi, Agata Spaziante and Chiara Murano, "Problem Structuring and Participation in Sustainable Urban Planning"

Papiers Soumis à Discussion / Papers Submitted for Discussion

- Sghaier Tahar, Khouja Mohamed Larbi, "Comportement des provenances de pin d'Alep (Pinus halepensis Mill.) dans le semi aride tunisien"
- Popi Konidari, Fotios Thomaidis, "Clim-AMS the software tool for climate policy evaluations"
- Nikos Tsourakis, Dimitris Pratsolis, Nikos Matsatsinis, " Web-Based Decision Support System for the Quantitative Analysis of the Customers' Behavior"

***Vendredi, 29 Septembre* / Friday, September 29**

9:00-11:00 Session 4: *Aspects Théoriques* / Theoretical Aspects

Président / Chairman: Constantin Zopounidis

• Panos Pardalos, Recent Developments in Multiobjective Optimization (type A presentation)

• Vasile Postolica, "A Survey On The Efficiency" (type A presentation)

• Horst W. Hamacher, Stefan Ruzika, "Solving Bicriteria Real-World Problems"

11:00-11:30 *Pause café* / Coffee break

11:30-13:00 Session 5: *Aspects Théoriques* / Theoretical Aspects

Président / Chairman: Yannis Siskos

• George Mavrotas, "Effective implementation of the e-constraint method for the generation of efficient solutions in multiobjective mathematical programming problems"

• Trabelsi Hedia, "Aide multicritère à la décision participative et gestion durable des nappes souterraines"

• Dimos Loukas, Ioannis Papadimitriou, "Choosing a final set of indices: Correspondence analysis as a tool to MCDA"

13:00-14:00 *Déjeuner* / Lunch

14:00-14:30 *Vie du Groupe et Prochaines Réunions*

Working Group Matters and Next Meeting

Président / Chairman: Bernard Roy

14:30-16:30 Session 6: *Aspects Théoriques et Applications* / Theoretical Aspects and Applications

Président / Chairman: Salvatore Greco

• Vladimir I. Kalika, "Modeling stock buying-selling on stock exchange using a new MCDM methodology accounting for uncertainty"

• Inès Saad, Camille Rosenthal-Sabroux, "L'apport de l'aide multicritère à la décision pour la gestion des connaissances"

• George Rigopoulos, John Psarras, Dimitrios Askounis, "A Framework for Group Multicriteria Decision Support on Financial Sorting Decisions"

. Risto Lahdelma, Pekka Salminen, "Modelling incomplete preference information through probability distributions"

Papiers soumis à discussion / Papers submitted for discussion

- Vladimir I. Kalika, "A New MCDM Methodology Accounting For Uncertainty And Its Application For Modeling Stock Buying-Selling On Stock Exchange"
- Nabil Belgasmi, Lamjed Ben Said, Khaled Ghédira, "Evolutionary Multiobjective Optimization of The Multi-Location Transshipment Problem"

16:30-17:00 *Pause café* / Coffee break

17:00-19:00 Session 7 : *Applications MCDA* / MCDA Applications

Président / Chairman: Roman Słowinski

• Edmond E. Vardumyan, Aram Arakelyan, "Foreign trade as a MCDM problem"

• Nebojsa Bojovic, Milos Milenkovic, "Determining an optimal rail fleet composition"

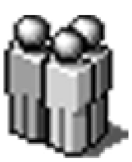
• Yoannis Marinakis, Magdalene Marinaki, Michael Doumpos, Y. Efremidis, Nikolaos Matsatsinis, Constantin Zopounidis, "Metaheuristic Algorithms for Feature Selection in Credit Risk Assessment"

• Stelios Rozakis, Nikos Boretos, "Enhancing optimisation capacities of GIS for bioenergy project evaluation"

Papiers soumis à discussion / Papers submitted for discussion

- XIE Zhi- jian, BO Yu-cheng, "Evaluating Weapon Systems by means of a New Method"
- S. Kotsiantis, A. Kostoulas, S. Lykoudis, A. Argiriou, K. Menagias, "A Hybrid Data Mining Technique For Estimating Mean Daily Temperature Values"
- Rigas G., Kantas D., Rigas N., Goulas P., Makridis Ch., " Production function and total cost function in determining optimum factor input. An empirical evidence for turkeys."
- Georgios Samaras, Pandelis Ipsilandis, Nikos Mplanas, Ilia Spyrou, "A MUSA Application for Evaluation of Programme Results"

19:00 *Clotûre* / Closing



Forthcoming Meetings

(This section is prepared by Carlos Henggeler Antunes)

Forthcoming EWG Meettings/ Prochaines réunions du Groupe

Note:

- It should be remarked again that this is a bilingual group; all the papers should be presented in both official languages of the group (i.e. French with English slides, and *vice-versa*).
- Ceci en un groupe bilingue ; tous les papiers doivent être présentés dans les deux langues officielles du groupe (i.e. en français avec les transparents en anglais et *vice-versa*).

65th Meeting of the EURO Working Group on *Multiple Criteria Decision Aiding*. Poznań, Poland. April 12-13, 2007. Hosted by the Laboratory of Intelligent Decision Support Systems of the Institute of Computing Science, Poznań University of Technology. Organizer: Roman Słowiński (roman.slowinski@cs.put.poznan.pl).

66th Meeting of the EURO Working Group on *Multiple Criteria Decision Aiding*. Marrakech, Marroc. October 2007, 18-20 or 25-27.

Other Meetings

XIII CLAIO - Latin American Conference on Operations Research, Montevideo, Uruguay; Nov 27-30, 2006; http://www.fing.edu.uy/inco/eventos/claio06/eng/

International Conference on Computational Intelligence for Modelling, Control and Automation, Sydney, Australia; Nov 28 - Dec 1, 2006; http://www.ise.canberra.edu.au/conferences/cimca06/

SIGEF: XIII Congress of International Association for Fuzzy-Set Management and Economy, Hammamet – Tunisia; Nov 30 - Dec 2, 2006; http://www.isg.rnu.tn/SIGEFXIII

Japanese Symposium on the Analytic Hierarchy Process 2006, Meijo University, Aichi, Japan; Dec 2, 2006; http://www.urban.meijo-u.ac.jp/zkinoshi/jsahp_e.html

Winter Simulation Conference 2006, Monterey Conference Center & Portola Plaza Hotel Monterey, CA, USA; Dec 3 - 6, 2006; http://www.wintersim.org

The Veszprém Optimization Conference: Advanced Algorithms, Veszprém, Hungary; Dec 13-15, 2006; http://www.dcs.vein.hu/vocal/

10th. Annual Conference of the Society of Operations Management, Ahmedabad, India; Dec 21-23, 2006; http://www.socopm.org/conferences/acsom2006

INFORMS Computing Society Conference, Omni Colonnade Hotel, Coral Gables, Florida, USA; Jan 3-5, 2007; http://www.bus.miami.edu/ics2007/

5th International Symposium on Data Envelopment Analysis and Performance Management (DEA2007), Hyderabad, India; Jan 5-7, 2007; http://astro.temple.edu/~banker/DEA2007.html

EURO WINTER INSTITUTE ON LOCATION AND LOGISTICS, Estoril, Portugal; Jan 7 – Feb 10, 2007; http://ewi2007.fc.ul.pt

2nd International Conference on Algorithmic Operations Research (AlgOR 2007), Surrey, BC, Canada; Jan 21-23, 2007; http://math-ptima1.surrey.sfu.ca/algor2007/orc.htm

Evolutionary Multicriterion Optimization 2007, Hotel Taikanso, Matsushima, Japan; March 5-8, 2007; http://www.is.doshisha.ac.jp/emo2007/

Second International Conference on Modeling, Simulation, and Applied Optimization (ICMSAO' 07), Abu Dhabi, United Arab Emirates; March 24-27, 2007; http://www.pi.ac.ae/ee/ICMSAO/Default.htm

2007 IEEE Symposium Series on Computational Intelligence and Scheduling (CISched 2007), Honolulu, Hawaii, USA; April 1-5, 2007; http://www.cs.nott.ac.uk/~rxq/cis/CIS2007.htm

IEEE Symposium Series on Computational Intelligence (IEEE SSCI 2007), Hawaii, USA; April 1-5, 2007; http://www.ieee-ssci.org/

First IEEE Symposium on Computational Intelligence in Multi-Criteria Decision-Making (MCDM 2007), Hawaii, USA; April 1-5, 2007; http://www.ieeecis-multidecision.org/

Seventh European Conference on Evolutionary Computation in Combinatorial Optimization, Valencia, Spain; April 11-13, 2007; http://www.evostar.org/

66ème Reunion du Groupe de Travail EURO "Aide Multicritère à la Dècision" / 66th Meeting of the EURO Working Group on MCDA, Poznan, Poland, April 12-12, 2007;

International Network Optimization Conference 2007 (INOC 2007), Spa, Belgium; April 22-25, 2007; http://www.poms.ucl.ac.be/inoc2007/

INFORMS Practice Conference: Applying Science to the Art of Business, Sheraton Vancouver Wall Centre, Vancouver, BC, Canada; April 29 - May 1, 2007; http://meetings.informs.org/Practice07/

18th Annual Conference of the Production and Operations Management Society (POM-2007), Dallas, USA; May 4-7, 2007; http://www.poms.org/

EWG ECCO-XX 20th anniversary meeting of the European Chapter on Combinatorial Optimization, Limassol, Cyprus; May 24-26, 2007; hercules@ucy.ac.cy

TRISTAN VI - Sixth Triennial Symposium on Transportation Analysis, Bentota, Sri-Lanka; June 10-15, 2007; http://tristan.epfl.ch/

ICEIS 2007 - 9th International Conference on Enterprise Information Systems, Funchal, Madeira, Portugal; June 12-16, 2007, Tuesday Wednesday Thursday Friday Saturday [http://www.iceis.org]

Twelfth Conference on Integer Programming and Combinatorial Optimization, Cornell University, USA; June 25-27, 2007; http://ipco2007.orie.cornell.edu

INFORMS Marketing Science Conference Singapore Management University, Singapore, June 28-30, 2007; http://www.business.smu.edu.sg/mks2007/

Eighth Workshop on Models and Algorithms for Planning and Scheduling Problems (MAPSP2007) Istanbul, Turkey; July 2-6, 2007; http://mapsp2007.ku.edu.tr/

EURO XXII - 22nd Conference of the Association of European Operational Research Societies Prague, Czech Republic; July 8-11, 2007; http://euro2007.vse.cz

INFORMS Puerto Rico International 2007, Rio Grande, Puerto Rico; July 8-11, 2007, http://www.informs.org/Conf/PuertoRico2007/

11th Conference on Stochastic Programming (SPXI), Vienna, Austria; Aug 27-31, 2007; http://www.spxi.org/

Operations Research 2007, Saarbrücken, Germany; Sep 5-7, 2007; http://www.or2007.de

Operations Research Peripatetic Postgraduate Programme (ORP3), Guimarães, Portugal; Sep 12-15, 2007; http://www.norg.uminho.pt/orp3/

IEEE Congress on Evolutionary Computation (CEC), Singapore; Sep 25-28, 2007; http://www.cec2007.org/

INFORMS Annual Meeting 2007, Seattle, WA, USA; Nov 4-7, 2007.

IFORS 2008, 18th Triennial Conference of the International Federation of Operational Research Societies, Sandton, South Africa; July 7-11, 2008; http://www.orssa.org.za

Announcements

Dear Colleague, dear Friend,

The EDDA (EURO Doctoral Dissertation Award), a new EURO instrument, will now be awarded each time a EURO-K conference takes place. It will be awarded for the third time at the closing session of the EURO-2007 conference (Prague-***July 9-11, 2007***). The purpose is to identify the best PhD. thesis defended in the EURO countries during the last year. (For more information see: http://www.euro-online.org/). We therefore invite you to disseminate the information here under.

Eligibility

The entries will consist of doctoral dissertations that were completed after the competition deadline of the previous EURO Doctoral Dissertation Award, i.e. after January 15, 2006.
The dissertation must have been defended at an European University and the author must be a member of an EURO member society.
To be considered, a dissertation must be nominated by the thesis supervisor, who must submit the following items, as far as possible in electronic version:

1. Dissertation.
2. Extended abstract (3 to 5 pages) in English.
3. If the thesis was not written in English the nomination must include a paper in English (10 to max. 30 pages) describing the core ideas of the thesis that has been submitted for publication in an international journal or a prestigious conference.
4. Nomination letters (or reports) from two referees selected by the dissertation supervisor, supporting the submission and stating their assessment of why the thesis should win the award.

No nomination will be considered without these four items.

Award

The prize is endowed by 1.000 € for the final winner and includes a certificate. The 3 finalists are granted the early registration fee at the EURO K conference at which they participate as such. EURO will also contribute to their travel and journey expenses.

The ***deadline*** for submitting applications will be ***February, 15, 2007***.

As hundreds of PhD's in OR are achieved each year in Europe, we ask you to meet as far as possible the following rules:

1. Please limit the applications to outstanding pieces of work.
2. In order to facilitate the circulation of the contributions between the members of the jury, we ask you to send, as far as possible, only electronic versions to the following address: http://www.euro-online.org/escudero@umh.es. Otherwise, contact me for other alternatives.

We thank you in advance for your cooperation and your nominations.

Yours sincerely,

Laureano F. Escudero, Chairman EDDA-2007.

Call for Paper

Web site for Call for Papers:
www.inescc.fe.uc.pt/~ewgmcda/CallforPapers.html

Books

Concepts et Méthodes pour l'Aide à la Décision

Volume 1. Concepts et Méthodes pour l'Aide à la Décision : Outils de Modélisation

Volume 2. Concepts et Méthodes pour l'Aide à la Décision : Risque et Incertain

Volume 3. Concepts et Méthodes pour l'Aide à la Décision 3 : Analysis Multicritère

Sous la direction de:

Denis Bouyssou
Didier Dubois
Marc Pirlot
Henri Prade

Editions Hérmes-Lavoisier, 2006. Collection Informatique et Systèmes de d'Information.
Web : www.lavoisier.fr

*** *** ***

Multiple Criteria Discrite and Combinatorial Optimization (Special Issue)

Edited by

Matthies Ehrgott
José Rui Figueira
Xavier Gandibleux

Annals of Operations Research, Vol. 147, October 2006.

*** *** ***

Guide du choix d'investissement - Préparer le choix - Sélectionner l'investissement - Financer le projet.

par

Nathalie Taverdet-Popiolek

Editions d'Organisation, 2006, Paris

*** *** ***

Evaluation du Risque Pays :
Méthodes et Cas d'Application

par

Christian Hurson
Michael Doumpos
Nadine Ricci-Xella
Constantin Zopounidis

Résumé

Le risque pays et son évaluation constituent un sujet d'importance majeure qui s'adresse à tout investisseur en relation avec des pays ou entreprises étrangères. Dans cet ouvrage le concept de risque pays est présenté dans son évolution et son actualité (différentes formes de risque, identification des critères d'évaluation, outils et études académiques). Dans un premier temps l'ouvrage présente la notion de risque pays, discute de ces différentes formes et offre une présentation critique des méthodes classiques utilisées pour l'évaluer. Une approche novatrice et originale d'évaluation du risque pays est ensuite proposée et illustrée de quelques cas d'application, celle de l'aide multicritère à la décision. Celle-ci présente notamment l'avantage de permettre une prise en compte explicite des différentes formes du risque pays, ainsi que des préférences et de l'expertise des investisseurs concernés.

Auteurs

Christian HURSON, est maître de conférences en gestion à l'université de Rouen ou il dirige l'IUP Assurance. Il s'est spécialisé dans l'application de l'aide multicritère à la décision en finance et a à son actif de nombreuses publications sur ce sujet.

Nadine RICCI-XELLA est maître de conférences en gestion à Aix-Marseille où elle est responsable du Master Comptabilité Contrôle Audit et de la licence gestion. Elle a publié de nombreux articles en finance de marché.

Michael DOUMPOS est professeur assistant de recherche opérationnelle à l'université technique de Crète (Grèce). Ses intérêts de recherche et ses nombreuses publications s'inscrivent dans le domaine de l'analyse multicritère et de l'analyse de classification.

Constantin ZOPOUNIDIS est Professeur à l'Université Technique de Crète. Éditeur en chef de journaux spécialisés, il est l'auteur d'un très grand nombre de publications sur l'analyse multicritère et ses applications en finance. La "MOISIL

International Foundation” lui a décerné une médaille d’or en sciences humaines et sociales.

Editeur : Economica, Paris, 2006

Articles Harvest

(This section is prepared by Juscelino ALMEIDA DIAS)

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Seminars

SÉMINAIRE «MODÉLISATION DES PRÉFÉRENCES *ET AIDE MULTICRITÈRE À LA DÉCISION»*

Responsables : Bernard ROY,

Daniel VANDERPOOTEN

(le mardi, à 14.00, en salle P 510)

Prochaines réunions

17 octobre 2006 Discussion des travaux de **Chabane Mazri** (LAMSADE et INERIS) : *Contribution au développement d'une politique participative de communication des risques dans le cadre des Plans de Prévention des Risques technologiques*.

14 novembre 2006 Conférence de **Yves de Smet** (Université Libre de Bruxelles, Belgique) : *Enchères multicritères.*

12 décembre 2006 Conférence de **Sébastien Damart** (ENS Cachan) : *La cartographie cognitive comme démarche de structuration de la participation pour l'aide à la décision*.

9 janvier 2007 Discussion des travaux de **Rim Kalaï** (LAMSADE) : *Une nouvelle approche de robustesse en aide à la décision.*

13 février 2007 Conférence de **Roman Slowinski** (Université de Technologie de Poznan, Pologne) : *Titre à préciser*.

6 mars 2007 Conférence de **Salvatore Greco** (Université de Catane, Italie) : *Titre à préciser.*

Dissertations

HYDE, Kilye. PhD Dissertation. 2006. "Uncertainty Analysis Methods For Multi-Criteria Decision Analysis". The University of Adelaide, Australia.

ABSTRACT .Planning, design and operational decisions are made under complex circumstances of multiple objectives, conflicting interests and participation of multiple stakeholders. Selection of alternatives can be performed by means of traditional economics-based methods, such as benefit-cost analysis. Alternatively, analyses of decision problems, including water resource allocation problems, which involve trade-offs among multiple criteria, can be undertaken using multi-criteria decision analysis (MCDA). MCDA is used to assist decision makers (DMs) in prioritising or selecting one or more alternatives from a finite set of available alternatives with respect to multiple, usually conflicting, criteria. In the majority of decision problems, MCDA is complicated by input parameters that are uncertain and evaluation methods that involve different assumptions. Consequently, one of the main difficulties in applying MCDA and analysing the resultant ranking of the alternatives is the uncertainty in the input parameter values (i.e. criteria weights (CWs) and criteria performance values (PVs)). Analysing the sensitivity of decisions to various input parameter values is, therefore, an integral requirement of the decision analysis process. However, existing sensitivity analysis methods have numerous limitations when applied to MCDA, including only incorporating the uncertainty in the CWs, only varying one input parameter at a time and only being applicable to specific MCDA techniques. As part of this research, two novel uncertainty analysis approaches for MCDA are developed, including a distance-based method and a reliability based approach, which enable the DM to examine the robustness of the ranking of the alternatives. Both of the proposed methods require deterministic MCDA to be undertaken in the first instance to obtain an initial ranking of the alternatives. The purpose of the distance-based uncertainty analysis method is to determine the minimum modification of the input parameters that is required to alter the total values of two selected alternatives such that rank equivalence occurs. The most critical criteria for rank reversal to occur are also able to be identified based on the results of the distance-based approach. The proposed stochastic method involves defining the uncertainty in the input values using probability distributions, performing a reliability analysis by Monte Carlo Simulation and undertaking a significance analysis using the Spearman Rank Correlation Coefficient. The outcomes of the stochastic uncertainty analysis approach include a distribution of the total values of each alternative based upon the expected range of input parameter values. The uncertainty analysis methods are implemented using a software program developed as part of this research, which may assist in negotiating sustainable decisions while fostering a collaborative learning process between DMs, experts and the community. The two uncertainty analysis approaches overcome the limitations of the existing sensitivity analysis methods by being applicable to multiple MCDA techniques, incorporating uncertainty in all of the input parameters simultaneously, identifying the most critical criteria to the ranking of the alternatives and enabling all actors preference values to be incorporated in the analysis.

Five publications in refereed international journals have emerged from this research, which constitute the core of the thesis (i.e. PhD by Publication). The publications highlight how uncertainty in all of the input parameters can be adequately considered in the MCDA process using the proposed uncertainty analysis approaches. The methodologies presented in the publications are demonstrated using a range of case studies from the literature, which illustrate the additional information that is able to be provided to the DM by utilising these techniques. Publications 1 and 2 (Journal of Environmental Management and European Journal of Operational Research) demonstrate the benefits of the distance-based uncertainty analysis approach compared to the existing deterministic sensitivity analysis methods. In addition, the benefits of incorporating all of the input parameters in the uncertainty analysis, as opposed to only the CWs, are illustrated. The differences between global and non-global optimisation methods are also discussed. Publications 3 and 4 (Journal of Water Resources Planning and Management and Journal of Multi-Criteria Decision Analysis) present the stochastic uncertainty analysis approach and illustrate its use with two MCDA techniques (WSM and PROMETHEE). Publication 5 (Environmental Modelling & Software) introduces the software program developed as part of this research, which implements the uncertainty analysis approaches presented in the previous publications. Despite the

benefits of the approaches presented in the publications, some limitations have been identified and are discussed in the thesis. Based on these limitations, it is recommended that the focus for further research be on developing the uncertainty analysis methods proposed (and in particular the program, and extension of the program) so that it includes additional MCDA techniques and optimisation methods. More work is also required to be undertaken on the Genetic Algorithm optimisation method in the distance-based uncertainty analysis approach, in order to simplify the specification of input parameters by decision analysts and DMs.

LEMESTRE, Julien. PhD Dissertation, 2006. « Methodes exactes pour l'optimisation combinatoire multi-objectif : conception et application ». Université de Lille I, Villeneuve d'Ascq. Le Jury : Evripidis Bampis, Universite d'Evry, rapporteur Vincent T'Kindt, Université de Tours, rapporteur Jacques Teghem, Faculté Polytechnique de Mons, examinateur Sophie Tison, examinateur Clarisse Dhaenens, co-encadrante El-Ghazali Talbi, directeur

RESUME. Cette thèse s'inscrit dans le domaine de l'optimisation combinatoire multi-objectif. Elle porte, plus particulièrement, sur les méthodes de résolution exacte trouvant l'intégralité du front Pareto. Pour tester et comparer nos méthodes, nous utilisons un problème de flow-shop multi-objectif (problème d'ordonnancement). Nous présentons différentes méthodes exactes de la littérature et analysons leurs périmètres d'utilisation efficace. Afin de résoudre le problème de flow-shop bi-objectif, nous proposons en premier lieu une application de la méthode deux phases optimisée en fonction des spécificités de notre problème. Ensuite, nous proposons une nouvelle méthode exacte de résolution des problèmes bi-objectif (la méthode parallèle par partitions "PPM" Parallel Partitioning Method). Nous présentons une extension de cette méthode vers une méthode exacte multi-objectif générale (admettant plus de deux objectifs) et son application à un problème de flow-shop tri-objectif.
Les méthodes proposées étant exactes, elles demandent un temps de calcul important. Dans un dernier temps, nous étudions deux moyens de réduire les temps de calcul afin d'obtenir le front Pareto exact : le parallélisme et l'hybridation avec une méthode heuristique. Afin d'ouvrir le sujet de thèse, nous présentons aussi une hybridation entre une méthode exacte et une méta-heuristique retournant un résultat heuristique. Ceci nous montre une des utilisations possibles des méthodes exactes sur les problèmes de grandes tailles.

SERRE, Damien. PhD Dissertation, 2006. « Evaluation de la performance des digues de protection contre les inondations. Modélisation de critères de décision dans un Système d'Information Géographique. ». Université Aix en Provence.

RESUME. La France et plus généralement le monde subissent de fréquents épisodes de crues dévastatrices. Les inondations provoquent d’importants dégâts et les coûts induits sont considérables. Les digues de protection contre les inondations, souvent sous-dimensionnées et mal entretenues, ont montré leurs faiblesses à plusieurs reprises et leurs ruptures augmentent la violence des inondations. A l’échelle nationale, le linéaire conséquent de digues (environ 7 500 km) et le manque de données sur l’ensemble de ce parc d’ouvrages compliquent leur gestion. A l’échelle du gestionnaire local se pose la question de l’optimisation des opérations de maintenance. En effet, un gestionnaire de digues ne dispose généralement pas d’un budget suffisant pour réaliser l’ensemble des opérations de maintenance sur la totalité du parc d’ouvrages. Ce long linéaire pose donc une question majeure : par où commencer les actions de maintenance pour à la fois assurer le bon fonctionnement des digues et optimiser les choix budgétaires ? Dans ce contexte, les gestionnaires de digues ont besoin de méthodes et d’outils d’aide à la décision. Un premier Système d’Information Géographique (SIG), le SIRS Digues, est opérationnel. Il contient les informations détaillées sur les ouvrages : géoréférencement des digues à l’échelle 1/10 000ème et informations relatives aux digues (constitution, désordres, réseaux, voiries,...). Toutefois en l’état, cet outil ne permet pas d’évaluer l’état des digues. Notre recherche vise à développer des méthodes d’évaluation de la performance des digues. A partir des informations disponibles (inspections visuelles détaillées, essais réalisés, données historiques, etc.), nous proposons des

indicateurs capables d’évaluer leur état et leur performance. Notre démarche comporte trois étapes :

- l’élaboration d’un modèle fonctionnel des mécanismes de rupture, bâti à partir de l’Analyse Fonctionnelle (AF) et l’Analyse des Modes de Défaillance et de leurs Effets (AMDE), et utilisant une représentation sous forme de graphes causaux et d’arbres de défaillances ;
- la construction d’indicateurs de performance pour chaque mécanisme de rupture, sur la base de critères et d’une méthode d’aide à la décision multicritère : l’agrégation à base de règles ;
- l’intégration du modèle multicritère d’évaluation de la performance des digues dans le SIRS Digues. Cette opération permet de cartographier et de visualiser la performance d’un parc d’ouvrages.

Après une application sur une digue existante de ces méthodes, nous proposons divers développements et perspectives à cette recherche, dont la principale est, à moyen terme, le développement d’un outil opérationnel pour l’aide à la décision dans les actions de maintenance des digues de protection contre les inondations. **Mots clés :** Digue de protection contre les inondations, gestion patrimoniale, analyse fonctionnelle, AMDE, indicateur de performance, aide à la décision multicritère, SIG.

ANGEL, Eric. Dssertation HDR. Université d’Evry, 2006. « De l'approximation standard vers l'approximation multicritère et multijoueur ». Le jury sera composé de : Euripides Bampis ; Philippe Chrétienne (Rapporteur) ; Pierre Fraigniaud (Rapporteur) ; Claire Kenyon (Rapporteur) ; Dominique de Werra (Rapporteur) ; Vassilis Zissimopoulos

RESUME : Face à des problèmes NP-durs, la conception d'algorithmes approchés avec garantie de performance est un domaine classique de l'optimisation combinatoire. Les problèmes habituellement considérés sont souvent de type monocritère, c'est-à-dire ne possédant qu'une seule fonction objectif à optimiser, et sont souvent étudiés dans un contexte où un preneur de décision central a toute autorité pour imposer sa solution. Il est cependant nécessaire dans certains cas de remettre en cause ces hypothèses. Les problèmes auxquels est confronté un preneur de décision sont souvent multiobjectifs. On ne cherche plus alors à trouver une solution optimale, mais plutôt des solutions offrant de bons compromis entre les différents critères. Une autre source de difficultés apparaît lorsque la solution peut être remise en cause par des utilisateurs individualistes et mener à une solution moins bonne du point de vue de la collectivité. De plus, les utilisateurs n'ont peut-être pas toujours intérêt à déclarer leurs vraies caractéristiques s'ils peuvent obtenir des solutions meilleures pour eux. Il est alors nécessaire de développer des algorithmes et/ou protocoles qui mènent à des équilibres stables et de bonne qualité malgré le comportement individualiste des utilisateurs. Nous présenterons les principaux résultats que nous avons obtenus dans ces deux contextes. Ils seront illustrés sur des problèmes classiques d'optimisation combinatoire telles que le problème du voyageur de commerce et des problèmes d'ordonnancement faisant intervenir la somme pondérée des temps de complétude des tâches et la date de fin de l'ordonnancement.

Announcement:

The "Useful links" section of the group's homepage

(http://www.inescc.pt/~ewgmcda)

is being enlarged. Contributions of URL links to societies, research groups and other links of interest are welcome.

A membership directory of the European Working Group on "Multiple Criteria Decision Aiding" is available at the same site. If you would like to be listed in this directory please send us your data (see examples already in the directory).

Contact: José Figueira (figueira@fe.uc.pt) and Luís Dias (ldias@inescc.pt)

Web site for the EURO Working Group "Multicriteria Aid for Decisions"

A World Wide Web site for the EURO Working Group on "Multicriteria Aid for Decisions" is already available at the URL:

http://www.inescc.pt/~ewgmcda

This WWW site is aimed not just at making available the most relevant information contained in the Newsletter sections, but it also intends to become an online discussion forum, where other information and opinion articles could appear in order to create a more lively atmosphere within the group.

Groupe de Travail Européen "Aide Multicritère à la Décision" /
European Working Group "Multiple Criteria Decision Aiding"

President of the EURO Working Group:
Bernard Roy

Newsletter editor:
José Figueira

Permanent Collaborators:
Maria João Alves, Carlos Henggeler Antunes,
Luís Dias, Juscelino Almeida-Dias

Contributions should be sent to:
José Rui Figueira
CEG-IST, Instituto Superior Técnico,
Dpt. Economia e Gestão, TagusPark
2780-990 Porto Salvo, PORTUGAL
E-mail: figueira@ist.utl.pt

or by fax to:
+351 21 423 35 68

or by electronic mail to:
figueira@ist.utl.pt

URL:
http://www.inescc.pt/~ewgmcda

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