Preference elicitation for
Multiple Criteria Decision Aiding

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Algorithmic Decision Theory: MCDA and MOO
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Introduction

- $n$ criteria $g_1, g_2, \ldots, g_n$, $A = \{a_1, a_2, \ldots, a_m\}$ and $\Delta$ the dominance relation on $A$.
- preference information ($I$) = any piece of information that can discriminate pairs of alternatives not in $\Delta$,

→ Decision processus,

→ Decision aid process,

→ Preference elicitation process
Preference elicitation process

\[ \mathcal{I} = \mathcal{I}^{\text{in}} \cup \mathcal{I}^{\text{res}}, \]

- \( \mathcal{I}^{\text{in}} \): input oriented preference information
  - “criterion \( g_3 \) is the most important one”
  - “the substitution rate between \( g_1 \) and \( g_4 \) is 3”
  - “The frontier between \( \text{Cat}_3 \) and \( \text{Cat}_2 \) on \( g_1 \) is equal to 12”

- \( \mathcal{I}^{\text{res}} \): result oriented preference information result
  - “I prefer \( a_2 \) to \( a_7 \)”
  - “\( a_{11} \) should be assigned at least to category \( C_3 \)”
  - “I prefer \( a_2 \) à \( a_7 \) more than I prefer \( a_5 \) à \( a_1 \)”
Preference elicitation process

- \( \mathcal{P} \) an MCAP to which \( k \) preference parameters are attached
  \[ \overline{v} = (v_1, v_2, \ldots, v_k), \]

- \( \Omega \) the space of acceptable values for \( \overline{v} \) in absence of preference information,

- The knowledge on \( \overline{v} \) (stemming from \( \mathcal{I} \)) is defined by
  \( \Omega(\mathcal{I}) \subseteq \Omega \) a list of constraints on \( \overline{v} \),

- **Specific case:** \( \Omega(\mathcal{I}) = \{\omega\} \)
  \( \mathrel{\leftrightarrow} \) the value of preference parameter is fully determined,

- Otherwise, the value of at least one preference parameter is imprecisely known.
Preference elicitation process

- Applying an MCAP $\mathcal{P}$ to a subset of alternatives $A' \subseteq A$ using $\omega \in \Omega$, lead to a result $R_\mathcal{P}(A', \omega)$:
  - Choice: a subset of selected alternatives $A^* \subseteq A'$
  - Sorting: the assignment of each $a \in A'$ to a category
  - Ranking: an partial preorder on $A'$

- Applying an MCAP $\mathcal{P}$ to a subset of alternatives $A' \subseteq A$ using $\Omega(I) \subset \Omega$, lead to a result $R_\mathcal{P}(A', \Omega(I))$,

- $R_\mathcal{P}(A', \Omega(I))$ should account for each $\omega \in \Omega(I)$
Given an MCAP $\mathcal{P}$ selected to model the DM’s preferences, a preference elicitation process consists in an interaction between the DM and the analyst and leads the DM to express information on his/her preferences within the framework of $\mathcal{P}$.

Such information is materialized by a set $\Omega(\mathcal{I}) \subseteq \Omega$ of plausible values for the parameters of $\mathcal{P}$. At the end of the process, $\Omega(\mathcal{I})$ should lead, through the use of $\mathcal{P}$, to a result which is compatible with DM’s view.
Preference elicitation process

- Preference elicitation process = element of the decision aiding process (stakeholder identification, definition of $F$ and $A$),

- The definition is grounded on the prior selection of a MCAP,

- The notion of DM/analyst interaction is a constituent of the elicitation process (sequence of Q/A in which the DM progressively express preference information ),

- During the elicitation process $\Omega(I) \subseteq \Omega$ is defined progressively (by the sequence of Q/A),

- the obtained $\Omega(I) \subseteq \Omega$ should lead, using $P$, to a result consistent with the DM’s view. Otherwise, the process should go on so as to revise $\Omega(I)$ consequently,
Nature of the preference elicitation activity

Two ways to consider the preference elicitation process

→ the *descriptivist* approach,

→ the *constructiviste* approach.
Preference elicitation: descriptivist approach

- The way alternatives compare is defined is the mind of the DM before the preference elicitation process starts,

- The elicitation process does not alter the pre-existing structure of preferences,

- Preference information is considered stable and refer to a reality,

- The preference model should account for the existing preferences as reliably as possible,

- There is a “distinction between true and estimated weights and it is possible that subjects’ true weights remain constant at all times, but become distorted in the elicitation process” [Beattie et Barron 91]
The constructivist approach considers preferences as not fully pre-established in the DM’s mind,

The purpose of preference elicitation is to specify and even to modify pre-existing elements,

Parameters’ values reflect, in the MCAP, statements expressed by the DM along the elicitation process.
Constructive learning preference elicitation

Beyond the preference model elaboration, the elicitation process gives a concrete expression of DM’s convictions about the way alternatives compare,

Elaboration of such convictions are grounded on:
  - pre-existing elements such as his/her value system, past experience related to the decision problem, ...
  - the preference elicitation process itself.
Constructive learning preference elicitation

Decision Maker

\( \mathcal{I} : \text{pref. info.} \)
- value system
- constructed preferences
- cognitive limitations
- MCAP understanding

Preference Model

\( \Omega(\mathcal{I}) \subset \Omega \)
- precise semantic of preference parameters
- model result
Preference elicitation tools for constructive learning

- Tools versus practice,
- Various “ingredients” can contribute to give birth to an Constructive Learning Preference Elicitation (CLPE) interaction,
  - aggregation / disaggregation (inference procedure),
  - elicitation and robustness,
  - inconsistency detection and resolution.
Disaggregation

Preference Information $\mathcal{I}$

Inference procedure

inferred parameters: $\omega^*(\mathcal{I})$

$(\mathcal{P}, \omega^*(\mathcal{I})) = \text{preference model des préférences that “best” match } \mathcal{I}$
Elicitation and Robustness

Preference information $\mathcal{I}$
$\Omega'(\mathcal{I}) \subset \Omega$

Robustness
Modification of $\mathcal{I}$

Result
$R_P(A, \Omega'(\mathcal{I}))$
Inconsistency detection and resolution

\[ I \subseteq \mathcal{I} \]

\[ I_1 \subset \mathcal{I} \]

\[ I_2 \subset \mathcal{I} \]

\[ I_3 \subset \mathcal{I} \]

... 

\[ I_k \subset \mathcal{I} \]
UTA-GMS

- Robust elicitation of a ranking model,
- Preference model = set of monotone additive value functions,
- Preference information = pairwise comparisons of alternatives/evaluation vectors and information about intensities of preference.
Problem statements

- **Choosing**, from a set of potential alternatives, the best alternative or a small sub set of the best alternatives

- **Sorting** alternatives to pre-defined and (ordered) categories

- **Ranking** the alternatives from the best to the worst (the ranking can be complete or not)
Choice problem statement
Problem statements

- Assigning alternatives to pre-defined and order categories
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Sorting problem statement
Problem statements

- **Ranking** the alternatives from the best to the worst (the ranking can be complete or not)
Ranking problem statement
Ordinal regression paradigm

- **Traditional aggregation paradigm**: The criteria aggregation model is first constructed and then applied on set $A$ to get information about the comprehensive preference.

- **Disaggregation-aggregation (or ordinal regression) paradigm**: Comprehensive preferences on a subset $A^R \subset A$ is known a priori, and a consistent criteria aggregation model is inferred from this information to be applied on set $A$. 
In $\text{UTA}^{\text{GMS}}$, the preference model is a set of additive value functions compatible with a non-complete set of pairwise comparisons of reference alternatives and information about comprehensive and partial intensities of preference.

We focus on the ranking problem statement (but the ideas can be extended to choice and sorting).
Elementary notation

- $A = \{a_1, a_2, \ldots, a_i, \ldots, a_m\}$ is finite set of alternatives
- $g_1, g_2, \ldots, g_j, \ldots, g_n$ $n$ criterion functions, $F$ is the set of criteria indices
- $g_j(a_i)$ is the evaluation of the alternative $a_i$ on criterion $g_j$
- $G_j$ - domain of criterion $g_j$,
- $\succsim$ - weak preference (outranking) relation on $G$: for each $x, y \in G$
  - $x \succsim y \iff \text{“} x \text{ is at least as good as } y \text{”}$
  - $x \succ y \iff [x \succsim y \text{ and not}(y \succsim x)] \text{ “} x \text{ is preferred to } y \text{”}$
  - $x \sim y \iff [x \succsim y \text{ and } y \succsim x] \text{ “} x \text{ is indifferent to } y \text{”}$
Reminder on UTA

- For each $g_j$, $G_j = [\alpha_j, \beta_j]$ is the criterion evaluation scale, $\alpha_j \leq \beta_j$.

- $U$ is an additive value function on $G$: for each $x \in G$, $U(x) = \sum_{j \in F} u_j[g_j(x)]$.

- $u_j$ are non-decreasing marginal value functions, $u_j : G_j \mapsto \mathbb{R}$, $\forall j \in F$. 
The preference information is given in the form of a complete pre-order on a subset of reference alternatives $A^R \subseteq A$, called reference pre-order.

$A^R = \{a_1, a_2, \ldots, a_{m_1}\}$ is rearranged such that $a_k \succsim a_{k+1}$, $k = 1, \ldots, m_1 - 1$, where $m_1 = |A^R|$. 

Reminder on UTA
The inferred value of each $a \in A^n$ is:

$$U(a) + \sigma^+(a) - \sigma^-(a),$$

In UTA, the marginal value functions $u_i$ are assumed to be piecewise linear, so that the intervals $[\alpha_i, \beta_i]$ are divided into $\gamma_i \geq 1$ equal sub-intervals,

$$[x_i^0, x_i^1], [x_i^1, x_i^2], \ldots, [x_i^{\gamma_i-1}, x_i^{\gamma_i}],$$

where,

$$x_i^j = \alpha_i + \frac{j(\beta_i - \alpha_i)}{\gamma_i}, j = 0, \ldots, \gamma_i, i = 1, \ldots, n.$$
Reminder on UTA

The piecewise linear value model is defined by the marginal values at break points: \( u_i(x^0_i) = u_i(\alpha_i), \) \( u_i(x^1_i), u_i(x^2_i), \ldots, u_i(x^\gamma_i) = u_i(\beta_i) \)

\[
\begin{align*}
0 & \quad \alpha_i = x^0_i \\
& \quad x^1_i \\
& \quad x^2_i \\
& \quad g_i(a) \\
& \quad x^3_i \\
& \quad \beta_i = x^4_i
\end{align*}
\]
The $UTA^{GMS}$ method: Main features

$UTA^{GMS}$ method generalizes the UTA method in two aspects:

- It takes into account all additive value functions compatible with indirect preference information, while UTA is using only one such function.

- The marginal value functions are general monotone non-decreasing functions, and not piecewise linear only.
General monotone non-decreasing value functions

The marginal utility function $u_i(x_i)$

Characteristic points of marginal utility functions are fixed on actual evaluations of actions from $A$. 

$y, v, w, z \in A^R$
General monotone non-decreasing value functions

The marginal utility function $u_i(x_i)$

$y, v, w, z \in A^R$

Marginal values in characteristic points are unknown
The marginal utility function $u_i(x_i)$

\[ u_i(x_i) \]

\[ y, v, w, z \in A^R \]

In fact, they are intervals, because all compatible utility functions are considered.
General monotone non-decreasing value functions

The marginal utility function $u_i(x_i)$

Area of all compatible marginal value functions
General monotone non-decreasing value functions

The marginal utility function $u_i(x_i)$

In the area the marginal compatible value functions must be monotone
The $\text{UTA}^{GMS}$ method: Main features

The method produces two rankings in the set of alternatives $A$, such that for any pair of alternatives $a, b \in A$,

- In the \textit{necessary order}, $a$ is ranked at least as good as $b$ if and only if, $U(a) \geq U(b)$ for \textit{all value functions compatible with the preference information}.

- In the \textit{possible order}, $a$ is ranked at least as good as $b$ if and only if, $U(a) \geq U(b)$ for \textit{at least one value function compatible with the preference information}.
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Additional preference information

\[ x \geq y, \quad z \geq w, \quad \text{and} \quad u \geq t, \quad z \geq u, \quad u \geq z, \quad x \geq w \]

Includes necessary ranking and does not include the complement of necessary ranking

necessary ranking enriched

possible ranking impoverished
Computing necessary and possible relations \((\succeq^N \text{ and } \succeq^P)\)

- Let \(d(x,y) = \min_{U \in \mathcal{U}} U(x) - U(y)\) and 
  \(D(x,y) = \max_{U \in \mathcal{U}} U(x) - U(y)\)
  where \(\mathcal{U} = \{\text{value functions compatible with the DM's statements}\}\)

- \(x \succeq^N y \iff d(x,y) \geq 0\)
- \(x \succeq^P y \iff D(x,y) \geq 0\)

Properties:
- \(x \succeq^N y \Rightarrow x \succeq^P y\),
- \(\succeq^N\) is a partial preorder (reflexive and transitive),
- \(\succeq^P\) is strongly complete (\(x \succeq^P y\) or \(y \succeq^P x\)), but not necessarily transitive.
20 alternatives, 5 criteria (all alternatives are efficient).

\[
\begin{align*}
\mathbf{s}_1 &= (14.5, 147, 4, 1014, 5.25) \\
\mathbf{s}_2 &= (13.25, 199.125, 4, 1014, 4) \\
\mathbf{s}_3 &= (15.75, 164.375, 16.5, 838.25, 5.25) \\
\mathbf{s}_4 &= (12, 181.75, 16.5, 838.25, 4) \\
\mathbf{s}_5 &= (12, 164.375, 54, 838.25, 4) \\
\mathbf{s}_6 &= (13.25, 199.125, 29, 662.5, 5.25) \\
\mathbf{s}_7 &= (13.25, 147, 41.5, 662.5, 5.25) \\
\mathbf{s}_8 &= (17, 216.5, 16.5, 486.75, 1.5) \\
\mathbf{s}_9 &= (17, 147, 41.5, 486.75, 5.25) \\
\mathbf{s}_{10} &= (15.75, 216.5, 41.5, 662.5, 1.5) \\
\mathbf{s}_{11} &= (15.75, 164.375, 41.5, 311, 6.5) \\
\mathbf{s}_{12} &= (13.25, 181.75, 41.5, 311, 4) \\
\mathbf{s}_{13} &= (12, 199.125, 41.5, 311, 2.75) \\
\mathbf{s}_{14} &= (17, 147, 16.5, 662.5, 5.25) \\
\mathbf{s}_{15} &= (15.75, 199.125, 16.5, 311, 6.5) \\
\mathbf{s}_{16} &= (13.25, 164.375, 54, 311, 4) \\
\mathbf{s}_{17} &= (17, 181.75, 16.5, 486.75, 5.25) \\
\mathbf{s}_{18} &= (14.5, 164.375, 41.5, 838.25, 4) \\
\mathbf{s}_{19} &= (15.75, 181.75, 41.5, 135.25, 5.25) \\
\mathbf{s}_{20} &= (15.75, 181.75, 41.5, 311, 2.75)
\end{align*}
\]
First information: $s_1 \succ s_2$. 
Second information: \( s_4 \succeq s_5 \).

Illustrative example
Third information: $s_8 \succ s_{10}$.
Inconsistency management

- When DM’s statement are not representable in the additive model
  → inconsistency,

- DM’s statements induce linear constraints on the variables (marginal values of alternatives)

- When such inconsistency occurs, we should check how to “solve” inconsistency,

- Which modification of the DM’s input will lead to representable preferences?

- Are they different ways to do so?

- What is the minimum number of constraints to delete?
solution of minimal cardinality is not necessarily the most interesting one for the DM,

The knowledge of the various ways to solve inconsistency is useful for the DM,

This permits to:

- help the DM to understand the conflictual aspect of his/her statement,
- create a context in which the DM can learn about his/her preferences,
- make the elicitation process more flexible,
Inconsistency resolution via constraints deletion

- \( m \) constraints induced by the DM’s statements

\[
\begin{align*}
\sum_{j=1}^{n} \alpha^j_{1} x_j & \geq \beta_1 \\
& \vdots \\
\sum_{j=1}^{n} \alpha^j_{m-1} x_j & \geq \beta_{m-1} \\
\sum_{j=1}^{n} \alpha^j_{m} x_j & \geq \beta_{m}
\end{align*}
\]  

- \( I = \{1, \ldots, m\} \); subset \( S \subset I \) resolves [1] iff \( I \setminus S \neq \emptyset \)

- We search for \( S_1, S_2, \ldots, S_p \subset I \) such that:
  
  (i) \( S_i \) resolves [1], \( i \in \{1, 2, \ldots, p\} \);
  
  (ii) \( S_i \not\subset S_j, i, j \in \{1, \ldots, p\}, i \neq j \);
  
  (iii) \( |S_i| \leq |S_j|, i, j \in \{1, 2, \ldots, p\}, i < j \);
  
  (iv) if \( \exists S \) that resolves [1] s.t. \( S \not\subset S_i, \forall i = 1, 2, \ldots, p \), then \( |S| > |S_p| \).
Inconsistency management

- Soit $y_i$ ($\in \{0, 1\}$, $i \in I$), t.q. :
  
  $y_i = \begin{cases} 1 & \text{if constraint } i \text{ is removed} \\ 0 & \text{otherwise} \end{cases}$

$$
\begin{align*}
P_1 \quad \text{Min} & \quad \sum_{i \in I} y_i \\
\text{s.t.} & \quad \sum_{j=1}^{n} \alpha_{ij} x_j + \alpha'_i \lambda + My_i \geq \beta_i, \quad \forall i \in I \\
& \quad x_j \geq 0, \quad j = 1, \ldots, n \\
& \quad y_i \in \{0, 1\}, \quad \forall i \in I
\end{align*}
$$

- $S_1 = \{i \in I : y_i^* = 1\}$ corresponds to (one of the) subset(s) of constraints resolving [1] of smallest cardinality,

- We define $P_2$ adding to $P_1$ the constraint $\sum_{i \in S_1} y_i \leq |S_1| - 1$
Inconsistency management

- $P_{k+1}$ is defined adding to $P_k$ the constraint $\sum_{i \in S_k} y_i \leq |S_k| - 1$
- We compute $S_1, S_2, \ldots, S_k$, and stop when $|S_{k+1}| > \Omega$.

Begin
\[
\begin{align*}
&k \leftarrow 1 \\
moresol \leftarrow \text{true} \\
\text{While} \text{ moresol} \\
&\text{Solve } PM_k \\
&\text{If } (PM_k \text{ has no solution}) \text{ or } (PM_k \text{ has an optimal value } > \Omega) \\
&\text{Then moresol } \leftarrow \text{false} \\
&\text{Else} \\
&\quad S_k \leftarrow \{i \in I : y^*_i = 1\} \\
&\quad \text{Add constraint } \sum_{i \in S_k} y_i \leq |S_k| - 1 \text{ to } PM_k \text{ so as to define } PM_{k+1} \\
&\quad k \leftarrow k+1 \\
&\text{End if} \\
&\text{End while} \\
\end{align*}
\]
End
Inconsistency management

- Each $S_i$ corresponds to a set of DM’s preference statements (presented to the DM),
- Sets $S_i$ represent (for the DM) “incompatible” comparisons, each one specifies a way to solve inconsistency.
The GRIP method: Main features

GRIP extends UTAGMS method by taking into account additional preference information in form of comparisons of intensities of preference between some pairs of reference alternatives. For alternatives \( x, y, w, z \in A \), these comparisons are expressed in two possible ways (not exclusive),

1) **Comprehensively**, on all criteria, “\( x \) is preferred to \( y \) at least as much as \( w \) is preferred to \( z \)”.

2) **Partially**, on each criterion, “\( x \) is preferred to \( y \) at least as much as \( w \) is preferred to \( z \), on criterion \( g_i \in F \)”. 
The GRIP method: Preference Information

DM is expected to provide the following preference information,

- A partial pre-order \( \succeq \) on \( A^R \) whose meaning is: for \( x, y \in A^R \)
  \[ x \succeq y \iff x \text{ is at least as good as } y. \]

- A partial pre-order \( \succeq^* \) on \( A^R \times A^R \), whose meaning is: for \( x, y, w, z \in A^R \),
  \[ (x, y) \succeq^* (w, z) \iff x \text{ is preferred to } y \text{ at least as much as } w \text{ is preferred to } z. \]

- A partial pre-order \( \succeq^*_i \) on \( A^R \times A^R \), whose meaning is: for \( x, y, w, z \in A^R \),
  \[ (x, y) \succeq^*_i (w, z) \iff x \text{ is preferred to } y \text{ at least as much as } w \text{ is preferred to } z \text{ on criterion } g_i, \ i \in I. \]
Software demonstration

Software demonstration: Visual-UTA 2.0

- AGRITEC is a medium size firm (350 persons approx.) producing some tools for agriculture,
- The C.E.O., Mr Becault, intends to double the production and multiply exports by 4 within 5 years.
- He wants to hire a new international sales manager.
- A recruitment agency has interviewed 17 potential candidates which have been evaluated on 3 criteria (sales management experience, international experience, human qualities) evaluated on a [0,100] scale.
## Software demonstration

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<th>Crit 2</th>
<th>Crit 3</th>
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</table>
Software demonstration

\begin{enumerate}
\item \textit{it0} without preference information,
\item \textit{it1} Ferret $\sim$ Frechet $\succ$ Fourny $\succ$ Fleichman,
\item \textit{it2} Ferret $\sim$ Frechet $\succ$ Martin $\succ$ Fourny $\sim$ El Mrabat $\succ$ Fleichman, \textit{inconsistency:} Ferret $\sim$ Frechet vs Fourny $\sim$ El Mrabat
\item \textit{it3} Ferret $\sim$ Frechet $\succ$ Martin $\succ$ Fourny $\succ$ Fleichman,
\end{enumerate}
Conclusion

More work should be devoted to preference elicitation in MCDA,

UTA-GMS:
- General additive value function,
- Intuitive information required from the DM,
- Robust elicitation of a ranking model,
- Necessary and Possible rankings,
- Inconsistency management.
Unsufficient attention is devoted in MCDA to develop elicitation tools an methodologies which should contribute to the definition of a doctrine for MCDA practitioners.

More research is needed to:

- develop methodologies/tools to organize the interaction with DMs in a given MCAP,
- test the operational validity of the developed tools.