Comparing Multiple Attribute System Selection and Social Choice Preference Aggregation

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Problem:

- Comparison of information systems by evaluation of several specified criteria
- Critical and often arduous process in organizational IT
- Compilation and consolidation of utility values using weights for the criteria
- Ample room for manipulation and misrepresentation of system aspects via the use of utility values and weights

Approach:

- Preference aggregation methods used in Social Choice
- Avoid the use of utility values and weights
- Only ordinally scaled expert judgment along the criteria is neccessary
- Greatly facilitating the process
- In a large majority of simulated cases arriving at the same results

MADM

- Decision makers seek the "best" alternative
- i.e. maximize the achievement of a number of goals reflected by the attributes
- Typical IT system attributes: reliability, user friendliness, ...
- Other scenario: evaluations from different departments (accounting, sales, ...)

Weighted sum method

- Simple method that is widely used for supporting decision making
- For each alternative and attribute a single value is derived, usually from expert judgements
- Values are summed up to represent the overall utility of an alternative
- Weighting scheme is employed to reflect to relative importance of attributes

Problems of Weigthed Sum Method

- Deceptively simple, as the mathematics are easily implemented in a spreadsheet, and the whole process seems objective and rational, BUT...
- High demands on experts and decision makers — rationally scaled utility values
- Important preconditions are often violated: scale types are misused, ordinally scaled values are used as if they were cardinally scaled
- Definition of attribute weights is a major challenge for decision makers
- Ample opportunity for manipulation

Social Choice Preference Aggregation

- Demands less rigorous information from the experts and decision makers: ordinal scale is sufficient
- Therefore should appeal to business practioners
- Neither single-attribute value functions nor weighting of attributes are needed
- Analogy between voting and multiple criteria decision support
  - Voters are replaced by attributes
  - Candidates replaced by decision alternatives

In the following:

- small number of preference aggregation methods are presented
- applied in a simulation based on an enterprise IT case study
- results of weighted sum and preference aggregation are compared
- shown to be to a large extend identical where winners are concerned
- while demanding much less information from experts and decision makers

Rank aggregation in IT case study and simulation

- Number of alternatives is typically small
- Study has shown it to be around three for typical system selection tasks in enterprise IT [1]
- For each attribute the alternatives are put into a ranking by the experts and decision makers
- Data derived ex post from weighted sum values, therefore indifferences are allowed
- Complete set of preferences for all attributes over all alternatives is called a "profile"
- Preference aggregation problem consists in finding an aggregate ranking that represents the individual preferences in some meaningful way,
- while at the same time ensuring some properties for the result, such as being free of cycles

Profile p

n rankings for m alternatives
e.g., alternatives $\{a, b, c\}$ and rankings
$\{a \succ b \succ c,\ b \succ c \succ a,\ c \succ a \succ b,\ b \succ c \succ a\}$.
no cycles such as $a \succ b \succ c \succ a$.
find aggregate ranking $x \succeq y \succeq z$ such that

- individual preferences are somehow expressed in the aggregate ranking; e.g., a suitable aggregation from the example above is $b \succ c \succ a$, where alternative b is the (only) winner.
- aggregate ranking may contain indifferences, e.g. $b \succ (c = a)$,
- winner set may contain more than one alternative, e.g. $(b = c) \succ a$.

Some demands on aggregation results

- No cycles
- No dictator
- Condorcet criterion
  - if an alternative x exists that beats all other alternatives in pairwise comparisons, x is the Condorcet winner
  - obvious demand on an aggregation rule is that it select x as a winner

Different voting rules fulfill these and other demands to differing degrees.

Margin-based voting rules

- Not all social choice aggregation rules can be applied to preference sets including indifferences.
- The following methods of rank aggregation are based on "margins":
  margin of x versus y is $|x \succ y| - |y \succ x|$
  i.e. the number of rankings where x is preferred to y minus the number of rankings where y is preferred to x
- extend this definition for profiles with indifferences by excluding the indifferent voters from the count: rankings with indifference of x and y do not contribute to the margin of x versus y

List of voting rules used here

Maximin (MM): The Maximin rule scores the alternatives with the worst margin they each achieve and ranks them according to those scores.

Copeland (CO): The Copeland rule scores the alternatives with the sum over the signs of the margins they achieve and ranks them according to those scores.

Kemeny (KE): The Kemeny rule chooses the strict ordering with minimal distance to all rankings in the profile, where distance is defined as the number of different pairwise relations.

Borda (BO): The Borda rule scores the alternatives with their sums over the margins and ranks them according to those sums.

all methods can be applied to margin data alone, including Borda and Kemeny

Some Notes

- Borda rule is usually described by assigning decreasing points to consecutive positions
  but resulting ranking is identical to the ranking based on the sums of the margins
- Kemeny rule is computationally very expensive for high numbers of alternatives
  rarely a problem in MADM applications where the number of alternatives is usually small
- Simple majority is a well-known and intuitive procedure based on margins
  Positive margin results in $x \succ y$ in the aggregate relation
  Unfortunately, this rule can easily result in cycles (remove fourth ranking in example above)
  This limits the use of the simple majority rule in practical applications

Case Study

- Decision problem faced by an international wholesaler of liquid and gaseous fuels, Enterprise Resource Planning (ERP) adoption process
- simple weighted sum approach
- desired system to achieve a high ERP utility score through simple additive weighting based on a number of pre-selected attributes
- (1) controlling and reporting, (2) accounting, (3) logistics, (4) purchasing, (5) needs of local divisions, (6) services and engineering, (7) sales, and (8) business management.
- To simplify the following analysis we set all weights to one and arrive at the sums given in Table 1.

Alternative B outranks its opponents whereas A and C seem to have a tie, i.e. they can be considered as almost equally good

Utility values and rankings

Attribute	A	B	C	Ranking
Controlling and Reporting	13	15	14	$B \succ C \succ A$
Accounting	14	21	16	$B \succ C \succ A$
Logistics	9	6	6	$A \succ B = C$
Purchasing	8	7	5	$A \succ B \succ C$
Local Divisions	12	13	9	$B \succ A \succ C$
Services and Engineering	15	18	18	$B = C \succ A$
Sales	24	25	27	$C \succ B \succ A$
Management	13	16	14	$B \succ C \succ A$
Total	108	**121**	109	

Table: The total scores correspond to the ranking $B \succ C \succ A$.

Aggregation rules applied to derived rankings

Rule	Ranking
SM	$B \succ C \succ A$
BO	$B \succ C \succ A$
CO	$B \succ C \succ A$
MM	$B \succ C = A$
KE	$B \succ C \succ A$

Table: Compare with weighted sum ranking $B \succ C \succ A$

- all methods validate B as the winner
- Maximin rule stating indifference for C and A which corresponds well to the almost identical utility values of the weighted sum method

Simulation

- based on the case study generate more data and simulate a much larger number of cases
- number of attributes set to 8 as in the case study, number of alternatives set to 3
  both values fall within the typical range found in ERP selection problems in an empirical study of medium and large scale enterprises [1]
- generate random attribute values uniformly distributed over the range of minimum and maximum attribute values in the case study
  sample size is 100000
- for each generated case the sum of the attribute values for each alternative was calculated, and the winner determined
- from the generated attribute values the corresponding rankings were derived, and
  social choice aggregation methods were applied to arrive at aggregate rankings

Simulation Results

how often differ the winning alternatives for the individual methods:

	BO	CO	MM	KE	WS
BO	0.000	0.157	0.254	0.204	0.272
CO	0.157	0.000	0.113	0.219	0.332
MM	0.254	0.113	0.000	0.264	0.391
KE	0.204	0.219	0.264	0.000	0.278
WS	0.272	0.332	0.391	0.278	0.000

Table: Fraction of simulation cases where the two respective methods return different winning alternatives, e.g., the Borda rule winner and the weighted sum (WS) winner are different in only about 27% of the cases.

Interpretation

- About 73% of the cases the Borda rule arrived at the same winner as the weighted sum method
  - Borda count is easy to understand
  - and easy to implement with a spreadsheet
- The Kemeny method fares almost as well
  - however, algorithm is harder to explain to business users
  - and it is significantly more difficult to implement
- Copeland and Maximin rules deliver different results from the weighted sum method much more often than Borda and Kemeny

Distance of results for different winners

- measured by the number of switches neccessary to make the winner of one ranking into a winner in the other ranking

	BO	CO	MM	KE	WS
BO	0.000	0.602	0.524	0.860	1.003
CO	0.602	0.000	0.555	0.732	0.914
MM	0.524	0.555	0.000	0.623	0.842
KE	0.860	0.732	0.623	0.000	1.144
WS	1.003	0.914	0.842	1.144	0.000

- distances below one occur when there is more than one winner, e.g. when rule i produces the ranking $(A = B) \succ C$ and rule j produces $A \succ B \succ C$.
- In these cases, moving B out of the winner set counts as 0.5 switches

Conclusions

- Lower amount of information neccessary from the experts and decision makers when using social choice aggregation rules
  - Ranking alternatives is much easier than specifying rationally scaled utility values
  - The fact that no weighting scheme has to be defined further facilitates the process
- Simulation data further showed that in about 73% of the simulated cases the winners of the social choice rules and the weighted sum method were identical
- Borda rule emerges as delivering the closest results

Future work will concentrate on the acquisition of more case study data and subsequent simulation, as well as practical application and user feedback for the social choice aggregation methods in enterprise decision processes

References

E. Bernroider and J. Mitlöhner (2005), "Characteristics of the Multiple Attribute Decision Making Methodology in Enterprise Resource Planning Software Decisions", *Communications of the International Information Management Association (CIIMA)*, 5(1), pp 49-58