Working Group 3: EMO in Interactive Multiobjective Optimization

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1 Focus

Subgroup 1 (Human Aspects): We focused on different interaction styles, mathematical vs. psycological convergence of proceduces, termination rules, and the underlying human behavioral assumptions. The discussion addressed both EMO and MCDM areas without distinction.

Subgroup 2 (Formalization of Preferences): The group members were discussion the expression of preferences and integration of preferences into the search process.

Subgroup 3 (Computational Aspects): The main questions are:

- What is MCDM, what is EMO? MCDM is preference based, while EMO/MOMH is computation based. Hybrid MCDM-EMO means: tackling computationally difficult problems involving DM's preferences.
- Why looking for interactive methods? Reasons are efficiency and the handling of many objectives.
- Robust optimization and interactive methods: robust optimization increases the number of objectives, that means a previously single objective is transformed into multiple ones.

2 Overview of State-of-the-art

Subgroup 1 (Human Aspects)

We can distinguish the following principles, which most MCDM approaches use implicitly or explicitly in solving MCDM problems:

1. Assume the existence of a value function v, and assess it explicitly.
2. Assume the existence of a stable value function v, but do not attempt to assess it explicitly. Make assumptions of its general functional form.
3. Assume the existence of a value function v, but do not assume it stable. Let it change with time, and assume that the DM's final choice is based on its specific form.

Dagstuhl Seminar Proceedings 09041
Hybrid and Robust Approaches to Multiobjective Optimization
http://drops.dagstuhl.de/opus/volltexte/2009/2004

4. Do not assume the existence of a value function v.

Those principles lead to the following general approaches to solving MCDM problems:

- **Approach 1: Prior Articulation of Preferences.** The value function v is explicitly constructed by means of preference information received from a DM.
- **Approach 2: Interactive Articulation of Preferences.**
  - Based on an Implicit Value Function. The value function is neither assumed to be known nor tried to be estimated explicitly. DM's responses to specific questions are used to guide the solution process towards an "optimal" or "most preferred" solution.
  - Based on No Stable Value Function. These approaches are typically based on the idea to generate nondominated solutions for the DM's evaluation without making any specific assumptions concerning the value function. The DM is free to make a search on the efficient frontier and stop at any time (s)he likes.
- **Approach 3: Posterior Articulation of Preferences.** This approach tries to find a good approximation to a nondominated frontier. The choice problem does not play a significant role.

Interaction styles

We can distinguish the following interaction styles:

1. Pairwise comparisons.
2. Choosing a set of solutions.
3. Trade–off ratios.
4. Dynamic interaction.
5. Aspiration levels (reference points).
6. Listing the indexes of the criteria to be improved or sacrificed, also specifying the amounts of improvement or sacrifice.

For further details see (Shin and Ravindran: 1991).

With respect to EMO, most popular is to specifiy one or several reference points according to which the approximation set should be biased. There are different ways to modify the fitness assignment procedure to integrate reference points to guide the search, e.g., (Rachmawati, Srinivasan: 2006; Deb, Sundar: 2006; Zitzler, Brockhoff, Thiele: 2007). Another possibility consists in giving reference direction, which has been proposed in combination with NSGA-II (Deb, Kumar: 2007). Especially for dominance-based fitness assignment

scheme, a promising approach is to modify the underlying dominance relation to include priorities, goals, or acceptable trade-off ratios (Fonseca, Fleming: 1998, Branke et al.: 2001). Furthermore, different set measures have been proposed that make use of sets of weight combinations, e.g., (Hansen, Jaszkiewicz: 1998); based on the measures, preferences can be integrated in EMO in form of weights that represent trade-off proportions among the objectives (Zitzler, Thiele, Bader: 2008).

Some new ideas in the EMO field are: (i) to combine dominance-based classification with a preference-based classification, e.g., using convex cones (Wallenius, Korhonen, Zions: 1984), or to (ii) specifiy lines with according density distributions to define the what type of Pareto set approximation is sought (Auger, Bader, Brockhoff, Zitzler: in preparation).

Mathematical vs psychological convergence of procedures

In mathematical algortihms we consider the convergence and check the optimality of the final solution by Kuhn–Tucker–type conditions. On the other hand, in interactive MCDM approaches, at each iteration the DM checks whether better solutions can be found in the local environment. In EMO we need also to specify the number of generations that will take place.

Behavioural assumptions which may be questioned

- Linear value function.
- Stable value function.

Search process is based on learning and can exhibit exploratory behaviour. Ties to Kahneman and Tversky propect theory.

Subgroup 2 (Formalization of Preferences)

- How the DM expresses preferences
  - Reference values / reference directions
  - Selection / ranking of a subset of solutions / pairwise comparisons
  - Fuzzy sets
- How preferences are integrated in the algorithm
  - Selection level
    - Outranking relations
    - Scalarizing functions
    - Fuzzy sets
- Preferences about approximation sets
  - Outranking relations (epsilon-dominance)

  - Scalarizing functions (dominated hypervolume)

- Inconsistencies handled by implicit averaging by the population

Subgroup 3 (Computational Aspects)

- Incorporation of EA as a single-objective solver: Sakawa (1998), Miettinen (1999)
- A posteriori approaches: Tanaka (1995), Jaszkiewicz (2002)
- Interactive multi-objective metaheuristic Tanino (1993), Kita (1999)

See corresponding slides and references below for more information.

3 Major Research Challenges

Subgroup 1 (Human Aspects)

- To find out which interaction styles work best for EMO.
- To test the impact of decision maker's inconsistencies on EMO.
- Develop stopping rules for EMO.

Subgroup 2 (Formalization of Preferences)

- How to use preference information to speed up search (beyond the selection phase)?
- How to express preference information about sets?
- How to integrate solution-related preferences with set-related preferences?
- How to use local preference information (directions for improvement in objective space) with EMO?
- How to evaluate the effectiveness of different interactive methods?
- How to quantify the degree of association between expressed preferences and obtained solutions?

Subgroup 3 (Computational Aspects)

- How can we ensure computational efficiency?
- Is there any use of a multi-objective optimizer within the interactive loop (besides computational efficiency)?
- How to incorporate various preference models into multi-objective search?

- How do we handle many objectives?
- Can we take advantage of dynamic changes in the preference model (instead of restarting the search everytimes)?

4 References and Keywords

Subgroup 1 (Human Aspects)

MCDM

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