Enhancement of Multi-objective Optimization Algorithms and Methods

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Overview

- Multiobjective optimization
- Challenges in practice
- Networking inside SIMPRO
- Conclusion
Multiobjective optimization

Problems are usually of the form:

\[
\begin{align*}
\text{minimize} & \quad \{f_1(x), f_2(x), \ldots, f_k(x)\} \\
\text{subject to} & \quad x \in S \subseteq \mathbb{R}^n, \\
\text{with} & \quad k \geq 2 \text{ conflicting objectives} \\
\text{objective vector} & \quad f(x) = \{f_1(x), f_2(x), \ldots, f_k(x)\}
\end{align*}
\]  

Has several optimal solutions called Pareto optimal solutions

- Different trade-offs
- Mathematically equally good

A decision maker chooses one among them based on her/his preferences

Main focus on evolutionary multiobjective optimization algorithms
Examples of multiobjective optimization problem

Design of a permanent magnet synchronous generator.

- Minimize deviation of output power from its target value of 3MW
- Maximize Torque density
- Minimize Mass
- Maximize Efficiency
- Maximize Power factor
- Minimize Cost
Challenges in practice

Suitable method to use: **Needle in a hay stack**!
- Literature spread over numerous journals in diverse fields of engineering and science
- Mommoth task to gain an overview of the methods proposed

Involves computationally expensive problems
- Use black-box simulators
- Most algorithms cannot be used

Limited decision support to the decision maker to choose her/his preferred solution
- Functions are computationally expensive
- Limited scope for learning about the problem, and
- No emphasis on psychological aspects of decision making
Needle in a hay stack!

**Scope:** Articles published between 2008 – 2014 considered
- Proposed different frameworks that classify solution methods

**Common:**
- Nature inspired algorithms
  - NSGA-II
  - Particle swarm optimization and Differential evolution used to solve scalarized problems
- Surrogates (metamodel) for function approximation
  - Which surrogate, when to use and update issues remain
  - Heuristics with limited scope are commonly used
- Separate metamodels for every objective and constraint functions
- Parallel and GPU computing
  - Island model
  - Heterogeneous computing resources

**Limited focus:**
- Problems involving high dimensional decision and objective spaces
- Decision maker and preference handling
- Noisy objective functions


Under preparation:
Technical report
Sindhya, K., A survey on using parallel approaches for computationally expensive multiobjective optimization problems
Handling computationally Problems

- Usually algorithms generate a set of solutions representing the entire set of Pareto optimal solutions
  - Undesirable solutions are calculated
  - Wastage of computational time

- Preference based algorithms proposed:
  - Dominance based:
  - Indicator based:
  - Generate solutions only desirable to the decision maker
Decision support system

- We propose a three-stage interactive method E-NAUTILUS for computationally expensive multiobjective optimization problems.
- A set of pre-calculated Pareto optimal solutions enables a solution process without waiting times.
- No new optimization problem is solved when the decision maker interacts with the method.
- Improvement in all objectives on each iteration enables free search and avoids anchoring.
  - Kahneman and Tversky (1979): Prospect theory
    - Our attitudes to losses loom larger than gains

Networking inside project:
Collaboration with VTT

- Multiobjective design algorithm for surface mounted permanent magnet synchronous generators
  - Practitioners in the field of electrical engineering at VTT with the multi-objective optimization method developers at JYU.
  - Large number of objectives never before considered in design of generators
    - Study the applicability and usefulness of using interactive multiobjective optimization to the decision maker

- Multiobjective Optimization problem
  - 7 objectives
  - 3 constraints
  - 14 design variables

- To be submitted to a relevant journal
Conclusion

- This subproject has mainly addressed the issue of computationally expensiveness in solving industrial multiobjective optimization problems.
- Literature survey clearly indicates several issues to be addressed:
  - Provide motivation for further collaboration with industries and universities.
- Preference based algorithms has shown potential on academic problems.
- Decision support system proposed shall enable decision makers to easily handle computationally expensive multiobjective optimization problems.
- Both preference based algorithms and decision support systems are ready for practical use arising from industries.
Thank You