Interactive Poster: Interactive Multiobjective Optimization -
A New Application Area for Visual Analytics

Suvi Tarkkanen* Kaisa Miettinen† Jussi Hakanen‡
Department of Mathematical Information Technology
University of Jyväskylä, Finland

ABSTRACT

The poster introduces interactive multiobjective optimization (IMO) as a field offering new application possibilities and challenges for visual analytics (VA), and aims at inspiring collaboration between the two fields. Our aim is to collect new ideas in order to be able to utilize VA techniques more effectively in our user interface development. Simulation-based IMO methods are developed for complex problem solving, where the expert decision maker (analyst) should be supported during the iterative process of eliciting preference information and examining the resulting output data. IMO is a subfield of multiple criteria decision making (MCDM). In simulation-based IMO, the optimization task is formulated in a mathematical model containing several conflicting objectives and constraints depending on decision variables. While using IMO methods the analyst progressively provides preference information in order to find the most satisfactory compromise between the conflicting objectives. In the poster, the implementations of two new IMO methods are used as examples to demonstrate concrete challenges of interaction design. One of them is described in this summary.

KEYWORDS: Interactive multiobjective optimization, visual analytics, information visualization, interaction design.

INDEX TERMS: G.1.6. [Numerical Analysis]: Optimization—Nonlinear Programming; H.1.2 [Models and Principles]: User/Machine Systems—Human Factors; H.5.2 [Information Interfaces and Presentation]: User Interfaces—Interaction Styles

1 PROBLEM CHARACTERISTICS

In our poster, we consider complex decision making problems with multiple objectives in the form of continuous, numerical data. These problems involve multiple conflicting criteria or objectives that should be optimized simultaneously. The field of MCDM is devoted to such problems [1]. Here we concentrate on so-called nonlinear multiobjective optimization problems [2], being a subfield of MCDM. The objectives (to be minimized or maximized) depend on continuous variables and the variable values may be bounded by constraint functions. An example of continuous multiobjective optimization problem is simultaneous consideration of investment costs, product quality, operational costs, and environmental aspects related to some industrial process. Both objective and constraint functions are based on mathematical models, and their values may be obtained from the output of a simulator. For this reason, the problems considered can also be called simulation-based optimization problems.

Because of the conflicting nature of the objectives, there does not exist a single solution that could be optimal for all the objectives. Instead, we can identify compromise solutions where none of the objectives can be improved without impairing any of the others. These compromise solutions are often called Pareto optimal solutions in the MCDM field. In continuous problems, we typically have an infinite number of such Pareto optimal solutions and we need some preference information given by a human domain expert (sometimes called an analyst or a decision maker) to direct the search for the most preferred compromise solution. As the amount of alternative solutions is infinite, and as the problems are open-ended and cognitively burdensome to solve, we need efficient and user-friendly decision support tools.

2 IMO APPROACH AND CHALLENGES FOR DEVELOPERS

In IMO, the solution process is iterative and highly interactive, and the analyst progressively provides preference information and analyzes information gained until a preferred compromise solution is found. The idea is also to enable the analyst to gain understanding and insight about the trade-offs available and the interdependencies between the objectives. In simulation-based IMO, we are dealing with such problems where the solutions are computationally generated (by means of combined simulation and optimization) during the iterative analytical reasoning process performed by a domain expert. It should be emphasized that at first, the data is not readily available in any form, but by means of the inputs given by the analyst, combined simulation and optimization process iteratively provides new solutions (solution vectors including a numerical value for each objective) trying to obey the user preferences as well as possible. Thus, the amount of data to be examined increases as the analytic reasoning process continues.

Here, a clear connection between IMO and VA can be seen. As stated in [3], an analysis session is more of a dialogue between the analyst and the data: “The analyst observes the current data representation, interprets and makes sense of what he or she sees, and then thinks of the next question to ask, essentially formulating a strategy for how to proceed. Undoubtedly, new questions occur to the analyst and new factors must be considered”. At each iteration, IMO methods generate new compromise solutions based on the user preferences, thus enabling the expert to concentrate only on the most desirable solutions with minimal cognitive load.

The analyst needs support in directing the solution process towards more preferred solutions by specifying new preference information after having analyzed the strengths and weaknesses of the current compromise solutions already generated. Similarly, the analyst should be supported in examining and analyzing the resulting solutions provided by the combined simulator and optimizer. Therefore, the challenge for the developers is, what kind of interaction techniques could be the most intuitive, and what kind of representation and visualization techniques could be the most efficient for insight gaining and decision making. In our poster, we present two examples of new IMO methods and their tentative user interface sketches. One of the methods, called Pareto Navigato, is described next.
3 AN EXAMPLE OF IMO METHOD: PARETO NAVIGATOR

Pareto Navigator [4] is an IMO method developed for nonlinear problems where simulations typically take lots of time. The idea of Pareto Navigator is to enable convenient examination of tradeoffs between the objectives using an approximation of the set of Pareto optimal solutions without continual delays due to time taking simulation processes. An approximation allows real-time generation and consideration of desirable compromise solutions.

An overview of the Pareto Navigator algorithm is given in Figure 1. At the first iteration, the analyst must select the starting point for the consideration (in step 1 of the flowchart). This can be for example one of the Pareto optimal solutions used to generate the approximation. The next important phase is specifying preference information for directing the navigation phase (steps 3 and 4 in the flowchart). Finally, one must show the approximated solutions generated to the analyst (step 5 in the flowchart). The analyst must also be able to conveniently select any point found so far as a point where the search direction is changed, that is, new preference information is specified (step 4 in the flowchart). The analyst must be able to indicate when to stop or to see the real compromise solution closest to the approximated solution selected. The solution process continues until the analyst has found a solution (s)he is satisfied with (stopping criterion in step 2 of the flowchart).

An example user interface sketch for this method is represented in Figure 2. According to [3], combining controls with visual representations can speed access, and improve productivity for the combined human, analytical, and data system. Mirel [5] suggests single, compressed, multipurpose visualizations. The analyst should not have to divide her/his attention between multiple targets, e.g. graphical entities, screens or windows.

First, before navigation begins, the analyst selects one of the starting points among Pareto data (by dragging the bold, vertical selection tool), and specifies preferences by setting goals (by dragging the horizontal dash lines). The values can be fine-tuned with the numeric up-down controls on the right. Navigation starts when the analyst clicks a start button (not visible in the sketch), and stops when the analyst wants to elicit new preference information (or change the direction). With the help of the selection tool (bold vertical line) the analyst can examine the values of each point (the changes in values are shown synchronously in the Value column) and select any approximated solution of interest to be converted into “a real one”. In addition to the Pareto data column, the real Pareto optimal solution appears in the Approx. data column for comparison purposes. The overall approximation can then be updated.

In our poster, we also present a user interface sketch of another method (called Nautilus [6]). In the conference, our goal is to bring the IMO into consciousness of VA researchers as well as collect new ideas for further development. In addition to the poster, we show some demos with a laptop.

REFERENCES