I-MODE: An Interactive Multi-objective Optimization and Decision-Making Using Evolutionary Methods

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Abstract. With the popularity of efficient multi-objective evolutionary optimization (EMO) techniques and the need for such problem-solving activities in practice, EMO methodologies and EMO research and application have received a great deal of attention in the recent past. The first decade of research in EMO area has been spent on developing efficient algorithms for finding a well-converged and well-distributed set of Pareto-optimal solutions, although EMO researchers were always aware of the importance of procedures which would help choose one particular solution from the Pareto-optimal set for implementation. In this paper, we address this long-standing issue and suggest an interactive EMO procedure by collating most salient research in EMO and putting together a step-by-step EMO and decision-making procedure. The idea is implemented in a GUI-based, user-friendly software which allows a user to supply the problem mathematically or by using user-defined macros and enables the user to evaluate solutions directly or by calling an executable software, such as popularly-used MATLAB software for a local search or ANSYS software for finite element analysis, etc. Starting with standard EMO applications, continuing to finding robust, partial, and user-defined preferred frontiers through standard MCDM procedures, the well-coordinated software allows the user to first have an idea of the complete trade-off frontier, then systematically focus in preferred regions, and finally choose a single solution for implementation.

1 Introduction

In the past decade of research and application activities of evolutionary multi-criterion optimization (EMO), major focus has been made in finding a set of trade-off solutions, representing the entire Pareto-optimal front. Although these efforts were the first steps in evaluating the potential of EMO methodologies as a true multi-objective optimizer, it is now time to address an equally important matter of choosing a single solution from the Pareto-optimal front for implementation. Such a task should involve a decision-making activity in which higher-level information must be provided by the decision-maker. It is obvious to

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realize that such a decision-making activity is subjective and must depend on the problem being solved. Thus, any effort in this direction must be spent on devising a procedure which will help a decision-maker (DM) to arrive at a solution of his/her choice, rather than one which will recommend a solution automatically. The multi-criterion decision-making (MCDM) approaches address a similar issue and some MCDM ideas can be borrowed to address the decision-making issue in an EMO study. Besides the higher-level decision-making approaches, there are some other more direct decisions which most decision-makers may like to follow. Some such decision-making ideas may include (i) preference of a robust frontier, instead of a Pareto-optimal frontier, (ii) preference of locally-optimal solutions obtained from EMO solutions, instead of simply choosing the EMO solutions, preference of knee solutions and preference of some specific regions detected by various means, instead of the entire trade-off Pareto-optimal frontier.

In this paper, we give shape to an earlier proposal by the authors [6] in combining EMO procedures with a number of direct (less subjective) decision-making tools and a number of higher-level (subjective) decision-making tools with a procedure which can go back and forth between many such tools and an EMO procedure. The main motivation behind such a repetitive procedure is that often the choice of a higher-level decision-making tool or fixation of parameter values associated with such a tool cannot be done a priori. When an idea of the entire trade-off frontier is obtained, a decision-making tool with all its associated parameters can be chosen adequately. The decision-making task is subjective to the DM and the final outcome of such a task will be dependent on the desires of the DM. To make the task of decision-making easier and possible, we also develop a GUI-based software (currently developed for a linux operating system) with visualization tools. Starting with a set of trade-off solutions, the developed I-MODE software will allow a decision-maker to finally choose a single preferred solution by performing a number of decision-making tasks. Currently, the procedure can be used for any number of objectives, but the software is restricted to a maximum of three objectives due to lack of suitable efficient visualization procedures. The working of the procedure is demonstrated on a welded-beam design problem having two objectives. The proposed methodology is one of many possible implementations of hybrid EMO and decision-making tools.

2 Existing Methodologies for Hybrid Multi-objective Optimization and Decision-Making

There exist different interactive multi-objective optimization methods in the literature based on the classical optimization methods. Some popular methodologies, as described in [12] are as follows: Interactive Surrogate Worth Trade-off (ISWT) method [2], Reference point method [15], NIMBUS approach [12] etc. Each method is different from each other, but uses a single solution in each iteration. A guess solution is usually modified to another solution iteratively and by gathering some information from a DM. Since a single solution is used in an iteration, the DM only can find local information (such as a local trade-off or search