Multi-attribute Decision-making through Incorporating Machine Learning to Model Value Function and Multi-objective Evolutionary Optimization Method[1]

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Abstract

In recent years, society has faced critical challenges, including pandemics, global warming, and societal fragmentation. While these issues may not fall within the scope of multi-attribute decision-making in engineering, they share a fundamental characteristic: the need to identify optimal trade-offs among alternatives under conflicting objectives and complex constraints. We assert that engineering methodologies can contribute to addressing these challenges. To this end, it is essential to develop a comprehensible and adaptable methodology applicable to diverse scenarios.

This paper proposes a multi-attribute decision-making procedure to obtain a preferentially optimal solution along with its nearby alternatives. To achieve this, we incorporate machine learning techniques into our previously developed approaches for modeling the decision maker's (DM's) value function in a novel manner. This approach includes problem reformulation for solving single-objective optimization problems using a multi-objective evolutionary algorithm (MOEA), an integrated elite-induced approach, and a downsizing procedure (integrated elite-induced downsizing MOEA). We then introduce post-optimal evolution to enhance the performance of the proposed procedure and present the concept of post-optimal analysis to improve adaptability in response to the inherent imperfections of mathematical models in practical engineering applications. The downsizing procedure is both effective and straightforward in deriving nearby alternatives, facilitating post-optimal analysis.

As a preliminary numerical experiment, we compare various MOEAs in a simple mechanical design problem to evaluate their respective properties. We then apply our method to a practical car structure design problem, previously analyzed using only a linear value function. By solving this problem with value functions incorporating nonlinear and human-specific characteristics, we demonstrate the effectiveness of the proposed method in achieving robust multi-attribute decision-making.

Keywords: Multi-objective optimization, Machine learning, Integrated elite-induced downsizing MOEA, Post-optimal analysis, NSGA-II, Multiple car structure design

1. Introduction

The COVID-19 pandemic has underscored the challenge of balancing economic viability with public health measures, such as virus transmission prevention. These inherently conflicting objectives necessitate an optimal trade-off, aligning with the principles of multi-attribute decision-making, even when an explicit mathematical formulation is not feasible. Similar trade-offs arise in addressing economic growth while mitigating climate change or managing societal fragmentation.

In contemporary complex societies, multi-objective optimization—an approach for achieving comprehensive evaluations—has gained increasing attention as a tool for supporting rapid and flexible decision-making under diverse and competing values. The demand for such methodologies extends beyond traditional engineering domains. More broadly, optimization engineering (Shimizu, 2010) has emerged as a structured framework for flexible and practical optimization in technology.

Recent research in multi-objective optimization has primarily focused on the development and application of multi-objective evolutionary algorithms (MOEAs) for deriving Pareto fronts (Deb et al., 2000; Coello, 2012). Additional advancements include research on many-objective optimization problems (Hughes, 2005; Fleming, 2005;

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