Single, multi-, and many-objective optimization of manufacturing processes using two new simple and efficient algorithms and decision-making

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ABSTRACT

Manufacturing processes are inherently complex, multi-objective in nature, and highly sensitive to process parameter settings. Achieving optimal performance requires simultaneously balancing conflicting objectives such as productivity, quality, cost, and energy consumption. This paper introduces two elegant and efficient optimization algorithms, namely the Best-Mean-Random (BMR) and Best-Worst-Random (BWR) algorithms, designed to address both constrained and unconstrained optimization tasks of the data driven manufacturing processes considering single-, multi-, and many performance objectives. Distinctively, these algorithms are free from metaphorical inspirations and require no algorithm-specific parameters, which often complicate other metaheuristics. The BMR method operates by leveraging the best, mean, and randomly selected solutions from the current population, while the BWR approach utilizes the best, worst, and random solutions for its computations. Comprehensive testing demonstrates that these novel, minimalist techniques offer competitive—often superior—performance when compared with existing methods. The multi- and many-objective versions of the BWR and BMR methods are named MO-BWR and MO-BMR and are successfully applied to solve the 2-, 3-, and 9-objective problems of selected advanced manufacturing processes of friction stir processing, ultra-precision turning, laser powder bed fusion, and wire arc additive manufacturing. The proposed BHARAT decision-making method can be used to find out the best compromise nondominated solution from amongst a large number of Pareto-optimal solutions. The results highlight the potential of these lightweight algorithms as viable tools for intelligent decision-making in real-world manufacturing processes. The study also discusses comparative performance metrics including hypervolume, spacing, generational distance, and coverage, providing a comprehensive evaluation of algorithmic effectiveness.

Keywords: Manufacturing processes; Parameters optimization; Multi- and many-objective optimization; BWR algorithm; BMR algorithm; Multi-attribute decision-making; BHARAT.

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