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# A novel adaptive hybrid crossover operator for multiobjective evolutionary algorithm

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ABSTRACT

In this paper, a novel recombination operator, called adaptive hybrid crossover operator (AHX), is designed for tackling continuous multiobjective optimization problems (MOPs), which works effectively to enhance the search capability of multiobjective evolutionary algorithms (MOEAs). Different from the existing hybrid operators that are commonly operated on chromosome level, the proposed operator is executed on gene level to combine the advantages of simulated binary crossover (SBX) with local search ability and differential evolution (DE) with strong global search capability. More opportunities are assigned to DE in the early evolutionary stage for gene-level global search in decision space; whereas, with the generation grows, more chances are gradually allocated to SBX for gene-level local search. The balance between the gene-level global and local search is well maintained by an adaptive control approach in AHX. To validate the effectiveness of AHX, it is studied by substituting the original recombination operators in the four state-of-the-art MOEAs (i.e., NSGA-II, SPEA2, SMS-EMOA, and MOEA/D), and the performance of revised algorithms is significantly improved. Furthermore, AHX is also compared to three recently proposed recombination operators, such as a newly DE inspired (DEI) recombination operator, a learning paradigm based on jumping genes (JGBL) and a bandit-based adaptive operator selection approach (FRRMAB). The experimental studies validate that AHX can be effectively integrated into different frameworks of MOEAs, and performs better than SBX, DE, DEI, JGBL and FRRMAB in solving various kinds of MOPs.

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## 1. Introduction

In the past several decades, various kinds of evolutionary algorithms (EAs) have been proposed to solve optimization problems, which are modeled from many scientific and application fields, such as science, economic and engineering [1,53,66]. Based on the inspired evolutionary mechanisms, EAs can be classified into the following categories, such as genetic algorithms (GAs) [13,24], evolutionary strategies (ESs) [2,29], genetic programming (GP) [27,28], evolutionary programming (EP) [5,17], and other nature-inspired algorithms [4,7,18,51,52,56]. Among the existing EAs, GAs are widely recognized as the most popular and commonly used optimization algorithms, which have been applied in many engineering applications [30,48,49]. Naturally, as a kind of population-based random search approach, GAs mimic the natural selection principle "survival of the fittest" from the biological world. In the early study of GAs, the candidate solutions are mostly encoded by

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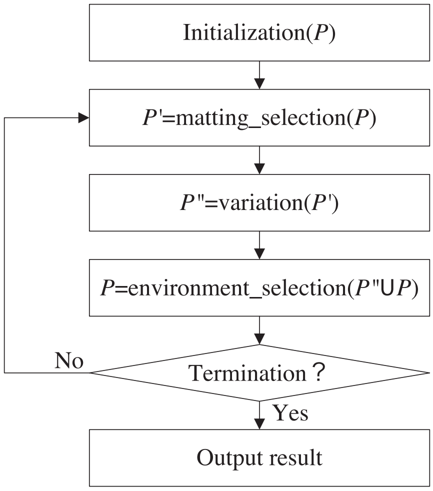


**Fig. 1.** A general framework of MOEAs.

the binary values to simulate the chromosome [23,50]. However, when tackling the optimization problems with continuous search space, the real-coded approach is found to be more suitable for the representation, where a chromosome in GAs is expressed by a vector of real numbers [13,55].

When dealing with multiobjective optimization problems (MOPs), evolutionary algorithms have been recognized to be effective and efficient due to their population-based property to obtain an approximation of the Pareto-optimal set in a single run. Since the pioneering work of Schaffer [50], numerous multiobjective evolutionary algorithms (MOEAs) have been proposed. Based on the used type of selection mechanism, most of MOEAs can be classified into the following three categories: Pareto-based approaches [13,69], indicator-based approaches [3,35,68], and decomposition-based approaches [38–40]. The Pareto-based methods incorporate the Pareto optimality into the selection process. The representative of this category includes NSGA-II [13] and SPEA2 [69]. They are further extended to solve many-objective optimization problems (more than 3 objectives) by revising the environment selection method, named NSGA-III [12] and SPEA2-SDE [32]. The indicator-based approaches integrate the convergence and diversity into a single indicator, such as hyper-volume [70], to guide the selection process. The representative of this category includes IBEA [68] and SMS-EMOA [3]. The decomposition-based techniques decompose a MOP into a set of sub-problems and optimize them in a collaborative manner. The representative of this category includes MOEA/D [40] and MOEA/D-STM [39]. Recently, some interesting approaches are designed to combine the Pareto-based and decomposition-based methods, such as ND/DDP [36] and NSGA-III [12].

In general, there are essentially three fundamental evolutionary operators in MOEAs, i.e., selection, crossover and mutation, which are employed to gradually approach the optimal solution. The selection operator usually has two aspects, including matting selection and environment selection [69]. Matting selection is aimed at picking out the better-fit chromosomes, which are evolved by the variation operators such as crossover and mutation. Crossover operator exchanges the gene information of the parents, in order to share the better gene segment. After that, mutation operator randomly alters some genes of the chromosome to perform a local search, attempting to find better fitness landscape. At last, the environment selection operator determines the survived population for the next generation, which is usually selected from the union population of parents and their offspring. This general framework of MOEAs is illustrated in Fig. 1, where the variation operators include crossover and mutation operators.

Considering the crossover operator, many research works have been conducted on improving the performance. This is because crossover is a very important evolutionary procedure in the three fundamental operators as justified in [6,41–45,47,54,61]. According to the expected position of the offspring distributed in solution space, most of the existing crossover operators can be generally classified into two kinds: parent-centric crossover [10,11,15] and mean-centric crossover [22,43,59]. However, the quality of the offspring produced by the parent-centric crossover or mean-centric crossover is highly dependent on the characteristics of target problems, which in turn means that different crossover operators may behave diversely in solving various kinds of optimization problems. Thus, multiple crossover operators are combined, which can repair the weakness of a single crossover operator and is able to deal with various types of optimization problems [62].

These existing hybrid crossover approaches [31,44,45,47,57,63] have been experimentally validated to perform better than the single use of one crossover operator, especially in solving some complicated optimization problems. In these schemes, a child population is built by using different crossover operators, and a child solution is derived by certain selected crossover operator. That is to say, all genes of child chromosome are inherited from the parents using the same recombination manner, which may not provide sufficient diversity in child chromosome. Therefore, in this paper, we propose a novel adaptive hybrid crossover (AHX) method, attempting to produce each gene of child chromosome using different crossover operators. By this way, AHX is essentially a gene-level hybrid crossover operator. In our scheme, a parent-centric crossover operator

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