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Adaptive pair bonds in genetic algorithm: An application to real-parameter optimization

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ABSTRACT

Genetic algorithm (GA) is a heuristic search technique that draws inspiration from principles and mechanisms of natural selection. Conventionally, parents selection takes place at every generation and offspring are reproduced through genetic operators like crossover and mutation. The process reiterates until some termination conditions are met. Until recently, little attention has been paid on the enduring relationship between parent solutions. In this paper, we take on and further extend the idea of monogamous genetic algorithm to solving real-coded numerical optimization problems. In this GA model, each monogamous pair of parents yields two offspring, and only the best two offspring survive into the next generation. Occasional infidelity generates variety and promotes diversity in the population. Simulation results over the IEEE-CEC'13 (IEEE Congress on Evolutionary Computation 2013) contest for real parameter single objective optimization with 28 benchmark functions demonstrate the effectiveness of the proposed approach.

1. Introduction

Genetic algorithm (GA) belongs to a class of the Evolutionary Computing (EC) that draws inspiration from processes of natural evolution. GA evolves a population of potential solutions (known as individuals or chromosomes) via fitness-biased selection and breeding through genetic operators (crossover and mutation). Compellingly, after almost five decades, a plethora of variants of GAs enumerated briefly as island models [7], cellular models [45], hierarchical models [49], heterogeneous population-based models [25,1] have been proposed. The first three models represent spatial differentiation approaches where a population commonly segmented into sub-populations, grid-based or hierarchical-based. Restricted interactions are permitted across the boundaries usually at specific time interval. Meanwhile in heterogeneous population-based approach, different groups of interacting individuals exist in the form of male–female attraction, predator–prey, or competitor–cooperator players. For further readings on structured population GAs, we refer readers to [29].

Conventionally, parents are selected at every generation during reproduction to generate offspring. Until recently, little attention has been paid on the partnering relationship between parent solutions.

In Zoology, pair bond refers to the exclusive relationship formed between mating partners. Besides modern human society, 90% of bird species are monogamic and usually exhibit biparental care of young [42]. Some fish [34], rodents [47], and lizards [26] species also exhibit enduring relationships between mating partners. Such observation has strongly motivated

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our present work. In an initial attempt, a new variant of GA is proposed, called the Monogamous Pairs Genetic Algorithm (MopGA) [30]. Unlike classical GAs, parents form an enduring partnership over a specific number of generations (known as pair bond tenure). Bonded parents continue to mate until the pair bond tenure expires, after which parents selections take place again. Each monogamous pair of parents yields two offspring, and only the best two offspring survive into the next generation. Occasional infidelity generates variety and promotes diversity in the population. Preliminary experimental results show that MopGA is able to reduce overall computational time (due to reduction in parent selection mechanism) without trading off solution quality when compared to the standard GA.

Nevertheless, the previous work is preliminary in nature and procedurally differs from the present algorithm. This work has been taken on and extended by applying adaptive pair bonds in GA to more challenging real-parameter optimization problems, in particular the Special Session and Competition on Real Parameter Single Objective Optimization of the IEEE Congress on Evolutionary 2013 (IEEE CEC'13) that comprises a set of 28 functions, ranging from unimodal, multimodal to composition functions [27].

The proposed methodology is coined as Adaptive Monogamous Pairs Genetic Algorithm (AMopGA). The four major adaptations introduced to AMopGA include:

1. Adaptive mutation rate.
2. Adaptive pair bond tenure and infidelity rate.
3. Adaptive selection of crossover operators.
4. Applying Levy mutation to elite individual during infidelity to promote diversity and guide search towards promising regions.

The rest of the paper is organized as follows. We begin by introducing the bio-inspiration to Monogamous Pairs Genetic Algorithm (Section 2.1), followed by the motivation of pair bonds in GAs (Section 2.1.1). Detailed description of the AMopGA framework can be found Section 3. Section 4 is dedicated to performance verification of the proposed approach over 28 IEEE CEC'13 benchmark functions. Finally, the paper ends with concluding remarks and future work in Section 5.

2. Background

2.1. Bio-inspiration: monogamy

In nature, *monogamy* implies a social organization in which the male and female organisms breed exclusively with each other, even though extrapair copulations or infidelity are common [48,17].

Modern human society and 90% of bird species are monogamic. They also usually exhibit biparental care of young [42]. Other species exhibiting enduring relationships between mating partners include some fish [34], rodents [47], and lizards [26].

The benefits of monogamy among others include (relative) certainty of access to the partner's reproductive potential. However, it also restricts the access to other potential partners [42].

In socially monogamous birds, infidelity is a common phenomenon. Numerous hypotheses have been attempted to explain such observation, including the good genes and future partnerships hypotheses [39]. The former predicts mating success with bias against maladaptive alleles while the latter favors potential mates.

As far as we are aware of, conventional GAs do not conform to monogamous structure. Selection of parents for mating takes place at every generation. Nonetheless, if social monogamy survives the evolution of Nature, we believe such structure may have some strength in itself.

2.1.1. Motivation for pair bonding in GA

It is worth a moment to investigate the essence of pair bonding before proceeding further since it underpins the concept of AMopGA. Though the following explanation takes binary encoding as example, the general idea should be applicable to real encoding as well.

Traditionally, crossover is a binary operator that takes at least two parents and swaps segments between them to produce offspring (equivalent to new potential solutions). Though genetic materials are inherited from parents, there is no guarantee that offspring are always fitter than their parents. When crossing over repeatedly, the same pair may produce fitter or even weaker offspring all by chance.

Typically, there are large sets of possibilities to be explored between each pair. These sets are known as *search spaces*. Assume each chromosome position (locus) as a dimension of the space. The number of possible unique offspring (new solutions) that can be created depends upon the prevalence of parents schema order. For simplicity, in a one-point binary crossover, this number U can be generalized as:

$$U = 2 * [L - 1 - o(H)] \tag{1}$$

where L = chromosome length, $o(H)$ = common schema order of parents. The multiplication by 2 in Eq. (1) is due to the assumption that each crossover generates two offspring. Michalewicz [32] and Holland [19] provide excellent introductions to schemata and building blocks theories.