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An analysis of selection methods in memory consideration for harmony search

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ABSTRACT

This paper presents an analysis of some selection methods used in memory consideration of Harmony search (HS) Algorithm. The selection process in memory consideration entails selecting the value of the decision variable from any solution in the Harmony memory (HM). Quite recently, there has been a tendency to adopt novel selection methods that mimic the natural phenomena of the 'survival of the fittest' to replace the random selection method in memory consideration. Consequently, the value of decision variable selected using memory consideration is chosen from the higher promising solutions in HM. The adopted selection methods include: proportional, tournament, linear rank, and exponential rank. It has been demonstrated that experimenting with any of these methods in memory consideration directly affects the performance of HS. However, the success of these methods is based on choosing the optimal parameter value of each. The wrong parameter settings might affect the balance between exploration and exploitation of the search space. Accordingly, this paper studies the effect of the selection method parameters in order to show their effect on HS behavior. The evaluation is conducted using standard mathematical functions used in the literature for HS adoptions. The results suggest that the optimal setting of the selection method parameters is crucial to improve the HS performance.

1. Introduction

Evolutionary algorithms (EA) are a class of optimization methods starting with a set of provisional solutions that are normally generated randomly. They iterate toward the global optimal solution using specific operators controlled by certain parameters [1]. In principle, they imitate the Darwinian's natural selection of the 'survival of the fittest'. Iteratively, they explore a wide range of problem search space regions,while, at the same time, they exploit the existing solutions utilizing learning strategies to manage information that will result in an efficient solution [2,3]. Naturally, EA deals with optimization problems that can be generally modeled as an n-dimensional minimization problem as follows:

$$\min\{f(\boldsymbol{x})|\boldsymbol{x} \in \mathbf{X}\},$$

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where $f(\boldsymbol{x})$ is the objective function; $\boldsymbol{x} = \{x_i | i = 1, \ldots, N\}$ is the set of decision variables. $\mathbf{X} = \{\boldsymbol{X}_i | i = 1, \ldots, N\}$ is the possible value range for each decision variable, where $\boldsymbol{X}_i \in [LB_i, UB_i]$, where LB_i and UB_i are the lower and upper bounds for the decision variable x_i respectively and N is the number of decision variables.

The Harmony search (HS) algorithm is a recent EA proposed by Geem et al. [4] which mimics the musical process of improvising a pleasing Harmony. It has several advantages over other EAs: it has a novel stochastic derivative [5], it necessitates fewer mathematical requirements which generate a new solution after considering all the existing solutions at each iteration [6]. In other words, such advantages are related to simplicity, flexibility, adaptability, generality, and scalability [7,8].

Therefore, HS has been adopted for a wide variety of optimization problems such as engineering optimization problems, scheduling problems, bio-informatics and biomedical problems, Clustering, [9–12] any many others [13–21]. To keep with the combinatorial nature of some optimization problems, the performance of HS algorithm has been improved by hybridizing, modifying, replacing, and adopting the HS operators [6,22,23,19]. Furthermore, the parameter tuning of HS is also studied leading to a parameter-less HS [24]. However, very few investigation directed toward the analysis of the search power of the HS algorithm to reveal why it succeed [25,7].

HS terms and strategies can be connected to the Harmonized tuning that musicians endeavour to achieve in a musical rehearsal. HS algorithm begins with a population of individuals randomly generated and stored in the Harmony memory (HM). A new individual is evolutionary generated using three operators: (i) memory consideration, (ii) random consideration, and (iii) pitch adjustment. The new individual then substitutes the worst individual in HM, if better. This process is evolved until a termination criterion is met.

Memory consideration (MC) operator of HS is the main concern of this paper. In MC, the HS *selects* a value of a decision variable from the individuals stored in HM through the process of generating a new one. Initially, the MC randomly selects any individual from HM, then the value of each decision variable is taken from that individual. To avoid the random selection process in MC, Al-Betar et al. [7] initially explored some selection schemes adapted from EA methods to employ in the MC process for the purpose of imitating the natural selection of the 'survival of the fittest' principle. These were Global-best, proportional, tournament, linear rank, and exponential rank selection methods. In their study, Al-Betar et al. [7] maintain that these selection methods are proposed and adapted to be workable with MC in the HS algorithm.

The main objective of this study is to analyze some selection methods proposed in [7] in terms of their effect in the selection pressure concepts (i.e., the amount of bias that selection expresses toward the better individuals in the population during search) and the effect of their parameters on the behavior of HS algorithm. Furthermore, the proportional selection method is scaled in this study to overcome its shortcoming in dealing with problems of negative fitness values.

The rest of this paper is organized as follows: basic acquired knowledge for HS algorithm is presented in Section 2. The selection methods are expressed in Section 3. The analysis of the results obtained by selection schemes in MC is discussed in Section 4. Finally, Section 5 provides a conclusion to the findings and suggests possible future guidelines.

2. Fundamentals to the harmony search algorithm

The recent evolutionary algorithm that mimics the musical improvisation process is the HS algorithm developed by Geem et al. [4]. The musical improvisation process in the musical context consists of a set of musicians each playing on his own instrument. The process is launched aiming for a pleasing Harmony resulting from musicians' practices. Each pitch is tuned at each practice in line with the following rules: (i) considering one pitch stored in memory; (ii) adjusting a pitch in the memory; (iii) randomly picking a pitch from its available instrument range. At each practice, each musician tunes his/her instrument one pitch at a time while the pitches of all instruments played ensemble represent a new complete Harmony. That new Harmony is measured using an audio-aesthetical standard and replaces the worst harmony stored in the musician's memory. This improvisation process is repeated until a pleasing harmony is accomplished.

Algorithm 1. Basic HS algorithm

Set HMCR, PAR, NI, HMS, FW.
$x_i^j = LB_i + (UB_i - LB_i) \times U(0,1), \forall i = 1, 2, \ldots, N$ and $\forall j = 1, 2, \ldots,$ HMS {generate HM solutions}
Calculate $(f(\boldsymbol{x}^j))$, $\forall j = (1, 2, \ldots,$ HMS$)$
Sort (HM)
$itr = 0$
while $(itr \leqslant$ NI$)$ **do**
  $\boldsymbol{x}' = \phi$
  for $i = 1, \cdots, N$ **do**
   if $(U(0,1) \leqslant$ HMCR$)$ **then**
      $x_i' \in \{x_i^1, x_i^2, \ldots, x_i^{\text{HMS}}\}$ {memory consideration}
      if $(U(0,1) \leqslant$ PAR$)$ **then**
        $x_i' = x_i' + U(-1,1) \times$ FW {pitch adjustment}