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An intelligent global harmony search approach to continuous optimization problems

Ehsan Valian, Saeed Tavakoli *, Shahram Mohanna

Department of Information and Management, Taipei Chengshih University of Science and Technology, No. 2, Xueyuan Rd., Beitou, 112 Taipei, Taiwan

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ABSTRACT

Harmony search algorithm is a meta-heuristic optimization method imitating the music improvisation process, where musicians improvise their instruments' pitches searching for a perfect state of harmony. To solve continuous optimization problems more efficiently, this paper presents an improved harmony search algorithm using the swarm intelligence technique. Applying the proposed algorithm to several well-known benchmark problems, it is shown that it can find better solutions in comparison with both basic harmony search algorithms, and improved harmony search algorithms such as the self-adaptive global-best harmony search as well as novel global harmony search. Furthermore, a study on the effect of changing the parameters of the proposed algorithm on its performance is carried out. Finally, the proper values of the algorithm parameters are suggested.

1. Introduction

Harmony search (HS) algorithm is a meta-heuristic algorithm developed by Geem et al. [1]. In the HS, the solution vector is analogous to the harmony in music, whilst the local and global search schemes are analogous to musician's improvisations. HS algorithm imposes fewer mathematical requirements and can be easily adapted for solving various kinds of engineering optimization problems [2–5].

HS algorithms have been successfully applied to a wide range of practical optimization problems, such as structural optimization, parameter estimation of the nonlinear Muskingum model, design optimization of water distribution networks, vehicle routing, combined heat and power economic dispatch, design of steel frames, bandwidth-delay-constrained least-cost multicast routing, and transport energy modelling [4–23]. Also, several algorithms, such as novel global harmony search (NGHS), have recently been developed based on the adoption of search behaviour of the HS [27,28].

In this paper, the swarm intelligence technique is used to enhance the performance of the NGHS. The proposed version is named intelligent global harmony search (IGHS) and is described in Section 3. In Section 4, several simulations are carried out to test and compare the performance of the IGHS with several HS-based algorithms. The conclusions are presented in Section 5.

2. HS, IHS, GHS, SGHS, and NGHS algorithms

In this section, several harmony search methods, including basic HS, improved harmony search (IHS) [2], global-best harmony search (GHS) [3], self-adaptive global-best harmony search (SGHS) [26], and the NGHS [27,28] algorithms are reviewed.

* Corresponding author.
E-mail address: tavakoli@ece.usb.ac.ir (S. Tavakoli).

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2.1. HS algorithm

In basic HS algorithm, each solution, called a ''harmony'', is represented by an n-dimension real vector [1]. First, an initial population of harmony vectors is randomly generated and stored in a harmony memory (HM). Then, a new candidate harmony is generated from all of the solutions in the HM by performing a memory consideration rule, a pitch adjustment rule and a random re-initialization. Next, the HM is updated by comparing the new candidate harmony and the worst harmony vector in the HM. Finally, the worst harmony vector is replaced by the new candidate vector if the latter is better. The above process is repeated until a certain termination criterion is met. The basic HS consists of three basic phases, which are initialization, improvisation of a harmony vector and updating the HM. These phases are described as follows.

2.1.1. Initialization of the algorithm parameters

In general, the global optimization problem can be written as follows.

$$\begin{aligned} &\min f(x) \\ &\text{st} : x(j) \in [\text{LB}(j), \text{UB}(j), \quad j = 1, 2, \ldots n], \end{aligned} \tag{1}$$

where $f(x)$ is the objective function, n is the number of decision variables, $X = [x(1), x(2), \ldots, ,x(n)]$ is the set of decision variables, and LB(j) and UB(j) are the lower and upper bounds for the decision variable $x(j)$, respectively.

The parameters of the HS algorithm are harmony memory size (HMS), i.e. the number of solution vectors in harmony memory, harmony memory consideration rate (HMCR), pitch adjusting rate (PAR), distance bandwidth (BW), and number of improvisations (NI), i.e. the total number of function evaluations. Obviously, a good set of parameters can enhance the algorithm's ability to search for the global optimum or near optimum region with a high convergence rate.

2.1.2. Initialization of the harmony memory

The number of harmony vectors in the HM is HMS. Let $X_i = [x_i(1), x_i(2), \ldots, x_i(n)]$, which has Randomly been generated, represents the ith harmony vector, as follows

$$\begin{aligned} &x_i(j) = \text{LB}(j) + (\text{UB}(j) - \text{LB}(j)) \times r \\ &j = 1, 2, \ldots, \text{HMS}, \end{aligned} \tag{2}$$

where r is a uniform random number between 0 and 1. Then, the HM matrix is filled with harmony vectors as follows.

$$H = [X_1, X_2, \ldots, X_{\text{HMS}}]^T. \tag{3}$$

2.1.3. Improvisation of a new harmony

A new decision variable $x_{new}(j)$ is improvised by applying three rules, which are a memory consideration, a pitch adjustment and a random selection. First, a uniform random number r_1 is generated in the range [0,1]. If r_1 is less than the value of HMCR, the decision variable $x_{new}(j)$ is generated by the memory consideration. Otherwise, $x_{new}(j)$ is obtained by a random selection, i.e. random re-initialization between the search bounds. In the memory consideration, $x_{new}(j)$ is substituted by a random selection of the jth harmony vector in the HM. Next, if each decision variable $x_{new}(j)$ is updated by the memory consideration, it will undergo a pitch adjustment with a probability of PAR. The pitch adjustment rule is given by

$$x_{new}(j) = x_{new}(j) \pm r \times \text{BW}, \tag{4}$$

where r is a uniform random number between 0 and 1.

2.1.4. Updating the harmony memory

Once a new harmony vector X_{new} is generated, the HM must be updated by the survival of the fitter competition between X_{new} and the worst harmony vector, X_w. If the fitness value of X_{new} is better than that of X_w, the latter will be replaced by X_{new} and become a new member of the HM.

2.1.5. Computational procedure

The computational procedure of the basic HS algorithm for a minimization problem can be summarized as follows [1].

Step 1: Set the parameters HMS, HMCR, PAR, BW and NI.
Step 2: Initialize the HM and calculate the objective function values for each harmony vector.
Step 3: Improvise a new harmony X_{new} as follows.