Probabilistic Harmony Search

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ABSTRACT

Harmony Search (HS) is a new meta-heuristic algorithm imitating the music improvisation process where musicians search for a better state of harmony. In this paper, a new improvisation scheme is proposed that explicitly uses a probabilistic model of candidate solutions stored in the harmony memory. Pitch adjustment uses a probability distribution to mutate a decision variable while random selection has been replaced by generating samples from the probability distribution. The proposed scheme favors diversification in the early stages and intensification during the final stages of the search process. The performance of the proposed method is investigated and compared with a state-of-the-art HS variant and other recent methods when applied to 18 benchmark functions. The experiments conducted show that the proposed method generally outperforms the other methods when applied to the benchmark problems.

Keywords: Estimation of Distribution, Harmony Search, Meta-Heuristic, Phenomenon-Mimicking Algorithm, Probabilistic Algorithms

1. INTRODUCTION

Harmony Search (HS) is a population-based phenomenon-mimicking algorithm (PMA) which imitates the improvisation process of musicians (Geem et al., 2001). Unlike traditional gradient-based optimization algorithms which have performed well only for continuous-valued variables, HS has performed well for both continuous-valued and discrete-valued variables because it possesses a new stochastic derivative (Geem, 2008) which is a new-paradigm derivative based on musicians’ experiences. In this derivative, the searching direction to the optimal solution can be stochastically determined based on musicians’ historical preferences.

HS has also considered various theoretical factors such as correlation among decision variables, theoretical background of best fret width (bw), global searching by suppressing local prematureness, global searching by managing multiple harmony memories, adaptive parameter setting along the iteration, and so forth (Geem, 2006a, 2009a; Mukhopadhyay et al., 2008). The algorithm has been also hybridized with other techniques such as genetic algorithm, simulated annealing, ant colony optimization, particle swarm optimization, chaos theory, fuzzy theory, artificial neural network, simplex method, Taguchi method, sequential quadratic

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programming, and commercial optimization module.

In line with the above-mentioned various theoretical backgrounds, the HS algorithm has been successfully applied to various optimization problems such as project scheduling, text mining, image tracking, robotics, power system design, structural design, water infrastructure design, dam scheduling, hydrologic model calibration, groundwater management, geotechnical stability analysis, ecological conservation, vehicle routing, heat exchanger design, offshore structure anchoring, bioinformatics, medical physics, medical imaging, etc. (Kim et al., 2001; Geem et al., 2002, 2005; Lee & Geem, 2004, 2005; Geem, 2006b; Jang et al., 2008; Coelho & Bernerta, 2009). For more details, readers can refer to several books on the HS algorithms (e.g., Geem, 2009a).

In fact, HS is very efficient if the number of parameters to be optimized is small (<25). However, some researchers (Omran & Mahdavi, 2008; Cheng et al., 2008) claimed that HS did not work well for relatively large problems although this is not always the case, since Geem (2009b) showed that the original HS is much better than GA, Simulated Annealing and Tabu Search when applied to 454-variable water network problem.

A new class of optimization methods is Probabilistic algorithms. Probabilistic methods search a problem space using a probabilistic model of potential solutions. They explicitly use probability models in problem solving. Thus, in probabilistic methods a population is approximated with a probability distribution and new potential solutions are generated by sampling this distribution. Two representative probabilistic algorithms are the Estimation of Distribution Algorithm (EDA) (Larranaga & Lozano, 2002) and the more recent Cross-Entropy (CE) method (Rubinstein & Kroese, 2004). Probabilistic algorithms have been successfully applied to a wide range of optimization problems (Pelikan et al., 2006).

In this paper, we propose a probabilistic harmony search (PHS) method that explicitly uses a probability model to enhance the performance of HS. Several well-known benchmark problems are used to compare the proposed approach against HS and other recent methods.

The remainder of the paper is organized as follows: Section 2 provides an overview of HS. The proposed method is presented in Section 3. Benchmark functions to measure the performance of the different approaches are provided in Section 4. Results of the experiments are presented and discussed in Section 5. Finally, Section 6 concludes the paper.

2. THE HARMONY SEARCH ALGORITHM

Harmony Search (HS) (Lee & Geem, 2005) is a new meta-heuristic optimization method imitating the music improvisation process where musicians improvise their instruments’ pitches searching for a perfect state of harmony. The HS works as follows:

Step 1: Initialize the problem and HS parameters

The optimization problem is defined as

Minimize (or maximize) $f(x)$ such that $L_i \leq x_i \leq U_i$ for $i=1,\ldots,N$.

Where $f(x)$ is the objective function, $\bar{x}$ is a candidate solution consisting of $N$ decision variables ($x_i$), and $L_i$ and $U_i$ are the lower and upper bounds for each decision variable, respectively.

In addition, the parameters of the HS are specified in this step. These parameters are the harmony memory size (HMS), harmony memory considering rate (HMCR), pitch adjusting rate (PAR) and the number of improvisations (NI).

Step 2: Initialize the harmony memory

The initial harmony memory is generated from a uniform distribution in the ranges $[L_i, U_i]$, where $1 \leq i \leq N$. This is done as follows:

$$x'_i = L_i + r \cdot (U_i - L_i), j = 1, 2, \ldots, \text{HMS}$$
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