Expert Systems with Applications 42 (2015) 2026–2035

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

# Island-based harmony search for optimization problems

Mohammed Azmi Al-Betar [a,*], Mohammed A. Awadallah [c], Ahamad Tajudin Khader [b], Zahraa Adnan Abdalkareem [d]

[a] Department of Information Technology, Al-Huson University College, Al-Balqa Applied University, P.O. Box 50, Al-Huson, Irbid, Jordan
[b] School of Computer Sciences, Universiti Sains Malaysia, 11800 Pinang, Malaysia
[c] Faculty of Computer Science, Al-Aqsa University, P.O. Box 4051, Gaza, Palestine
[d] Department of Quality Assurance and Performance, College of Imam Azam University, P.O. Box 72002, Baghdad, Iraq

ARTICLE INFO

*Article history:*
Available online 23 October 2014

*Keywords:*
Harmony search
Island model
Structured population
Diversity

ABSTRACT

Harmony search (HS) algorithm is a recent meta-heuristic algorithm that mimics the musical improvisation concepts. This algorithm has been widely used for solving optimization problems. Moreover, many modifications in this algorithm have been carried out in order to improve the performance of the search. Island model is a structured population mechanism used in evolutionary algorithms to preserve the diversity of the population and thus improve the performance. In this paper, the island model concepts are embedded into the main framework of HS algorithm to improve its convergence properties where the new method is refer to as island HS (*i*HS). In the proposed method, the individuals in population are distributed into separate sub-population named (islands). Then the breeding loop is separately involved in each island. After specific generations, a number of individuals run an exchange through a process called migration. This process is performed to keep the diversity of population and to allow islands to interact with each other. The experimental result using a set of benchmark function shows that the island model context is crucial to the performance of *i*HS. Finally the sensitivity analysis and the comparative study for *i*HS prove the efficiency of the island model.



## 1. Introduction

Harmony search (HS) algorithm, a recent Evolutionary Algorithm (EA), was proposed by Geem, Kim, and Loganathan (2001) to emulate the musical phenomena of the improvisation process. In musical rehearsal, a group of musicians play the tunes of their musical tools, practice after practice to formulate a pleasing harmony. Analogously in optimization, a set of variables, taken selective values, iteration by iteration, to formulate most probably an optimal solution. The set of successful stories introduced by adapting HS algorithm to a wide variety of optimization problems gets credit from the emergence of the tremendous research tendency to the domain. Some examples that adopted HS solutions include Engineering, timetabling, nurse rostering, space allocations, bioinformatics, image processing (Abual-Rub, Al-Betar, Abdullah, & Khader, 2012; Al-Betar & Khader, 2012; Al-Betar, Khader, & Zaman, 2012b; Alkareem, Venkat, Al-Betar, & Khader, 2012; Awadallah, Khader, Al-Betar, & Bolaji, 2013, 2012; Geem, Yang, & Tseng, 2013; Landa-Torres, Manjarres, Salcedo-Sanz, Del Ser, & Gil-Lopez, 2013), and many others as recorded in Manjarres et al. (2013).

The main merits of HS over other optimization methods are summarized as follows: a novel stochastic derivative is embedded within the HS (Geem, 2008); it needs less mathematical requirements which iteratively generate a new solution after manipulating all existing solutions (Mahdavi, Fesanghary, & Damangir, 2007). Put simply, it is simple, flexible, adaptable, general, and scalable (Al-Betar, Khader, Geem, Doush, & Awadallah, 2013b). However, the performance of HS has continuously attracted researcher attention account for the optimization problems combinatorial nature (Alia & Mandava, 2011). Therefore, the HS theory has been improved by either replacing, adding, tailoring its operators or hybridizing HS with other effective algorithms (Al-Betar, Khader, & Doush, 2014; Awadallah, Khader, Al-Betar, & Bolaji, 2014; Maheri & Narimani, 2014; Zhao, Suganthan, Pan, & Fatih Tasgetiren, 2011). Furthermore, adaptive parameters of HS have been also studied (Geem & Sim, 2010; Gholizadeh & Barzegar, 2013). The majority of improvements in HS performance have adjusted the process of its operators to cope with the "survival of the fittest" principle of natural selection (Al-Betar, Doush, Khader, & Awadallah, 2012a; Xiang, An, Li, He, & Zhang, 2014).

* Corresponding author.
*E-mail addresses:* mohbetar@cs.usm.my (M.A. Al-Betar), ma.awadallah@alaqsa.edu.ps (M.A. Awadallah), tajudin@cs.usm.my (A.T. Khader), zahraa2010@yahoo.com (Z.A. Abdalkareem).

http://dx.doi.org/10.1016/j.eswa.2014.10.008
0957-4174/

One of the shortcomings of simple HS algorithm is its inability to maintain diversity of population due to genetic drift (Al-Betar, Khader, Awadallah, Alawan, & Zaqaibeh, 2013a). The structured population mechanisms has recently captured the EA researcher to improve the performance by means of maintaining the diversity among the population members during the search, thus the conical premature convergence can be avoided. In structured population, instead of all the other solutions in the population being treated as potential mates as in *panmictic* populations, only those that are in the same neighborhood can share their information and interact (Tomassini, 2005). The island model is the most popular structured population EA method that divides the whole individuals of a large panmictic population into smaller independent subgroups called "*islands*" (Kushida, Hara, Takahama, & Kido, 2013). The EA method is run to each subgroup independently and the interaction between subgroups is achieved through the migration process which will be periodically performed. Consequently, the island EA can preserve the population diversity and can be implemented into parallel machines.

In this paper, the concepts of island model have been embedded with the framework of HS algorithm in a bid to improve the diversity of population concepts and trigger the new " island HS algorithm (*i*HS)". In *i*HS, the individuals in the Harmony Memory (HM) are divided into several islands. The individuals on each island are independently evolved using HS operators. The islands interact using a migration process depending on a random ring topology. The IEEE-CEC2005 mathematical optimization functions have been used for evaluation purposes. The results suggest that incorporating the island model within the HS framework preserves the population diversity and therefore the performance is directly improved.

The remaining part of this paper is arranged as follows: The background to the harmony search and to island model is presented in Section 2. The proposed *i*HS is thoroughly explained in Section 4. Experiments and comparative results are presented in Section 5. Finally, the a conclusion and some useful research indications are given in Section 6.

## 2. Background

The global optimization problems are normally formulated in terms of objective function as follows:

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

where $f(\boldsymbol{x})$ is the objective function; $\boldsymbol{x} = \{x_i|i = 1,\dots,N\}$ is the set of decision variables. $\mathbf{X} = \{\boldsymbol{X}_i|i = 1,\dots,N\}$ 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.

### 2.1. Harmony search (HS) algorithm

HS has five main procedural steps summarized in Algorithm 1 and described as follows:

Step 1: Initialize the parameters. The parameters of the HS algorithm required to solve the optimization problem are specified in this step: the Harmony Memory Consideration Rate (HMCR) which determines the rate of selecting the value from the memory; the Harmony Memory Size (HMS) is similar to the population size in other EAs; Pitch Adjustment Rate (PAR) determines the probability of local improvement; the fret width (FW), determines the distance of adjustment, and Number of Improvisations (NI) or number of iterations.

Step 2: Initialize the harmony memory. The harmony memory (HM) is a repository of the population individuals, $\mathbf{HM} = [\boldsymbol{x}^1, \boldsymbol{x}^2, \dots, \boldsymbol{x}^{\text{HMS}}]^{\mathbf{T}}$, of size HMS. In this step, these individuals are randomly generated as follows: $x_i^j = LB_i + (UB_i - LB_i) \times U(0,1),\ \forall i = 1,2,\dots,N$ and $\forall j = 1,2,\dots,\text{HMS}$, and $U(0,1)$ generate a uniform random number between 0 and 1.

Step 3: Improvise a new harmony. A new harmony vector is generated, $\boldsymbol{x}' = (x'_1, x'_2, \dots, x'_N)$, based on three operators: (1) memory consideration (MC), (2) pitch adjustment (PA), and (2) random consideration (RC). The three operators assign a value for each decision variable $x'_i$ in the new harmony as formulated in Eq. (1).

$$x'_i \leftarrow \begin{cases} x'_i \in \{x_i^1, x_i^2, \dots, x_i^{\text{HMS}}\} & \text{w.p. HMCR} \times (1 - \text{PAR})\ \{\text{MC}\} \\ x'_i = x'_i + U(-1,1) \times \text{FW} & \text{w.p. HMCR} \times \text{PAR}\ \{\text{PA}\} \\ x'_i \in \boldsymbol{X}_i & \text{w.p. 1 - HMCR}\ \{\text{RC}\} \end{cases} \tag{1}$$

Step 4: Update the harmony memory. The new harmony vector, $\boldsymbol{x}' = (x'_1, x'_2, \dots, x'_N)$, replaces the worst harmony $\boldsymbol{x}^{\text{worst}}$ stored in HM if better.

Step 5: Check the stop criterion. Step 3 and step 4 of HS algorithm are repeated until the stop criterion (Normally it depends on NI) is met.

**Algorithm 1.** Harmony search algorithm

```
Set HMCR, PAR, NI, HMS, FW.
x_i^j = LB_i + (UB_i − LB_i) × U(0,1), ∀i = 1,2,...,N and
  ∀j = 1,2,...,HMS
Calculate (f(x^j)), ∀j = (1,2,...,HMS)
itr = 0
while (itr ⩽ NI) do
  x' = φ
  for i = 1,...,N do
  if (U(0,1) ⩽ HMCR) then
    x'_i ∈ {x_i^1, x_i^2, ..., x_i^HMS}   {memory consideration}
    if (U(0,1) ⩽ PAR) then
      x'_i = x'_i + U(−1,1) × FW   {pitch adjustment}
    end if
  else
      x'_i = LB_i + (UB_i − LB_i) × U(0,1)   {random consideration}
    end if
  end for
  if (f(x') < f(x^worst)) then
    Include x' to the HM.
    Exclude x^worst from HM.
  end if
  itr = itr + 1
end while
```

## 3. Island model concepts

Island model is the most popular *non-panmictic* EA model introduced by Corcoran and Wainwright (1994). In island model, the total population is divided into sub-populations (i.e., islands). Each subpopulation independently runs a standard sequential EA (Tomassini, 2005). Periodically, the islands interact using migration process which is responsible for sending and receiving certain individuals across islands controlled by *migration rate* and *migration frequency*. If there is no migration, an island model is nothing more than a set of separate runs and thus migration is very important (Skolicki & De Jong, 2005). The migration process is