International Symposium on Research in Innovation and Sustainability 2014 (ISoRIS '14) 15-16 October 2014, Malacca, Malaysia
Specia issue
Sci.Int.(Lahore),26(4),1745-1749,2014 ISSN 1013-5316; CODEN: SINTE 8

AN OPTIMIZATION SOLUTION USING A HARMONY SEARCH ALGORITHM

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ABSTRACT: A Harmony Search (HS) algorithm is a population based-meta-heuristics approach that is superior in solving diversified large scale optimization problems. Several studies have pointed that Harmony Search is an efficient and flexible tool to resolve optimization problems in the diverse areas of construction, engineering, robotics, telecommunication, health and energy. Considering its increasing usage in diverse areas, this paper presents a brief review of HS for optimization problems. This paper also presents a simple approach of applying HS in the prototype development. This initial work is expected to provide guidance and encouragement for researchers to adopt HS as a means to solve their optimization problems and thus making HS as general solver frame work in optimization field. To execute experimental analysis, programming language C++ is used to develop the prototype using Dev-C++ version 5.6.3.

Keywords: Harmony Search Algorithm, Optimization, Meta heuristics Approach

1.0 INTRODUCTION

The Harmony Search (HS) algorithm existed in 2001, and it is one of the latest techniques developed by scientist Zong Woo Geem [1]. It has been claimed as an efficient algorithm in the field of combinatorial optimization [2]. It also has been recognized as a powerful tool in solving optimization algorithm since the structure of the design algorithm is found to be simple, efficient and flexible. Additionally, it involves less mathematical equation compared to the conventional techniques. In addition, it has been created and used in various fields of optimization, such as music composition [3], Sudoku puzzle solving[4], tour planning [5], structural design [6], water network design [7], vehicle routing [8], dam scheduling [4], soil stability analysis, energy system dispatch[9], and image segmentation [10].

HS can be classified as meta-heuristics algorithm techniques which have been increasingly used in resolving many problems in numerous fields of optimization algorithms. Its algorithmic framework has the flexibility to be applied to various optimization problems with only a few alterations in order to suit particular problem. Meta-heuristics are also highly efficient in achieving the global optimum solution especially for problems that are restricted to a specific precision, where the range of application does not encompass the entire class of NP – complete problems in which the accurate solution cannot be identified in polynomial time [11]. Currently, there are many variations of Harmony Search (HS) have been conducted by researchers to enhance the performance of the classic HS. Hence, HS has been considered as a robust and flexible tool and has become a general algorithmic prototype for different optimization problems without any boundary. To carry out this study, algorithm is coded in C++ language and the experiment is implemented by using Intel Core i7 2.00 GHz with 4GB memory. This paper is divided into three major parts which are investigated with different viewpoint of the subject. The first part is introduction to the background of HS and a brief overview of meta-heuristics. The next part is comprehensive review of HS algorithm. The third part is the discussion for the procedure of HS and last part indicate conclusion.

2.0 LITERATURE REVIEW

In this section, we will provide a brief overview on the harmony of search algorithm and recently developed variants. Mahdavi et al. [12] proposed the Improved HS algorithm (IHS) where PAR and BW are always updated dynamically while in standard HS, value of PAR and BW are fixed. In addition, Kattan et al in [13] proposed modified improved HS (MIHS) in which PAR and BW values are determined dynamically based on the best-to-worst (BtW) harmony ratio. The BtW is used for dynamic setting of both PAR and BW value as well as to determine the termination condition. Global best HS algorithm (GHS) which is proposed by Omran and Mahdavi [14] is intended at introducing the modification of the pitch adjustment rule so that the new harmony is able to consider the best harmony in the HM by using the concept of particle swarm optimization.

3.0 BASIC HARMONY SEARCH ALGORITHM

Harmony Search (HS) algorithm is a new population-based solutions meta-heuristics search technique that mimics the process of music improvisation to achieve the perfect state of harmonies played simultaneously by more than one music instrument. This means that the pitch from every instrument is combined together to obtain the most harmonic rhythm, and this is evaluated based on aesthetic standards. HS is termed as a population-based solution because the improvisation of the pitch occurred iteratively using a set of solutions in Harmony Memory (HM). Harmony in music corresponds to a solution vector; each musical instrument corresponds to each decision variable; the pitch range of the musical instrument corresponds to the decision variable's value range; audience's esthetic corresponds to the objective function and the musical improvisations correspond to the

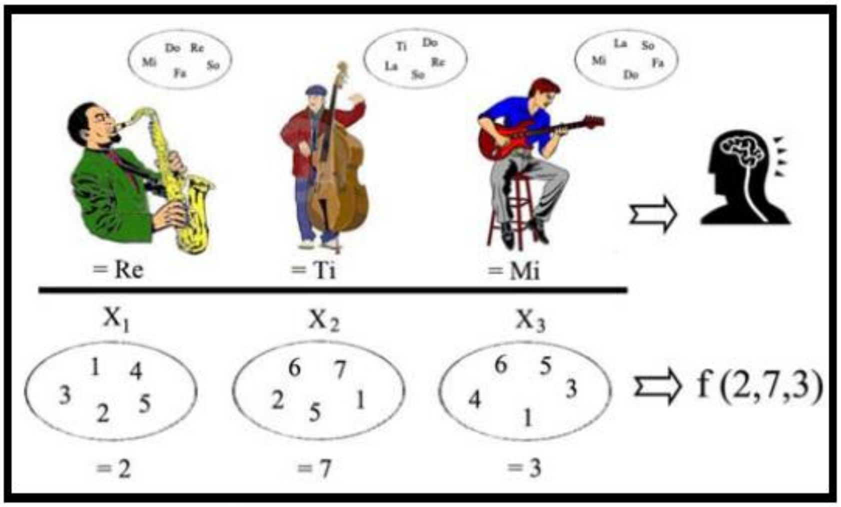

Figure 1: Analogy between music improvisation and optimization [15]

local and global search in optimization. Figure 1 illustrates the relationship between music improvisation and optimization.

A set of parameters is applied to HM in order to yield New Harmony vector so that the local optimum can be accomplished for every single iteration. To execute the algorithm, there are five basic steps involved in HS, which are (i) initializing the problem and algorithm parameters, (ii) initializing the HM (iii) improvising the new harmony, (iv) updating the HM with the exclusion of the worst and the best harmony, (v) checking the stopping criteria; if it is not satisfied, go to step (iii).

To improvise a single pitch for each instrument, a musician has three choices, which are (1) playing any pitch from HM, (2) playing a pitch that is slightly different from HM with a PAR value, or (3) playing a totally random pitch from permissible pitch ranges. In a standard HS algorithm, the term "harmony" refers to each solution stored in HM in the form of n-dimensional real vector [16]. At the beginning of HS process, the initial population of harmony vectors is randomly generated. Next, New Harmony vectors are generated from the three choices like what has been mentioned previously. Then, the HM is updated by making an evaluation between the New Harmony solutions with the existing one. If the existing HS is worse than the New Harmony solutions, it will be excluded and replaced by a new HS in HM. The process continues and ends when the number of improvisations is met. The detail of the process is described in the next part and Table 1 summarizes the steps involved in the HS algorithm.

\+ \+ + 3(1)

Table 1: The approach of the procedure involved in developing the HS prototype

Step	Process	Description
Step 1	Initialization	- Define objective function - Initialize variables X_i equal to random values X_i = rand; where i= 1, 2….n; n is number of variables. lower value $\leq$ rand $\leq$ upper value. - Parameter setting of Harmony Memory Size (HMS), HMCR, PAR, BW and NI are defined.
Step 2	Improvisation	There are three methods for each variable to be improvised in order to achieve optimal solutions. **Method 1: Harmony Memory Consideration Rate (HMCR)** - If ran < HMCR, random number is small than HMCR value, the new candidate harmony vector (NCHV) is selected from HM. **Method 2: Pitch Adjustment Rate (PAR)** - If ran2 < PAR, random number is smaller than PAR, NCHV is further modified with small value of bandwidth (BW) using Eq. (2) as given by [16]. $x_{new}(j) = x_{new}(j) \pm r \times BW$ (2) **Method 3: Randomization** - If ran1 > HMCR, random number is smaller than HMCR. - NCHV is taken from permissible range of variable value.
Step 3	Update HM	The worst objective function is substitute with a better objective function and sorted into ascending order.
Step 4	Check NI	The process is terminated if number of improvisation (NI) is achieved.

Table 2: The pseudo-code for HM Algorithm applied in the prototype.

Begin
Define Objective Function, HMS, HMCR, PAR, BW and NI.
Initialize of HM with range of variables, X_i randomly.
While *(current Iteration<maximum Iteration)*
For *(i<=number of variables)*
If *(ran<HMCR), Choose a value from HM for the variable* X_i
If *(ran2< pitch adjusting rate), Modify the value by adding or subtract of certain amount of BW*
End if
Else *Choose a random value*
End if
Evaluate *the new Fitness (current objective function) and compare its value with the worst function available.*
End while
Sort the objective function by ascending order
Look for Satisfied Number of iteration (NI)
End

4.0 HARMONY SEARCH ALGORITHM FOR OPTIMIZATION

The following are the approach adopted to develop the prototype which has been summarized in Table 1. The main procedure involved in HS is initialization, improvisation, sorting and updating HM and finally termination criterion check. Table 2 presented the pseudo-code of HS algorithm while Figure 2 indicated the output yield from the execution of simple optimization problem where Eq. (1) is representing the objective function.

The pseudo-code above is used as a reference to code in the C++ programming language as to solve the optimization problem. Our intention is to find the optimal solutions of variables x_1, x_2 and x_3 in (1) using the Standard Harmony Search Algorithm. The optimal solutions of variables x_1, x_2 and x_3 in (1) is shown below. This experiment is focused on HMCR operator by observing the effect to the results achieve by having different values. At the beginning of generalization, the harmony memory (HM) is fully occupied the generated solutions randomly. To carry out this experiment, HMS, PAR is defined at the value 6 and 0.1 respectively but with varieties of HMCR value such as 0.1, 0.5 and 0.95. Theoretically, the higher the HMCR forced the algorithm to search the existing solutions in HM while the small rate of HMCR leads to search solutions in the allowable range. In addition, the convergence rate will also increase in accordance with the escalation value of HMCR. Table 1 displayed the results obtained at different parameter value of HMCR and number of iteration

.5.0 EXPERIMENTAL RESULT

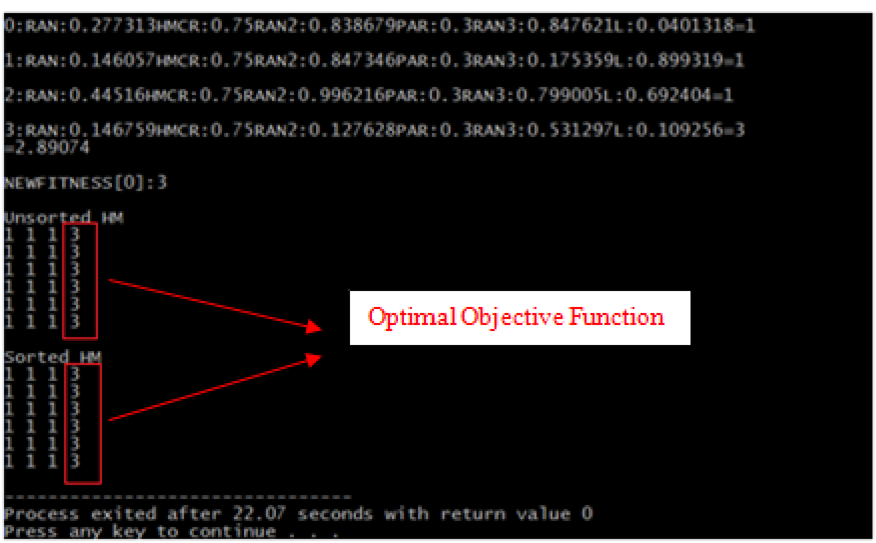

Figure 2: Result obtained from the prototype utilizing C++ language.

Table 1: HMCR at 0.10, 0.50 and 0.95 iteration number at 200, 300,and 400

Number of Iteration	HMCR	Result for each variables			Convergence Rate at th iteration
		x_1	x_2	x_3	
200	0.10	5	6	7	195
300	0.10	6	5	7	297
400	0.10	0	6	7	394
200	0.50	0	3	7	191
300	0.50	1	1	1	197
400	0.50	1	1	0.999858	377
200	0.95	1.00013	1	0.999782	108
300	0.95	0.999981	1	1	284
400	0.95	0.999815	1	1	216

Based on the result shown in Table 1, it is proved theoretically that the higher HMCR; assist the algorithm to speed up the convergence rate by means of focusing on the existing solutions in HM. Conversely, the lower HMCR will delay the convergence by considering all permissible range of solutions. Figure 2 indicate the value of optimal solutions for this experiment is three where the result for each

variablesx_1, x_2 and x_3 is one respectively.

6.0 CONCLUSION

The HS algorithm is considered as a successful optimization tool and has a very big potential to be applied effectively in various range of problem. Its unique features allow for a balance between intensification and exploration of searching the best candidate solution will provide the best result within a reasonable time. HS becomes a preferable method because it is flexible to be integrated with another algorithm. To date, HS is still experiencing the enhancement phase, despite the classic HS has proven to be successfully implemented in different areas of optimization (civil engineering, electrical engineering, computer science, economy and operations research). With this comprehensive overview of conceptual model of HS prototype with the concern of overcoming the optimization problems, researchers are encouraged to look forward to consider HS as a tool in solving their optimization problems.

6.0 FUTURE RECOMMENDATION

In the future, we suggest that the value of HMCR should be a dynamic change for the whole generation in order to achieve optimized solution globally as we know the static value could lead us to trap into local optima. HMCR can linearly and exponentially increase or decreased. These conditions can be adopted at the beginning or final stage of generation. Some goes to the other two operators' of HS, PAR and BW which can also experience dynamic adjustment.

ACKNOWLEDGEMENTS

This work was supported by research grants RAGS/2013/FTMK/ICT02/01/B00039 under Ministry of Education of Malaysia and UniSZA for financial support.

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