Highly Reliable Harmony Search Algorithm

Nima Taherinejad, *Student Member, IEEE*

***Abstract*—In this paper, after a literature overview, studies will be concentrated on Pitch Adjustment Ratio function of Harmony Search Algorithm. A more rational function will be proposed which increase the robustness of algorithm and therefore leads to a highly reliable algorithm. Simulations on a set of Standard TSP Problems, demonstrates that Parameter of Reliability (Variance over Average), has experienced 75% of improvement. Cost paid for this considerable improvement, is completely negligible; 0.7% decrease in quality of responses.**

***Index Terms*—Optimization Algorithms, Harmony Search, Reliability, Pitch Adjustment Ratio.**

I. Introduction

NOWADAYS one encounters very complex optimization problems which is really hard, or in many cases impossible, to solve them deterministically. Heuristic Algorithms such a Genetic Algorithm [1], Simulated Annealing [2] and Ant Colony Optimization [3] has been developed to solve these problems in rational time period with an answer really close to the general optimum.

Harmony Search algorithm is of the same group of algorithms, recently introduced and developed [4]. In spite of its youth ness it has been used in many practical applications [5-8] and it is attracting more attentions day by day.

In this paper, after studying the most recent versions of this algorithm, some changes will be proposed which cause to reliability improvement. Indeed, whatever the result of running algorithm in each iteration is closer to the average result of several iterations, the algorithm would be more reliable. Being more reliable lets the algorithm to be run only one time in many practical applications. Because high reliability means that the chance role has been minimized and one can rely on the solitary answer. Proposed changes in the algorithm will lead to a 75% improvement on the Parameter of Reliability (PR), whereas its results quality has been decreased just 0.7% which is completely negligible. Therefore using the new algorithm, one can be sure that even in a one time iteration of the algorithm, he will have the near optimal result which could be achieved in several iterations.

Eventually, to test the performance of new algorithm, it was used to solve a set of famous Traveling Salesman Problem (TSP) which is a common approach to evaluate many optimization algorithms. Problems were gained from *Standard TSP Library* [9]. It is noteable has been proved that TSP problem is an NP_Hard problem which its complexity explodes with increase in the size of problem [10].

The paper will be organized so; A literature overview in section two. Proposed algorithm will appear in section three whereas the simulation results and comparisons will proceed that section. Finally, it's section five to conclude the paper.

N. Taherinejad is with the Electrical Engineering Department of Iran University of Science and Technology (corresponding author; e-mail: ntaherinejad@ee.iust.ac.ir).

II. Literature Overview

A. Review Stage

Heuristic Algorithms are usually nature inspired [11]. Genetic Algorithm has been inspired from diversity in generations [12], Ant Colony Optimization from ants' behavior through process of finding food [13] and Simulated Annealing from physical phenomena of annealing in nature [14]. Harmony Search algorithm is nature inspired as well, indeed it tries to somehow imitate behavior of musicians while composing new song.

When a group of musician gather to compose something new, they may start it with a random note, each. Then they evaluate the harmony of their played notes and if it is not well enough they may give it up. In the next step, they may play the some note from their memory or something else regarding to their available choices. Aesthetic sense of musicians rules all over this period as the fitness function and so they optimize the harmony of their composition.

As seen in Fig. 1, every musician could be considered as the decision parameter of algorithm, and whatever they play could be model of the value these parameters may retain. Finally, as mentioned before, the aesthetic sense of musicians is the model of fitness function in an optimization problem [15].

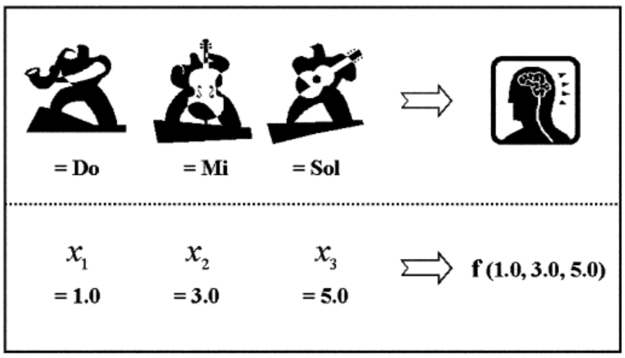

Fig.1. Mapping natural phenomena of music composition to artificial algorithm of optimization; Harmony Search [15].

978-1-4244-3896-9/09/$25.00 ©2009 IEEE

Fig. 2. demonstrated complete Flow chart of most recent Harmony Search algorithm [16]. First, parameters are initialized and some random solutions are generated. In contrast with primary versions, during the iterations Pitch Adjustment Ratio (PAR) and Band Width (BW) are not constant, but dynamically updated in recent versions.

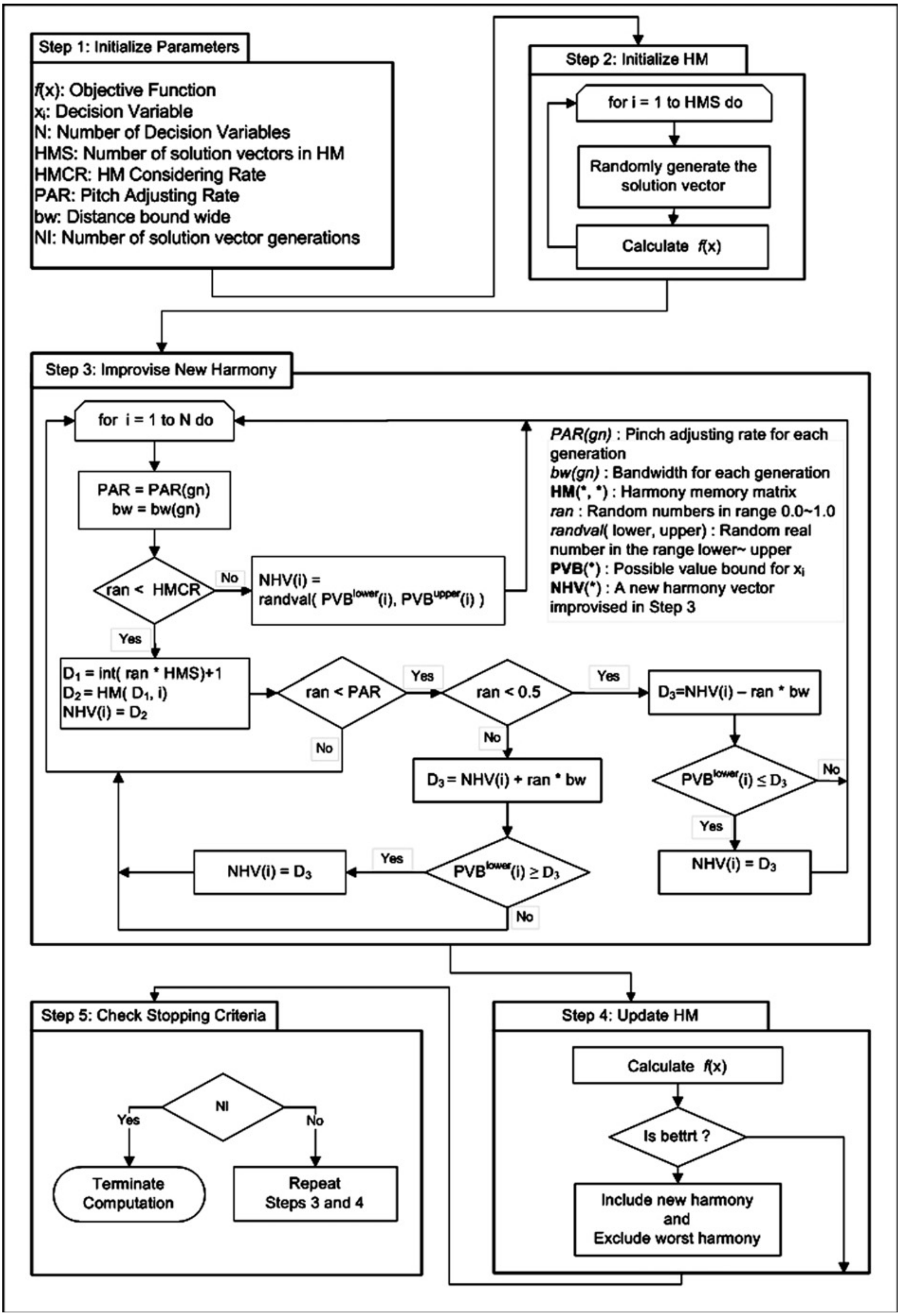

Fig. 2. Flowchart of the most recent Harmony Search Algorithm [16].

Anyway, whether PAR and BW are updated or not, a new value will be selected for decision parameter, using (1).

$$x_i' \leftarrow \begin{cases} x_i' \in \{x_i^1, x_i^2, ..., x_i^{HMS}\} & ;HMCR \\ x_i' \in X_i & ;(1-HMCR) \end{cases} \quad (1)$$

where with the probability of *HMCR* (Harmony Memory Consideration Rate), the new value is selected from Harmony Memory, and with *(1-HMCR)* from all other permitted values.

In the next step, if the value was selected from Harmony Memory, then regarding to *PAR* and a random number, previous value may experience some changes or not. Rule of this change is seen in (2).

$$x_i' \leftarrow \begin{cases} x_i^{(k \pm m)} & ;PAR \\ x_i' & ;(1-PAR) \end{cases} \quad (2)$$

where *k* is the selected parameter index and *m* is a random integer in *BW* range.

When a complete solution is generated, it will be evaluated using the fitness function. Respecting to Harmony Memory Size (*HMS*) and fitness of new solution, it may be inserted in Harmony Memory or not.

Eventually, if termination criteria (for example specific count of iterations or reaching to specific quality of solution) is met, the algorithm will stop and otherwise the loop will be repeated.

As mentioned before, in the recent versions, the value of *PAR* and *BW* are dynamically changed during the iteration [8, 16, 17]. The rule for changes in *PAR* is (3).

$$PAR(gn) = PAR_{\min} + \frac{PAR_{\max} - PAR_{\min}}{NI} \times gn \quad (3)$$

where *gn* is the abbreviated form of generation and in fact is a counter for number of loops ran before and *NI* is total number of iterations. Therefore *PAR* will experience changes between lower bound (PAR_{min}) and upper bound (PAR_{max}).

Finally, changes in *BW* obeys (4);

$$BW(gn) = BW_{\max} e^{c.gn} \quad (4)$$

in which

$$c = (Ln \frac{BW_{min}}{BW_{\max}}) / NI \quad (5)$$

III. PROPOSED ALGORITHM

The point to concentrate here is the changes that *PAR* and *BW* parameters experience. It is obvious that whatever the *PAR* is less, the value selected from memory will be unchanged with greater chance. On the contrary, when *PAR* is greater, with more probability the algorithm enters to where the value should be changes regarding to the Band Width (*BW*). Now the question is; when the greater band width is useful and helps the procedure of algorithm? Is current function effective enough?

Fig. 3, is graphical demonstration of changes in *PAR* and *BW*, using (3) and (4). As it is conspicuous, when *BW* is maximum the *PAR* is minimum. It means that reference to that part of algorithm -where large *BW* maybe useful- is minimum. In other words when *BW* is high, cause of minimum *PAR*, it is not referred and it is practically useless. On the other hand, when *PAR* is high, *BW* is minimum, and so range of changes is very limited. It means high value of *PAR* is somehow useless, because changes are not considerable (*BW* is minimum). Therefore the space around good results saved in memory is not well explored.

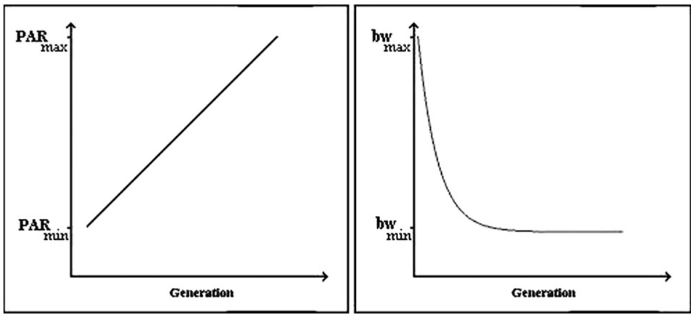

Fig. 3. Change of Parameters (PAR and BW) during the iterations.

Having the concept of Simulated Annealing (SA) in mind [2, 14], the space which is probed should be vast in the start of algorithm (High temperature in SA literature) and slowly should be limited around optimums found out (lowering the temperature). Thus to translate this idea into mathematical functions and implement it on Harmony Search, (6) is proposed;

$$PAR(gn) = PAR_{\max} - \frac{PAR_{\max} - PAR_{\min}}{NI} \times gn \quad (6)$$

where *PAR* and *BW* are both maximum at initial state which means that maximum space is explored. This causes to have different local minimums in the memory from different points of search space. Then, slowly the parameters are decreased (the algorithm freezes) and it focuses on these local optimums and seeks the global optimum around them.

IV. SIMULATION AND COMPARISONS

Testing mentioned discussions, Proposed Algorithm and Old one were simulated at the same situations. Used set of nine problems are found in *Standard TSP Library* [9], and the simulation parameters are inserted in Table I. These parameters, if possible, were selected from suggestions in other works [16 – 18].

TABLE I
Parameters' Setup in Simulations

HMS = 10	HMCR = 0.92
PAR_{min} = 0.35	PAR_{max} = 0.99

Loop count in each iteration has been five thousand times.. To avoid good or bad results achieved by chance, the algorithm was iterated fifteen times on each problem and the average was inserted considered as the result for the problem.

Table II includes the results of simulations and some comparisons, where the Parameter of Reliability (*PR*) is as (7).

TABLE II
Simulation Results and Comparison between Results and Parameter of Reliability (PR)

Name of Problem	Old Algorithm Results	Old Algorithm PR	New Algorithm Results	New Algorithm PR	Results' Changes [%]	Percent of PR Changes
Gr24	2052.5	18.59	2160.1	6.15	-4.98	202.28
Fri26	1623.7	5.60	1629.4	8.48	-0.35	-33.96
Bayg29	2913.3	36.91	2996.9	10.66	-2.79	246.25
Bays29	3676.8	8.90	3699.9	12.21	-0.62	-27.11
Dantzig42	1964.3	12.19	1959.1	8.65	0.27	40.92
Swiss42	3132.3	15.37	3112.7	12.03	0.63	27.76
Gr48	13928.7	58.51	13719.3	46.82	1.53	24.97
HK48	33711.1	54.56	33824.3	36.68	-0.33	48.75
Brazil58	98515	0.44	98422.7	0.18	0.094	144.4

Therefore, less the *PR*, more reliable the algorithm. The Parameter of Reliability was selected to be as (7) because *Variance* demonstrates the perturbation from natural behavior of system (*Average*) and as the solitary *Variance* can not be a good criterion it should be normalized by dividing to the *Average*.

$$PR = {Variance}/{Average} \quad (7)$$

It can be simply understood that the reliability of new algorithm is effectively and notably better than its predecessor and has much lower *PR* value. It is because of wide search space in the proposed algorithm which in the beginning of algorithm observes and considers many local optimum. Also adequate freezing process which makes the results approaching from local optimums toward the global one, is important.

Referring to the Table II, it can be seen that even though there exist also some problems where both quality and reliability of old algorithm is slightly better, but they are absolutely in minority (two of nine). However, when the quality of results is not considerably decreased (more than -1%) -which happens in *GR24* and *Bayg29*- parameter of reliability has been improved too much more (two hundred order) than the old algorithm. This means that even though the old algorithm may lead in a little bit better result in those problems, it's not reliable at all. Specially for single iterations which a few percent of quality improvement is against some hundred decrease (improvement) in reliability parameter.

Hence, while computation complexity is the same, one can use new algorithm and rely on the single iterations result 75% more and neglect decrease in quality of result which is even less than one percent (0.7%).

V. CONCLUSION

In this paper, Harmony Search Algorithm Literature was studied. The focus was on the dynamic parameter changes which is used in the most recent versions. The functionally of these changes and their effects were deeply discussed.

It was mentioned that current changes are not adequate at all and also they're somehow against each other and neutralize one the other. Therefore a new function was proposed which could help the algorithm to explore a vast search space while focusing well on local and global optimums.

To observe the ideas, both algorithms were simulated in the same situation and tried to solve a set of standard TSP problems. Simulation results demonstrated that Parameter of Reliability has been improve by a 75% in proposed algorithm. The scarification of this achievement is less than one percent (0.7%) in the quality of answers (that is completely negligible).

Decrease in the value of *PR*, which is the sign of reliability improvement, means that variation and perturbation around the natural behavior of system is decreased. Therefore in many different practical applications, where -regarding to the time or other constrains- only a single iteration is possible, one can rely too much more on the new algorithm and be sure that the result is very close to natural behavior of algorithm.

REFERENCES

[1] Y. Nagata, S. Kobayashi, "Edge Assembly Crossover: A High-power Genetic Algorithm for the Traveling Salesman Problem", *Proceedings of Seventh International Conference on Genetic Algorithms (ICGA'97)*, East Lansing, Michigan, pp. 450-457, 1997.

[2] E. Rodriguez-Tello et al., "An effective two-stage simulated annealing algorithm for the minimum linear arrangement problem", *Computers & Operations Research*, Vol. 35, pp. 3331 – 3346, 2008.

[3] N. Taherinejad, H. Miar Naimi, "Robust and Efficient Ant Colony Algorithm; Using New Local Updating Rule", *IEEE International Conference on Signal Processing and Communications (ICSPC 2007)*, pp. 161-164, 2007.

[4] Z. W. Geem, J. H. Kim, G. V. Loganathan, "A New Heuristic Optimization Algorithm: Harmony Search," *Simulation*, Vol. 76, No. 2, pp. 60–68, 2001.

[5] Z. W. Geem, "School Bus Routing using Harmony Search", *GECCO 2005*, June 25–29, 2005.

[6] Z. W. Geem, H. Hwangbo, "Application of Harmony Search to Multi-Objective Optimization for Satellite Heat Pipe Design", *Proceeding of US-Korea Conference on Science, Technology and Enterpreneurship (UKC2006)*, 2006.

[7] H. Ceylan et al., "Transport energy modeling with meta-heuristic harmony search algorithm, an application to Turkey", *Energy Policy,* Vol. 36, pp. 2527– 2535, 2008.

[8] R. Forsati, A.T. Haghighat, M. Mahdavi, "Harmony search based algorithms for bandwidth-delay-constrained least-cost multicast routing", *Computer Communications*, Vol. 31, pp. 2505-2519, 2008.

[9] http://elib.zib.de/pub/Packages/mp-testdata/tsp/tsplib/tsplib.html. *Visited on October and November 2008.*

[10] E.L.Lawler, J.K.Lenstra, A.H.G.Rinnooy Kan and D.B.Shmoys, editors. *The Traveling Salesman Problem*. Wiley, 1985.

[11] Holland, J. H., "Adaptation in Natural and Artificial Systems", *University of Michigan Press, Ann Arbor*, 1975.
[12] Goldberg, D. E., "Genetic Algorithms in Search Optimization and Machine Learning", *Addison Wesley, MA,* 1989.
[13] Dorigo, M., Maniezzo, V., and Colorni, A., "The Ant System: Optimization by a Colony of Cooperating Agents", *IEEE Transactions on Systems, Man, and Cybernetics-Part B*, *26*, 1, 29-41, 1996.
[14] Kirkpatrick, S., Gelatt, C., and Vecchi, M., "Optimization by Simulated Annealing", *Science*, *220*, 4598, 671-680, 1983.
[15] K. S. Lee, Z. W. Geem, "A new meta-heuristic algorithm for continuous engineering optimization: harmony search theory and practice", *Comput. Methods Appl. Mech. Engrg.*, Vol. 194, p.p. 3902–3933, 2005.
[16] M. Mahdavi, M. Fesanghary, E. Damangir, "An improved harmony search algorithm for solving optimization problems", *Applied Mathematics and Computation*, Vol. 188, pp. 1567–1579, 2007.
[17] M. Fesanghary, M. Mahdavi, M. Minary-Jolandan, Y. Alizadeh, "Hybridizing harmony search algorithm with sequential quadratic programming for engineering optimization problems", *Comput. Methods Appl. Mech. Engrg.*, Vol. 197, p.p. 3080–3091, 2008.
[18] N. Taherinejad, S. A. Mirbozorgi, S. S. Rezaei D., "Tuning the Harmony Memory Considering Rate (HMCR) parameter of Harmony Search Algorithm", *2nd Joint Conference on Intelligent Systems and Fuzzy Systems*, 2008.