Improve of Harmony Search by Scramble Mutation for Global Optimizations Problems

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Abstract Harmony search (HS) 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 usage of HS has become a common thing for a variety of numerical and real-world problems. It has several advantages over other meta-heuristics. It considers all existing vectors to generate a new vector. It imposes fewer mathematical requirements. The main disadvantage of HS encompasses its tendency to converge prematurely, which in essence leads to lose diversity during the search. In this study, a new variant of HS, called Scramble Mutation Harmony Search (SMHS), is proposed in this work where concepts from Genetic Algorithm (GA) process are borrowed to enhance the performance of HS. The Scramble Mutation is original step of GA, and is popular with permutation representations. In this, from the entire chromosome, a subset of genes is chosen and their values are scrambled or shuffled randomly. The performance of the SMHS is evaluated and compared with HS (a recently developed variation of HS that is, DLHS, and MHS). The experiments conducted show that the SMHS generally outperformed the other approaches when applied to ten benchmark problems. The effect of the SMHS parameters is analysed. Finally, the results show that cellular approaches seem to be an efficient alternative for optimization problems.

Keywords: Genetic Algorithms (GA), Global Optimizations (GO), Genetic Scramble Mutation Harmony Search (SMHS), Evolutionary Algorithm (EA), Harmony Search (HS).

تحسين خوارزمية البحث عن التناغم باستخدام التغير بطفرة الجينية لحل مشاكل الأمثلية الشاملة

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ملخص "Harmony Search (HS)" هو عبارة عن طريقة meta-heuristic جديدة للتحسين حيث تقوم بتقليد عملية الارتجال الموسيقي حيث يقوم الموسيقيون بتحسين أدواتهم الموسيقية بحثًا عن حالة انسجام مثالية. أصبح استخدام (HS) أمرًا شائعًا لمجموعة متنوعة من المشكلات الرقمية والواقعية. لديها العديد من المزايا على غيرها من طرق heuristic -meta الاخرى. هذه الطريقة تأخذ في الاعتبار كل المتجهات الموجودة لإنشاء متجه جديد. حيث تفرض متطلبات رياضية أقل تعقيدا. يشمل العيب الرئيسي لنظام HS ميله لسرعة التقارب بشكل غير تام ، مما يؤدي في جوهره إلى فقد التنوع أثناء البحث. في هذه الدراسة ، تم اقتراح بديل جديد لنظام HS ، يُدعى (SMHS) Scramble Mutation Harmony Search ، حيث يتم استعارة خطوة من خطوات الخوارزمية الجينية (GA) المتمثلة في طفرة Scramble لتحسين أداء نظام HS، حيث يتم استخدامها في تمثيل التقليب. تعتمد فكرتها الاساسية على أحداث طفرة أو تغيير في طول الكروموسوم و ذلك بتبديل الجينات بشكل عشوائي. هذه الالية تودي الى زيادة التنوع المطلوب. يتم تقييم أداء SMHS ومقارنتها مع أنواع اخرى من نظام HS (DLHS and MHS) . أظهرت التجارب التي أجريت أن SMHS تفوقت بشكل عام على الطرق الأخرى عند تطبيقها على عشرة دوال قياسية مرجعية (Benchmark Function). كذلك تم تحليل تأثير معاملات SMHS. أخيراً ، توضح النتائج أن طريقة SMHS تبدو بديلاً فعالاً لمشاكل التحسين مقارنة بالطرق الاخرى التي تم ذكرها في هذا البحث.

الكلمات المفتاحية: الخوارزمية الجينية، الأمثلية الشاملة، تغير الطفرة بواسطة التناغم، خوارزمية التطوير، البحث عن التناغم.

Introduction

The optimization process is concerned with the finding of the best solution from all possible solutions for a given problem. The first step in the optimization process is modeling the optimization problem in terms of an objective function responsible for evaluating a candidate solution [1]. The Harmony Search algorithm (HS) is one of the recent evolutionary algorithms used for solving optimization problems [2]. HS imitates the musical improvisation process of music players, which tries to seek a pleasing harmony as determined by an audio-aesthetic standard. The

solution vector of an optimization problem is similar to harmonies of music [3].
Regarding the Genetic Algorithms (GA) are adaptive algorithms that are based on the evolutionary ideas of natural and genetic selection [4]. While the Harmony Search algorithm has been very successful in a wide variety of optimization problems [5]. HS has several advantages to be one of the most powerful current algorithms [6].
Similar to popular meta-heuristic algorithms like GA, the HS algorithm might converge to a local optimum due to the premature convergence

problem. Thus, several variants of HS are proposed to enhance its performance and maintaining its diversity from local optima, such as: improve HS (IHS) [7]. The researchers presented [8] HS multi-pitch adjustment operators (MHS) to improve its speed of 4 convergence. The same author proposed hybridized HS with the hill climbing optimizer to improve the local exploitation in search space. The paper [9] developed global-best HS (GSH), by taking advantage of global-best to enhance the performance of HS.

In this paper, a type of genetic mutation was scaled with the basic HS algorithm. When a new vector is generated in HS, the structure of the vector is reconstructed and rearrangement of the values contained in it is randomized in a given field, In the process of exploring diversity of values and avoiding the problem of early convergence. Some of the mutations (insert, swap, and reverse) [10].

1. The Harmony Search Algorithm

Harmony Search analogy with Optimization the harmony search algorithm mimics the musical improvisation process where the musicians seek for a pleasing harmony as determined by an audio-aesthetic standard. The analogy between musical improvisation and optimization can be stated as follows: Figure (1) Taken from [11] to show the analogy between optimization problem and HS concepts.
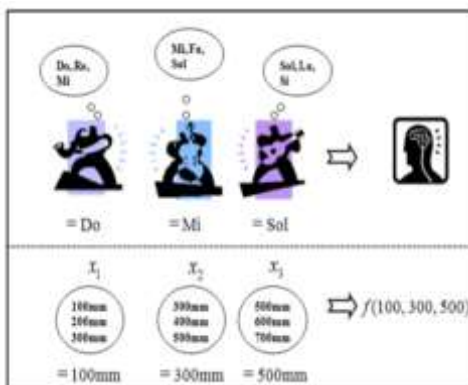

Fig. 1: Analogy between Improvisation and Optimization

1. Each musician corresponds to each decision variable.
2. A musical instruments pitch range corresponds to a decision variables range.
3. Musical harmony at a specific practice is equal to a solution vector at a specific iteration.
4. Audience aesthetics are corresponding to objective function in optimization

Generally, harmony among musicians improves over time. Similarly, solution vectors are improved upon iteration of the Harmony Search algorithm. The next section presents each step of the Harmony Search algorithm in detail.

i. The HS algorithm characteristics

The HS algorithm has several characteristics that make it an important and powerful meta-heuristic

algorithm [2]. It differs from other meta-heuristic algorithms: (i) in contrast to GAs, which consider only two vectors (two parents), the HS algorithm considers all existing vectors to generate a new vector; (ii) each vector variable is independently considered; and (iii) it does not require a fixed number of decision variables.

ii. Harmony Search procedures

HS has several advantages to be one of the most powerful current algorithms 6]. And its advantages include the following:

1. The HS algorithm generates a new vector, after considering the existing vectors;
2. The HS algorithm imposes fewer mathematical requirements;
3. The HS algorithm uses stochastic random searches;
4. The HS algorithm can handle both discrete and continuous variables;
5. The HS algorithm is simple, flexible and adaptable.

2. Improvements Harmony Search

The considered version of HS algorithms is meant to improve the performance of HS with variant problems. Several researchers have conducted studies with different modifications such as: parameter, improvisation step, and initialize harmony memory step.

2.1 Improved versions of the Harmony Search by Modifying the Initialization Step

The researchers propose HM structure by generating the solution twice (2×HMS), and stored only the best solutions in HM amongst them. Similarly, [11] suggest that using the spanning tree to generate the initial solution instead of random generation could be more effective and efficient. The initialization in this approach of the HM can give more promising harmonies.

2.2 Improved versions of Harmony Search by controlling the Setting of Parameters

To improve the performance of the harmony search in solving course timetabling problems, [8] propose a method based on dividing the pitch adjustment into eight procedures instead of using each one controlled by its pitch adjustment rate value range. Each procedure is responsible for making one change to generate a new harmony. Moreover, acceptance for all pitch adjustment procedures is modified to accept a new harmony if the new solution is better than or equal to the worst solution in the HM.

2.3 Improving the Harmony Search by Modifying of the Stopping Criteria

[12] Propose modifying the harmony search as proposed by [7] as a new method for training feed-forward artificial neural networks (ANN). According to this method, the modification is in Step 5 of the basic harmony search, and involves checking the stop criterion (NI) when using a dynamic iteration number based on the current improvisation number.

2.4 Application problems solved by Harmony Search

[13] overviewed most of application it has been created and used in various fields of optimization, such as music composition, [14], Timetabling [15], structural design [16], water network design [17].

i. Genetic Algorithm

The genetic algorithm (GA) is an exploratory search method used in artificial intelligence and computing [18]. This algorithm reflects the process of natural selection and evolutionary biology, and belongs to a larger category of evolutionary algorithms. Where the best breeding species are selected for the production of next-generation offspring. Genetic algorithms are excellent when searching through large and complex sets of data.

Natural selection begins with the selection of the most suitable individuals in the population. They produce offspring that inherit parental characteristics and will be added to the next generation. If parents have better fitness, their offspring will be better than parents and will have a better chance of survival. This process continues to repeat, and eventually, a generation of the right people will be found.

In the GA the gene array of an individual is represented by a string, in terms of the alphabet. Typically, (string of 1s and 0s) is used for binary values that we say we encodes genes in the chromosome," representation of the population depends on the problems".

The efficiency function determines the individual's ability to compete with other individuals. It gives a degree of efficiency for each individual. The probability of choosing an individual to reproduce depends on the degree of fitness.

The idea of the selection stage is to select the most appropriate people and allow them to pass their genes to the next generation. A pair of individuals (parents) is selected based on their degree of competence. Individuals with high fitness have a greater chance of being chosen for breeding.

The crossover is the most important stage in the genetic algorithm. Each pair of parents is mated, the intersection point is chosen randomly from within the gene.

3. Proposed Research Methodology

The proposed SMHS has procedures for optimization problems, whose idea is applied in terms of adjacent values only in this work. After improvisation, the basic HS algorithm begins with a step-by-step hybrid of the genetic algorithm known as mutation with basic HS, and a type of mutant called Scramble Mutation is used. The HM is modified to replace the worst solution with the new solution. Finally, the proposed HS method is evaluated using a set of global optimization functions.. Finally, a comparative analysis is performed with other methods. Figure (2) illustrates the proposed research methodology (SMHS).
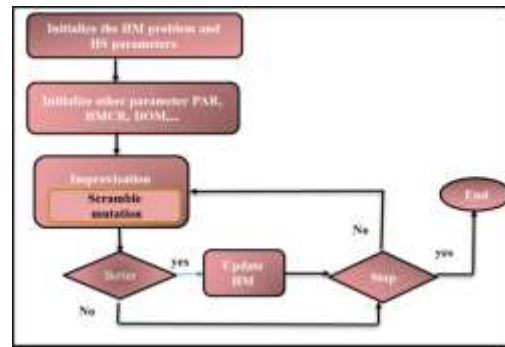

Fig. 2: Proposed Research Methodology (SMHS)

The New Harmony is evaluated against the objective function and replaces the worst harmony in HM. This process is repeated until a stopping criterion is reached. New solutions are typically developed based on three processes:

- **Memory consideration**. The memory study process takes into account all the solutions stored in HM without organization. Variable values in the new solution are set from the complete solutions stored in HM without being organized. This leads to diversity that can quickly lose in the final stage of research.

- **Random consideration.** Variables values in the new solution are allocated from the set available.

- **Pitch adjustment**. The values of the variables in the new memory-based solution are transferred to *Scramble Mutation*, the source of the improved local solution.

- Scramble mutation provides a specific mechanism for HS to improve its performance in terms of maintaining diversity through the iterations. In SMHS, a specific range of the solution is specified at each frequency.

The main objective of the proposed method is to make a quantum leap in the length of the solution, because it is possible to improve the behavior of the HS algorithm by changing its solution structure. This model proposes particularly to improve the performance of the basic search algorithm in the context of diversity.

4. Result

The proposed SMHS algorithm is experimentally evaluated by studying the effects of the different parameter settings of SMHS and HS. All the experiments are run using a computer with Intel(R) Core (TM) i3-3110 with 4GB of RAM. The operating system used is Microsoft windows 7 Service Pack1. The source code is implemented using MATLAB Version 7.14.0.739 (R2012a).

4.1 Global Minimization Benchmark Functions

This work uses a set of ten benchmark problems to evaluate the new variation of HS [8]. The benchmark functions are employed to investigate the performance of proposed algorithm (SMHS) in the main experiment. The results of benchmark

functions are used to compare the proposed method with other approaches in the literature

4.1.1 Benchmark functions use to evaluate the performance of SMHS

The global minimization benchmark functions are employed to evaluate the proposed method (SMHS) against the classic HS algorithm. Five functions are defined by [19] and the other five were described by [20] these functions used by [9]. These functions provide a balance between unimodal and multimodal functions. These functions are commonly used to evaluate the sate-of-the-art variations of harmony search algorithms [21], [9].

4.1.2 Functions used to compare SMHS with other approaches

Most of the benchmark functions have standard solution space range of the objective function. Otherwise, unsymmetrical initialization ranges are used for these functions whose global optima are at the center of the solution space. These benchmark functions are shown as follows in Figure (3):
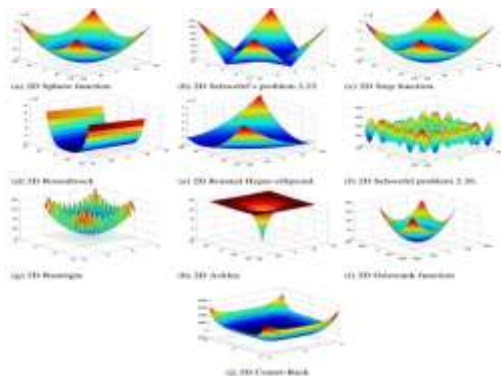

Fig. 3: benchmark functions

In order the reveal the impact of control parameter settings and compare the SMHS to HS, a study of different parameter settings of the common parameters (HMS, HMCR, PAR) is conducted for SMHS and HS.

It is revealed that both SMHS and the basic HS are not sensitive to the harmony memory size in different way. Where SMHS obtained the best results for big HMS (as shown in figures: 4, 5, 6 and 7). All cases have effect on result proportion to the size of the Domain(5, 10,15). Thus, to obtain the good solution in functions abovementioned HMS needs small Domain (i.e. HMS=16 need to =8 or bigger). From point of view, SMHS performs better for most of the functions because the overlap of the Domain provides an implicit mechanism of migration to the SMHS. Since the best solutions spread smoothly through the whole population, the SMHS diversity in the population is preserved longer than in HS.
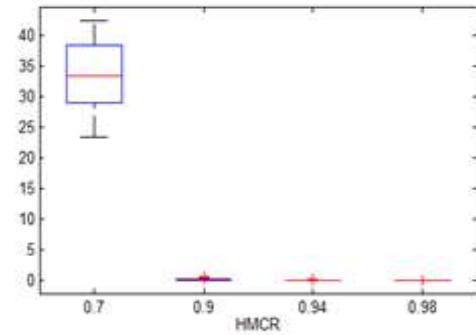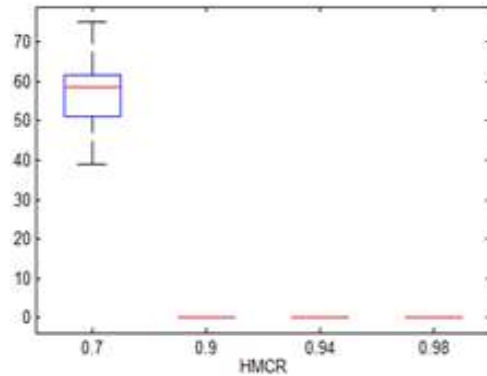

Fig. 4: Griewank function

Fig. 5: Rastrigin function
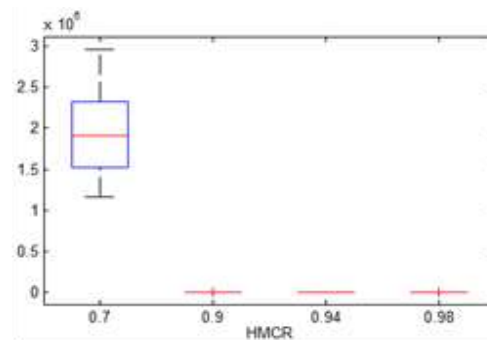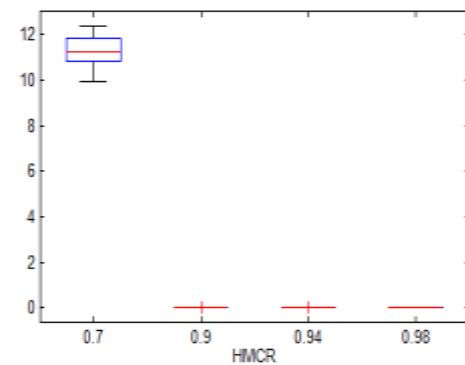

Fig. 6: Rosenbrock function
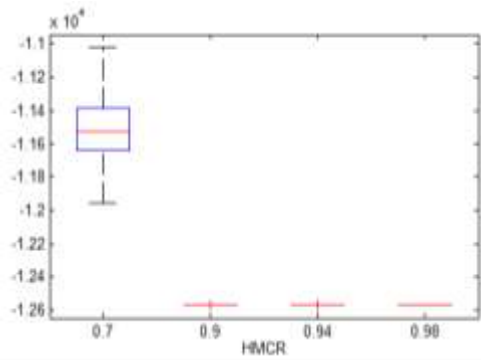

Fig. 7: Ackley function

Fig. 8: Schwefel's problem 2.26. function

HM is analogous to the short-term memory of a musician that is known to be small. A plausible interpretation may rely on the high number of similar harmonies within the HM when the HMS. that leads to shortages of diversity and, hence, lead to falling into local minima. Since SMHS is likely to be capable of maintaining more ability than HS with the cellular structure.

The results show that increasing the HMCR value improves the performance of the SMHS for All functions are true, HMCR increases the diversity and hence prevents the SMHS from convergence (i.e. it results in random search). Thus, it is generally better to use a large value for the HMCR (i.e. ≤ 0.9).

The high value of HMCR means high probability of using the harmony memory that leads to less exploration of search space. Using a probability of HMCR close to 1 (high value) might lead the algorithm to fall into the local minima trap. Using less probability of HMCR allows more randomly generated solutions. Therefore, the diversity increases in a way that prevents the convergence. The results reveal that SMHS and HS have identical sensitivity to the different values of HMCR for all functions, and in 0.98 probabilities to use HMCR they get the best for majority of optimization functions. Furthermore, the results produce by SMHS is better than those produced by HS.

5. Discussion
The results describe that no specific values for the PAR's values is best than other functions. In general, the results show that no single choice is superior to the others. However, it seems that using a relatively small value of PAR (i.e. ≤ 0.5) improves the performance of the SMHS and HS. The most results at large value of PAR can increase the convergence speed of HS algorithm, while a small value of PAR increases diversity of HM [21]. It is observed that SMHS is able to get the best results than the basic HS for some benchmark functions

Conclusion
In conclusion, the study performed the experimental evaluation of the proposed SMHS. The impact of the different parameter setting on the proposed method is analyzed, and the results are compared with the basic HS. In general, SMHS is sensitive to the value of HMCR and PAR.

The comparative results of the SMHS and others in literatures using the same benchmark functions show that the SMHS is able to produce superior results.

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