An Improved Adaptive Harmony Search Algorithm

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Abstract. Harmony search (HS) algorithm is a heuristic optimization algorithm which is newly developed in recent years. In this paper, according to the shortcomings of the existing harmony search algorithm, an improved adaptive harmony search algorithm (IAHS) is proposed. In the IAHS algorithm, the adaptive parameters HMCR and PAR and BW are used to adjust the global and local search, so as to improve the robustness and speed of convergence of the algorithm. IAHS algorithm is tested by five standard benchmark functions and contrasted with HS、HIS and GHS algorithm. Experimental results demonstrated that the proposed IAHS algorithm has the favorable abilities of accuracy and escaping local minimums.

Introduction

Harmony search (HS) algorithm is a new heuristic optimization algorithm which put forward by Geem, etc in 2001 [1]. Similar with Particle swarm optimization (PSO) algorithm, HS algorithm is based on the music improvisation process. In the process, musicians repeatedly adjusting the tone of each instrument in the band, and finally get a good harmony. HS algorithm has the advantages of simple model, strong randomicity, good ergodicity and global search ability. HS and its improved algorithm has been successfully applied to many practical optimization problems [2-5], such as environmental economic load dispatch optimization, traffic path optimization, the optimization of water distribution system and fault location in distribution networks and other issues.

Since the advent of harmony search algorithm, a series of achievements are made in various fields such as optimization problem: bus lines, water network design problem, the problem of reservoir scheduling, civil engineering problems. At present, this method has been widely applied in the problem of multi dimensional function optimization, pipeline optimization design, slope stability analysis etc. Research shows that the HS algorithm in solving multidimensional function optimization problems show a genetic algorithm and simulated annealing algorithm to optimize the better.

However, the standard HS exists some defects such as setting BW blindly harmony memory diversity gradually dissipating with iterations, falling into local optimum easily, low accuracy and so on[6].Therefore, in order to improve the performance of the HS, this paper propose an improved adaptive harmony search algorithm (IAHS) whose parameters are adjusted adaptively. IAHS algorithm is tested by five standard benchmark functions and contrasted with HS、HIS and GHS algorithm. Experimental results demonstrated that the proposed IAHS algorithm has the favorable abilities of accuracy and escaping local minimums.

Standard harmony search algorithm

Harmony search (HS) algorithm was inspired by the improvising process of composing a piece of music. In the play, each player generates a tone to constitute a harmony vector. If the harmony is better, write it down, so that the next time to produce better harmony. In the algorithm, the tones of music instrument are analogous to the decision variables $x_i^j\,(\mathrm{i}=1,2,\ldots,\mathrm{n})$ of the optimization problem, each harmony are analogous to the solution vector $x^j=(x_1^j,x_2^j,\ldots,x_n^j)$, aesthetic evaluation are analogous to the objective function $f\left(x^j\right)$, the musicians want to find the beautiful harmonies by defined by aesthetic evaluation, the researchers want to find the global optimal solution defined by objective function .HS algorithm contains a series of optimization factors, such as the harmony memory (HM), harmony memory size (HMS), harmony memory consideration rate (HMCR), pitch adjusting rate (PAR), bandwidth (BW).In the algorithm, HM stores the feasible solution vector, HMS determines the number of feasible solution, HMCR represents the probability of selecting new solution from HM, PAR is the probability of disturbing to the new solutions.

Aesthetic evaluation is issued by the participation of musical instruments sound collections of the decision, as the value of the objective function is designed by variable values as a set of decision. A brief description is given of the above statement in Table 1.

Table 1: Comparison of optimization and music

Analog elements	optimization procedure	implementation procedure
best condition	global optimal	great Harmony
be evaluated by	objective function	aesthetic evaluation
evaluation method	value of variables	tone
process unit	each iteration	each exercise

At the concert, the musicians on their own memory, by adjusting the instruments of the orchestra tones, and ultimately achieve a wonderful harmony state.

This phenomenon will instrument inspired I(=1,2,... M), in analogy to the optimization problem in the I variables, the musical tone is equivalent to the value of a variable, the musical tone harmonies are equivalent to the j group of optimization problems solution vector, music effect evaluation in analogy to the objective function, HS algorithm is proposed.

Harmony search algorithm can also be randomly given initial solution, can advance the use of other heuristic algorithm or other means to form a good initial solution. The harmony search algorithm is mainly based on neighborhood search, has a great influence on the performance of the initial solution search. Especially some very complex constrained optimization problems, the initial random solution given the likely is not feasible, even through multiple search is very difficult to find a feasible solution, this time should be according to the specific complex constraints, using heuristic method or other methods to find a feasible solution as the initial solution.

The algorithm first initialize the harmony memory, and then from the harmony memory randomly generated new harmony, if new harmony is worst than memory the harmony in the good, the new harmony into memory, the worst harmony swapped out of memory. So the cycle until the stopping criterion is satisfied.

In the process of iteration, each tone of new harmony vector $X^{new} = (x_1^{new}, x_2^{new}, \cdots, x_n^{new})$ can be generated by three ways: (1) learn from harmony memory; (2) pitch adjustment, and (3) random selection. The formula of learning from HM is as follows:

$$x_i^{new} = \begin{cases} x_i^j, j \in (1,2\ldots,HMS), rand_1 < HMCR \\ x_i \in X_i, others \end{cases} \tag{1}$$

Where $rand_1$ is a random number uniformly distributed between 0 and 1； X_i is the value space of the ith variable.

After the ith tone obtains its value from HM, it will be adjust with the probability of PAR. When X_i is continuous, the adjusting formula is as follows:

$$x_i^{new} = \begin{cases} x_i^j \pm rand_2 * BW, rand_2 < PRA \\ x_i^{new}, others \end{cases} \tag{2}$$

When X_i is discrete, the adjusting formula is as follows:

$$x_i^{new} = \begin{cases} x_i(k+m), m \in \{-1,1\}, rand_2 < PRA \\ x_i^{new}, others \end{cases} \tag{3}$$

Where $rand_2$ is a random number uniformly distributed between 0 and 1.

The optimization procedure of the standard HS algorithm is as follows:

Step1: Initialize HS algorithm parameters. (1) the dimensions of the variable D;(2) the scope of each variable;(3) HMS;(4)HMCR;(5)PAR;(6) the largest number of iterations NI.

Step2: Initialize the harmony memory (HM).

Step3: Improvise a new harmony from the HM.

Step4: Update the HM. If the new solution is superior to the worst solution in the HM, Then the worst are replaced by the new solution, and generating a new HM.

Step5: Inspect termination condition. Adjusting the algorithm whether meet the termination conditions, if it is satisfied, the iteration will be stop and outputting the best solutions. Else go to Step 3 and step 4.

Improved adaptive harmony search algorithm

Harmony memory consideration rate (HMCR)

HMCR values is an important parameter in HS algorithm, and its scope is [0, 1]. It determines the way of generating new solutions in each iteration[7]. In this paper, in order to ensure the solution is diverse, HMCR adopts the following linear increasing strategy.

$$HMCR(t) = HMCR_{\max} - \frac{(HMCR_{\max} - HMCR_{\min})*t}{NI} \tag{4}$$

Where $HMCR_{\max}$ and $HMCR_{\min}$ are the maximum and minimum harmony memory consideration rate, respectively.

Pitch adjusting rate (PAR)

Pitch adjusting rate (PAR) play a role of controlling of local search. It can it can avoid search falling into local optimum[8]. Therefore, this paper introduces the dynamic change strategy for PAR. its formula is as follows:

$$PAR(t) = \frac{PAR_{\max} - PAR_{\min}}{\pi/2} * \arctan t + PAR_{\min} \tag{5}$$

Where $PAR_{\max}$ and $PAR_{\min}$ are the maximum and minimum pitch adjusting rate, respectively.

Bandwidth (BW)

Standard HS algorithm adopts the fixed value of BW. In the whole optimization process, the value of BW remains the same, which did not make full use of BW's influence on the global or local optimization[9]. According to the nonlinear regressive strategy, this paper dynamically adjusts the BW. The formula is as follows:

$$BW(t) = (BW_{\max} - BW_{\min}) \times e^{-t} + BW_{\min} \tag{6}$$

Where $BW_{\max}$ and $BW_{\min}$ are the maximum and minimum bandwidth, respectively.

The optimization steps after algorithm improved

Step1: Initialize HS algorithm parameters.

Step2: Initialize the HM.

Step3: Generate new solutions. Use Esq. (1), (2), (3), (4), (5) and (6) to generate M new solutions in each iteration.

Step4: Calculate the value of new solutions using objective function. Select HMS better solutions from N new solutions and HMS solutions in the HM.

Step5: Inspect termination condition. If the termination conditions cannot be met, then return to step 3. Otherwise the algorithm ends.

Simulation experiment and performance analysis

In order to verify the performance of the IAHS, this paper adopted the following 5 standard testing functions [10,11] to test, and contrasted with HS, HIS and GHS. The programming of proposed IAHS are developed in MATLAB 2011b and run on PC with 3.19 GHz core duo processor of 3.25 GB RAM. The parameters of the algorithms are shown in Table 2:

1）Rosenbrock function

$$f_1=\left(100(x_2-x_1^2)\right)^2+\left(x_1-1\right)^2, -30 \le x_1, x_2 \le 30 \tag{7}$$

Where n = 10, the best solution is 0.

2）Schaffer function

$$f_2=0.5+\frac{\sin^2\sqrt{x_1^2+x_2^2}-0.5}{\left[1.0+0.001*\left(x_1^2+x_2^2\right)\right]^2}, -100 \le x_1, x_2 \le 100 \tag{8}$$

This multi-peak function has the minimum value at (0, 0).

3）Ackley function

$$f_3=\left[-20\exp\left(-0.2\sqrt{\frac{1}{5}\sum_{i-1}^{5}x_i^2}\right)+20\right]-\left[\exp\left(\frac{1}{5}\sum\cos 2\pi x_i\right)-\exp(1)\right], -30 \le x_1, x_2 \le 30 \tag{9}$$

This function has a minimum value at (0,..., 0).

4）Rastrigin function

$$f_4=\sum_{i=1}^{10}\left(x_i^2-10\cos 2\pi x_i+10\right), -5.12 \le x_i \le 5.12 \tag{10}$$

This function has a lot of local extremum points and get a minimum value at (0,…, 0).

5）Griewank function

$$f_5=\frac{1}{4000}\sum_{i=1}^{10}x_i^2-\prod_{i=1}^{10}\cos\frac{x_i}{\sqrt{i}}+1, -600 \le x_i \le 600 \tag{11}$$

Where this function has a minimum value at (0,..., 0).

Table 2: The parameters Setting for algorithms

Algorit-hm	HM-S	HMCR	PAR	BW	NI
HS	30	0.9	0.3	0.01	1000
HIS	30	0.9	PARmin=0.01 PARmax=0.99	BWmin=0.0001 BWmax=(UB-LB)/20	1000
GHS	30	0.9	PARmin=0.01 PARmax=0.99	—	1000
IAHS	30	HMCRmin=0.6 HMCRmax=0.9	PARmin=0.01 PARmax=0.9	BWmin=0.0001 BWmax=1.0	1000

50 independent runs are made for each case function. In terms of worst solution, best solution, average solution and standard deviation, Statistic the result of the 50 times experiments. The comparison results are shown in Tables 3-7.

Table 3:The optimization results of Rosenbrock function

Algorithm	Worst solution	Best solution	Average solution	Standard deviation
HS	10.5622	3.6670e-007	3.1369	3.5652
IHS	12.3831	8.9563e-013	1.7458	3.1472
GHS	1.3455	0.0158	0.3996	0.4005
IAHS	2.0358e-009	4.9469e-014	6.586e-010	6.9447e-010

Table 4: The optimization results of Schaffer function

Algorithm	worst solution	best solution	Average solution	Standard deviation
HS	0.0368	0.0095	0.0162	0.0124
IHS	0.0372	4.8848e-015	0.0089	0.0075
GHS	0.0785	4.0185e-007	0.0151	0.0188
IAHS	0	0	0	0

Table 5: The optimization results of Ackley function

Algorithm	Worst solution	Best solution	Average solution	Standard deviation
HS	5.1578e-005	1.1060e-005	2.8372e-005	1.1584e-005
IHS	8.3365e-005	4.7451e-005	2.4284e-005	1.0529e-005
GHS	0.0260	5.5362e-005	0.0077	0.0073
IAHS	0	0	0	0

Table 6: The optimization results of Rastrigin function

Algorithm	Worst solution	Best solution	Average solution	Standard deviation
HS	4.9418e-005	5.3281e-006	2.2516e-005	1.1433e-005
IHS	3.889e-006	1.3020-006	2.4548e-006	5.9923e-007
GHS	0.0015	1.1391e-008	2.4582e-004	3.5566-004
IAHS	0	0	0	0

Table 7: The optimization results of Griewank function

Algorithm	Worst solution	Best solution	Average solution	Standard deviation
HS	0.1423	0.0085	0.0714	0.0384
IHS	0.1795	0.124	0.0507	0.0375
GHS	0.4674	7.05204e-005	0.0868	0.1393
IAHS	0	0	0	0

Comparing the results of Tables 3-7, it can be found that the worst solution, the best solution, the average solution and the standard deviation by the proposed IAHS algorithm is better than that of any other method. IAHS algorithm shows a distinct advantage over HS, its and GHS. Therefore, in general, IAHS algorithm has the favorable abilities of accuracy and escaping local minimums.

Conclusion

To overcome the drawbacks of standard harmony search algorithm, this paper puts forward an improved adaptive harmonic search (IAHS) algorithm. This algorithm uses the adaptive parameter HMCR、PAR and BW to adjust the global and local search, so as to improve the robustness and the speed of convergence of the algorithm. IAHS algorithm is tested by five standard benchmark functions and contrasted with HS、HIS and GHS algorithm. Experimental results demonstrated that the proposed IAHS algorithm has the favorable abilities of accuracy and escaping local minimums.

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