Design of Routing Algorithm for Communication of Power Wireless Sensor Networks Based on Improved Harmony Search

Guo Li[1,*] and MingHuaWang[2]

[1]*College of Intelligent Manufacturing and electrical engineering, Nanyang Normal University, Nanyang, Henan 473000, China*
[2]*Shandong Gete Aviation Technology Co., Ltd, Jinan, ShanDong 250000*
E-mail: liguo198011@163.com; 13064053502@163.com
[*]*Corresponding Author*

Received 07 August 2024; Accepted 25 September 2024

Abstract

In this paper, a routing algorithm for the communication of power wireless sensor networks based on improved harmony search is proposed to reduce the communication routing delay and energy consumption of power wireless sensor networks. Firstly, according to the composition of communication routing delay and energy consumption of power wireless sensor networks, the delay model and energy consumption model are constructed respectively, and the objective function is constructed by assigning different weights. Then, artificial bee colony algorithm and Levy flight mechanism improved harmony search algorithm are adopted for solving the objective function. Experiment results reveal that the algorithm can meet different users' different demands on delay and energy consumption. If the user needs low delay, set the low delay weight to 1 and the power consumption weight to 0, then the

Journal of ICT Standardization, Vol. 12_2, 189–214.
doi: 10.13052/jicts2245-800X.1223

average delay is 7s, and the average power consumption is 3203J. When user demand is low energy consumption, set the delay weight to 0 and the energy consumption weight to 1, so that the average energy consumption is 2667J and the average delay is 15s, which can meet the needs of users.

Keywords: Harmony search algorithm, power wireless sensor, artificial bee colony algorithm, levy flight mechanism, low delay, low energy consumption.

1 Introduction

As an efficient technology, communication routing for power wireless sensor networks plays a crucial role in modern smart grids due to its high flexibility, strong reliability, and strong scalability. In smart grids, power wireless sensor networks are usually deployed in all aspects of power transmission, power consumption, and distribution. On the one hand, it can provide users with flexible electricity solutions, on the other hand, it can also improve the operation efficiency of power companies, and at the same time, it can realize the energy monitoring of smart grid and the efficient distribution of power resources. When deploying communication routing for power wireless sensor networks, various aspects such as transmission delay and energy consumption are involved, which have a significant impact on the operation of smart grids. Therefore, it is of great significance to analyze transmission delay and energy consumption of communication routing for power wireless sensor networks.

Aiming at reducing the transmission delay of communication routing for power wireless sensor networks, Han Hongzhang et al. propose an optimal routing deployment scheme with improved ant colony algorithm. By taking node position as reference node and anchor node, and using improved ant colony algorithm to solve optimal path, low-delay optimization of communication routing for power wireless sensor networks is realized, which is conducive to promoting the development of smart grid [1]. To reduce the transmission delay of communication routing for power wireless sensor networks, Soudarajan S et al. combine the enhanced scheduling algorithms and stochastic classical game theory to extend the lifecycle of the entire network, thereby effectively reducing the transmission delay of communication routing for power wireless sensor networks [2]. To reduce the transmission delay of communication routing for power wireless sensor networks, Abbou NA et al propose a delay-effective routing measurement method using RPL protocol and wireless sensor networks. By measuring the communication routing delay of power wireless sensor networks and reducing the delay caused by load management, the overall communication routing delay of power wireless sensor networks is effectively reduced [3]. Radhika K et al. construct a wireless sensor network graph model and proposed a delay optimization algorithm. By reducing the maximum topology delay and maximum node power time complexity, the communication routing delay of power wireless sensor networks is effectively reduced [4]. Wei S et al. propose an end-to-end delay optimization method by constructing a communication routing delay model for power wireless sensor networks, which reduce the end-to-end delay with a maximum reduction of 20.3% [5].

Aiming at reducing the energy consumption of communication routing, Shreedhar Y et al propose a dynamic arithmetic reinforcement learning method of double deep Q learning based on energy-efficient clustering and scheduling of reliable routes, which effectively reduce the energy consumption of each sensor node [6]. Wang L et al. improve ant colony algorithm by adopting pseudo-random proportional rules to optimize the state transition formula, solve the lowest energy consumption routing path, thus reducing the communication routing energy consumption of power wireless sensor networks [7]. Liu W et al. realize the multi-dimensional path planning of communication routing for power wireless sensor networks by constructing an auxiliary positioning model of mobile anchor nodes for communication routing in power wireless sensor networks, and plan the static and dynamic paths of mobile anchor nodes, which effectively reduce the communication routing energy consumption of power wireless sensor networks [8]. To improve spectrum utilization efficiency and reduce energy consumption, M. Y R et al. dynamically selected the optimal spectrum frequency band for seamless data transmission, significantly reducing the communication routing energy consumption of power wireless sensor networks [9]. Anand V et al. propose a method of phase sleep data capture according to their current moving layer count, which effectively reduce the communication routing energy consumption of power wireless sensor networks by initiating sleep mode for moving objects beyond the receiving limit [10].

The above results show that communication routing optimization for power wireless sensor networks mostly focuses on a single delay optimization or energy consumption optimization. In practical applications, it is usually necessary to achieve collaborative optimization of both delay and energy consumption, and can be adjusted according to different needs of users. Therefore, the existing communication routing optimization algorithms of power wireless sensor networks cannot meet the needs of practical applications. To solve this problem, a communication routing algorithm for power wireless sensor network is proposed by combining a novel intelligent optimization algorithm, harmony search algorithm. The harmony search algorithm has the characteristics of simple logical thinking and few control parameters, and plays an important role in solving complex problems. It is widely used in fields such as power system optimization and information network optimization [11]. For example, Sankaranarayanan S et al. use harmonic search algorithm to solve the deployment nodes of wireless sensor networks, which reduces the energy resource consumption of wireless sensor networks [12]. Zaher A. et al. optimize the resident location of sink in wireless sensor networks by using the harmonic search algorithm to improve the network transmission speed [13]. Therefore, this article proposes an optimization of wireless sensor network communication routing based on harmony search algorithm, and improves the harmony search algorithm according to its existing problems.

The innovation of this paper is to use the global search performance of harmony search algorithm, and combine artificial bee colony algorithm with Lévy flight strategy to improve harmony search algorithm, so as to avoid the algorithm falling into the local optimal solution.

The specific content of this paper is arranged as follows: The first section provides an overview of the background and significance of this paper; The second section constructs an objective function with low delay and low energy consumption as optimization objectives; The third section adopts artificial bee colony algorithm and Levy flight mechanism to improve harmony search algorithm, and designs objective function solving algorithm of improved harmony search algorithm. The fourth section discusses the work of this paper and elaborates on existing problems and future prospects in the work.

2 Construction of Communication Routing Objective Function of Power Wireless Sensor Networks

Power wireless sensor network is a large-scale, self-organizing dynamic topology network, which is characterized by the use of communication routing algorithms to achieve energy saving and low cost, and to reduce communication latency during the communication process. In this study, delay model and energy consumption model of power wireless sensor networks are constructed, and different weights are assigned according to the needs of users to construct objective functions.

(1) Construction of delay model

The communication delay of power wireless sensor networks includes four parts, namely data processing delay, data queuing delay through a certain node, data transmission delay, and data propagation media delay. Among them, data processing delay is determined by the data processor, queuing delay is determined by the queuing data volume, transmission delay is determined by network bandwidth, and propagation delay is determined by propagation speed. Since determining conditions of data processing delay, transmission delay and propagation delay are constant, it can be considered that these three types of time delay weight factors are the same, and the fewer the number of intermediate nodes passing through, the smaller the time delay.

Based on the above analysis, assuming that there is a path $(V_0, V_1, \ldots, V_n)$, data V_0 can be transmitted to V_n, the intermediate node is P, and the transmission delay between any node i and its previous node i-1 is $d_i = \tau + k_i w$. Where τ is the network delay of a single node, w is the network delay waiting to receive a data packet, and k_i is the ith data packet to be received, then the network delay D_P of point P can be expressed as [14]:

$$D_P = \sum_{i=1}^{n} d_i \tag{1}$$

If there are m transmission paths when V_0 is transmitted to V_n, the probability of each path being selected can be expressed as:

$$f_1 = \frac{1/D_P}{\sum_{j=1}^{m} 1/D_P} \tag{2}$$

(2) Construction of energy consumption model

In this paper, communication energy consumption of power wireless sensor networks includes three parts: microcontroller unit energy consumption E_1, sensor motherboard energy consumption E_2, and transceiver unit energy consumption E_3. The total energy consumption can be calculated [15, 16].

$$E = E_1 + E_2 + E_3 \tag{3}$$

The transceiver unit energy consumption E_3 includes 2 parts of energy consumption generated by sending and receiving data, which is expressed as:

$$E_3 = E_4 + E_5 \tag{4}$$

Equation (4) can be transformed into:

$$E = \sum_{i=1}^{N}(E_1 + E_2 + E_4 + E_5) = C_1 + \sum_{i=1}^{N}(E_5) \tag{5}$$

where $C_1 = \sum_{i=1}^{N}(E_1 + E_2 + E_4)$ is a constant, E_5 can be calculated by Equation (6) :

$$E_5 = \begin{cases} E_B + E_F d_i^2, d_i < d_0 \\ E_B + E_A d_i^4, d_i > d_0 \end{cases} \tag{6}$$

where E_B is the energy consumption of circuit; E_F and E_A are energy amplification factors related to the data transmission distance; d_0 is the threshold.

When $d_i < d_0$, using the free space model to calculate energy consumption, it can be obtained that energy consumption is directly proportional to the square of distance; When $d_i > d_0$, adopting the multi-channel attenuation model to calculate the energy consumption, it can be obtained that energy consumption is proportional to the fourth power of distance. Therefore, the total energy consumption can be simplified [17, 18]:

$$E = C_1 + C_2 + C_3 \sum_{i=1}^{N} d_i^2 \tag{7}$$

where C_2=E_B.

If there are m transmission paths when V_0 is transmitted to V_n, then the probability of each path being selected can be expressed as:

$$f_2 = \frac{1/E_P}{\sum_{j=1}^{m} 1/E_P} \tag{8}$$

(3) Construction of objective function

Considering that in practical applications, users have different requirements for delay and energy consumption of communication routing in power wireless sensor networks, thus weights of delay and energy consumption are different. Set delay weight to a, energy consumption weight to b, and a + b = 1, then objective function of low delay and low energy consumption of the communication routing of power wireless sensor networks is shown as follows [19, 20]:

$$f = af_1 + bf_2 \tag{9}$$

3 Solution of Communication Routing Objective Function of Power Wireless Sensor Networks Based on Improved Harmony Search

3.1 Harmony Search Algorithm

Harmony search algorithm, as a global search algorithm that simulates the musician adjusting the pitch of an instrument to achieve harmonic state, has the characteristics of few parameters and simple structure, and is widely used in solving various complex problems [21, 22]. Moreover, its principle is to consider the harmony composed of various instrument tones as the optimal solution vector in solving function, and to use harmony evaluation as the objective function value.

$$\min_{X} f(X) \tag{10}$$

Where, $f(X)$ is objective function, which is usually solved by selecting the decision variable $X = (x_1, \ldots, x_n)^T$.

The execution process of the harmonic search algorithm consists of four steps. Firstly, the harmony memory is initialized, and new solutions are randomly generated and put into harmony memory. Then, select random number rand1 and conduct HMCR comparison on it with the storage consideration probability of harmony memory. If rand1<HMCR, a harmony variable x is randomly selected from harmony memory. When x is less than the fundamental fine-tuning probability PAR, x is fine-tuned according to the fine-tuning bandwidth bw to generate a new harmony variable x_{new}. Afterwards, x_{new} is evaluated, and when x_{new} is greater than the worst value in harmony memory library, the worst value is replaced with x_{new}. Finally, determine whether the maximum number of iterations has been reached, and if so, end the operation [23, 24].

The above process can be illustrated in Figure 1.

3.2 Improvement of Harmony Search Algorithm

Although harmony search algorithm has excellent global search ability, it is easy to fall into the local optimal solution because the new solution depends on the current population, and the search range is small, so its convergence speed and precision need to be improved. To solve above problems, this study combines artificial bee colony algorithm and Lévy flight strategy to improve harmony search algorithm [25, 26].

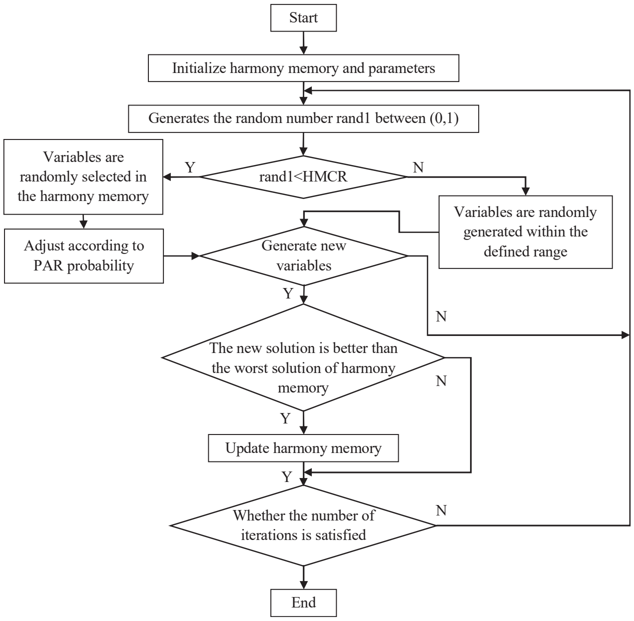


Figure 1 Process of harmony search algorithm.

Firstly, in the stage of generating new solutions, linear adaptive method is adopted to enhance the robustness of generating new solutions in the harmony memory library, as shown in Equation (11):

$$X_{new,j} = X_{new\_L,j} + (X_{new\_U,j} - X_{new\_L,j}) \times rand(0,1) \tag{11}$$

where $X_{new,j}$ is new solution; $X_{new\_U,j}$ and $X_{new\_L,j}$ are the optimal and worst values in harmony memory, respectively, and can be calculated by Equations (12) and (13).

$$X_{new\_U,j} = \left(1 - \frac{t}{T_{\max}}\right) \times X_{new\_U,j} + \frac{t}{T_{\max}} \times \max(HM(:j)) \tag{12}$$

$$X_{new\_L,j} = \left(1 - \frac{t}{T_{\max}}\right) \times X_{new\_L,j} + \frac{t}{T_{\max}} \times \min(HM(:j)) \tag{13}$$

Where, t is current iterations; $T_{\max}$ is the maximum number of iterations; $HM(:j)$ is the j column element of harmony memory matrix.

Then, in search and update stage of harmony memory database, artificial bee colony algorithm is adopted to solve the suboptimal solution to avoid the algorithm falling into local optima, thereby improving its convergence speed and precision [27, 28]. The suboptimal solution solved by the artificial bee colony algorithm is:

$$X_{new,j} = X_{worst,j} + rand(-1,1) \times (X_{best,j} - X_{worst,j}) \tag{14}$$

Finally, in order to expand the range of harmony search, improve diversity of algorithm population, and avoid the algorithm falling into local optimum, the optimal solution of harmony memory matrix is solved by combining Lévy flight. The specific operation is as follows:

$$X_{new,j} = X_{best,j} + \alpha \otimes Levy(\lambda) \tag{15}$$

Compared with improved harmonic search algorithm in literature [29] and literature [30], the improved harmonic search algorithm in this paper uses artificial bee colony algorithm and Levy flight strategy to increase the search range of algorithm population, avoid the algorithm falling into the local optimal solution, and improve its optimization accuracy and speed.

Process of improving harmony search algorithm can be summarized into the following four steps:

Initialize the maximum number of iterations, search space and other parameters, as well as harmony memory library;

Generate a harmony solution vector according to Equation (16), and generate rand1 from random numbers, and determine the size of rand1 and HMCR. When rand1 $>$ HMCR, the harmony vector can be generated by Equations (14) and (13); When rand1 $<$ HMCR, the harmony vector can be generated by Equation (16);

$$\begin{aligned} X_{new,j} = &\begin{cases} X_{new,j} \pm rand(0,1) \times bw, & r \leq PAR \\ X_{new,j}, & r > PAR \end{cases} \\ &+ X_{worst,j} + rand(-1,1) \times (X_{best,j} - X_{worst,j}) \end{aligned} \tag{16}$$

Determine whether the new harmony solution vector is better than the worst harmony solution vector in harmony memory library. If so, update the current harmony memory, update optimal solution in harmony memory according to Equation (14), and solve the sub-optimal solution in harmony memory according to Equation (13); Otherwise, go to step (4).

Determine whether the current harmony memory has reached the maximum number of iterations. If so, output optimal solution; Otherwise, return to step (2) and update HMCR and PAR using Equations (17) and (18).

$$HCMR = HCMR_{\min} + HCMR_{\max} \times \frac{t}{T_{\max}} \tag{17}$$

$$PAR = PAR_{\min} + PAR_{\max} \times \frac{t}{T_{\max}} \tag{18}$$

Figure 2 summarizes the above process.

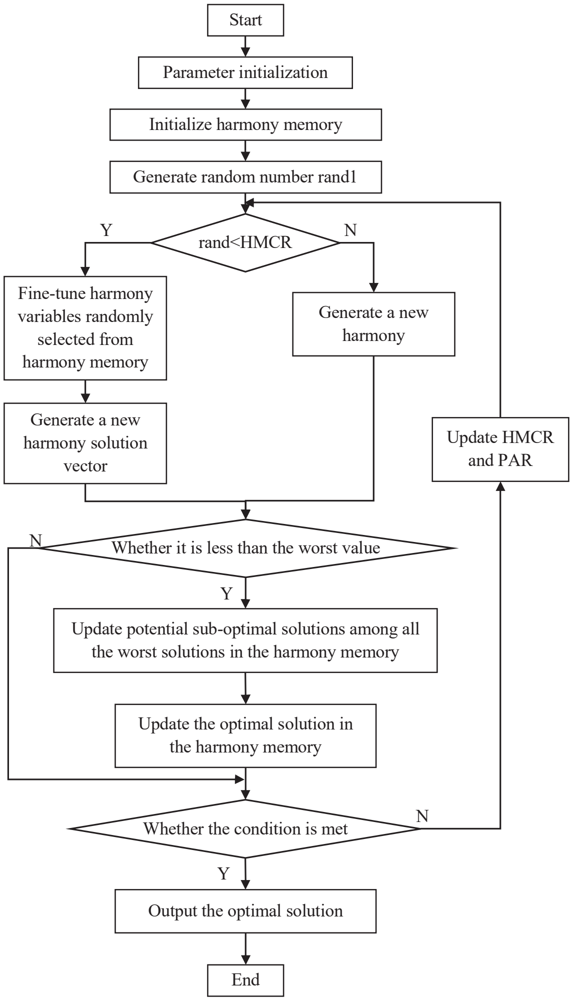


Figure 2 Process of improving harmony search algorithm.

3.3 Objective Function Solution Based on Improved Harmony Search Algorithm

Based on the improved harmonic acoustic search algorithm, communication objective function of power wireless sensor networks is solved. Firstly, decision variables and parameters of improved harmony search algorithm are initialized, and its initial priority value is generated to form memory. Then, objective function is calculated, and a new solution is generated. Finally, whether the new solution is better than the worst solution in memory database is determined. If so, update the memory database. When the iterative termination condition is satisfied, the algorithm is terminated, and its output is the result of solving the objective function. The specific process is shown in Figure 3.

It is important to encode the network path into the harmony memory. To achieve this purpose, priority path encoding method is adopted.

The idea of this encoding method is to assume that there are $N_{\max}$ nodes in the network, with corresponding numbers 1 to $N_{\max}$, the set of

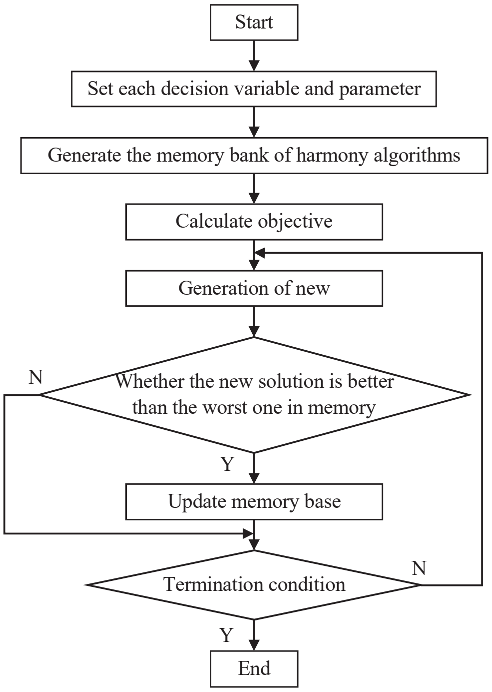


Figure 3 Solution process of objective function.

transmission path nodes is V_P^k, and variable in the harmony memory is x_k. Where, x_k is a random number ranging from $-2/N_{\max}$ to $2/N_{\max}$. Starting from node 1, paths are generated one by one. When a new node is added to V_P^k, the corresponding value of this node is $-2/N_{\max}$, and this node is no longer selected.

4 Simulation Experiment

4.1 Construction of Experimental Environment

The simulation experiment includes two parts: verification of harmony search algorithm improvement and solution of communication routing objective function of power wireless sensor networks by improved harmony search.

Among them, the verification of harmony search algorithm improvement are conducted based on Python 3.7 compiler and Windows 10 operating system. Moreover, The system is equipped with a Core-i7 8700K CPU, 16GB memory and GTX1080 graphics card.

The simulation experiment to solve communication routing objective function of power wireless sensor networks by improved harmonic search is carried out based on MATLAB software. The operating system and system configuration are the same as that of verifying the improvement of harmony search algorithm. In order to simulate a more realistic power scenario, 50 sensor nodes are deployed in a space of 100 × 100 m, and distance between adjacent sensor nodes is less than 30. The distribution of 50 nodes is shown in Figure 4.

4.2 Test Functions

The validation of harmony search algorithm improvement is carried out using three classic test functions, namely Equations (19) to (21). Where, f_1 function is a single-mode single-peak function, the value range is $[-100,100]$, and its optimal value is 0; f_2 function is multi-mode multi-peak model, the value range is [-600,600], and its optimal value is 0; f_3 function is a fixed-dimensional composite multi-modal function, the value range is $[-5,5]$, and its optimal value is -1.0316. The optimal solutions of f_4 to f_6 are all 0.

$$f_1(x) = \sum_{i=1}^{n} x_i^2 \tag{19}$$

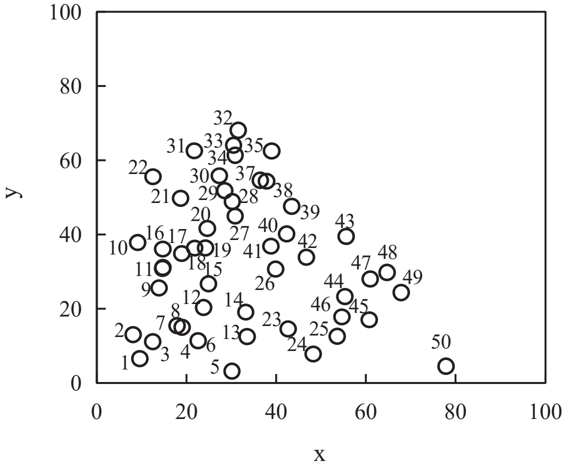


Figure 4 Specific distribution of nodes.

$$f_2(x) = \frac{1}{4000}\sum_{i=1}^{n} x_i^2 - \prod_{i=1}^{n} \cos\frac{x_i}{\sqrt{i}} + 1 \tag{20}$$

$$f_3(x) = 4x_1^2 + 2.4x_1^4 + \frac{1}{3}x_1^6 + x_1x_2 - 4x_2^2 + 4x_2^4 \tag{21}$$

$$f_4(x) = \sum_{i-1}^{w} x_1^2 - 10\cos(2\pi x_i) + 10 \tag{22}$$

$$f_5(x) = \max(|x|) \tag{23}$$

$$f_6(x) = \sum_{i=1}^{w} (|x_i + 0.51|)^2 \tag{24}$$

4.3 Parameter Settings

In this paper, parameters of improved harmonic search algorithm are set as follows: Its harmony memory size is 10, $HCMR_{\min}$ and $HCMR_{\max}$ are 0.4 and 0.5 respectively, $PAR_{\min}$ and $PAR_{\max}$ are 0.1, and the number of iterations is 1000. Moreover, the weights a and b for the delay model and energy consumption model have three values, namely 0.5 and 0.5, 0 and 1, 1 and 0, respectively.

4.4 Results and Analysis

(1) Verification of the improvement of harmony search algorithm

(1) Convergence curve

Verifying the effectiveness of the improvement conducting on harmonic search algorithm in this paper, $f_1 \sim f_6$ test functions are solved by using the harmony search algorithms before and after improvement respectively, and convergence processes are plotted as figures. Figures 5 and 6 show the obtained results.

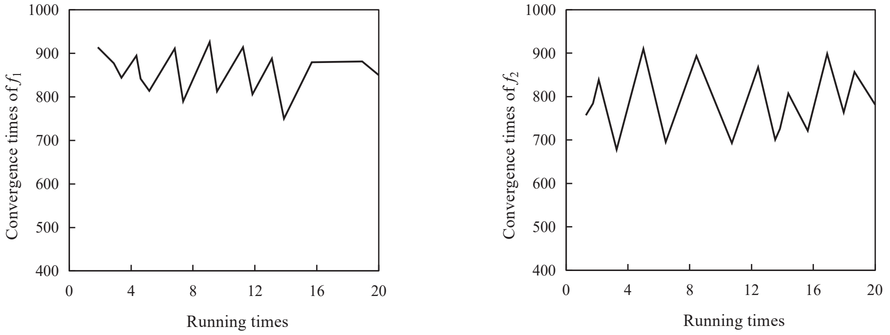
Comparing Figures 5 and 6 reveals that convergence speeds of harmony search algorithm on $f_1 \sim f_6$ test functions are significantly lower than those of improved harmony search algorithm, and fluctuation amplitudes of convergence curves is significantly higher than those of improved harmony search algorithm. It proves that the improved harmony search algorithm has better convergence performance and can improve its convergence speed, which preliminarily proves the effectiveness of improvements performing in this paper.

(2) Optimal value

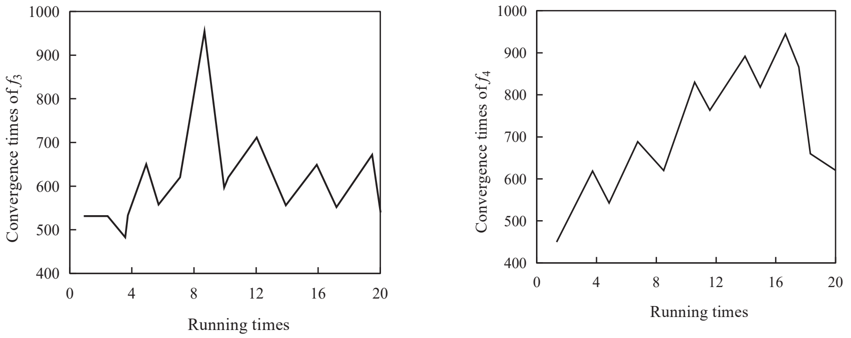
Figures 7–8 show the optimal solutions of the $f_1 \sim f_6$ functions solved by the harmony search algorithm before and after improvement. Analyzing figures shows that the optimal solution of the improved harmonic search algorithm is closer to the optimal solution of the function, which indicates that the improvement performing on harmony search algorithm is effective and can improve the precision of solving the algorithm.

(2) Harmony search algorithm improvement comparison

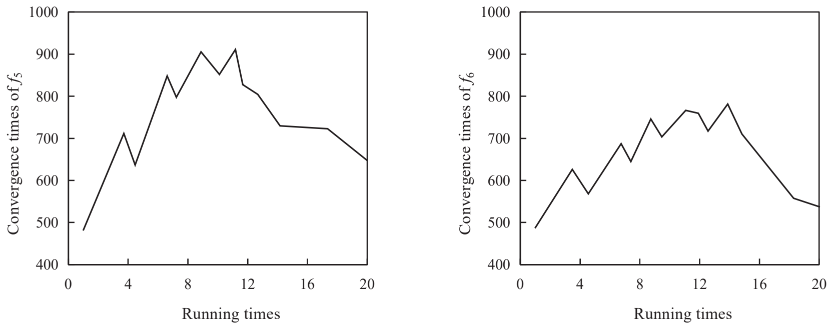
To further verify the superiority of improved harmony search algorithm in this paper, it is compared with harmony search algorithms improved by other algorithms, and $f_1 \sim f_3$ is taken as an example for testing. The results are shown in Table 1. Where, GAHS represents harmony search algorithm improved by genetic algorithm, PSOHS is the algorithm improved by particle swarm optimization algorithm, and ACOHS is the algorithm improved by artificial bee colony algorithm. As can be seen, compared with other improved harmony search algorithms, harmony search algorithm jointly improved by the artificial bee colony algorithm and Levy flight in this paper has better search performance, and the solved optimal solutions of $f_1 \sim f_3$ functions is consistent with the theoretical optimal solutions. This indicates that harmony search algorithm after improvement has certain advantages and higher search precision.



(a) Convergence curve on f_1 function (b) Convergence curve on f_2 function

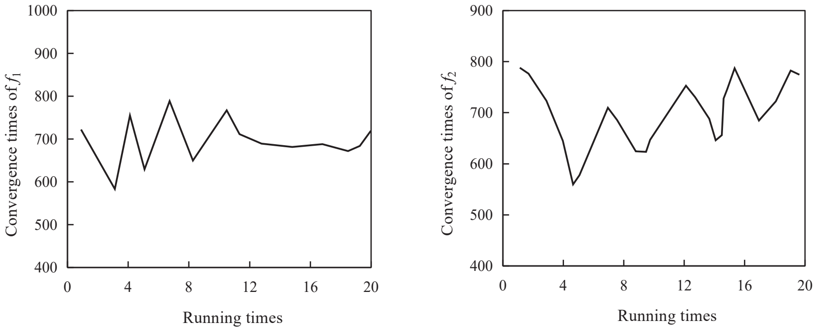


(c) Convergence curve on f_3 function (d) Convergence curve on f_4 function

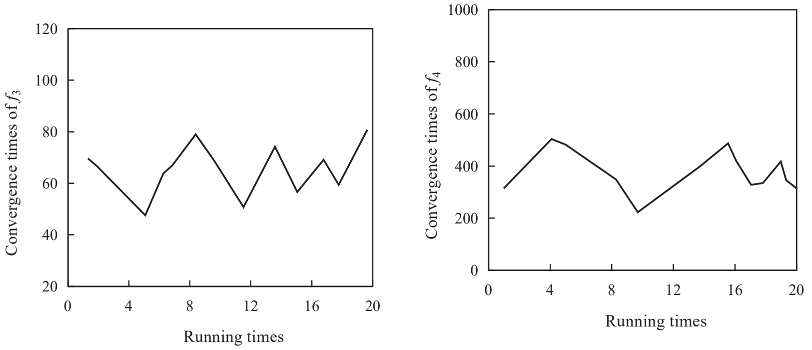


(e) Convergence curve on f_5 function (f) Convergence curve on f_6 function

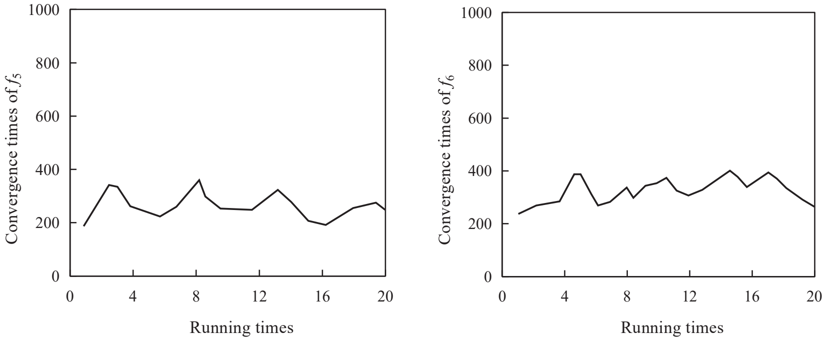
Figure 5 Convergence curve of $f_1 \sim f_6$ functions solved by harmony search algorithm.



(a) Convergence curve on f_1 function (b) Convergence curve on f_2 function

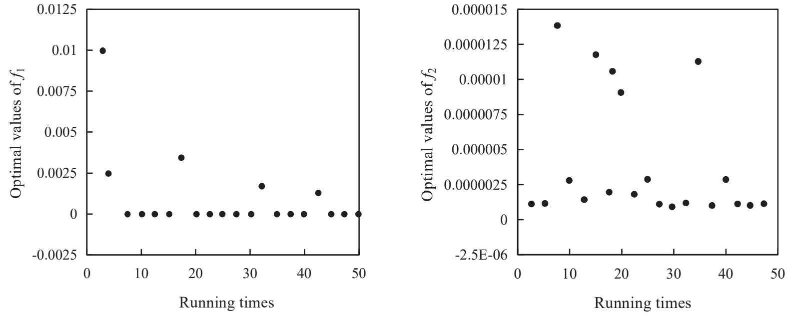


(c) Convergence curve on f_3 function (d) Convergence curve on f_4 function

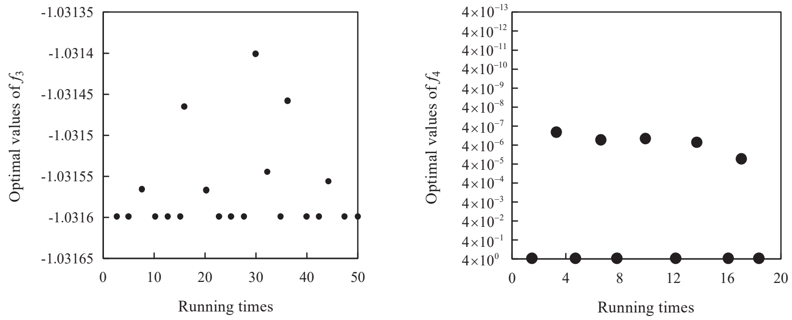


(e) Convergence curve on f_5 function (f) Convergence curve on f_6 function

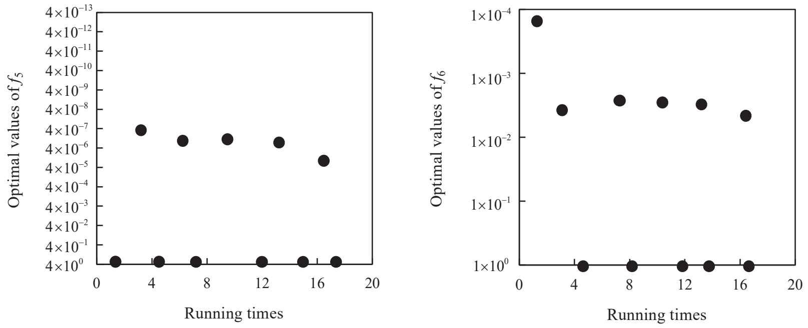
Figure 6 Convergence curve of $f_1 \sim f_6$ functions solved by improved harmony search algorithm.



(a) Optimal solutions on f_1 function (b) Optimal solutions on f_2 function

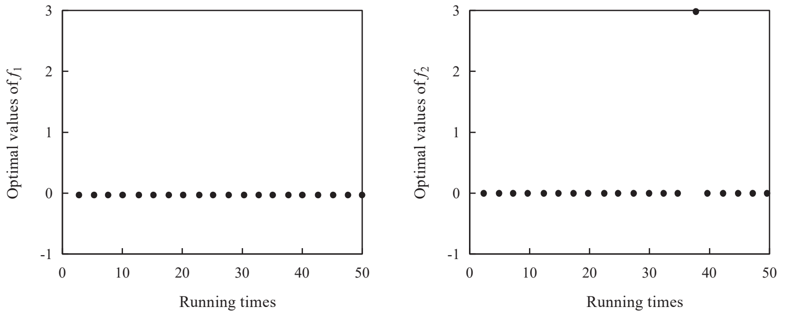


(c) Optimal solutions on f_3 function (d) Optimal solutions on f_4 function

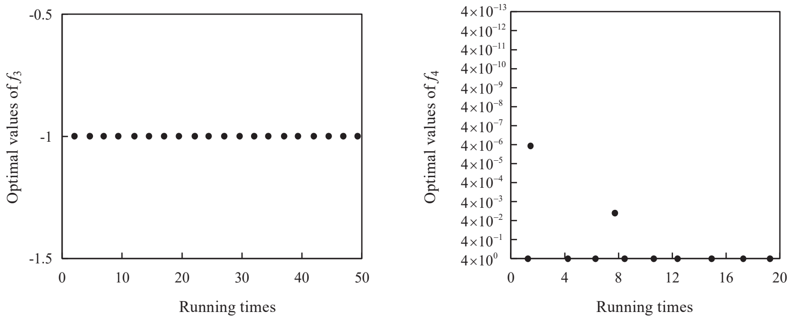


(e) Optimal solutions on f_5 function (f) Optimal solutions on f_6 function

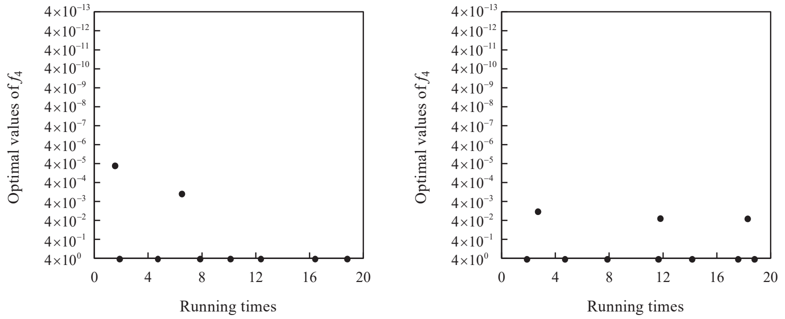
Figure 7 Optimal values of $f_1 \sim f_6$ functions solved by harmony search algorithm.



(a) Optimal solutions on f_1 function (b) Optimal solutions on f_2 function



(c) Optimal solutions on f_3 function (d) Optimal solutions on f_4 function



(e) Optimal solutions on f_5 function (f) Optimal solutions on f_6 function

Figure 8 Optimal values of $f_1 \sim f_6$ functions solved by improved harmony search algorithm.

Table 1 Comparison of optimal solutions solved by different algorithms

Test Functions	Algorithm	Optimal Solution
f_1	GAHS	1.42E-102
	PSOHS	1.16E-04
	ACOHS	1.95E-12
	The proposed algorithm	0
f_2	GAHS	1.45E-01
	PSOHS	5.41E+03
	ACOHS	2.23E+01
	The proposed algorithm	0
f_3	GAHS	2.28E-05
	PSOHS	1.16E-03
	ACOHS	2.61E-04
	The proposed algorithm	−1.0316

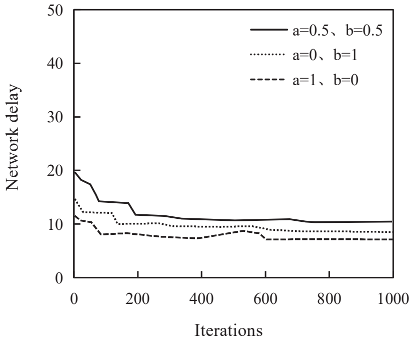


Figure 9 Network delay.

(3) Objective function solving based on improved harmony search algorithm

(1) Solving results

Figure 9 shows the network delay solved by improved harmony search algorithm under different weights of delay model and energy consumption model. Where, the network delay solved by harmonic search algorithm after improvement is low, and the network delay is 10 s under different weights of the delay model and the energy consumption model.

Figure 10 shows the network energy consumption solved by the improved harmony search algorithm under different weights of delay model and energy consumption model. As can be seen, the network energy consumption solved by the improved harmonic search algorithm is about 3000 J. Among them, the lowest energy consumption is the solving result when weight a = 0 and b = 1.

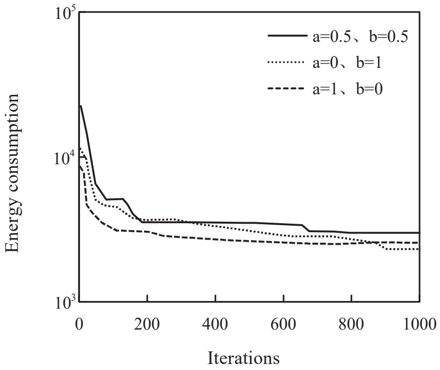


Figure 10 Network energy consumption.

To quantitatively analyze the network delay and network energy consumption solved under different weights of delay model and energy consumption model, the delay and energy consumption results are counted through repeated experiments, as shown in Table 2. When a = 1 and b = 0, network delay is the lowest, and average delay is 7 seconds. However, its energy consumption is the highest, and its average energy consumption is 3203 J; When a = 0 and b = 1, the average delay is the longest, which is 15 seconds. However, its energy consumption is the lowest, and its average energy consumption is 2667 J. Therefore, users can choose the corresponding optimization path according to the actual application requirements. Overall, the average delay of this transmission path is 11 s and the average energy consumption is 2884 J, which meets the demand for an optimal transmission path. This indicates that the proposed method solving communication routing of power wireless sensor networks in this paper is effective, and can achieve communication routing transmission of power wireless sensor networks with different user needs, reducing the delay and energy consumption during the transmission process.

(2) Comparison of solving results

To further validate the effectiveness of the proposed algorithm, experiments are conducted to compare the communication routing of power wireless sensor networks solved by harmony search algorithm after improvement, as well as solving results of commonly used delay optimization algorithms and energy consumption optimization algorithms. Compared with delay optimization algorithms, delay weight allocated by the proposed algorithm is set to 1, and its energy consumption weight is set to 0, that is, a = 1, b = 0. Compared with the energy consumption optimization algorithms, the delay

Table 2 Statistical results of delay and energy consumption

		Running Times			
Objective Function	Weights	1	3	5	Mean
Time delay (s)	a = 0.5 b = 0.5	12	11	10	11
	a = 0 b = 1	14	15	17	15
	a = 1 b = 0	6	5	9	7
Energy consumption (J)	a = 0.5 b = 0.5	2836	2874	2943	2884
	a = 0 b = 1	2678	2564	2639	2667
	a = 1 b = 0	3159	3211	3240	3203

Table 3 Comparison of delay optimization results of different algorithms (s)

	Running Times			
Algorithm	1	3	5	Mean
Literature [3]	8	9	12	10
Literature [4]	9	12	13	11
Literature [5]	8	10	12	10
The proposed algorithm	6	5	9	7
Harmony search algorithm	8	10	12	10

weight allocated is set to 0, and its energy consumption weight is set to 1, that is, a = 0, b = 1.

Table 3 shows the comparison of solving results of proposed algorithm and delay optimization algorithm. Where, data show that the average delay solved by the proposed algorithm is about 7 seconds, which is significantly lower than the average delay solved by references [3–5] and harmony search algorithm, fully proving the superiority of the proposed algorithm in optimizing communication routing delay of power wireless sensor networks.

Table 4 shows the comparison of solving results of proposed algorithm and energy consumption optimization algorithm. Analyzing data shown in Table 4 reveals that energy consumption of the proposed algorithm is lower than that of comparison algorithm under multiple operating conditions, and its average energy consumption is 2667J, which is lower than that of energy consumption optimization algorithms proposed in references [8–10] and harmony search algorithm, which fully verifies the superiority of the proposed

Table 4 Comparison of energy consumption optimization results of different algorithms (J)

	Running Times			
Algorithm	1	3	5	Mean
Literature [8]	3126	3265	3318	3236
Literature [9]	3056	3109	3210	3125
Literature [10]	3724	3712	3789	3742
The proposed algorithm	2678	2564	2639	2667
Harmony search algorithm	2897	2901	2836	2878

algorithm in optimization of communication routing energy consumption of power wireless sensor networks.

5 Conclusion

In conclusion, the routing algorithm for communication of power wireless sensor networks based on improved harmony search innovatively combined artificial bee colony algorithm and Levi flight mechanism to improve harmony search algorithm, which improved its convergence speed and precision, and avoided the algorithm falling into local optima. Then, harmony search algorithm after improvement was used to optimize the routing delay and energy consumption of power wireless sensor networks. Moreover, weights of delay and energy consumption could be assigned according to different needs of users. As can be seen, the algorithm could effectively reduce communication routing delay and energy consumption of power wireless sensor networks, and had certain advantages, which met the needs of different users, and provided a reference for the collaborative optimization. Although this paper achieves collaborative optimization of routing delay and energy consumption of power wireless sensor networks, there are still some shortcomings that need to be improved due to condition limitations. Fore example, when constructing the initial harmony memory, a random approach is adopted, which may have an impact on subsequent results. Therefore, the next step of the research will try to optimize the initial harmony memory, thereby further improving algorithm performance.

Funding

This work was supported by the Science and Technology Project of Henan (Optical image compression and encryption based on depth learning and high-quality reconstruction, 242102210058).

References

[1] Hongzhang H, Jun T, Zhengjun J., 'Wireless sensor network routing optimization based on improved ant colony algorithm in the Internet of Things', Heliyon, 2024, 10 (1): e23577–e23579.

[2] Soundararajan S, Lalitha S, B. J, et al., 'Delay-aware optimized scheduling algorithm for high performance wireless sensor networks', Automatika, 2024, 65 (1): 92–97.

[3] Abbou N A, Manner J, 'ETXRE: Energy and delay efficient routing metric for RPL protocol and wireless sensor networks', IET Wireless Sensor Systems, 2023, 13 (6): 235–246.

[4] Radhika K, Anjana G, Sangita K, 'Optimization of energy and delay on interval data based graph model of wireless sensor networks', Wireless Networks, 2023, 29 (5): 2293–2311.

[5] Wei S, Lei Z, Qiushuo L, et al., 'Dynamic collaborative optimization of end-to-end delay and power consumption in wireless sensor networks for smart distribution grids', Computer Communications, 2023, 20(2):87–96.

[6] Shreedhar Y, M S J, 'Efficient energy consumption and fault tolerant method for clustering and reliable routing in wireless sensor network', Peer-to-Peer Networking and Applications, 2024, 17 (3): 1552–1568.

[7] Wang L, Luo Y, Yan H, 'Optimization analysis of node energy consumption in wireless sensor networks based on improved ant colony algorithm', Sustainable Energy Technologies and Assessments, 2024, 6(4):103680–103687.

[8] Liu W, Wei G, Zhu M, 'A survey on multi-dimensional path planning method for mobile anchor node localization in wireless sensor networks', Ad Hoc Networks, 2024, 15(6):103416–103419.

[9] M Y R, B U M, M A, et al., 'Energy optimization in spectrum sensing using cognitive radio wireless sensor networks', Wireless Personal Communications, 2024, 133 (3): 1675–1691.

[10] Anand V, M S J, 'Novel phase adjournment data capturing technique for a mobile object in wireless sensor network', International Journal of Information Technology, 2023, 16 (2): 993–1004.

[11] Ma N, Wang S, Hao S, 'Enhancing reptile search algorithm with shifted distribution estimation strategy for coverage optimization in wireless sensor networks', Heliyon, 2024, 10 (15): e34455–e34455.

[12] Sankaranarayanan S, Vijayakumar R, Swaminathan S, et al., 'Node localization method in wireless sensor networks using combined crow

search and the weighted Centroid method', Sensors (Basel, Switzerland), 2024, 24 (15): 4791-4791.

[13] Zaher A A, V P R P, R. R M, et al., 'iCapS-MS: an improved Capuchin search algorithm-based mobile-sink sojourn location optimization and data collection scheme for wireless sensor networks', Neural Computing and Applications, 2024, 36 (15): 8501–8517.

[14] Kishalay B, Sulata M, Uma B, 'Efficient approaches to optimize energy consumption in 3D wireless video sensor network under the coverage and connectivity constraints', Annals of Telecommunications, 2023,78(5–6): 329–346.

[15] Wang B, Zhang P, Wang X, et al, 'Three-way decision based island harmony search algorithm for robust flow-shop scheduling with uncertain processing times depicted by big data', Applied Soft Computing, 2024, 16(2):111842–111848.

[16] Makhmudov F, Kilichev D, Cho I Y, 'An application for solving minimization problems using the Harmony search algorithm', SoftwareX, 2024, 2(7):101783–101788.

[17] Xue G, Wang Z, Wang Y, 'The restaurant delivery problem with uncertain cooking time and travel time', Computers & Industrial Engineering, 2024, 19(1):110039–110045.

[18] Simsir Sakir, 'Symbol detection based on a novel discrete harmony search algorithm in MIMO-FBMC/OQAM system', Wireless Networks, 2024, 30 (4): 2895–2916.

[19] Charu A, Anurag M, Gaurav D, 'Correction: A novel gray-scale image watermarking framework using harmony search algorithm optimization of multiple scaling factors', Multimedia Tools and Applications, 2024, 83 (8): 21823–21823.

[20] Abdul Q, Aas M, 'A novel approach for optimal synthesis of path generator four-bar planar mechanism using improved harmony search algorithm', Australian Journal of Mechanical Engineering, 2024, 22 (1): 95–108.

[21] Riya K, Sandip C, Debabrata D, et al., 'Application of harmony search algorithm in optimizing autoregressive integrated moving average: A study on a data set of Coronavirus Disease 2019', Systems and Soft Computing, 2024, 6(1):200067–200069.

[22] Shaoqiang Y, Kaiqing Z, Mohd A Z, et al., 'A modified harmony search algorithm and its applications in weighted fuzzy production rule extraction', Frontiers of Information Technology & Electronic Engineering, 2023, 24 (11): 1574–1590.

[23] Hwansuk K, Seungwan H, Gabriel A L, et al., 'Improving water quality modelling for green roof runoff using storm water management model', Urban Climate, 2023, 52(1):1578–1584.

[24] Zhe D, Haohao Z, Hai L, et al., 'Improved harmony search algorithm for enhancing efficiency and quality in optimization of the distillation process', ACS omega, 2023, 8 (31): 28487-28498.

[25] Jian M, 'Dynamic obstacle avoidance and trajectory planning of five-axis redundant industrial manipulator', Journal of Vibroengineering, 2023, 25 (4): 778–791.

[26] Ala'a S A, A. B M, Mohammad A, 'Retraction note: Hybrid harmony search algorithm for social network contact tracing of COVID-19', Soft Computing, 2023, 27 (15): 11069–11069.

[27] Charu A, Anurag M, Gaurav D, 'A novel gray-scale image watermarking framework using harmony search algorithm optimization of multiple scaling factors', Multimedia Tools and Applications, 2023, 83 (8): 21801–21822.

[28] Singh S S, Sai G C, 'Fuzzy modeling and cost optimization for machine repair problem with retrial under admission control F-policy and feedback', Mathematics and Computers in Simulation, 2023, 21(1): 214–240.

[29] Cinthia P, Oscar C, Patricia M, et al., 'A type-3 fuzzy parameter adjustment in harmony search for the parameterization of fuzzy controllers', International Journal of Fuzzy Systems, 2023, 25 (6): 2281–2294.

[30] NagSeop J, YoungHwan K, HongSeob O, 'Comparison of the prediction of effective moment of inertia of FRP rebar-reinforced concrete by an optimization algorithm', Materials, 2023, 16 (2): 621–621.

Biographies

Guo Li was born in Henan, China, in 1980. From 1999 to 2009, he studied in Airforce Engineering University and received his bachelor's degree in 2003, and received his Master’s degree in 2006, and received his Doctor’s degree in 2009. Currently, he works in Nanyang Normal University. He has published ten papers, five of which has been indexed by SCI and EI. His research interests are included intelligent information processing and loT.

MingHua Wang was born in Anhui, China, in 1974. From 1992 to 1996, he studied in Air Force Telecommunications Engineering College and received his bachelor’s degree in 1996. From 2005 to 2007, he studied in ShanDong University and received his Master’s degree in 2007. Currently, he works in Shandong Gete Aviation Technology Co., Ltd. His research interests are included flight information processing and loT.