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Research Article

Optimal Arrangement of Structural Sensors in Landfill Based on Stress Wave Detection Technology

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Sensor arrangement is the primary link of landfill structure health monitoring, and the number of measuring points and the quality of data directly affect the effect of modal identification. Therefore, how to ensure the service safety of landfill structure has become an important research content in the field of landfill structure health monitoring. In this paper, the stress wave propagation principle and stress wave detection theory are analyzed, and an optimal sensor arrangement method based on AGSA (adaptive gravity search algorithm) algorithm is proposed. Use CS (Cuckoo search) algorithm to optimize the objective function value. The corresponding response value is calculated by the finite element model, and the initial proxy model is constructed. By comparing and analyzing the results of model correction, it is found that the error of parameters before and after correction is less than 2.5%. It is further verified that AGSA algorithm can be used to solve the optimal sensor placement problem. In this paper, the use of structural health monitoring technology for health diagnosis and performance evaluation is an important means to ensure structural safety, prolong service life, and reduce maintenance cost. As the primary link of structural health monitoring, sensor system directly determines the accuracy of structural safety diagnosis.

1. Introduction

With the rapid development of industry, hazardous waste disposal has become a major environmental problem faced by countries all over the world. At present, the disposal of solid hazardous waste in China is mainly landfill [1]. An extremely important problem to be considered in landfill treatment is the impact on the surrounding environment. To prevent the water pollution caused by the solution leaching of waste and rainwater runoff, the anti-seepage lining system of landfill is an essential facility. The investigation shows that the impervious layer will be damaged due to mechanical or artificial nonstandard operation during construction, and the impervious layer will leak due to uneven settlement of foundation, shrinkage deformation, and chemical corrosion during operation. Landfill leachate produced by rain dripping and fermentation contains a large number of toxic and harmful components. When there is leakage in landfill, these toxic and harmful components seep into the ground along with landfill leachate, polluting the surrounding soil and groundwater, and the groundwater pollution caused by this seriously threatens people's life, health, safety, and quality of life [2].

China's landfill waste accounts for such a large proportion of the total waste disposal. How to improve the level of landfill and make it a real "sanitary" landfill instead of a general "landfill" is the most urgent problem to be solved in China's waste disposal and also an urgent problem to be solved by Chinese environmental protection workers. Jiang et al. [3] point out that some landfills have poor seepage control effect and obvious groundwater pollution due to poor environmental geological and hydrogeological conditions or poor construction quality. Zhijun et al. [4] have developed the steel wire grid detection technology, which is to lay two layers of steel wires under the impermeable membrane, each layer of steel wires is arranged in parallel, clay is used as the medium, and the vertical distribution of the two layers of steel wires is grid-shaped, and the existence and location of leakage points can be judged by detecting whether the upper and lower layers of steel wires have short circuits. This detection method is low in operation cost and easy to install, and is suitable for long-term leakage detection of landfill. Sun and Ge [5] studied the double-electrode method, dipole method, and electrode grid method, and successfully developed a leakage detection system based on high-voltage DC method, which solved the problems of large amount of collected data and long transmission distance caused by large detection area of landfill. Zheng et al. [6] combine effective independence method with modal kinetic energy method, and put forward a fast calculation method of effective independence method coefficient, which avoids the problem of matrix inversion. Dai et al. [7] introduce the constraint equation into the expression of kinetic energy or strain energy of the system to reduce the mass or stiffness matrix. The principal coordinates that play a major role in modal response are reserved as measuring points. Yulianti et al. [8] combine information redundancy function with TMAC (Three-dimensional Modal Assurance Criteria), establish a sensor TMAC, and propose a hierarchical wolf pack algorithm to optimize the layout of 3D sensors. Huang et al. [9] solve the problem that it is difficult to accurately identify and select the high-order vibration modes in the weak axis direction of the structure due to the coupling vibration of nodes, aiming at the optimized sensor arrangement method based on simplified model. Yu et al. [10] By combining the condition number index of information entropy sensitivity matrix with Fisher information matrix criterion by weight, a multi-target sensor optimal arrangement method is proposed, which can be robust and accurate in parameter identification, and the effectiveness of the method is verified by a certain launch pad as an example.

The working principle of stress wave detection technology is similar to that of earthquake detection system. The initial purpose of stress wave detection technology is to detect the geological changes in mines. At present, although some achievements have been made in the research of stress wave detection technology in China, most of the stress wave detection systems that have been built at present still rely on the introduction from abroad [11]. In this paper, an optimal arrangement method of landfill structural sensors based on stress wave detection technology is proposed. Through the determination of the sensor optimal arrangement scheme of the improved optimization algorithm, the foundation is laid for the information acquisition of structural modal parameter identification. The improved intelligent optimization algorithm is introduced into the agent model to modify the structure model, which improves the precision of the structure's mathematical model.

In this paper, the principle of stress wave propagation and the theory of stress wave detection are analyzed, and a sensor optimal layout method based on adaptive gravity search algorithm (AGSA) is proposed. Research and innovation contributions include the following: (1) Vibration detection cannot be used for the detection of high vibration and noise equipment, but the effective signal frequency band of stress wave monitoring is high. This paper can solve this problem well and is suitable for the detection of high vibration and noise equipment. (2) Through the sensitivity analysis of the main parameters in the algorithm, the optimal parameters of AGSA algorithm for solving the optimal sensor placement problem are determined. (3) Solve the parameter correction value through CS. After introducing CS, it is found that the parameter error before and after correction is less than 2.5%. It can be seen that the introduction of CS usually improves the effect of model correction. Selecting a limited number of locations from large-scale nodes to be tested in order to achieve the optimal layout effect is the core problem of this paper.

This paper is divided into five parts. The first part expounds some achievements in the research of stress wave detection technology in China. The second part describes the research methods and analyzes the overall design of the sensor optimization layout toolbox. At the same time, the stress wave signal processing is discussed. The third part analyzes the optimal layout of landfill structure sensors. The fourth part analyzes the results. Vibration detection cannot be used for the detection of high vibration and noise equipment, but the effective signal frequency band of stress wave monitoring is high, which can solve this problem well and is suitable for the detection of high vibration and noise equipment.

2. Research Method

2.1. Overall Design of Sensor Optimization Layout Toolbox. Optimal sensor placement is a problem integrating structural dynamics, finite element theory, advanced mathematics, and computer programming language, which involves complex basic theories of many disciplines and disciplines. With the continuous research of scholars at home and abroad, the theory and method of optimal sensor placement are constantly being innovated and developed. In the existing sensor arrangement methods, the modeling error and the prediction error caused by measurement noise are usually assumed to be a vector that obeys Gaussian distribution [12, 13]. This assumption does not give the specific physical meaning of modeling error, and cannot consider the influence of modeling error on the uncertainty of modal identification and sensor arrangement. In the sensor arrangement, it is meaningful to separate the measurement noise and modeling error from the prediction error, give the concrete manifestation of modeling error, and further discuss the influence of modeling error on the uncertainty of modal identification.

In structural dynamics, the modal vectors of structures are mutually orthogonal. However, in the actual test, due to the limitation of measuring instrument accuracy and environmental influence such as noise, the modal vector of the tested structure cannot be completely orthogonal. When the optimal arrangement of sensors is unreasonable, some important modal information will be lost. According to the structural dynamics, the modal vectors of each order on the structural nodes are orthogonal to each other. However, because the degree of freedom of testing with sensors is far less than the measurable degree of freedom of the structural model, and affected by the measurement error, it is difficult to ensure the orthogonality of the measured modal vectors. If the sensors are not properly configured, the spatial intersection angle between modal vectors will be too small, and important structural information will be lost [14].

In order to solve the orthogonality problem caused by measurement error, the modal guarantee criterion is used in this paper. MAC (Modal Assurance Criteria) can effectively evaluate the orthogonality of modal vectors, choose a larger spatial intersection angle, and keep the characteristics of the original model as much as possible. The orthogonality of modes and the integrity of modal information are ensured. Therefore, in this paper, MAC is used as the fitness function of optimal sensor placement to evaluate the independence of each test mode. The expression for MAC is:

$$\mathrm{MAC}_{i,j} = \frac{\left(\varphi_i^T \cdot \varphi_j\right)^2}{\left(\varphi_i^T \cdot \varphi_i\right)\left(\varphi_i^T \cdot \varphi_j\right)}, \quad (1)$$

where i, j is the modal vector of order i and order j, respectively.

The quantitative index to evaluate the sensor configuration effect in MAC criterion is the maximum value of off-diagonal elements of MAC matrix. The goal of sensor configuration optimization algorithm is to minimize the maximum off-diagonal elements of MAC matrix. In the optimization method, this is a minimization problem, and the objective function is described as:

$$f(\varphi_{slc}) = \min \max_{i \neq j}\left(\mathrm{mac}_{ij}\right). \quad (2)$$

$0 \leq f(\varphi_{\mathrm{slc}}) \leq 1 \;\; i, j = 1, 2, \cdots, s$. The idea of solving the optimization problem is to constantly select the degree of freedom of measuring points from φ, update the content of φ_{slc}, and minimize the value of objective function f, that is, to achieve the goal of continuously optimizing the sensor configuration scheme.

The sensor optimization layout toolbox can complete the sensor optimization layout of the test structure by itself without the operator having in-depth theoretical foundation, professional scientific research personnel, and any programming operation, which improves the timeliness and initiative of engineers in monitoring the actual project, and has very important practical engineering significance.

The post-processing module of toolbox (result display and report output) should include the test structure model, calculation parameters, evaluation criteria, and the selection of candidate measuring points, and the final layout scheme can be visually output by visual layout renderings. No matter researchers or engineers, they can study the optimal arrangement of sensors in any kind of engineering structure through the toolbox. The development concept of the functional module of the sensor optimization layout toolbox is shown in Figure 1:

2.2. Stress Wave Signal Processing. The stress wave signals collected in the working equipment all contain the damage properties of the equipment, but at the same time they are also mixed with a lot of noise, such as environmental noise, equipment vibration, and voltage fluctuation. The only way to get the stress wave signal is to use the stress wave sensor to get the original stress wave signal [15, 16], and then process it by hardware or software to get effective signal data. The original stress wave data processing methods can be divided into two types: parameter analysis and waveform analysis.

Wavelet transform overcomes the shortcomings that the window size does not change with frequency, and can provide a "time-frequency" window that changes with frequency. It is an ideal tool for signal time-frequency analysis and processing. Its main feature is that it can fully highlight the characteristics of some aspects of the problem through transformation, and can analyze the localization of time (space) frequency. In this paper, wavelet denoising is realized by hardware, and the collected stress wave signal is processed by hardware. The biggest advantage of wavelet transform is that it solves the problems that Fourier transform and windowed Fourier transform cannot solve while ensuring the accuracy of time domain and frequency domain. With the in-depth study of wavelet transform, wavelet transform has been applied to a wide range of fields and plays a very important role in modern data processing.

The research of wavelet transform has become a new and flourishing field. The mathematical meaning of wavelet transform is the inner product of given function $x(t)$ and wavelet basis function, which is defined as follows:

$$\psi_{j,k}(t) = \frac{1}{\sqrt{|j|}}\psi\left(\frac{t-k}{j}\right); a, b \in R, a \neq 0. \quad (3)$$

Among them, the parameter j is a scaling factor or a scaling factor, which reflects the amplitude change and width of the wavelet function. The parameter k is a translation factor or a time shift factor, which reflects the advance or lag of the wavelet function on the time axis. The family of wavelet functions $\psi_{j,k}(t)$ is obtained by translation and expansion of wavelet function $\psi(t)$, and $\psi(t)$ is also called mother wavelet.

The mathematical expression of wavelet transform is:

$$X(j, k) = \int x(t)\psi_{j,k}(t)dt. \quad (4)$$

Because wavelet transform adopts multi-resolution method, it can well describe the non-stationary characteristics of signals, such as spikes, edges, and breakpoints. It can denoise according to the characteristics of signal and noise distribution at different resolutions, and wavelet transform can flexibly choose the basis.

The continuous wavelet transform of a signal $f(t) \in L^2(R)$ is defined as:

$$W(a, b) = \frac{1}{\sqrt{|a|}}\int_R f(t)\phi\left(\frac{t-b}{a}\right)dt \; b \in R, a \in R - \{0\}. \quad (5)$$

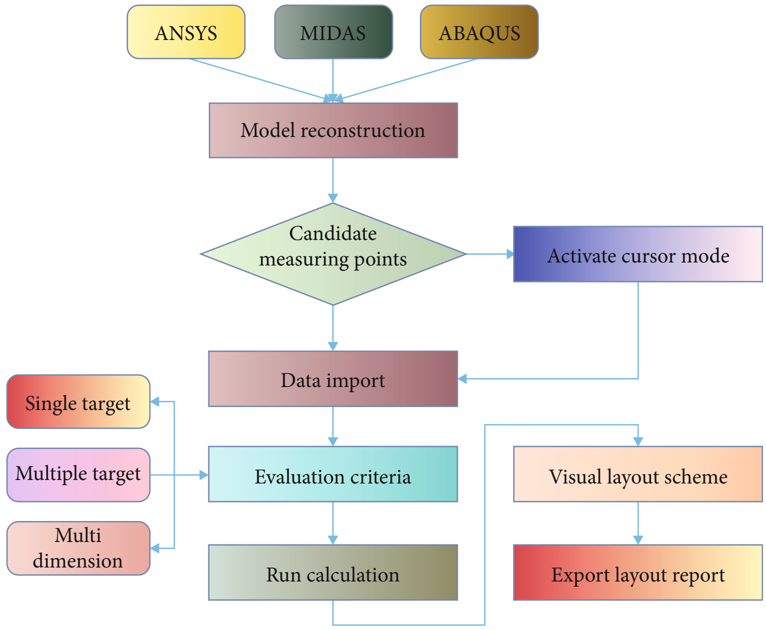

Figure 1: Optimization of sensor layout toolbox operation process.

If $f(t)$ is continuous at t, $f(t)$ can be reconstructed as:

$$f(t) = \frac{1}{C_\phi} \iint_2 W_f(a, b)\phi_{a,b}(t)\frac{da}{a^2}db. \quad (6)$$

From the point of view of signal processing, wavelet function is a high-pass filter. It has a window function with variable window shape. For high-frequency signals, the time window becomes narrower and the frequency window becomes wider, which is beneficial to the description of signal details. For low-frequency signals, the time window becomes wider and the frequency window becomes narrower, which is very suitable for detecting transient abnormal signals entrained in normal signals and displaying their components [17].

The principle of landfill leakage detection system based on stress wave detection technology is similar to that of earthquake monitoring system. The hardware design mainly includes the selection of stress wave sensor, the design of front-end conditioning modules such as amplification circuit and analog-to-digital conversion circuit, and the design of back-end digital processing modules such as data storage module, communication module, and human-computer interaction module. The hardware schematic diagram of stress wave detection system is shown in Figure 2.

The stress wave detection system mainly consists of three parts: data processing terminal, data collector, and stress wave sensor. The signal collected by the stress wave sensor is preliminarily screened by the filter circuit, then the filtered analog signal is analog-to-digital converted by the analog-to-digital conversion circuit, then the signal is amplified by the programmable amplifier, then the signal is sent to the main control chip for storage and preliminary analysis, and finally the data is transmitted to the data processing terminal by Ethernet communication.

2.3. Optimal Arrangement of Landfill Structure Sensors. In practical situations, strain sensors are often placed at large deformation positions of structures to obtain local deformation information of structures as much as possible. Therefore, in the proposed multi-type sensor arrangement method, firstly, the large deformation position of the structure is taken as the initial arrangement position of the strain sensor, such as the mid-span position of each span of the multi-span landfill structure [18]. Then, the displacement modal shapes of structural joints are estimated by using the strain modal shapes at the strain positions, hoping that the positions of strain sensors can contain as much information as possible about the displacement modal shapes of joints.

After determining the specific position of the strain sensor, it is necessary to add sensors such as acceleration to the existing sensor arrangement. Here, the displacement modal shapes are obtained by using MAC criterion parity, and the arrangement of acceleration sensors is guided. When the value of the maximum non-diagonal element of MAC is less than 0.2, the distinguishability between the obtained vibration mode vectors is acceptable. Therefore, it is hoped that the maximum off-diagonal element value of MAC corresponding to the modal shapes comprehensively obtained by strain sensors and acceleration sensors will be as small as possible.

Or similar symmetrical sensor positions contain approximate modal information, so it is necessary to avoid the occurrence of such redundant modal information as much as possible. Here, a redundancy coefficient is used to measure the similarity of displacement modal shapes corresponding to different positions, that is, the redundancy of the displacement modal information contained:

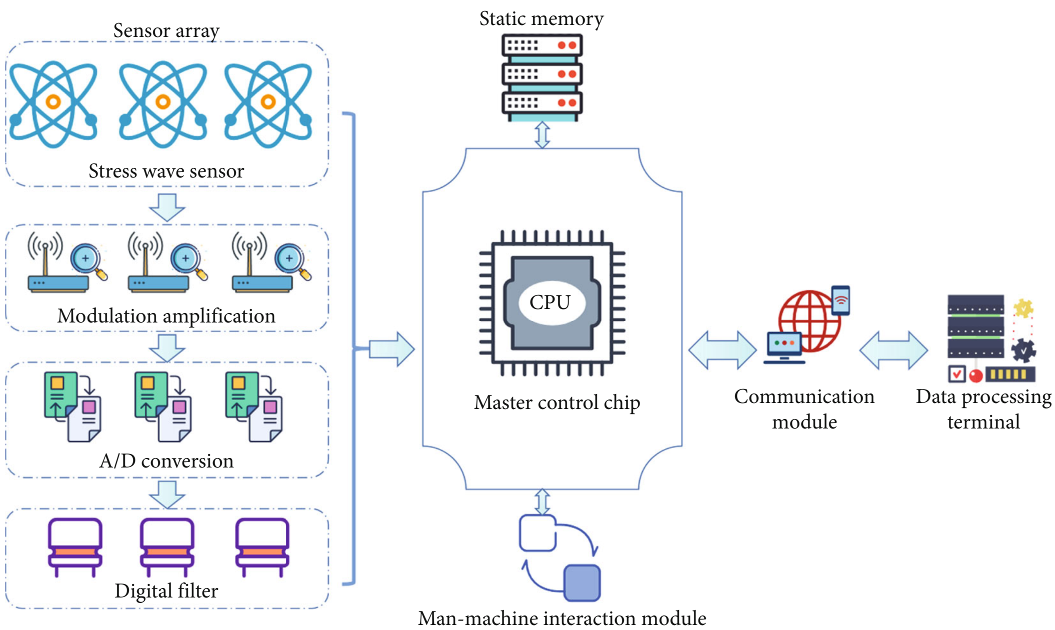

FIGURE 2: Hardware system of stress wave detection system.

$$R_{ij} = 1 - \frac{\|\Phi_i - \Phi_j\|}{\|\Phi_i\|_F + \|\Phi_j\|_F}, \quad (7)$$

where R_{ij} is the redundancy coefficient of displacement mode shape between the i and j degrees of freedom; Φ_i, Φ_j represents the displacement modal shape line vector corresponding to the i and j degrees of freedom, respectively; $\|\cdot\|_F$ represents the Frobenius norm. If the value of R_{ij} is close to 1, it means that these two positions contain nearly the same information of displacement modes, and only one of these two positions can be reserved.

We apply AGSA (adaptive gravity search algorithm) algorithm to the solution of low-dimensional test function, and the optimal placement of sensors is a discrete problem of 0-1 programming, so it is necessary to adjust the encoding mode of the adaptive gravity search algorithm to ensure that AGSA algorithm can solve the optimal placement of sensors.

The points to be arranged for the optimal arrangement of sensors are all nodes of the landfill structure, so in the coding process, 0 is used to indicate that no sensors are arranged at this node, and 1 is used to indicate that sensors are arranged at this node. The way of double coding is shown in Tables 1 and 2:

The ordered pair (x_i, s_i) composed of additional code x_i and variable code s_i is used to represent the sensor arrangement results corresponding to individual i in the population [19]. This double coding method enables AGSA algorithm to solve the problem of optimal sensor placement.

Firstly, the finite element model of the landfill structure is established, and the modal matrix of all nodes of the model is obtained by modal analysis. The obtained modal matrix is used as the input value, and the degrees of freedom corresponding to all nodes are used as the candidate points for sensor arrangement.

Secondly, assuming that the number of points to be selected is n, and the number of sensor layout points is set to m, the n candidate positions are numbered integer from $1-n$ in turn.

The binary values calculated by different position components x_{ij} are different, so it is necessary to set a threshold δ to satisfy the following formula:

$$s_{ij} = \begin{cases} 1 & \text{if } s_{ij} > \delta \\ 0 & \text{else} \end{cases}. \quad (8)$$

In order to speed up the particle convergence, mutation operator is introduced into the particle velocity formula to increase the guiding effect of the global optimal solution on particles. The expression of mutation operator is shown in formula (9).

$$\eta = \text{rand}\left(p_g^d(t) - x_i^d(t)\right). \quad (9)$$

In the process of updating the position, the calculated acceleration and velocity components will be non-integer. Therefore, the location update in this paper is shown in the following formula:

$$\begin{aligned} v_i^d(t) &= \text{ran d}_2 \times v_i^d(t) + a_i^d(t), \\ x_i^d(t+1) &= \text{rand}\left(x_i^d(t) + v_i^d(t+1)\right), \end{aligned} \quad (10)$$

where rand is an integer function, which ensures that the updated particle position component is in integer form.

The position component of the particle is an integer randomly generated from [-5,5]. During the position update of the particle, the value range may be exceeded. Therefore, this

Table 1: Dual coding mode.

Extracode	Variable code
$x(1)$	$s_x(1)$
$x(2)$	$s_x(2)$
⋮	⋮
$x(i)$	$s_x(i)$
⋮	⋮
$x(f)$	$s_x(f)$

Table 2: Double coding result.

Extracode	Variable code
4	0
2	1
1	0
6	0
7	1
2	0
8	1

paper stipulates that when the position component is greater than 5, take 5; when the position component is less than -5, take -5.

Figure 3 is a flow chart of optimal sensor arrangement based on AGSA algorithm.

Influenced by various uncertain factors, there are inevitably errors between the established finite element model and the test model. Therefore, it is necessary to use dynamic correction method to correct the established finite element model. The basic idea of model updating is to make the modal analysis results consistent with the experimental results by constantly changing the parameters of the finite element model [20].

CS (Cuckoo search) algorithm solves the optimization problem by simulating the parasitic brooding of cuckoo in nature. The research shows that Cuckoo search has good search accuracy and efficiency. The formula for updating the path and location of cuckoo nesting is:

$$x_i^{t+1} = x_i^t + \alpha \oplus \mathrm{Levy}(\lambda), i = 1, 2, \cdots, n, \\ \alpha = \alpha_0 \left\| x_t^i - x_{\mathrm{best}}^t \right\|, \tag{11}$$

where x_i^t represents the nest position of the ith nest in the t generation; $\oplus$ represents point-to-point multiplication; α is the step size, and the adaptive $\mathrm{Levy}(\lambda)$ of the step size realized by formula is Lévy flight random search path; x_{best}^t represents the best individual in the t generation.

CS algorithm has attracted the attention of many scholars because of its advantages such as few parameters, simple operation, and easy realization. Therefore, CS is used to solve the optimization problem in the model updating in this paper.

3. Result Analysis

In the health monitoring of landfill structure, strain sensors are usually placed at the large deformation position of the structure to obtain the local deformation information of the structure. On the benchmark model of landfill structure, considering the monitoring of large deformation information, the positions of strain sensors are initially located on four mid-span sections. The strain mode shapes need to contain as much information of displacement mode shapes as possible to avoid invalid estimation. Therefore, the position of the strain sensor must meet both the conditions of being in the large deformation section of the structure and containing enough information of displacement modes.

Because the mid-span section where the strain sensor is located is located at the node position of the element, the strain modal shapes at each section are related to the node displacement modal shapes of two adjacent beam elements. Table 3 gives the numerical values of the error quantification indexes at eight estimated node positions.

It can be seen from Table 3 that the estimation errors of displacement modal shapes at these eight estimation nodes are similar. Because the division of beam elements in the finite element model is basically uniform, and the transformation matrices of each element are almost identical, the relative estimation errors of displacement modal shapes of the eight estimated nodes are similar.

Figure 4 shows the trend diagram of the off-diagonal element value of the maximum MAC matrix of the displacement modal shape matrix with the number of acceleration sensors under four different redundancy thresholds (1, 0.6, 0.4, and 0.2).

It can be seen from Figure 4 that when the number of acceleration sensors increased is less than 3, the maximum MAC off-diagonal element values under different redundancy thresholds are the same. This shows that after adding the first several acceleration sensor positions, the redundancy coefficient between the existing sensor arrangement positions is less than 0.2, so the same position can be selected under different redundancy thresholds.

When the redundancy threshold is 0.6 or 1, the number of positions of acceleration sensors that can be increased exceeds 15. With the decrease of the redundancy threshold, the performance of sensor arrangement on MAC criterion is getting worse, and the number of acceleration sensors that can be increased is also getting smaller. If the number of available measuring points is less, the performance of MAC criterion will naturally deteriorate.

When calculating the optimal arrangement of sensors, each working condition is calculated continuously for 5 times, and the optimal value is taken as the final value of the objective function. After calculation, the objective function values under four working conditions are shown in Table 4.

It can be seen from Table 4 that the objective function value of TMAC (Three-dimensional MAC) criterion when 35 sensors are arranged is less than that of 25 sensors, but there is little difference between them. The arrangement schemes obtained under working conditions (1) and (2)

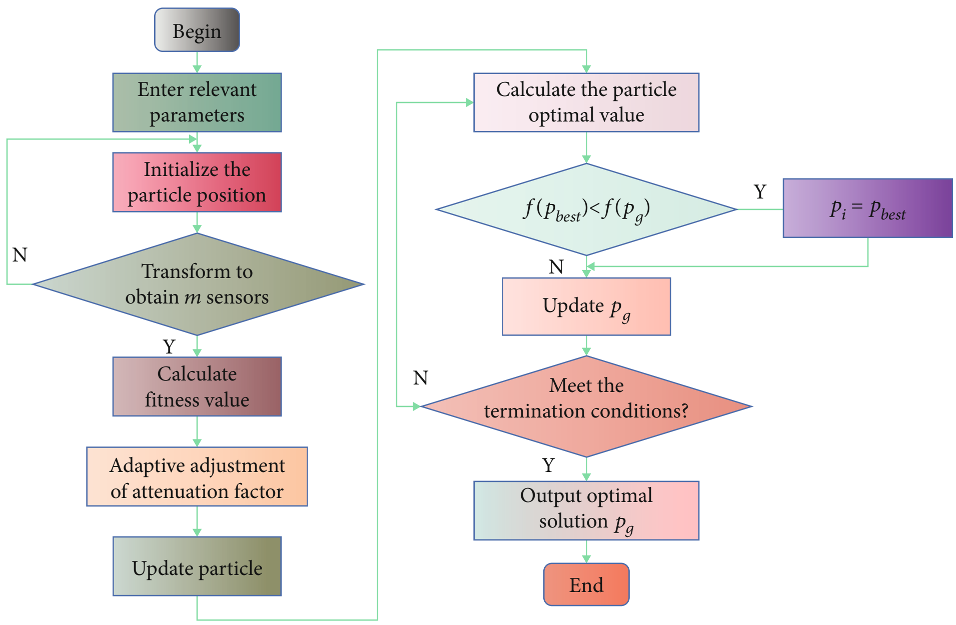

Figure 3: Optimal sensor layout process.

Table 3: Error quantification index values of 8 estimated node positions.

Node number	Index value (10^{-2})
1	1.67
2	1.71
3	1.82
4	1.71
5	1.66
6	1.73
7	1.81
8	1.82

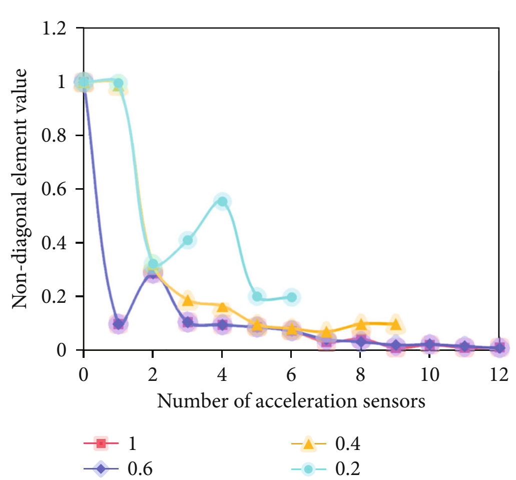

Figure 4: Maximum number of off-diagonal elements in MAC matrix.

Table 4: Objective function values of sensor optimal layout under four working conditions.

Working condition	Evaluation criteria	Number of sensors	Objective function value
1	TMAC	24	0.5238
2	TMAC	36	0.5122
3	TSVD	24	6.6247
4	TSVD	36	6.2239

are mainly distributed on the second ring, the third ring, and the outer ring support structurally. It shows that the increase of the number of sensors makes the modal identification effect better and improves the discrimination between vibration modes. The layout scheme obtained by TSVD (three-dimensional singular value ratio criterion), that is, working condition (3) and working condition (4), has better structural distribution than that obtained by TMAC criterion.

Figure 5 shows the graph of the maximum off-diagonal elements in each column vector of TMAC matrix. It can be clearly seen that the maximum value of 8 column vectors is 0.0378 and the minimum value is 0.0103. It can be seen that the optimal sensor placement results obtained by AGSA algorithm can meet the needs of practical engineering, and it also proves that AGSA algorithm is feasible for solving the optimal sensor placement problem.

With the introduction of CS, the performance of the proxy model of landfill structure, which is constructed by Kriging model, RBF (radial basis function), SVM (support vector machine), and RSM (Response Surface Methodology), is evaluated, respectively.

Assuming that the test parameter values are within the range of finite element parameter values, CS is used for iterative optimization. The number of nests is 25, and the

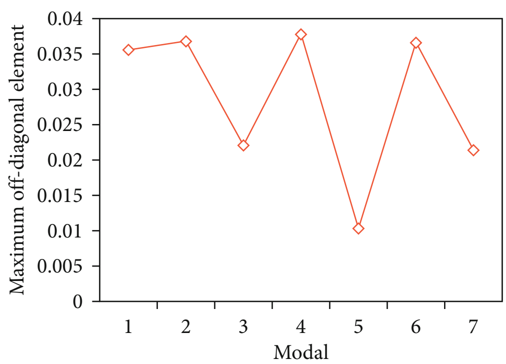

Figure 5: Maximum off-diagonal element of each column vector of TMAC matrix.

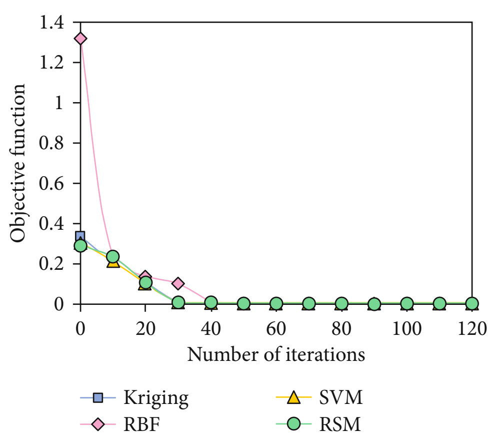

Figure 6: Evolution curve of agent model based on CS.

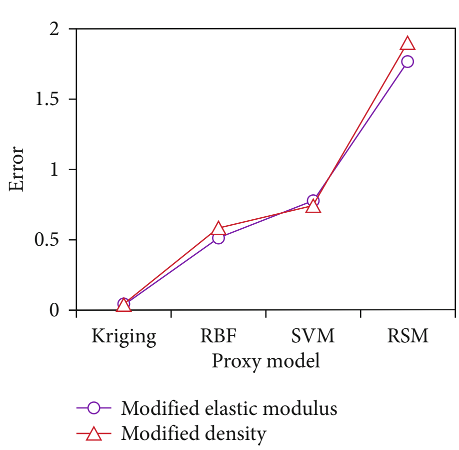

Figure 7: Correction results of four kinds of proxy models.

maximum number of iterations is 120. The iterative convergence curves of the evolution process of the four proxy models are shown in Figure 6.

From the figure, it can be seen that the objective function can converge to 0 when the number of iterations is before 20 times, which indicates that the CS's optimization ability is stable and the four proxy models meet the accuracy requirements.

Through the model modification of the same truss structure, the modification results of four proxy models are shown in Figure 7.

It can be seen from the comprehensive analysis that after the model modification of the same landfill structure, after the introduction of CS, the four proxy models have good fitting accuracy for the modification of the finite element model, and the error of the parameters before and after the modification is less than 2.5%. Considering the accuracy and operation efficiency at the same time, compared with other agent models, Kriging model has higher accuracy, shorter average operation time, and better comprehensive performance.

4. Conclusion

Sensor layout is the primary link of landfill structural health monitoring. The number and location of sensors directly affect the quantity and quality of monitoring data, and then affect the uncertainty of modal identification. How to select a limited number of locations from large-scale nodes to be tested in order to achieve the optimal layout effect is the core problem of this paper. Vibration detection cannot be used for the detection of high vibration and noise equipment, but the effective signal frequency band of stress wave monitoring is high, which can solve this problem well and is suitable for the detection of high vibration and noise equipment. Using the double coding method to initialize the population, the above problems are solved, and the AGSA algorithm successfully solves the problem of optimal sensor placement. Through the sensitivity analysis of the main parameters in the algorithm, the optimal parameters of AGSA algorithm for solving the optimal sensor placement problem are determined. The frequency response function is solved by minimizing the target parameter, and the frequency difference is corrected. After introducing CS, it is found that the parameter error before and after correction is less than 2.5%. It can be seen that the introduction of CS usually improves the effect of model correction. This paper has some innovation, but different types of sensors are not discussed separately, so further analysis is needed in future research.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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