Design and implementation of power mobile inspection system based on Improved Particle Swarm Optimization

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Abstract. Power line inspection is a basic work to effectively guarantee the safe operation of power transmission lines, improve the safe and reliable operation of power transmission lines, and reduce the occurrence of faults. Mobile inspection system is used to analyze the main influencing factors of power grid, and multiple linear regression method, BP neural network method and grey system theory method are used to detect the mobile inspection system. In order to obtain more accurate detection results, a combination algorithm based on improved particle swarm optimization (IPSO) is adopted, and the detection results of the three methods are optimally combined to obtain the final detection value. The analysis of an example shows that this method can effectively improve the detection accuracy and get better detection results.

Keywords: IPSO, Power mobile inspection system, Power grid.

1. Introduction
With the rapid development and wide application of information technology, people's demand for information gradually extends from the office to the work site, and information technology is also developing from a centralized to a distributed and embedded direction. People need to get the information they need anytime, anywhere [1]. Electricity supply is a solid foundation and backing for industrial and agricultural production and daily life of residents. The degree of informatization of the power system determines the vitality of social and economic development to a large extent [2]. With the further development of China's modernization, the contradiction between the distribution network and the user's demand is becoming increasingly prominent, which is mainly manifested in the following aspects: the structure of the distribution network is becoming more and more complex, the number of electrical equipment components is increasing, especially the changes of the urban power network are greater, the power load is increasing, the majority of users put forward higher requirements for the quality and reliability of power supply Management and other methods are not suitable for the demand of power grid growth [3]. At the same time, some emerging technologies and products have entered daily work and life from the laboratory. Personal digital assistants (PDAs) with embedded operating systems and mobile communication devices with integrated PDA functions are gradually valued and widely used [4].

PDA has the characteristics of small size, easy to carry around, and offline and online access to the server, it is a suitable product for mobile computing at present. The Global Positioning System (GPS) is a new generation of space satellite navigation and positioning system jointly developed by the United
States Army, Navy, and Air Force in the 1970s. After more than 30 years of development, the United States has opened up GPS for public utilities and commercial functions, providing public services for government departments. Business and enterprise development of commercial applications provide all-round support. Many PDAs also reserve interfaces for GPS receivers [5]. Geographic Information System (GIS) is a kind of decision support system. It has all kinds of characteristics of information system. At the same time, it meets the application needs of users for geographical location and scope, and provides the function of correlation analysis between attributes and geography. Therefore, GIS has gradually penetrated into the fields of management, decision-making and other social life related to geography. The improvement and development of these technologies and the continuous upgrading of corresponding products provide guarantee for the power sector to develop a mobile inspection system suitable for the power sector according to its working characteristics and business needs [6]. In view of the advantages and disadvantages of traditional algorithms, this paper adopts a combination algorithm, which designs the Power mobile inspection system through the improved particle swarm optimization algorithm. The infeasible solution is specially treated to make it feasible and improve the quality of the solution. Finally, the correctness and effectiveness of the algorithm are verified by an example. This scheme can realize coordinate transformation with low precision, which meets the needs of engineering practice. In the process of system design, it is an effective solution to improve the usability of the system with the help of mature design patterns [7].

2. Inspection system requirements

2.1. Current status of power equipment inspection work

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In the power distribution system, overhead lines, transformers, cables, and switching stations are important components. In order to ensure the safe and stable operation of high-voltage transmission lines and corresponding power equipment, line maintenance must be strengthened, such as regular inspections and irregular inspections. Inspection to ensure the normal operation of power transmission lines and the reliable transmission of electrical energy by the distribution network. Therefore, patrolling transmission lines is the focus of maintenance work [8].

The traditional way of power equipment inspection is to rely on the power inspector to inspect the power equipment by looking, smelling, listening and touching. When the power inspector finds that the appearance of the power equipment is abnormal, and there is abnormal sound and odor inside the equipment during operation, it is necessary to timely record and report the problem to the maintenance department, and then carry out the maintenance work [9]. However, with the rapid development of the power industry, there are more and more types, larger quantities and wider distribution of equipment in power enterprises. Due to the problems of many types, large quantities and unconcentrated distribution of equipment, problems such as missing inspection, missing inspection items and wrong inspection positions often occur during the traditional inspection, which leads to poor quality and low efficiency of power equipment inspection. In addition, there are still some problems in the work, such as untimely inspection and inadequate inspection [10].

The technical basis of modern power equipment intelligent inspection system is radio frequency identification technology, which is mainly composed of three parts: electronic tag, handheld instrument, and data management system. Electronic tags are installed next to the equipment that needs to be inspected, and the inspection items of each device are stored. The handheld instrument is composed of two parts: a radio frequency technology card reader and a mobile device. During the inspection work, the inspectors use the handheld instrument to identify the electronic tags, and then check the corresponding equipment according to the inspection items prompted by the electronic tags Enter the device information [11]. The data management system is mainly composed of computer and communication transmission module. After completing the inspection work, the data information in the handheld instrument will be transmitted to the computer through the communication module for
archiving. This system is the most widely used system in China at this stage, but there are still many disadvantages. For example, 1. There is no corresponding prompt function for line inspection. There is still the problem of equipment missing inspection. 2. In the inspection of specific equipment, it is still judged by the experience of inspection personnel, and there are still hidden dangers that have not been found. 3. The system cost is high. 4. The data transmission is not timely, so further design and exploration are needed to fully realize the intellectualization of power equipment inspection system [12].

2.2. Characteristics and Classification of Patrol Inspection System

The intelligent reform of power grid puts forward newer and higher requirements for the inspection work. The inspection work of power grid is not only a simple independent work at fixed time, but also takes into account the real-time load of the whole power grid, the service life of equipment and other factors, and arranges the inspection tasks as a whole [13]. Assuming that a certain group of equipment in the system has been operating at high load or full load during the peak power consumption period. In this case, the number of inspections of the equipment should be appropriately increased to prevent overload operation from affecting the service life of the equipment and reduce occurrences. The probability of failure. When the inspection task reaches the management department of the production line, it will also be directly downloaded to the inspection mobile terminal through the network, which puts forward new requirements for the business ability of the electric power enterprise [14].

At present, in order to adapt to the trend of increasingly complex distribution network structure and improve the work efficiency of outdoor inspection personnel, the power mobile inspection technology for GIS is developing rapidly. Mobile inspection technology is based on mobile platform, such as Windows CE platform, using PDA and GPS satellite receiver, combined with GIS system, to meet the needs of project management personnel for on-site inspection route query, plan change and completion data entry. Meet the needs of patrol maintenance personnel to inquire about the work plan, equipment information and geographic information on site, record the equipment information of distribution network, record defects, record the check-in status, etc. Using PDA for patrol inspection can conveniently realize the standardization of work, accelerate the field information collection, and accumulate data in a detailed and standardized way.

![Figure 1. Line inspection flow chart](image)

The data collected by PDA can be directly uploaded to the server, and other systems are allowed to use it directly, which greatly shortens the process of traditional work data sharing. When the transmission line is in normal operation, the patrol at the specified time is called regular patrol or normal patrol, also called periodic patrol. In the case of drastic changes in the weather, or sudden natural disasters, ground faults or overload operation of the line, and other emergencies, it is necessary to inspect...
the fault points of the transmission line and the important transmission equipment. In this case, the inspection is called a special tour. In the patrol of the line, the inspectors find abnormal phenomena through observation, while some hidden defects are not easy to observe during the day. Such defects require patrol at night. This kind of inspection method is called night inspection. When the transmission line trips, it is necessary to check the fault point immediately. This patrol mode is called fault inspection. As a supplement to the ground inspection method, the patrol inspection which needs to be carried out on the tower is called the climbing patrol.

3. Design and implementation of IPSO's Power mobile inspection system

3.1. Design and implementation of Power mobile inspection system

The design of Power mobile inspection system should follow several principles: (1) the principles of reliability and safety. (2) First, standard principle. (3) Quick reactivity. (4) Scalability and applicability. (5) Economy. Based on the principle of system design, the Power mobile inspection system is preliminarily divided after careful consideration of system requirements analysis. Now it is decomposed into the following problems, as shown in Table 1:

| Mobile inspection system | Partition problem | Problem Description |
|--------------------------|-------------------|---------------------|
| Question one             | The inspector downloads the inspection task, and uploads the inspection information back to the server after the work is completed |
| Question two             | Inspectors collect power equipment information and data according to the inspection tasks and the prompts of the electronic topographic map |
| Question three           | The mobile inspection system records and processes information, and manages equipment information and inspection personnel |
| Question four            | The system administrator maintains the system |

There are the following participants in the Power mobile inspection system: managers, inspectors, other users, mobile devices (PDA). For the description of the participants, see Table 2:

| Mobile inspection system | Participant | Description |
|--------------------------|-------------|-------------|
| Management staff         | Mainly responsible for the management of the code table of the system, such as the management of departments, teams, and inspection personnel: the management of electronic topographic maps, such as updating operations. Maintaining the system. |
| Inspection personnel     | Responsible for outdoor inspections, collecting equipment information, recording equipment defects, and patrol inspection in place. |
| Other users              | View electronic topographic maps and equipment information, and supervise inspection work. |
| PDA                      | PDA used in the inspection process. |

The system is refined, and the use cases included in the Power mobile inspection system are shown in Table 3:
Table 3. System contains use cases

| Mobile inspection system | System use case |
|--------------------------|-----------------|
| PC-side use cases        | User login      |
|                          | Management of user information |
|                          | Customize inspection tasks according to inspectors |
|                          | Prepare electronic topographic maps |
|                          | Viewing electronic topographic maps |
|                          | Upload the data collected from the PDA terminal and the status of the inspection to the server |
| PDA -side use case       | User login      |
|                          | Update of code table and electronic topographic map |
|                          | Download inspection tasks from PC |
|                          | Viewing electronic topographic maps, GPS navigation |
|                          | Query, execute and complete inspection tasks |
|                          | Record of inspection arrival rate |
|                          | Upload the collected data and inspection status to the PC |

The functions of the Power mobile inspection system have been carefully divided, and the division of its functional modules is shown in Figure 2:

![Figure 2. Division of system function modules](image)

Power mobile inspection system consists of PC and PDA. Inspectors use PDA to collect data outdoors, and then upload it back to the server database. The login module and the data synchronization module provide the interface for users to enter the system and submit tasks after the completion of phased work. These two modules need the user's identity authentication, while the main business functions of the power mobile inspection system are reflected in other functional modules. The realization of Power mobile inspection system is mainly considered from three aspects: the realization of data, the realization of handheld GIS module and the realization of inspection in place. When the administrative system operates in the background, it is mainly divided into six modules to audit the actual inspection process. First, inspection management. Second, system management. Third, the management of equipment. Fourth, we should manage the statistical reports. Fifth, carry out the management of employees. Sixth, information document management.
3.2. IPSO

The combined algorithm can synthesize the detection advantages of various methods to achieve the improvement of detection accuracy. Among various detection methods, the multiple linear regression method has the advantages of straightforwardness and easy calculation in modeling. The BP neural network can get a good fitting curve. Grey system theory can build models and find rules through limited sample data, and it is convenient to calculate. When applied, due to the limitation of the method, the detection accuracy of a single method will be affected to a certain extent. Therefore, this paper adopts IPSO based on the appropriate weighted average of the detection results of the three methods to improve the accuracy of detection.

The contraction factor is introduced into the optimization process of particle swarm optimization (PSO) \(\beta\), \(\beta = 6 I / N, I = 1, 2, \ldots, n.\) \(\beta\) As the number of iterations increases, it decreases, which slows down the speed of particle swarm optimization and reduces the probability of the whole population falling into the local optimal solution. The velocity and position updating formula of the improved PSO is as follows

\[
\begin{align*}
   v_{i,j}(k + 1) &= \beta [\omega v_{i,j}(k) + c_1 r (p_{best,j}(k) - x_{i,j}(k)) + c_2 r (g_{best,j} - x_{i,j}(k))] \\
   x_{i,j}(k + 1) &= x_{i,j}(k) + v_{i,j}(k + 1)
\end{align*}
\]

Where \(\omega\) is inertia coefficient. \(c_1\) and \(c_2\) are acceleration constants. \(R\) is a random number varying within the range of \([0,1]\). \(j=1, 2, \ldots, D. X_i = (x_{i,1}, x_{i,2}, \ldots, x_{i,D})\) and \(V_i = (v_{i,1}, v_{i,2}, \ldots, v_{i,D})\) are the position and velocity of particles in \(D\)-dimensional search space. \(P_{best} = (p_{best,1}, p_{best,2}, \ldots, p_{best,D})\) and \(V_i = (v_{i,1}, v_{i,2}, \ldots, v_{i,D})\) are the best positions for a single particle and all particles in the whole population.

According to the speed and position update formula of PSO, the inertia coefficient \(\omega\) has a great influence on the optimization process. If \(\omega\) is too small, the algorithm will converge prematurely and fall into a local extreme. If \(\omega\) is too large, the algorithm will be near the global optimal solution. Hovering leads to reduced solution efficiency. Therefore, the inertia coefficient \(\omega\) is redefined, and the method of adaptively adjusting the inertia weight coefficient is adopted to improve the solution efficiency of the algorithm. The adaptive inertia weight coefficient is defined as:

\[
\omega_{i,j}(k + 1) = \begin{cases} 
\omega_{\text{min}} + \alpha (\omega_{\text{max}} - \omega_{\text{min}}), & f_i(k) < f_{\text{avg}}(k) \\
\omega_{\text{max}}, & f_i(k) \geq f_{\text{avg}}(k)
\end{cases}
\]

Type, \(\alpha = (f_i(k) - f_{\text{min}}(k)) / (f_{\text{avg}}(k) - f_{\text{min}}(k))\). \(\omega_{\text{min}}\) and \(\omega_{\text{max}}\) are the minimum and maximum inertia weight coefficients, respectively. \(f_{\text{min}}(k)\) and \(f_{\text{avg}}(k)\) are the minimum and average values of the whole population fitness in step \(k\), respectively. The \(f_i(k)\) is the \(k\)th fitness value of the \(i\)th particle.

After improvement, the algorithm has significantly improved its iterative solution speed in practical applications. The probability of falling into a local extreme is greatly reduced, and the algorithm can obtain the global optimal solution in a short time.

With the improvement of PSO, the efficiency of PSO is improved, and the global optimal solution can be obtained quickly and efficiently. Therefore, the combined algorithm is based on ipso, which takes the sum of the absolute value of the error between the detected value and the actual value as the fitness function of particle swarm optimization to determine the weight coefficient of the three detection methods: multiple linear regression, BP neural network and grey system theory. The combined detection model and fitness function are expressed as follows...
\[ Q = a_i p_i + b_i q_i + c_i r_i \]  
\[ f = \sum |a_i p_i + b_i q_i + c_i r_i - y_i| \]  

In the formula, \( p_i, q_i \) and \( r_i \) are the detection values of capital construction investment obtained by multiple linear regression, BP neural network and grey system theory respectively. \( y_i \) is the actual value. \( a_i, b_i \) and \( c_i \) are the weights of each detection method in the combination algorithm, and their final values are the weight coefficients that satisfy the minimum fitness function.

4. Conclusions

In the intelligent inspection system of China's electric power equipment, the use of intelligent mobile terminals as the carrier is a very common form. Use various modern technologies to collect, analyze, and organize data, and build an intelligent inspection platform. For China's inspection work, it is a breakthrough innovation. In the face of the rapid development of electric power enterprises, the information construction of enterprises will become the future development trend. How to improve the response speed of electric power enterprises to information, improve the management level of enterprises, reduce the cost of enterprise operation, and strengthen the ability of enterprises to cope with changes is the key to solve the problem. For this reason, this paper puts forward the design of power mobile patrol inspection, compares three different detection methods, and proposes a combined detection method based on IPSO according to the advantages and disadvantages of different detection methods. In the application of power detection, this method not only considers the actual influencing factors in the detection, but also effectively improves the detection accuracy, and can obtain more accurate and reasonable results during the detection, which is very suitable for the Power mobile inspection system. Sex.

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