

Retraction

Retracted: Active Compliance Control System for Intelligent Inspection Robot in Power Room

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation. The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

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Research Article

Active Compliance Control System for Intelligent Inspection Robot in Power Room

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In order to solve the problems of blind spot and time-consuming and laborious monitoring in manual inspection of power information and communication rooms, a kind of active compliant control system for intelligent inspection robots of power information and communication rooms is proposed. This research includes the noncontact detection method of the inspection robot in the power room based on machine vision; the optimization environment of the power room; the control of the inspection robot through the monitoring system terminal; the automatic visual inspection of the machine through the monitoring network transmission; the display of the monitoring terminal and the use of the calibration of the machine; and the edge detection method of the inspection robot is designed. The experimental results show that the ineffective fluctuation range of torque of each joint is the smallest when the inspection robot is disturbed by obstacles in the process of executing signal change instructions, and the average fluctuation range of robot limbs is 0.65%. *Conclusion*. Based on the research results of this essay, it is proved that the controllability of power signal lamp change can be optimized separately in the future, and the safety of circuit operation can be improved.

1. Introduction

With the development of robotic and artificial intelligence technology, the concept of an intelligent power room has been put forward. In order to promote the intelligence, information digitization and unmanned operation and management of power rooms, it has become a major trend to use inspection robots to gradually replace manual work, as shown in Figure 1 [1]. The inspection robot of the power room is mainly equipped with a high-definition visible light camera, combined with video image processing technology, to read the data of the values and positions of the meters in the power production area, including pressure gauge, temperature meter, digital display meter, electrical switch, and valve status. It automatically records and generates reports, and after calculation, issues a report. Meanwhile, real-time photos and videos are uploaded to the background for operation and maintenance personnel to call in and view at any time.

Compared with foreign countries, the research on electric inspection robots in China is relatively late, and it was not until the 1990s that relevant research on electric inspection robots began. An inspection robot can effectively deal with the interference caused by illumination change, shadow occlusion, angle of view change, and scale scaling. Power information communication room is the basic management facility of power grid, which plays a very important role in each link of power grid business, such as power marketing, dispatching, and operation [2]. However, in the process of manual inspection of electric power information and communication rooms, there are some shortcomings such as time and energy consumption, inspection blind area, and lag. These problems have caused huge security risks to the machine room as a whole, and more seriously, will affect the safety and stability of the entire power system [3]. Under this environment, exploring the active compliant control system of an intelligent inspection robot in the power room is conducive to improving



FIGURE 1: Robot control system in power room.

the flexibility and intelligence of manual inspection, avoiding the possibility of manual inspection omission, misreading, and misremembering, reducing the labor cost and improving the quality and efficiency of inspection.

2. Literature Review

Many achievements have been made in domestic researches on industrial Internet of things and intelligent inspection system of computer room. Song et al. designed and implemented the 3D visualization system for machine room operation and maintenance, and proposed optimization measures [1]. Chen et al. introduced the architecture of the industrial Internet of Things in the context of 5G technology [4]. Khan and Li analyzed the advantages and disadvantages of several development modes of the industrial Internet at home and abroad and developed a visualization system containing two-dimensional and three-dimensional scenes [5]. Zhang et al. optimized the performance of the automatic inspection function of the visualization system for computer room operation and maintenance [6]. Fu et al. designed a mobile terminal inspection system based on TWO-DIMENSIONAL code recognition, which improved the quality and efficiency of inspection [7]. Huang adopted a variety of algorithms to eliminate errors and realized a highprecision indoor real-time positioning system [8]. He et al. constructed a comprehensive emergency repair resource allocation model according to different failure situations and needed emergency repair materials so that the emergency repair personnel could complete multisided coordinated emergency repair. The multipopulation coevolution mechanism is used to improve the traditional artificial bee colony algorithm to distinguish the failure rate and realize the unified scheduling decision of emergency repair optimization [9]. Kara and Patoglu combined with the load variability of equipment and the limitation of rush repair time, proposed a distribution network failure rush repair recovery strategy considering load time-variability [10].

Aiming at the maximum load value of the transformer, the network frame was reconstructed, and the binary particle swarm algorithm was used to solve the model. The alternating relationship between rush repair and equipment recovery was analyzed, and the sequence of rush repair was obtained through a collaborative solution. Chen et al. compared and analyzed the data of a robot system with that of an electric power integrated automation system to enhance data confidence and make data more accurate [11]. Chen et al. analyzed the data collected by the robot and the data of its dynamic environment through the machine learning algorithm to understand the performance and capacity and determine the appropriate response to change settings or send alerts [12]. Zhang et al. conducted comprehensive energy consumption monitoring through big data and artificial intelligence. The energy consumption index calculation method is used to analyze energy efficiency based on data comparison, energy efficiency calculation and itemized statistics, output equipment transformation strategy and system energy saving strategy, and track energy saving tasks and verify their effects [13]. Based on the current research, this essay proposes a compliant control method for an inspection robot in a power signal room based on machine vision. The key to the compliant control method of the inspection robot in the power signal room is to ensure the resolution of the inspection robot to the power signal and the sensitivity of the inspection robot to the circuit accident [14]. Therefore, the principle of robot vision inspection is analyzed, the motion model of power signal inspection robot is established, and the computer interlocking algorithm, train control operation, CTC, intelligent power screen, high-power UPS, signal centralized monitoring, and ZPW2000A are called track circuit. When the work indicator light of the equipment board is abnormal, the centralized signal monitoring system gives a real-time alarm, and the design of the compliant control method of the inspection robot of the power signal room based on machine vision is completed.

3. Methods

3.1. Closed-Loop Analysis of Power Signal Flow. The robot inspection system is connected to the power signal centralized monitoring system network through a local area network. In power signal architecture, all inspection robot signals in a machine room are divided into two types. One is a color signal and the other is a sound signal. The two signals represent the running state of the circuit and the operating state of the circuit, respectively. Once the two signals conflict, an accident will occur. The recognition principle of the GRB color space positioning method is applied to convert every frame of image data into the form of signal output [15]. At any moment, the lights are affected by external light, weather, and mirrors, causing the correct signal color to be mismatched. The GRB color space localization method is the most effective color signal recognition method to solve the above problems. In order to achieve the highest sensitivity, red, green, and yellow colors are set to have the highest correlation in the GRB color space signal recognition method. After power signal identification is completed by the GRB color space positioning method, signal feature extraction is completed by using the following formula:

$$y = p \sum \sqrt{\frac{2\Pi\mu}{3k}},\tag{1}$$

where *P* represents the space vector represented by various colors, μ represents the signal conversion factor, and *K* represents the color signal component. If there are running trains on the track, the sensing point at the track entrance sends a busy signal to the railway control center. If there is no running train, the sensing point will send an idle signal to the signal control center [16]. Once the signal is different from the expected circuit transport signal, emergency treatment should be made immediately to prevent the occurrence of accidents. The judgment function is shown in the following formula:

$$f(x) = 2^{(1/2)} \frac{1}{\sqrt{N}} \varphi t \sum 2f(u) - k,$$
 (2)

where f(u) represents the wavelet transform scale function, φ represents the frequency of signal fluctuation, *T* represents the time period of signal prediction, and *N* represents the discrete Fourier transform coefficient.

3.2. Electric Power Abnormal Signal Alarm Judgment Method

3.2.1. Parameter Setting of the Inspection Robot in the Power Signal Room. The accuracy of machine vision is higher than that of traditional human vision. Machine vision captures signals mainly through camera calibration and image edge testing. In order to achieve the effect of machine vision signal conversion, the signal centralized monitoring system transmits the alarm information of mechanical room equipment to the inspection robot in real time. According to the received alarm information, the inspection robot automatically arrives at the location of the alarm device and identifies the alarm board card. Through image comparison, the accuracy of alarm information is reviewed intelligently, and the review results and confirmation pictures are sent to the signal centralized monitoring system [17]. Then, through the signal centralized monitoring terminal, the remote manual control inspection robot arrives at the specified location, shoots videos or pictures as required, and sends them to the monitoring and reading terminal through the signal centralized monitoring network channel in real time. The machine vision signal conversion process is shown in Figure 2.

Software calibration page control is shown in Figure 3: The inspection machine is a complicated automatic control machine [18]. According to the current structure analysis and functional design of robots in various fields, the optimal performance of robots consists of 6 degrees of freedom and 6 control joints. Too many or too few degrees of freedom and joints will affect the maximum action effect of the robot. The degree of freedom of the robot represents the maximum movement of each limb of the robot, and the joint represents the key point dominated by the action of the inspection robot. The joint vector and the variable formula of the degree of freedom of the inspection robot are as follows:

$$\begin{cases} x_1 = f_1(q_1, q_2, q_3, q_4, q_5, q_6) \\ x_2 = f_2(q_1, q_2, q_3, q_4, q_5, q_6) \\ \vdots \\ x_6 = f_6(q_1, q_2, q_3, q_4, q_5, q_6) \end{cases}$$
(3)

where x_n represents the joint of the robot; f_n represents the degree of freedom of the robot joint. The most important characteristics of inspection robot are coordination and mobility. Therefore, the effect of robot movement can be maximized by adjusting the length, height, and position of key nodes. The standard parameters set between robot nodes are as follows:

$$\tau = \iota^t \frac{F}{U}.$$
 (4)

 τ represents the torque vector of the terminal running node of the robot. t^t denotes the transpose of the comparable matrix of the inspection robot; *F* represents the moment vector of equivalent joint force of the inspection robot; and *U* is the constraint coefficient of force. Figure 4 shows the stress relationship between each node of the inspection robot.

Above, the basic design of the railway signal room inspection robot has been completed.

3.2.2. Compliance Control of the Inspection Robot in the Power Signal Room. In order to improve the performance of inspection robots, this essay designs a compliant control method based on machine vision for power signal room inspection robots. The compliance control principle of the inspection robot is shown in Figure 5.

Compliance control methods are divided into active compliance control and passive compliance control. According to the characteristics of the applied object, passive compliance control method is selected. The compliance





control principle of an inspection robot is to mix the robot's motion information with the actuator's setting information to control the force and position, forming a dynamic behavior control relationship. The biggest advantage of this method is that there is no need to reverse design the arrangement of key nodes of the machine, which not only reduces the amount of tasks controlled by the inspection robot but also improves the control accuracy. The specific inspection robot compliance control algorithm is shown in the following equation:

FIGURE 4: Stress relationship between each node of the inspection robot.



FIGURE 5: Inspection robot compliance control principle.

$$b = s_d \frac{\delta \theta}{\rho},\tag{5}$$

wherein s_d represents the joint space stiffness matrix of the inspection robot, δ represents the offset of joint position and the static relationship between joints, θ represents the error of the end node of the inspection robot, and ρ represents the joint space stiffness coefficient of the inspection robot [19].

4. Result and Discussion

Based on the above discussion, the design of the compliance control method of an inspection robot in a power signal room based on machine vision has been completed. In order to verify the validity and feasibility of this method, experimental tests are carried out. In the experiment, the compliance control method of the inspection robot in the signal room based on the sensor robot and the compliance control method of the inspection robot in the power signal room based on the artificial intelligence technology were used to complete the comparative test. Due to the particularity of the test, this essay sets up the test environment and carries out the experiment according to the following steps:

- (1) Select a 10 min circuit operation video in the power management center. Then, the effective railway signal lamp images in the video are extracted by data frame extraction technology, and the extracted circuit signal image is passed into the virtual software, and the testing software will simulate the operation of the circuit in the experimental testing process.
- (2) In order to maximize the comparison of experimental results, the order of circuit signals will be randomly changed in the experiment. The principle of signal change order is to drive the inspection robot to make some basic behavior guidance and realize the inspection of the inspection robot's compliance control performance.
- (3) According to the purpose of this essay, the basic interactive behavior test of the railway signal room inspection robot is designed.
- (4) The three methods were transferred to three computers, which were connected to three inspection robots of the same model and waited for the experimental test. After all the preparation operations

are completed, three test environments are triggered at the same time to start the experimental test. The computer records the experimental data generated by the test of each method at the same time, laying a data foundation for the experimental analysis.

- (5) When all the circuit signals set in this essay are transformed for 1 min, the experiment is finished. Then the experimental data and experimental site are sorted out, and the experimental data are analyzed. The test was completed according to the experimental process designed in this essay, and the experimental conclusions were as follows: draw the experimental test schematic diagram according to the experimental data captured by the computer, as shown in Figure 6.
- (6) According to the purpose of this essay, the basic interactive behavior test of the railway signal room inspection robot is designed.
- (7) Move the three methods to three computers, which are connected to three inspection robots of the same model, and wait for the experimental test. After all the preparation operations are completed, three test environments are triggered at the same time to start the experimental test. The computer records the experimental data generated by each method at the same time, which lays the data foundation for the experimental analysis.
- (8) When all the circuit signals set in this essay are transformed for 1 min, the experiment is finished, the experimental data and experimental site are sorted out, and the experimental data are analyzed. The test was completed according to the experimental process designed in this essay, and the experimental conclusions were as follows: draw the experimental test schematic diagram according to the experimental data captured by the computer, as shown in Figure 6.

In Figure 6 shows the torque amplitude of inspection robot joints in the circuit signal room under different compliant control methods in the experimental test process. Three fluctuation curves can be observed, among which the effective fluctuation range of curve 1 is the largest and that of curve 2 is the largest. Because under the condition of normal railway signals, the smaller the



FIGURE 6: Experimental results of inspection robot joint torque.



FIGURE 7: Collision experimental results of inspection robot in experimental test.

fluctuation range of robot joints is, the more reliable the robot's emergency response will be in case of accidents. Therefore, it can be proved that the compliance method of the circuit signal inspection robot based on machine vision has high stability. When the circuit signal has a special change, the inspection robot in the circuit signal room needs to make an execution action. When the robot collides with the obstacle designed in the experimental test during the execution of the action, the fluctuation curve of the robot's joint torque is shown in Figure 7.

According to Figure 7, it can be intuitively concluded that the two traditional inspection robot compliance control methods are compared. This essay designs a circuit signal inspection robot based on machine vision. When the robot is disturbed by obstacles in the process of executing signal change instructions, the invalid fluctuation range of each joint torque is the smallest. In addition, the average fluctuation range of robot limbs is 0.65%, which can better control the behavior of inspection robots without interference from external factors.

5. Conclusion

This essay presents a research method of an active compliance control system for intelligent inspection robots in power rooms. In this method, the inspection robot of the power signal room based on machine vision adopts the noncontact detection method and takes the railway signal room as the specific optimization environment. The inspection robot is controlled by the terminal of the monitoring system, and the alarm information and graphic information are transmitted through the monitoring network and displayed by the monitoring terminal to improve the interaction of the power signal monitoring system. Based on the motion model, the automatic visual inspection of the machine is realized by the calibration of the machine and the edge detection of the inspection image. The motion model of the inspection robot in the power signal room is constructed, and the compliant control method of the inspection robot in the power signal room is designed to improve the sensitivity and controllability of the inspection robot in the power signal room. Specifically, when the inspection robot in the power room is disturbed by obstacles in the process of executing signal change instructions, the invalid fluctuation range of torque of each joint is the smallest, and the average fluctuation range of robot limb is 0.65%.

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 that they have no conflicts of interest.

References

- L. Song, H. Wang, and P. Chen, "Automatic patrol and inspection method for machinery diagnosis robo-sound signalbased fuzzy search approach," *IEEE Sensors Journal*, vol. 20, no. 15, pp. 8276–8286, 2020.
- [2] T. Brito, J. Queiroz, L. Piardi, L. A. Fernandes, J. Lima, and P. Leitao, "A machine learning approach for collaborative robot smart manufacturing inspection for quality control systems," *Procedia Manufacturing*, vol. 51, no. 2, pp. 11–18, 2020.
- [3] C. Li, L. P. Zhou, and Y. H. Chao, "Self-balancing two-wheeled robot featuring intelligent end-to-end deep visual-steering," *IEEE*, vol. 26, no. 99, p. 1, 2020.
- [4] G. Chen, S. Guo, B. Hou, and J. Wang, "Compliance control and analysis for equivalent hydraulic legs," *IEEE Access*, vol. 8, 2020.
- [5] A. H. Khan and S. Li, "Sliding mode control with pid sliding surface for active vibration damping of pneumatically actuated soft robots," *IEEE Access*, vol. 8, 2020.
- [6] Y. Zhang, X. Kou, Z. Song, Y. Fan, M. Usman, and V. Jagota, "Research on logistics management layout optimization and

real-time application based on nonlinear programming," Nonlinear Engineering, vol. 10, no. 1, pp. 526–534, 2021.

- [7] L. Fu, W. Zhang, X. Tan, and H. Zhu, "An algorithm for detection of traffic attribute exceptions based on cluster algorithm in industrial internet of things," *IEEE Access*, vol. 9, 2021.
- [8] R. Huang, "Framework for a smart adult education environment," World Transactions on Engineering and Technology Education, vol. 13, no. 4, pp. 637–641, 2015.
- [9] Y. He, S. Lv, L. Zhao, G. L. Huang, and W. Lin, "A compact dual-band and dual-polarized millimeter-wave beam scanning antenna array for 5g mobile terminals," *IEEE Access*, vol. 9, 2021.
- [10] O. C. Kara and V. Patoglu, "Vnstylus: a haptic stylus with variable tip compliance," *IEEE Transactions on Haptics*, vol. 13, no. 4, pp. 777–790, 2020.
- [11] J. Chen, J. Liu, X. Liu, X. Xu, and F. Zhong, "Decomposition of toluene with a combined plasma photolysis (cpp) reactor: influence of uv irradiation and byproduct analysis," *Plasma Chemistry and Plasma Processing*, vol. 41, no. 1, pp. 409–420, 2020.
- [12] S. Chen, Z. Guo, J. Feng, and J. Zhou, "An improved contactbased high-resolution palmprint image acquisition system," *IEEE Transactions on Instrumentation and Measurement*, vol. 69, no. 9, pp. 6816–6827, 2020.
- [13] Q. Zhang, X. Liu, M. Chaker, and D. Ma, "Advancing graphitic carbon nitride-based photocatalysts toward broadband solar energy harvesting," ACS Materials Letters, vol. 3, no. 6, pp. 663–697, 2021.
- [14] G. Li, F. Liu, A. Sharma et al., "Research on the natural language recognition method based on cluster analysis using neural network," *Mathematical Problems in Engineering*, vol. 2021, Article ID 9982305, 13 pages, 2021.
- [15] L. Chen, J. Sun, Y. Xie et al., "Shape prior guided instance disparity estimation for 3d object detection," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 44, no. 9, pp. 5529–5540, 2022.
- [16] A. Raveendran and S. Raman, "Complex permittivity extraction of planar dielectrics using a non-invasive microwave transmission line resonant technique," *IEEE Transactions on Instrumentation and Measurement*, vol. 70, pp. 1–8, 2021.
- [17] J. Jayakumar, B. Nagaraj, S. Chacko, and P. Ajay, "Conceptual implementation of artificial intelligent based E-mobility controller in smart city environment," *Wireless Communications and Mobile Computing*, vol. 2021, Article ID 5325116, 8 pages, 2021.
- [18] J. J. Wang, L. K. Ma, W. Liang, and C. C. Yang, "Responses of cuckoo hosts to alarm signals of different nest intruders in non-nesting areas," *Zoological Research*, vol. 41, no. 3, pp. 345–350, 2020.
- [19] T. Black and M. Winkler, "Global weak solutions and absorbing sets in a chemotaxis-Navier–Stokes system with prescribed signal concentration on the boundary," *Mathematical Models and Methods in Applied Sciences*, vol. 32, no. 1, pp. 137–173, 2022.