Design and implementation of intelligent reservoir inspection system based on Internet of Things and deep learning

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Abstract. The safety test of reservoir dam is the focus of reservoir safety management. Aiming at the technical and management problems in the traditional inspection methods, this paper proposes an intelligent inspection system of reservoir based on Internet of things and deep learning. Based on the Internet of things and deep learning technology, the system constructs a system architecture including perception layer, information fusion layer, intelligent diagnosis decision-making layer and inspection terminal layer, which realizes the inspection requirements of intelligent perception, information fusion, safety identification, emergency management, etc. Taking ZhangJiang reservoir as an example, the intelligent inspection system of reservoir based on Internet of things is developed, which can meet the needs of daily management and safety management of reservoir. It is an important part of realizing intelligent water conservancy construction of reservoir engineering.

Keywords: Intelligent patrol; Internet of Things; Multi-source Information Fusion; Deep Learning; patrol standardization.

1. Research background and significance

Dam safety is the primary task of reservoir safety management. Dam safety monitoring can monitor and guarantee the safe operation of dams by means of manual inspection and instrument observation. According to the corresponding results of the survey, reservoir inspection is the main means to realize the safety detection of reservoir dams [1]. Due to the professional level of the inspectors and the management process of the inspection work, the traditional manual inspection and instrument observation methods lead to the imperfect management system, poor transmission of inspection information, and untimely processing during the inspection process. , Insufficient inspection and emergency response capabilities. With the continuous improvement of the requirements and level of water conservancy project management, and the continuous application and popularization of Internet of Things technology and artificial intelligence technology, traditional inspection methods have been unable to meet the informatization requirements of water conservancy project management [2].

This paper combines the daily and annual inspection requirements of the reservoir project, integrates the Internet of Things, big data analysis and artificial intelligence and other technical means to build a reservoir intelligent inspection system that integrates perception, diagnosis, disposal, and feedback, and realizes the intelligence of reservoir dams [3]. Inspection and damage detection, improve the efficiency of daily inspection and management of reservoir dams, and provide information technology support for smart water conservancy.

2. Fundamentals of system design and related research

2.1 System Information Fusion Requirements

Reservoir dam inspection information has the characteristics of diversity, randomness, uncertainty, etc. The intelligent inspection system needs to integrate monitoring equipment, artificial collection and other intelligent sensing equipment, and then use machine learning technology to integrate data and algorithms to achieve Intelligent identification, data quality control and feature extraction of multi-source dam engineering information, historical information, and real-time monitoring information, building a feature fusion model of multi-source information, and building a neural network model with intelligent identification and perception and multi-source information fusion to overcome intelligent The information fusion in the perception process handles the difference problem, and improves the analysis ability of the evolution law of the dam's properties and states and the time-varying characteristics [4]. The hierarchical structure of system information fusion is shown in Figure 1.

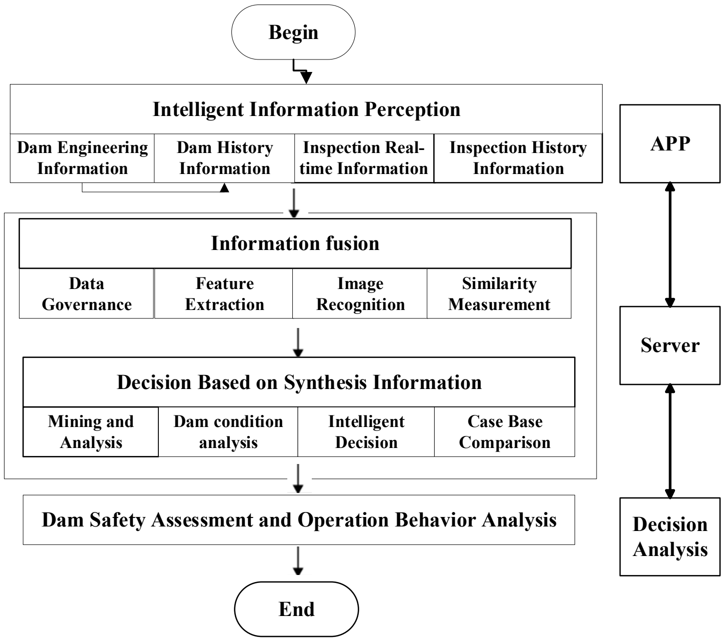

Figure 1. Intelligent perception and fusion process of inspection information

2.2 System business application requirements

The intelligent inspection system should be based on the Internet of Things technology, deep learning technology and big data analysis technology to build an inspection business application platform and APP to realize business functions such as intelligent perception, comprehensive decision analysis and management in the process of reservoir inspection [5].

The inspection APP receives the inspection tasks issued by the inspection business platform, and dynamically displays the specific information and inspection status of the inspection tasks; during the inspection process, the inspection APP realizes the automatic positioning of the inspection task points based on RFID technology, and automatically locates the inspection task points based on the RFID technology. The inspection task completes functions such as daily inspection of inspection points, self-intelligent identification of problems, and automatic upload of information. In addition, the inspection APP should provide inspection status and information query functions, and provide a complete inspection information interface [6].

3. Architecture Design of Intelligent Inspection System

3.1 System logical architecture design

Compared with traditional manual inspections, the intelligent inspection system aims at the pain points in the safety inspection of reservoir dams, and combines technologies such as Internet of Things, information fusion, big data analysis, and machine learning to realize the informatization of reservoir dam inspections. , intelligent and standardized, effectively reducing the erroneous detection and missed detection caused by human factors, and providing a scientific security guarantee for the inspection and management of reservoir dams. The logical architecture of the intelligent inspection system is divided into four layers, as shown in Figure 2. From bottom to top, they are the perception layer, the information fusion layer, the intelligent diagnosis decision-making layer and the intelligent application layer [7].

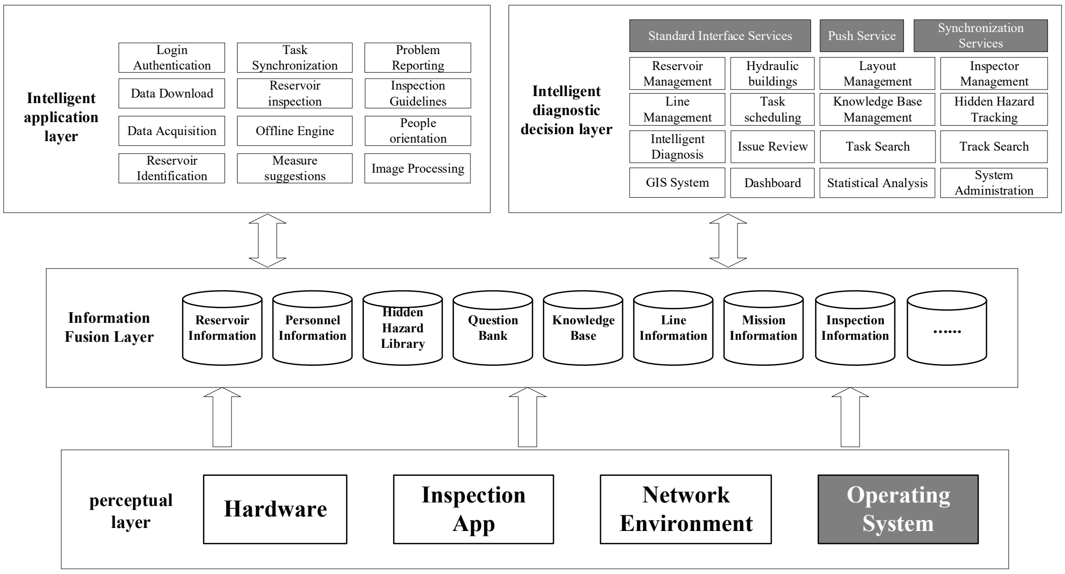

Figure 2. System logical architecture

3.1.1 Perception layer

As the basic capability layer of the Internet of Things, the perception layer is responsible for data collection, sensor network and information coordination processing. It identifies objects and collects data through inspection APP, sensors, RFID and other media, and then transmits data through short-distance, self-organizing networking, system Information processing, middleware and other technologies are used for network management, providing hardware support for the entire intelligent inspection system [8].

3.1.2 Information fusion layer

The information fusion layer adopts deep learning technology, constructs a neural network to realize information classification and clustering, eliminates harmful information and invalid information, simplifies effective information, and realizes data screening and multi-source information fusion. At the same time, the information fusion layer builds an inspection scheme library, an object type library, a defect type library, and a defect case library based on the knowledge graph technology to ensure the integrity constraints of the intelligent diagnosis decision-making layer[9].

3.1.3 Intelligent diagnosis decision-making layer

The intelligent diagnosis decision-making layer, based on the inspection database and knowledge base, based on the deep learning technology, realizes the intelligent diagnosis and inspection information and matches the disposal decision, intelligently handles the inspection defects found in the inspection process, and intelligently arranges the inspection tasks.

3.1.4 Intelligent Application Layer

The intelligent application layer, as the interface for the interaction between the entire intelligent inspection system and users, can realize application functions such as information collection, intelligent generation of inspection tasks, and image processing, so as to achieve intelligent applications [10].

3.2 System Deployment Architecture

The intelligent inspection system is composed of an inspection APP and an inspection business platform. Based on the B/S architecture, through the mobile terminal of the client and the management server in the background, the latest communication technology distributed computing technology, modern control technology and sensor technology are used to construct A set of intelligent real-time monitoring network based on the Internet of Things and wireless technology is developed, as shown in Figure 3.

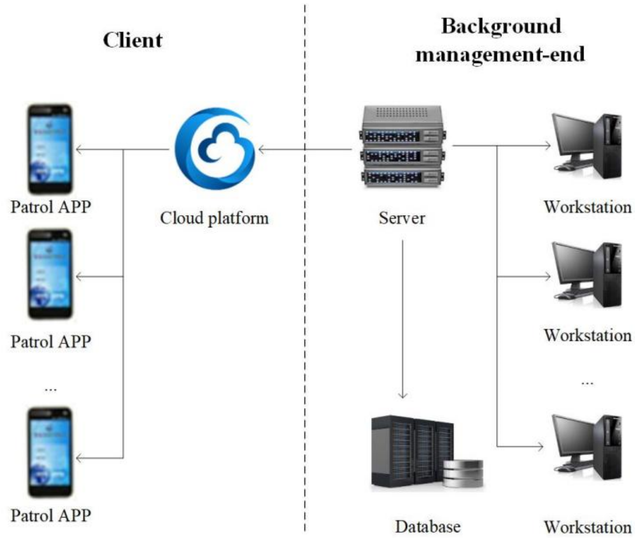

Figure 3. System Deployment Architecture

Through the IoT network of the intelligent inspection system, the inspector uses the inspection APP, downloads the inspection tasks, obtains the inspection tasks issued by the administrator, and executes the inspection; during the execution process, the inspector uses the inspection APP to shoot the inspection [11]. Check photos, record the inspection information, and complete the check-in through RFID information arranged around the reservoir to update the progress of the inspection task; After checking that the information is valid, end the inspection task.

4. Design and algorithm of key parameters of inspection system

4.1 RFID-based intelligent perception technology

RFID technology has the characteristics of high recognition rate, traceability, and unique identification [4]. The application of RFID-based intelligent sensing technology on dams is divided into two parts, one part is at the inspection point, and the other part is at the inspection APP. . The dot matrix display screen is used in the RFID setting of the inspection points to display the inspection status and safety status of the inspection points, and provide a unique identification feature to enable the inspection APP to establish interaction with the inspection points; the inspection APP The terminal is equipped with a unique RFID identification interface and an information update module for the inspection point[13]. After establishing interaction with the inspection point, the relevant information on the inspection point display can be updated in real time. The use of RFID enables the inspection APP and the inspection point to establish a unique identification feature, eliminating the need to manually input the inspection point, simplifying the inspection process and improving the efficiency and accuracy of the inspection process.

4.2 Dam crack detection technology based on residual FCN in multi-channel domain

Based on the deep learning algorithm based on the FCN neural network, the inspection App introduces residual structural units to construct a dam safety identification model to realize intelligent detection of dam cracks. The algorithm flow of dam crack identification: 1) Obtain the dam surface crack image through the data acquisition equipment in the APP section, 2) Use the Sobel operator to sharpen the filter layer to extract the edge features of the dam crack image, 3) Use the introduction channel The residual FCN of the domain mechanism is used to construct an intelligent fracture recognition model [14].

The dam crack detection model based on residual FCN in multi-channel domain is shown in Fig. 4. First, the target edge features are extracted from the original image through the sobel operator, such as formula (1) (2):

$$G_x = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} \qquad G_y = \begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \tag{1}$$

$$\theta = tan^{-1}\frac{G_y}{G_x} G = \sqrt[2]{{G_x}^2 + {G_y}^2} \tag{2}$$

Then, through a convolutional neural network with five 5*5*3 convolution kernels, an output image with a feature channel number of C=5 is obtained. Through a pooling layer, the pool size is selected as 2, and the two-dimensional features of each channel are compressed into a real number. For the results obtained after global pooling, a fully connected layer is used to reduce the feature dimension to C/r, where r is a constant and takes 2 in this model. The feature extraction layer uses the ReLU activation function, as in formula (3):

$$f(x) = \begin{cases} 0, & x \le 0 \\ x, & x > 0 \end{cases} \tag{3}$$

Then through a fully connected layer, the weight is selected as 256, and the feature dimension is restored to C. The Sigmoid function is used to convert all C feature channels into normalized weights ranging from 0 to 1 as in formula (4):

$$f(x) = \frac{1}{1+e^{-x}} \tag{4}$$

At the same time, a residual Shortcut connection is introduced between the original image and the normalized output image to implement linear regression as shown in formula (5):

$$y = F(x, \{W_i\}) + x \tag{5}$$

Finally, the final pixel classification prediction result is obtained by enlarging the feature image obtained by the transposed convolution layer of FCN using bilinear interpolation, as shown in formula (6):

$$y = y_0 + \frac{y_1 - y_0}{x_1 - x_0}(x - x_0) \tag{6}$$

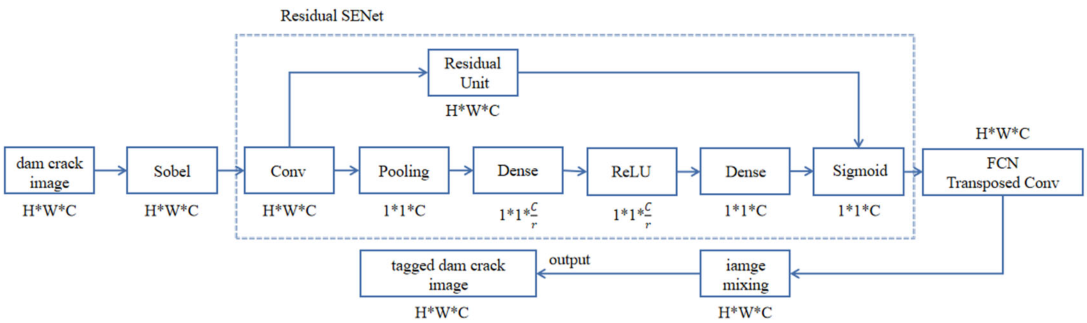

Figure 4. Model of dam crack detection based on residual FCN in multi-channel domain

The channel domain attention mechanism measures the importance of different channels and improves the reuse of information. The residual structural unit directly regards the identity mapping as a part of the network, which solves the problem of degradation in the process of deepening the number of neural network layers. When the activation function continues to increase and the data is mapped to a more discrete space, it can still achieve its own identity transformation and linear regression, thus solving the problem of gradient explosion and degradation caused by FCN in the process of deepening the number of layers. During the training process, image features are labeled with sufficient amount, and images are classified and labeled to ensure the stability of the data set. In the process of feature extraction, the residual FCN neural network is used to continuously adjust the parameters to ensure the robustness and limitations of the extraction approach, and retain the characteristics of traditional FCN for pixel-level classification of images [15].

4.3 GIS map information service

GIS information service has the basic functions of acquiring, storing, displaying and analyzing geographic data[16]. The use of GIS technology in the intelligent inspection system improves the spatial visualization of the work results of the staff. When using the intelligent inspection system, the staff marks the inspection content in space through the GIS in the system, so that the inspection results can be marked in space. There is precise spatial positioning [17].

4.4 Big Data Analysis Technology

During the inspection process, the inspectors use intelligent data collection equipment to input the dam characteristic information (text, photos or videos, etc.) in time. Compared with the traditional inspection method, the intelligent inspection system overcomes the problem of multiple redundancy of inspection information. After all kinds of inspection information are processed and analyzed by the information fusion layer, the effective information is classified and stored in each database, and corresponding decision-making information is generated. The intelligent inspection system adopts big data analysis technology and deep learning algorithm to comprehensively analyze the data collected by inspection, such as images, audio and video results, and judge the abnormal state of dam safety; Horizontal comparison, discovering the evolution law of dam shape, and predicting possible safety defect events of dams; a defect database constructed based on historical defect cases, intelligent matching of similar defect cases in the database and corresponding treatment plans, providing diagnostic analysis reference for hidden defects and treatment plan.

Take a specific inspection task submission as an example, as shown in Figure 5. Reservoir inspectors record the inspection task information on the inspection APP through text, images, etc., and submit the inspection task information at the end of the inspection. The inspection service platform checks the legitimacy of the inspection task information sent by the APP, and packages the information and sends it to the background server. After receiving the information sent by the platform, the background server updates the inspection information database and matches the hidden danger database and the problem database according to the reported inspection problems. After the matching is successful, the knowledge base and the inspection case base are queried according to the matching results, and the corresponding processing plan is presented to the inspection administrator. If the inspection administrator has set the function of automatically generating defect processing tasks, the intelligent inspection system will automatically generate inspection plans and regularly generate inspection tasks according to the matched defect treatment solutions.

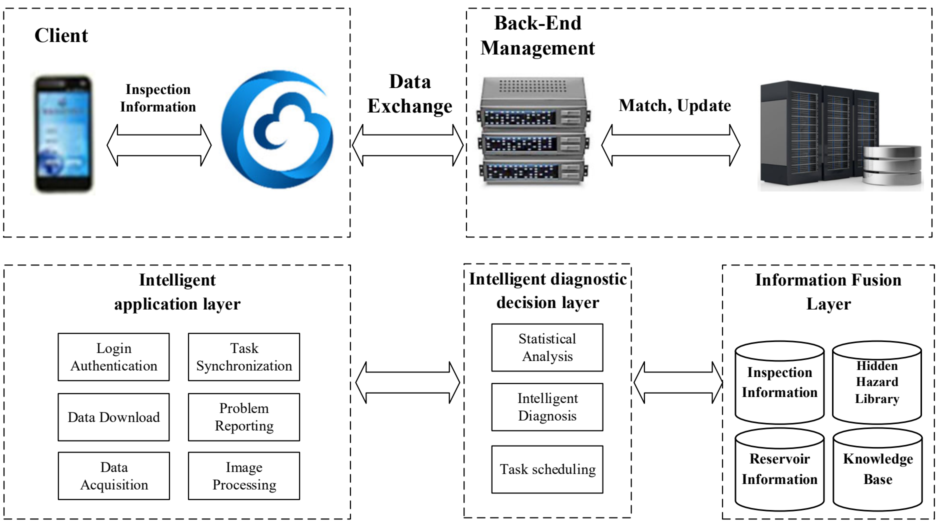

Figure 5. Schematic diagram of inspection task information processing

5. Conclusion

The intelligent inspection system uses the Internet of Things technology to associate the geographic information of the inspection points with the fixed QR code or RFID card, and obtains the real-time location of the inspectors and the geographic location information corresponding to the QR code or RFID card through GPS technology. Compare. While intelligently generating inspection tasks, managers can also query the position information of inspectors and the progress of inspection tasks in real time, achieving double assurance. Based on big data analysis technology, the intelligent inspection system can intelligently generate different inspection routes. It plays a very good role in responding to emergencies in a timely manner and improving the efficiency of inspection. In addition, the intelligent inspection system also solves the problems of complex inspection information and low robustness. Based on deep learning technology, intelligent information perception, feature information fusion and comprehensive information decision-making are realized, and a knowledge map-based inspection solution library, Object category library, defect category library, defect database.

References

[1] Research on UAV data collection and path planning based on deep reinforcement learning [J]. Mu Zhiyu, Zhang Yu, Fan Dian, Liu Jun, Gao Feifei. Journal of Internet of Things. 2020(03).

[2] Analysis of inspection scheme of pumped storage power station based on UAV [J]. Zou Bin, Luo Zixue, Chen Jinying, Liu Zhuang, Li Bin. Microcomputer Application. 2019(04).

[3] Design of remote monitoring system for rural intelligent distribution network based on GPRS and GPS [J]. Kuang Honghai, Zhang Shuyun, Zeng Liqiong, Li Shengqing, Zhou Zhiwei. New Technology of Electric Power. 2017(04).

[4] Application and effect of large-scale inspection of large-scale unmanned helicopter power lines in Guangdong Power Grid [J]. Qian Jinju, Mai Xiaoming, Wang Ke, Yi Lin, Peng Xiangyang, Rao Zhangquan. Guangdong Electric Power. 2016(05).

[5] Application of multi-rotor UAV in environmental monitoring of reservoir waters [J]. Li Xiang. Science and Technology Communication. 2016(01).

[6] Design and implementation of online monitoring and intelligent diagnosis system for metering devices based on data mining [J]. Xiao Jianhong, Yan Xiaowen, Zhou Yongzhen, Chen Yueyan. Electrical Measurement and Instrumentation. 2014(14).

[7] Similar literature readers recommend related fund literature related authors Batch download related videos.

[8] Application of sensing technology in fine inspection of transmission line multi-rotor UAV [J]. Li Jia, Zhao Xuekun, Lin Jie, Xiao Tianhao. Journal of Beihua University of Aerospace Engineering. 2021(02).

[9] Design of control system for quadrotor UAV[J]. Wang Xiaoyin, Zhang Xu, Li Jiaxiang, Li Long, Ren Jianwei. Microcomputer Application. 2022(01).

[10] Control research on autonomous landing of rotary-wing UAV on moving UAV [J]. Sun Yuting, Li Haodong. Electro-Optics and Control. 2021(01).

[11] Application of multi-rotor UAV in transmission line inspection [J]. Xing Zhigang, Wan Hongyu. Heilongjiang Science. 2020(24).

[12] Application of electric multi-rotor unmanned aerial vehicle in high-voltage circuit cooperative line patrol [J]. Yu Peng, Tian Jie, Liu Tiejun, Xi Xiaopeng. Automation Technology and Application. 2021(02).

[13] Design of intelligent power line patrol system based on quadrotor UAV [J]. Geng Ankun, Zhu Houyi. Rural Electrification. 2021(04).

[14] Design of quadrotor UAV control system based on deep learning [J]. Huang Liang. Electronic Production. 2021(17).

[15] Research on the control system of autonomous and precise landing of multi-rotor UAV [J]. Zeng Zhenhua, Zheng Huifeng, Zhu Yujie, Luo Zhiyong. Journal of Guangdong University of Technology. 2020(01).

[16] Research and application of line inspection skills enhancement of small multi-rotor UAVs [J]. Li Fei, Zhang Deqin, Liu Yuan. Science and Technology and Innovation. 2020(18).

[17] Research on autonomous inspection technology of transmission channel based on multi-rotor UAV [J]. Wu Yuwu, Liu Jialong, Chen Chun, Xing You, Luo Fang. Power Grid and Clean Energy. 2020(10).