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DESIGN OF REMOTE ACQUISITION SYSTEM FOR ECOLOGICAL WATER DEMAND INFORMATION OF AN ESTUARINE WETLAND

Diseño de un sistema de recolección remota de información sobre la demanda ecológica de agua de un humedal estuarino

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Key words: UML modeling, Gaussian pyramid, polling work, SIFT algorithm.

ABSTRACT

In order to improve data coverage and data collection efficiency, the design method for a remote collection system of ecological water demand information of an estuarine wetland is proposed. The hardware design of the remote information acquisition system is realized through the overall structure design, the Unified Modeling Language (UML), system outline design, system logic design, and system module division. The information is acquired by polling, and the acquisition frequency is adjusted according to the actual situation and user needs. In the system software design, the Scale-invariant feature transform algorithm (SIFT) is used to extract the image features of the estuarine wetland, and a support vector machine is used to cluster the collected information according to the image features to realize the remote acquisition of water demand information of the estuarine wetland. The experimental results show that the maximum data coverage of the proposed method is 95%, and the data acquisition time is less than 0.2 h, indicating that the proposed method has high information acquisition efficiency and high data coverage.

Palabras clave: Modelación UML, pirámide gaussiana, trabajo de sondeo, algoritmo SIFT.

RESUMEN

Con el fin de mejorar la cobertura de los datos y la eficiencia de su recolección, se propone el diseño de un sistema de recolección remota de información sobre la demanda ecológica de agua de un humedal estuarino. El diseño del *hardware* del sistema de adquisición de información remota se realiza a través del diseño general de la estructura, el lenguaje unificado de modelado (UML, por su sigla en inglés), el diseño del esquema del sistema, el diseño de la lógica del sistema y la división del módulo del sistema. La información se obtiene por sondeo y la frecuencia de adquisición se ajusta según la situación real y las necesidades del usuario. En el diseño del *software* del sistema, el algoritmo del método de detección de puntos SIFT (Scale Invariant Feature Transform) se utiliza para extraer las características de imagen del humedal del estuario y una máquina de vectores de apoyo se utiliza para agrupar la información recogida de acuerdo con las características de la imagen para realizar la adquisición remota de información de demanda de agua del humedal estuarino. Los resultados experimentales muestran que la cobertura máxima de datos del método propuesto es del 95 %, y el tiempo de adquisición de datos es inferior a 0.2 h, lo que indica que el método propuesto tiene una alta eficiencia de adquisición de información y una alta cobertura de datos.

INTRODUCTION

Wetlands have rich biodiversity and essential economic, social, and ecological values. It is one of the critical living environments for human beings and is known as "the kidney of the earth" (Yang et al. 2016). Wetland science studies the formation, development, evolution, ecological process, function and mechanism, protection, and utilization of wetlands (Li et al. 2016). The development of wetland science needs to improve the level of wetland field observation, which depends on advanced observation theory and technology (Li et al. 2018a). China is an extensive wetland country, with the fourth largest wetland area in the world and the first in Asia. In recent years, with the rapid development of China's reform and opening up and the rapid economic development, the development of natural resources has increased, and wetland protection has become more and more critical. Acquiring water demand information on estuarine wetlands is an essential link in wetland protection. It is necessary to study the design method of acquisition systems for water demand information of estuarine wetlands (Zhang et al. 2018, Guo et al 2019).

Mo et al. (2020) put forward a design method of information acquisition system based on cloud computing. This method combines the cloud computing technology with powerful data analysis function to design the water demand information acquisition system. By understanding the layout and design characteristics of wetland planning, the data control framework and theoretical structure model of regional information acquisition system are established, and the software control process and hardware of the acquisition system are analyzed (Geng et al. 2020, Zuo et al. 2020). The information integrity of this method is poor and the data coverage is low. Xu et al. (2016) put forward a design method of information acquisition system based on Internet of things. This method takes ARM microprocessor as the core, EC20 module as communication medium, and hardware circuit and embedded software program of multi-channel temperature and humidity sensors and wind speed sensors as the external devices to realize the design of water demand information acquisition system. The information acquired by this method is comprehensive and cross, resulting in low data coverage. Feng et al. (2017) put forward a design method of information acquisition system based on data quality control. This method adopts the structure framework of model-view-controller mode and PH language to develop an information acquisition system based on data quality control of Browser/Server mode. The method of information acquisition does not conform to the actual situation, which results in a long time for information acquisition and low efficiency of information acquisition.

In order to solve the problems existing in the above methods, the design method of remote acquisition system for ecological water demand information of estuarine wetland is proposed.

DESIGN OF THE REMOTE INFORMATION ACQUISITION SYSTEM

Overall structure of the system

The main task of the remote acquisition system for ecological water demand information of estuarine wetland is to acquire information in the background, which mainly involves the communication with the host equipment of intranet (Huang et al. 2017a). At the same time, as a part of the intranet management system, it accepts the control of the upper system, such as system configuration service, periodic polling, acquisition time change, etc. The ecological water demand acquisition system is connected with other systems through routers (Yang et al. 2020). Each system independently acquires the ecological water demand information. Each management terminal is equivalent to a proxy server, which is responsible for the management of a certain network segment. Each management end serves the upper central server and configures the command resources according to the command of the central server (Yu et al. 2020). The deployment diagram of ecological water demand information acquisition system is shown in **figure 1**.

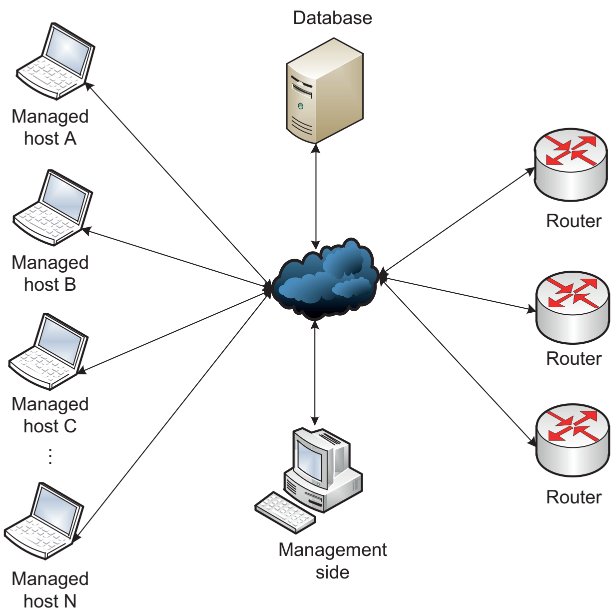

Fig. 1. Deployment of the remote acquisition system for ecological water demand information.

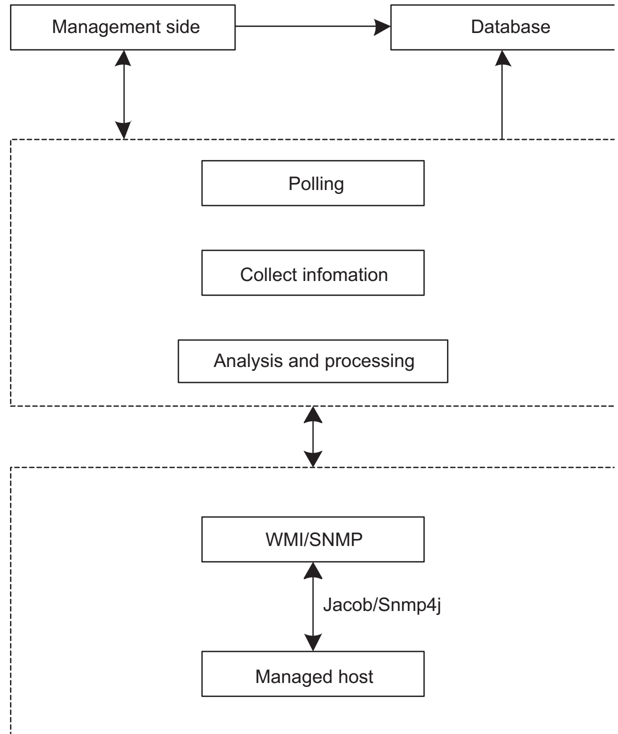

Fig. 2. Structure of remote acquisition system for ecological water demand information.

Each management end is responsible for collecting the ecological water demand information of a network segment to reduce the pressure of the central server (Lu et al. 2019). The management end connects with the external network through the router and uploads the collected and processed ecological water demand information to the central server. In fact, it is deployed in every management end of intranet as a proxy server (Zhang 2016, Ma et al. 2019). The structure of ecological water demand information acquisition system is shown in **figure 2**.

The diagram shows the function realization process of each module of ecological water demand acquisition system.

1) The management end collects the ecological water demand data of estuarine wetland through WMI and SNMP and can change the frequency of polling according to the user and actual requirements.
2) The management end can change the data acquisition scheme of ecological water demand according to the user's configuration or command.
3) In the management end, the collected ecological water demand information can be threshold analyzed, the cross-boundary data can be alarmed, and the useful data can be stored in the database (Li et al. 2019, Liang, 2018).
4) The whole web page of interest can be viewed and managed through the web monitoring system.

Unified Modeling Language

UML is a visual modeling language, which is widely used in business modeling, component modeling and software development modeling. It enables users of the system to establish a blueprint of the system that can express their intention in a standard and easy to understand way, and provides a mechanism for different users to share and communicate the design effectively (Huang et al. 2017b, Zhou and Wang 2018). UML unifies the basic concepts in the main schools of object-oriented, and provides the definition and expression of standard object-oriented model elements. UML absorbs the advantages of object-oriented technology, and has powerful object-oriented function; it also has rich visualization, strong ability to describe the system, rich information contained in the model, and strong visualization and representation ability. At the same time, UML is independent of object-oriented technology, and its development process is easy to master and use.

In the software design stage, UML is widely used. The design method of remote acquisition system for ecological water demand information of estuarine wetland uses UML and rational rose software to modularize and graphically express the objects and functions in the system (Guzman-Albores et al. 2020).

System outline design

The system outline design mainly involves the description of the main roles in the system and the analysis of the use case diagram of the system. Through the analysis of problem description, three roles are identified: monitored object, manager and database. Managers can send out command information, modify system configuration information, view the collected ecological water demand data information, and receive alarms (Han et al. 2019). The monitored object, namely the managed host, mainly provides the basic information needed for system management. The database is responsible for storing data, providing historical data information, and providing comparative data values for alarm information (Liu et al. 2017). The role description template of remote acquisition system for ecological water demand information of estuarine wetland is shown in **figure 3**.

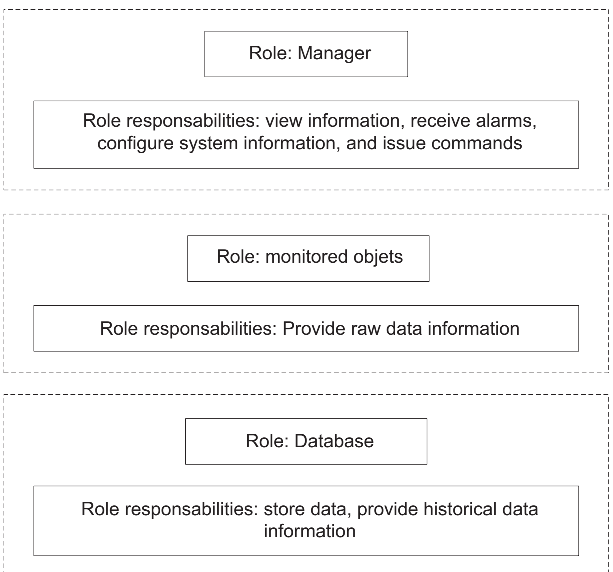

Fig. 3. Role description template of remote acquisition system for ecological water demand information.

Through the analysis of the problems, the use cases of the remote acquisition system of ecological water demand information can be preliminarily identified. The top use case diagram is shown in **figure 4**. Managers send commands to manage the monitored objects through the host monitoring, collect the information required in the requirements, and analyze the collected management data through certain processing work (Yan et al. 2016).

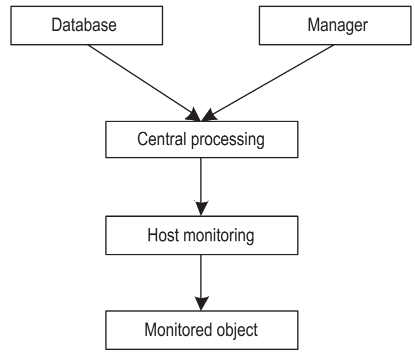

Fig. 4. Top use case diagram of host information acquisition system.

The top-level use case diagram is refined, and the main objects and functions in the remote acquisition system of ecological water demand information are extracted respectively. The host monitoring and central processing can be divided into:

1) Data acquisition: collect the specified information of the managed end through the command information of the management end.
2) Format data: convert ecological water demand data into fixed format and package.
3) Transmission data and command: transmit the command information to the managed end, and the managed end returns the collected ecological water demand data to the management end according to the command information.
4) Analysis data: analyze and compare the collected ecological water demand data to determine whether it exceeds the threshold information.
5) Database management: manage the data storage and extraction, store the collected ecological water demand information and the specific threshold information to facilitate threshold comparison (Li et al. 2018b).
6) Alarm: alarm the management personnel in the form of voice or e-mail for the data beyond the boundary after analysis.
7) Display: display the information of the monitored objects to the management personnel, according to the contents of the database.
8) Configuration management: configure the system operation information, such as IP address, port address, acquisition method, target device, polling frequency, etc.

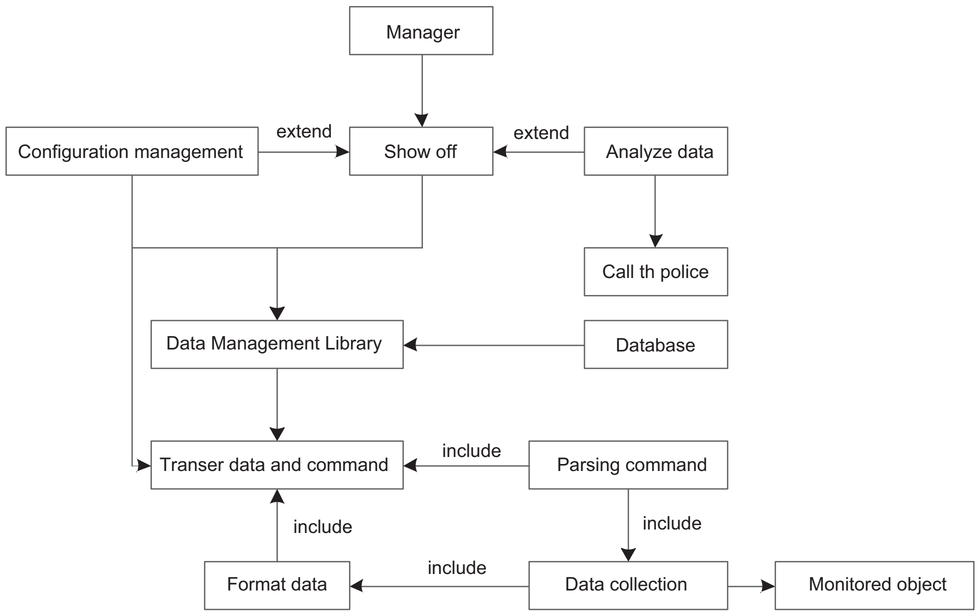

Fig. 5. Use case diagram of remote acquisition system for ecological water demand information in the second layer.

The second layer use case diagram of the remote acquisition system for ecological water demand information. It is generated as shown in **figure 5**.

System logic design

The logic design mainly involves the class diagram and sequence diagram of the remote acquisition system for ecological water demand information. According to the results of the previous outline design, the main objects in the remote acquisition system for ecological water demand information are extracted: managed object, proxy server, collected data, database, command and configuration information, display interface, alarm signal, administrator and so on. The class diagram of the system is shown in **figure 6**.

The remote acquisition system of ecological water demand information no longer installs an agent software on the managed host but collects the required information through the WMI/SNMP module on the managed host according to the user's command, and then transmits it to the management end. Although there is no agent software, in fact, WMI/SNMP already has the function of agent software to replace

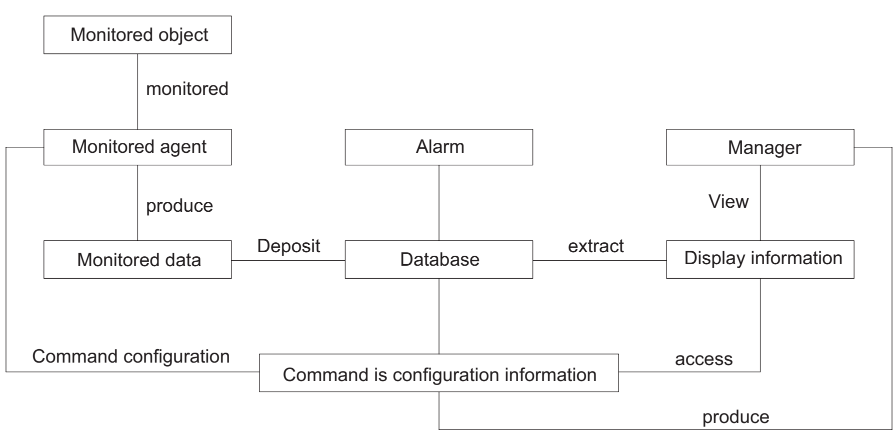

Fig. 6. Fact class diagram of the system.

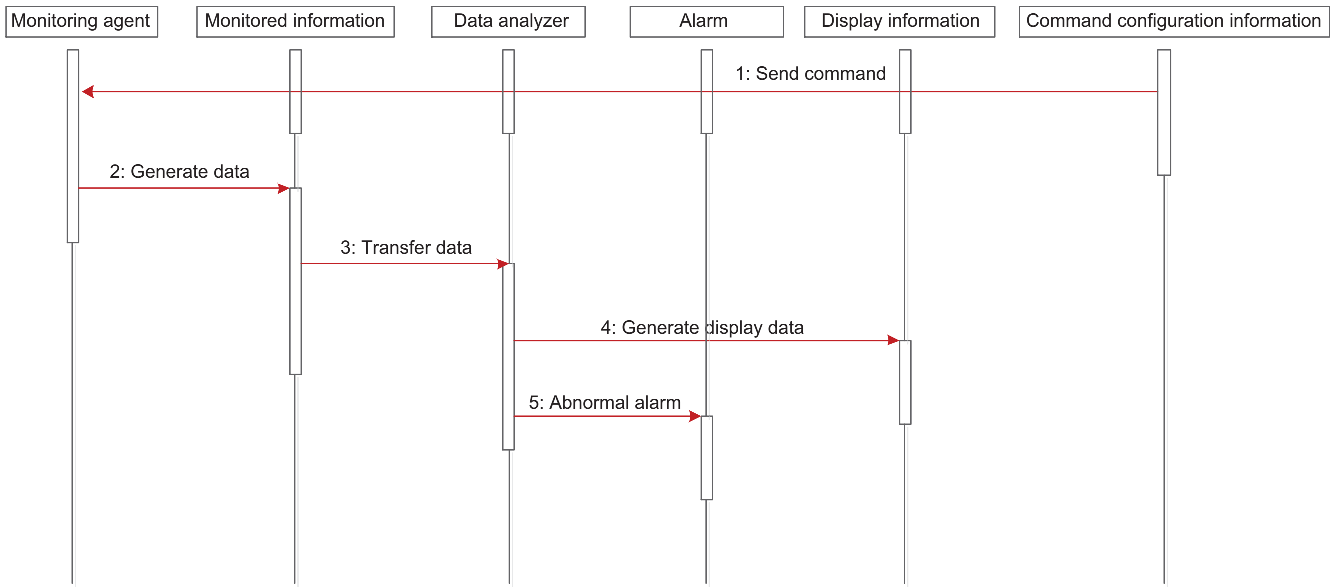

Fig. 7. Sequence diagram of system information acquisition process.

the specific agent software to realize the acquisition function (Li et al. 2018c). The complete process of ecological water demand information acquisition is shown in **figure 7**.

In **figure 7**, the following steps are implemented in sequence: The management end receives the relevant configuration information according to the user's command; uses the WMI/SNMP module to collect the specified information, transmits it to the management end according to the unified format specified in the database, and delivers it to the database for storage; generates the display information data in the form of pages. If the performance index of a certain device exceeds the threshold value, it will send out an alarm message (Chen et al. 2017).

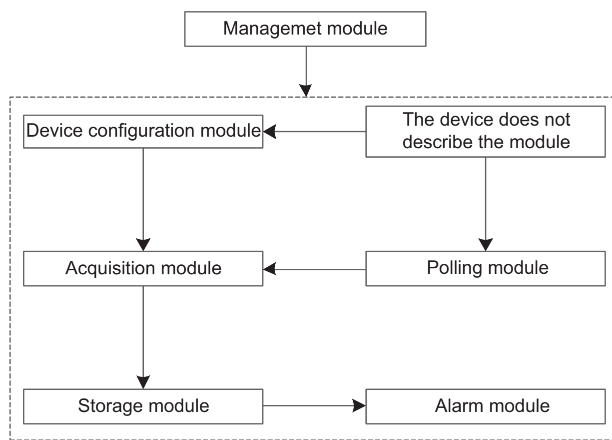

Fig. 8. Module division of remote acquisition system for ecological water demand information.

System module division

According to the above structure diagram of remote acquisition system for ecological water demand information, the system modules can be divided as shown in **figure 8**.

1) The management module is mainly responsible for initializing the whole system, including starting MySQL database, Apache Tomcat Web server, system service items, etc., so as to make the front and background of the system run according to the requirements, which is the prerequisite for the normal operation of the whole system.
2) The equipment description module provides the equipment description file for other modules of the system, provides the carrier for the system to realize the ecological water demand information acquisition, and describes the functions and user requirements of the equipment to be collected.
3) The device configuration module uses the relevant commands to modify the system configuration according to the user's requirements, such as the IP address of the target host, port address, acquisition mode, device name of the target acquisition, polling acquisition time, etc., and timely update the equipment to be collected (Ning et al. 2016).
4) The acquisition module is the basic module of the remote acquisition system for ecological

water demand information. It uses WMI/SNMP to collect the information of the managed end, and provides the most fundamental information acquisition and processing for the upper system. According to different acquisition methods, WMI/SNMP can collect different devices.

5) The polling module can set the periodic acquisition according to the user's requirements, and can change the polling acquisition frequency, which can better reflect the real-time and flexibility of the system.
6) The storage module is to store the collected ecological water demand information into the database in a specific way for future analysis and processing. The threshold information is stored in advance, which is convenient to compare with the corresponding information collected.
7) According to the default data of the system and the equipment data collected in the database, the alarm module alerts the administrator of the ecological water demand information exceeding the threshold value by voice, email, SMS, etc.

REALIZATION OF THE REMOTE ACQUISITION SYSTEM FOR ECOLOGICAL WATER DEMAND INFORMATION

The design method of the remote acquisition system for ecological water demand information of estuarine wetland adopts SIFT algorithm to extract the features of estuarine wetland image and input it into the classifier to cluster the collected information to realize the remote acquisition of ecological water demand information of estuarine wetland.

Constructing a Gaussian pyramid

The basic idea of constructing a Gaussian pyramid, that is, image scale space theory, is to introduce scale parameters into image scale transformation function. Through this function, the original image is continuously transformed to obtain images of different scales. The image scale space is generated by synthesizing these images. The construction process is divided into two steps. First, scale transformation is performed on the image, and each group contains several images with different scales. The scale space transformation of one image is obtained by convolution of the Gaussian function with the original image.

$$L(x, y, \sigma) = G(x, y, \sigma) * I(x, y) \tag{1}$$

where, $G(x, y, s)$ is the Gaussian filter function. When generating a new image group, the bottom image of the new group is obtained by down-sampling the upper group of intermediate layer images, which can not only ensure the continuity of the scale, but also reduce the complexity of subsequent operations (Li and Wang 2018).

It is assumed that the image has been blurred by the acquisition device, so the initial scale should be set with the following formula:

$$\sigma_0 = \sqrt{\sigma_{init}^2 - \sigma_{pre}^2} \tag{2}$$

Gaussian blur will lead to the loss of image information. The design method of remote acquisition system for ecological water demand information of estuarine wetland uses the interpolation method to double the bottom image, so as to reduce the negative impact of Gaussian blur and retain the details of the image.

Suppose that there are *O*-group and *S*-layer images in the image scale space, and the scale relationship between images is expressed as follows:

$$\sigma_{s+1} = 2^{1/S} \sigma_s \tag{3}$$

The scale relationships among groups are as follows:

$$\sigma_{o+1} = 2^{s+S/S} \sigma_0 \tag{4}$$

The number of groups of Gaussian pyramids is related to image size. Generally, 4 to 5 groups are selected, and 5 layers are selected for each group of images. In the image scale space, the bottom image is obtained by doubling the original image, the purpose is to retain image information to obtain more image features (Hu et al. 2017). In the same group, the scale value of two adjacent layers is k, and the value of k is $2^{1/S}$, then the scale factor of the second layer in the first group is $k\delta$. From the above, we can see that the first layer image of group 2 is obtained by sampling the middle layer scale image of group 1, and its scale is $k^2\delta$. The scale factor of the second layer of the second group is k times that of the first layer, that is, $k^3\delta$. The bottom image of the third group is still obtained by sampling the previous group of images, and the composition of other groups is analogical.

Key point detection

After obtaining the image scale space, the operator LOG can be constructed by the Gaussian function gradient operator. The operator GOG is:

$$\nabla^2 G = \frac{\partial^2 G}{\partial x^2} + \frac{\partial^2 G}{\partial y^2} \tag{5}$$

The LOG operator is:

$$LOG(x, y, \sigma) = \sigma^2 \nabla^2 G = \sigma^2 \left(\frac{\partial^2 G}{\partial x^2} + \frac{\partial^2 G}{\partial y^2} \right) \tag{6}$$

Formula (7) is obtained by deducing the above formula.

$$G(x, y, k\sigma) - G(x, y, \sigma) \approx (k-1)\sigma^2 \nabla^2 G \tag{7}$$

It can be seen from the derivation that operator LOG is directly related to the difference of the Gaussian kernel function. In order to extract stable scale independent feature points, the Gaussian difference operator DOG is introduced. The operator DOG is defined as follows:

$$D(x, y, \sigma) = L(x, y, k\sigma) - L(x, y, \sigma) \tag{8}$$

The operator DOG is obtained by subtracting adjacent images in the same group in the image scale space.

Features optimization

When extracting the key points, the difference operation of operator DOG will make the image edge effect. In order to solve this problem, a fitting quadratic function is introduced to eliminate the edge response and the low contrast key points (Xu et al. 2016b). This not only optimizes the extracted features, but also improves the denoising ability and enhances the accuracy of subsequent feature matching.

The location of the precise extremum point is calculated by sub-pixel interpolation, and the Taylor series expansion is performed on $D(x, y, \sigma)$ at the detected local extreme point (x_0, y_0, σ).

$$D(x, y, \delta) = D(x_0, y_0, \delta) + \frac{\partial D^T}{\partial X_0} X + \frac{1}{2} X^T \frac{\partial^2 D}{\partial X_0^2} X \tag{9}$$

By deriving the above formula, it can get more accurate location of the extreme point.

$$X_{max} = -\left(\frac{\partial^2 D}{\partial X_0^2} \right) - \frac{\partial D}{\partial X_0} \tag{10}$$

Combined with the above formula, the following formula is obtained:

$$D(X_{max}) = D + \frac{1}{2} \frac{\partial D^T}{\partial X_0} X_{max} \tag{11}$$

where, $D(X_{max})$ is the discriminant value, which is compared with the threshold value. If it is greater than the threshold value, the feature point is retained. If it is less than the threshold value, the feature point does not meet the requirements and belongs to the low contrast point.

The edge effect is eliminated by calculating the curvature. If the quality of the key points around the image edge is poor, the main curvature is larger, while the curvature in the vertical direction is smaller. In order to eliminate the unstable edge response points, the Hessian matrix is required firstly (Yin et al. 2018):

$$H = \begin{bmatrix} D_{xx} & D_{xy} \\ D_{xy} & D_{yy} \end{bmatrix} \tag{12}$$

Let α and β be the eigenvalues of Hessian matrix, and the following formula exists:

$$Tr(H) = D_{xx} + D_{yy} + \alpha + \beta \tag{13}$$

$$Det(H) = D_{xx} D_{yy} - (D_{xy})^2 = \alpha\beta \tag{14}$$

Let α be the larger eigenvalue; β be the smaller eigenvalue, and $\alpha = \gamma\, \beta$, then there are:

$$\frac{Tr(H)^2}{Det(H)} = \frac{(\alpha + \beta)^2}{\alpha\beta} = \frac{(\gamma\beta + \beta)^2}{\gamma\beta^2} = \frac{(\gamma + 1)^2}{\gamma} \tag{15}$$

where, the value of $(\gamma + 1)^2$ is the minimum when the two eigenvalues are equal, and increases monotonically with the increase of γ. Therefore, in order to detect whether the principal curvature is less than a certain threshold γ, it only needs to detect whether $Tr(H)^2 / Det(H) < (\gamma + 1)^2$ is true, when it is true, the key points will be retained, and vice versa.

Generation of SIFT feature descriptor

In SIFT algorithm, in order to ensure the rotation invariance of the key points, it is necessary to assign the main direction to the key points, which is determined by the gradient information of the neighborhood of the key points. The following formula is the determination method of pixel gradient:

$$m(x,y) = \sqrt{[L(x+1,y)-L(x-1,y)]^2+[L(x,y+1)-L(x,y-1)]^2} \quad (16)$$

where m is the gradient modulus value, θ is the gradient direction, and L is the pixel value corresponding to the point. When calculating the main direction of the key points, samples are taken in the circular neighborhood window with the key point as the center and 3σ as the radius, and the gradient information of the pixels in the neighborhood is counted by the histogram. The histogram divides the direction from 0º to 360º into 36 columns, that is, one column per 10 degrees. In the gradient histogram, the peak direction of histogram is the main direction at the key points.

Through the above steps, each key point contains the main direction information, but this information is not enough to make SIFT features have strong invariance. Therefore, it is necessary to construct a feature descriptor with more abundant information through the key points and the pixels around the key points. The process is as follows: First, the coordinate axis is rotated to the main direction of the key point. Then, the neighborhood near the key points is divided into 4 * 4 sub regions, in which each sub region is a rectangular region with a side length of 3σ. Then, the gradient histogram of pixels in each sub region is calculated independently, and the statistical results are distributed to eight directions. Finally, in order to remove the influence of illumination changes, 128 gradient information needs to be normalized to generate a 128 dimensional sift descriptor.

The SIFT description is input into the support vector machine classification function $f(x)$ to classify the ecological water demand information of the estuarine wetland, and complete the remote acquisition of ecological water demand information of estuarine wetland:

$$f(x) = sign\left\{\sum_{i=1}^{n}\alpha_i^* y_i K(x_i,x) + b^*\right\} \quad (17)$$

where α^* and b^* are Lagrange multipliers and $K(x_i, x)$ is Gaussian radial basis kernel function.

EXPERIMENT AND DISCUSSION

In order to verify the overall effectiveness of the design method of remote acquisition system for ecological water demand information of estuarine wetland, the design method needs to be tested. The experimental environment for the test is MatLab language programming environment, and the computer processor is Pentium (R) dual core CPU E5300, processing speed is 2.60GHz, and memory is 2 G. In order to ensure the accuracy of experiment conditions, such as the number of iterations of MatLab software, it is necessary to ensure the consistency of the experiment results.

Taking the data coverage and acquisition efficiency as the test indexes, the design method of remote acquisition system for ecological water demand information of estuarine wetland (Method 1), the design method of information acquisition system based on cloud computing (Method 2), the design method of information acquisition system based on Internet of things (Method 3) and the design method of information acquisition system based on data quality control (Method 4) are adopted to test respectively.

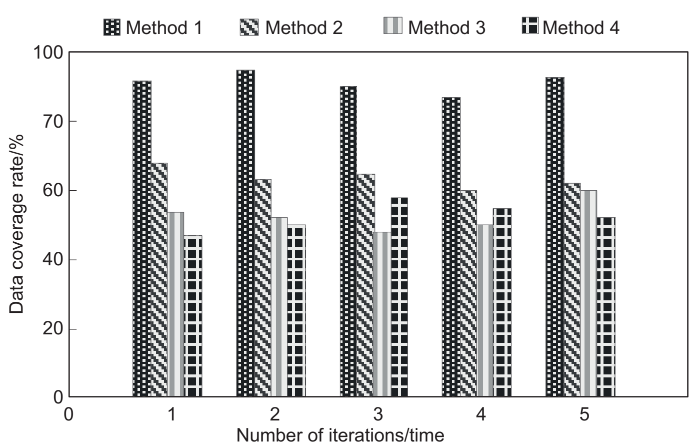

Fig. 9. Data coverage of different methods.

Data coverage

The data coverage of methods 1, 2, 3 and 4, are shown in **figure 9**.

The higher the data coverage, the more comprehensive and complete the ecological water demand information of estuarine wetlands collected by the method. By analyzing the data in **figure 9**, it can be seen that the data coverage of method 1 is higher than that of the other three methods, and its maximum data coverage reaches 95%, while the maximum data coverage of methods 2, 3 and 4 is 68%, 59% and 57% respectively. The test shows that method 1 has high data coverage and high data collection efficiency, because when designing the remote collection system of the estuarine wetland ecological water demand information, method 1 uses WMI and SNMP to collect the information at the management end, polling and collecting the estuarine wetland ecological water demand information, which improves the integrity and comprehensiveness of the information collection.

Data acquisition efficiency

The data acquisition time of methods 1, 2, 3 and 4 are shown in **figure 10**.

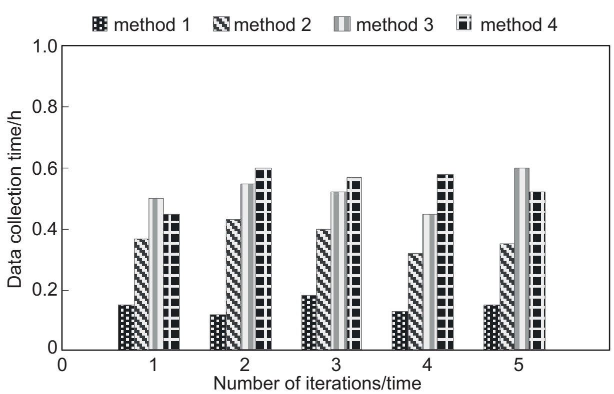

Fig. 10. Data acquisition time of different methods.

According to the analysis of **figure 10**, in multiple iterations, the time taken by method 1 to collect the ecological water demand information of estuarine wetland is less than 0.2 h, while the data collection time of method 2, method 3 and method 4 takes 0.42 h, 0.63 h and 0.61 h at most. From the above data, it can be seen that the data collection time of method 1 is much lower than that of methods 2, 3 and 4. The test shows that method 1 adjusts the polling collection frequency according to the user's requirements and the actual situation, which shortens the time used to collect information. This is because this method clusters the collected information through support vector machine, which can reduce the pressure of data collection caused by more data types and data quantity, and realize the efficient collection of ecological water demand information of estuarine wetlands.

CONCLUSION

At present, the design method of water demand information acquisition system has the problems of low data coverage and low acquisition efficiency. The design method of remote acquisition system for ecological water demand information of estuarine wetlands is proposed. The innovations of this method are as follows:

1) The system adopts the form of distributed deployment, and each management end is responsible for the collection of ecological water demand information of one network segment, which reduces the pressure of the central server.
2) By adjusting the polling collection frequency, the ecological water demand information of estuarine wetland is collected, which shortens the collection time, improves the integrity and comprehensiveness of the collected information, and provides a data basis for the progress of estuarine wetland ecological monitoring.
3) The experimental results show that the data coverage of the proposed method is high, the maximum value is 95%, the data acquisition time is short, and can be maintained within 0.2 h, which verifies the information acquisition effect of the proposed method.

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