RESEARCH ARTICLE

Design of marine biodiversity information resource sharing system based on cloud computing

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Marine biodiversity information resource sharing is a global cooperative mechanism to promote the conservation and sustainable use of marine life through the integration of data. Its main role is to enhance conservation capacity and address challenges such as climate change. Traditional methods of sharing marine biodiversity information resources have drawbacks including low sharing efficiency, low accuracy of resource recommendations, and low security factors. To increase the level of sharing, an optimal design of marine biodiversity information resource sharing system was carried out, and a design method of the system based on cloud computing technology was proposed. The framework of the system was given, and the data exchange module, access statistics module, query browsing module, and user management module were designed and analyzed. The results of the hardware design indicated that the most effective method for extracting statistical information features from marine biodiversity information resources was the use of cloud computing. Thus, an adaptive fusion cluster processing model could be built for marine biodiversity information resources. These could then be used for fuzzy planning and feature mining of marine biodiversity information resources when combined with the association statistical feature detection method. Moreover, by clustering marine biodiversity information resources in the database using the gridding block fusion method, it was possible to create an information storage center management database of marine biodiversity information resources. The results showed that, with this approach, there was a deeper level of marine biodiversity information sharing and better adaptive performance in resource sharing management. There was also better resource adaptive scheduling performance. Compared with the traditional methods, the resource sharing efficiency, safety factor, and information recommendation accuracy of this method were higher, which improved the level of marine biodiversity information resource sharing.

Keywords: cloud computing; marine life; diversity; information resources; sharing; mesh block fusion.

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Introduction

In addition to providing more space for humans to live and grow, marine biodiversity (MBD) is essential to maintaining the health of marine ecosystems. By conserving the oceans, protecting all marine species, and preserving human's common home as humanity, there is a commitment to conserve marine resources to protect MBD [1]. MBD is very high, but it suffers from human destruction and interference. Currently, the world largest open online database of point-based data is the Ocean Biogeographic Information System (OBIS) (https://www.iobis.org/) supplied by Columbia University, Brooklyn, NY, USA, which contains 37 million data of about 120,000 species. Another big database, World Register of Marine Species (WoRMS) (https://www.marinespecies.org/) provided by Vlaams Marine Institute, Oosteroks, Belgium has collected 220,000 species of marine creatures around world. Faced with such a massive amount of data, it is crucial to understand how to realize information resource sharing [2].

The emergence of MBD information resources (MBDIRs) lead to the adoption of intelligent information management systems for the classification and dissemination of biodiversity information resources (BIRs), which also lead to improved efficiency of MBDIRs and optimized management in cloud computing (CC) environments. Luoto *et al*. extracted the characteristics of the large-scale distribution of MBDIR data and designed an MBDIR management and sharing system that was aligned with the method of association information discovery to improve the overall management level of MBDIRs [3]. It was of great importance to conduct a detailed investigation of the sharing technology of MBDIRs. Ye *et al*. investigated MBDIR management methods based on integrated scheduling of MBDIRs and intelligent information processing combined with big data (BD) statistical analysis and fuzzy association rule scheduling methods to perform cloud integration and adaptive scheduling of MBDIRs. This approach enabled the extraction of a fuzzy association rule set, which could then be used to achieve optimal management of MBDIRs [4]. In addition, Jiang *et al*. proposed a method for analyzing the interruption probability of vehicle network information sharing to ensure that vehicles could share real road traffic information. The failure probability of vehicle network information sharing in general and specific highway were analyzed. Closed-form expressions were derived from both scenarios, taking into account specific channel settings. The efficacy of resource and technology integration (RTI) sharing was contingent upon the expression of interrupt probability, and an algorithm was devised to facilitate authentic RTI sharing. The results showed that the proposed method was capable of obtaining vehicle information. However, the efficiency of information sharing was insufficient, and the level of information security was inadequate [5]. Zhang *et al*. designed a marine geographic information sharing platform based on WebGIS. The platform used MapServer open-source platform and WebGIS as the implementation tool, which could provide convenient, effective, and interactive marine information sharing and visualization capabilities, and could improve the interaction and utilization capabilities of marine information in various fields through the internet and LAN. The results demonstrated that, while this approach could provide resource information based on user needs, resource sharing required a lengthy and inefficient process [6]. Wang *et al*. designed a cloud data sharing mechanism based on instant revocation aiming at the security of data sharing characteristics of cloud storage services. A cloud data sharing scheme based on proxy re-encryption mechanism with access authorization function and instant revocation support was proposed. The file revocation list realized instant revocation of user access rights, while the user key table realized binding between user and key the entity. The data exchange process and security were analyzed. The prototype cloud data sharing system based on Hadoop cloud storage platform was implemented by Java technology. The test and analysis results suggested that the effectiveness, security, and reliability of the system could be used as a reference for other cloud data sharing applications based on proxy re-encryption [7].

The MBDIR sharing system is a distributed data resource sharing network based on a local area network (LAN), which establishes a unified information sharing service portal for all units, departments, and users. The system is capable of exchanging data between a data subcenter and a data center, thereby facilitating the provision of distributed information services [8]. At present, there are many problems in the study and protection of MBD. Human activities, global climate change, marine pollution, overfishing, and habitat destruction have posed unprecedented threats to marine ecosystems, leading to an increased risk of species extinction and an imbalance in ecological equilibrium. Furthermore, the limitations of existing research methods and technologies make the monitoring, assessment, and prediction of complex marine ecosystems inadequate, which makes it difficult to achieve comprehensive protection of MBD. In addition, different countries and regions have uneven policies, technologies, and resource allocation for MBD conservation and management, which makes it lack of effective international cooperation mechanisms. This research analyzed and evaluated the health status of ecosystems in different marine regions by integrating multi-source MBD data to reveal the mechanism of human activities on MBD and to propose targeted conservation strategies and management schemes. Considering the shortcomings of traditional technology, an adaptive fusion cluster processing model for MBDIR was developed, which combined the feature mining (FM) and fuzzy scheduling (FS) of MBDIR, adopted the association statistical feature detection (FD) method for processing, and established the management database of the MBDIR information storage center. The research has important theoretical and practical significance for promoting the conservation of MBD. The results would provide important data and decision support for the scientific management and rational use of the global marine ecosystem. Moreover, it would also promote innovation and the development of technical means in related fields and make important contributions to the realization of the goals of sustainable development of the oceans.

Materials and methods

Hardware design of information resource sharing system

The hardware of the data sharing system mainly consisted of data exchange module, access statistics module, data download module, query and browse module, user management module, and other modules (Figure 1). The central node's ontology metadata (OM) described information *via* the web data interface. Each node's metadata information base housed the sub node and the central node. The module had the functions of OM information registration, automatic update, data audit, collection, and delivery log management, and supports the collection and delivery of text, image, multimedia, and spatial data [9]. Among them, the registration function was responsible for monitoring the semantic-based resource and service registration requests sent by each node, and calling the update function to register with the OM information based on the directory service. The registration information was stored as ontology conceptual metadata in the OM information repository, allowing users to retrieve or query it as needed. The automatic update function used semantic-based ontologies. The metadata information base was periodically updated in a dynamic and timely manner.

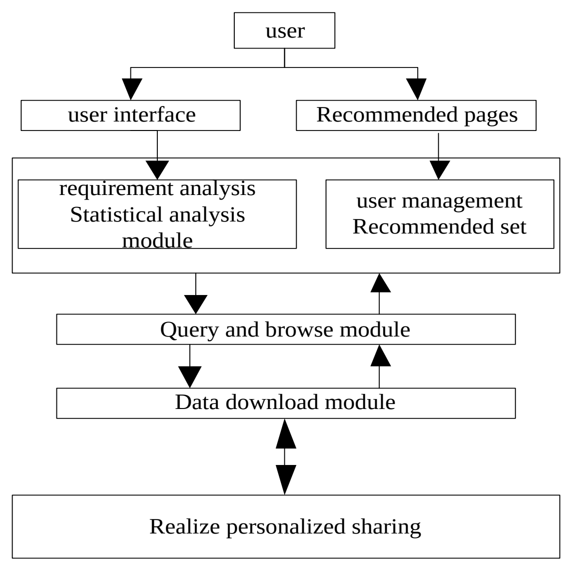

Figure 1. Overall framework of the information system.

The data exchange module provided data on the number of downloads of shared data resources, the frequency of access to data services, and the number of metadata delivered and collected by the relevant units, which could also be

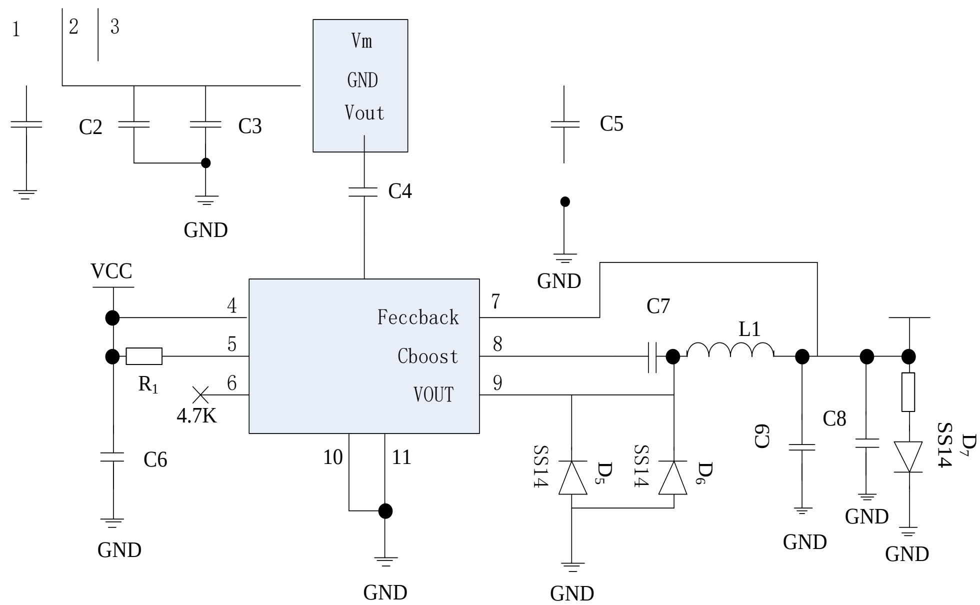

Figure 2. The circuit diagram of the data exchange module.

categorized for statistical analysis and presented graphically, making it easy for users to understand relevant MBD data. Meanwhile, it provided the basis for the administrator to manage the MBDIRs and a semantic-based transparent information retrieval and query service that helped users quickly identify relevant data (Figure 2). In addition, to meet the diverse needs of its users, the module provided intelligent query based on semantic reasoning capabilities and fuzzy search based on the use of multiple keywords. Semantic retrieval emphasized knowledge-based and semantic matching and was capable of performing reasoning tasks according to the reasoning rules combined with the ontology in the ontology knowledge base. Therefore, in the process of MBD information retrieval, the precision rate and recall rate were higher [11]. The system had the functions of providing various types of user identity authentication, authorization management, log recording and could record various information of different types of users with different access interfaces and permissions, while users could register, log out, manage, and modify their personal information. The hardware structure of the CC-based MBDIR sharing system facilitated the preprocessing of resources through the integration of various modules.

Distribution of the MBDIR shared scheduling node and big data analysis

The MBDIR inventory structure model was used as the basis for the directed graph analysis, which enabled the design of the distributed storage structure model of BIR information sharing scheduling (SS) node distribution (Figure 3).

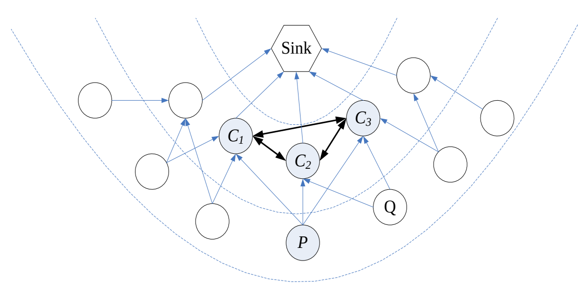

Figure 3. Shared dispatch node distribution model of MBDIRs.

Nodes and edges formed the SS map distribution pattern of MBDIRs. A modeling approach and principal component feature analysis were used to build an adaptive hierarchical scheduling model of BIRs. The datasets of BIR information were classified, and the information was fused and combined with statistical feature distribution to facilitate the construction of the above model. The primitive vector of useful data test sets in MBDIRs was expressed as follows.

$$E_{i,j} = \langle e_1, e_2, \ldots, e_m \rangle \tag{1}$$

To illustrate the main feature decision tree of MBDIR SS, the primary feature of the spatial planning dataset of MBDIRs was designated as $e_i \in \{1,0\}$ and was represented by a quaternion $\left(E_i, E_j, d, t\right)$, where E_i and E_j were the entity of MBDIRs bifurcation nodes, i.e. nodes i and j, d was the sub-empty cluster distribution of MBDIR. $D = \{S_{i,j}(t), T_{i,j}(t), U_{i,j}(t)\}$ was the time required for information interaction during the file SS process. To reduce the time required for MBDIR SS, it was necessary to model the primary characteristics of MBDIR distribution, define the graph model attribute set $S_{i,j}(t)$, and $T_{i,j}(t)$ of MBDIR SS nodes. These represented the ontology distribution concept correlation set of MBDIR sharing, which was calculated as follows.

$$T_{i,j}(t) = \frac{\left|p_{i,j}(t) - \Delta p(t)\right|}{p_{i,j}(t)} \tag{2}$$

The decision-making similarity (correlation) of MBDIRs was expressed as $U_{i,j}(t)$. The following feature vector set was utilized to examine the autocorrelation attribute of MBDIRs sharing.

$$V = \{v_{ij} \mid i = 1, 2, \ldots, c, j = 1, 2, \ldots, s\} \tag{3}$$

The V_i was the correlation analysis measure of MBDIRs.

$$U_{i,j}(t) = \exp\left[-b\left[z_i(t) - z_j(t)\right]^2\right] \tag{4}$$

The similarity measure between the SS nodes of MBDIRs was obtained below.

$$S_{i,j}(t) = \frac{p_{i,j}(t) - sp_{i,j}(t)}{p_{i,j}(t)} \tag{5}$$

where $p_{i,j}(t)$ was the probability of cross distribution of useful features in MBDIRs. $sp_{i,j}(t)$ was the correlation weight of MBDIRs. The fuzzy decision (FD) increment value of MBDIRs sharing a dispatch node was represented by $\Delta p(t)$. Likewise, $z_i(t)$ could be represented as the distribution weight coefficient of MBDIRs that shared a dispatch node. The data collecting and cluster analysis of the SS of MBDIRs had been effectively finished [12]. By using the linear mapping method to construct the balanced control model of MBDIRs, the FD function of the joint BD distribution of MBDIRs under the condition of dual FD was as follows.

$$x(t) = \mathrm{Re}\{a_n(t) e^{-j2\pi f_c \tau_n(t)} s_l(t - \tau_n(t)) e^{-j2\pi f_c t}\} \tag{6}$$

There were P sampling channels for MBDIR sharing. The relational decision function for the MBDIR distribution was as below.

$$\begin{aligned}(\bar{s}, \bar{a}) &= \varphi_2(((s_1, a_1), (\omega_1, a_1')), ((s_2, a_2), (\omega_2, a_2')), \ldots, ((s_n, a_n), \\ &(\omega_n, a_n'))) = \Delta\left(\frac{\sum_{j=1}^{n} \Delta^{-1}(\omega_j, a_j')\Delta^{-1}(s_j, a_j)}{\sum_{j=1}^{n} \Delta^{-1}(\omega_j, a_j')}\right) = \Delta\left(\frac{\sum_{j=1}^{n} \beta_j \beta_j'}{\sum_{j}^{n} \beta_j'}\right)\end{aligned} \tag{7}$$

where $\sum_{j=1}^{n} \omega_j = 1, \bar{s} \in S, \bar{a} \in [-0.5, 0.5]$. Thus, in MBDIRs, the problem of SS of distributed data was reformulated as a binary semantics decision-making problem, more precisely, the semantic index set $E_k \in E(k = 1, 2, \ldots, t)$ of MBDIR distribution. The map model of MBD information cross-scheduling was $I_j \in I(j = 1, 2, \ldots, n)$. The endogenous fusion scheduling method was used to mine MBDIR data for association rules [13].

$$TF(t, c_i) = \frac{P(t \mid c_i)}{\sum_{j \to n} P(t_j \mid c_i)} \tag{8}$$

where t was the statistical characteristic of the current MBDIR data. c_i was the classification property set of MBDIRs in the first category. t_j

was the *j* class property set in the MBDIR database. n was the total classification data in the MBDIR. The cross-compilation control method was employed to facilitate the MBDIR SS, resulting in the acquisition of the differential fusion characteristic quantity as below.

$$J_m(U,V)=\sum_{k=1}^{n}\sum_{i=1}^{c}\mu_{ik}{}^{m}(d_{ik})^2 \tag{9}$$

where *m* was the decision variable limited data set index of BIR information. $(d_{ik})^2$ was the related variable of MBDIR distribution. The decision independent variable of MBDIR was then as follows.

$$(d_{ik})^2=\|x_k-V_i\|^2 \tag{10}$$

$$\sum_{i=1}^{c}\mu_{ik}=1, k=1,2,\mathrm{L}\ ,n \tag{11}$$

Thus, the MBDIRs was constructed and combined with CC environment to perform MBDIR sharing and salience feature analysis. The resource SS was carried out in accordance with the forward association feature analysis method.

MBDIR sharing optimization

A method for MBDIRs with shared systems based on CC technology was designed [14]. Associative statistical FD was used for the extraction of FS and MBDIR features.

$$\mu_{ik}=1\Big/\sum_{j=1}^{c}\left(d_{ik}\big/d_{jk}\right)^{\frac{2}{m-1}} \tag{12}$$

$$V_i=\sum_{k=1}^{m}(\mu_{ik})^m x_k\Big/\sum_{k=1}^{n}(\mu_{ik})^m \tag{13}$$

The CC method was utilized for the statistical information feature extraction of MBDIRs in compliance with the previously specified constraint parameter index system. The total categories of MBDIRs was m, and the mutual information characteristic was used to express the concentration of MBDIRs data t in c_i class, which could be calculated as follows.

$$\log\frac{P(d\mid t,c_i)}{\sum_{i\to m}P(d\mid t,c_i)}=\log\frac{P(d\mid t,c_i)}{P(d\mid t)}=CON(t,c_i) \tag{14}$$

The set $\bar{d}_i$ = $\{x_{f1}, x_{f2}, \ldots, x_{fr}\}^T$ expressed the statistical feature vector of MBDIR storage area d_i reflected by MBDIRs. Combining with fuzzy association rule scheduling method, the autocorrelation feature matching of MBDIRs was obtained as below.

$$l_{d_{ij}\to c_x}=\left(\frac{\sum_{v=0}^{|c_x|}\mathrm{cosin}_{ij\to x}(d_{ij},d_{xv})}{|c_x|}\right)^{-1} \tag{15}$$

where $\mathrm{cosin}_{ij\to x}(d_{ij},d_{xv})$ was the fusion clustering (FC) feature collection of MBDIRs. The feature mapping formula of MBDIRs was normalized by using the sigmoid function as follows.

$$s_i=sigmoid(Md_i)=\frac{1}{1+e^{-a(Md_i+b)}} \tag{16}$$

The directional distribution vector set *si* of the SS set and MBDIR was now obtained by optimizing the association data vector d_i of the MBDIRs using a fuzzy association constraint matrix *M*. *A* and *B* stood for adjustable coefficients in this situation. The fuzzy center vector v_i, $v_i=((w_1, t_1), (w_2, t_2), \ldots(w_j, t_j))$, of adaptive FC of MBDIRs was determined as below.

$$\mathrm{S(i,j)}=\frac{\sum_{u\in U_{ij}}(V_{u,i}-3)(V_{u,j}-3)}{\sqrt{\sum_{u\in U_{ij}}(V_{u,i}-\overline{V}_{.i})^2}\sqrt{\sum_{u\in U_{ij}}(V_{u,j}-\overline{V}_{.j})^2}} \tag{17}$$

Among the aforementioned models, the priority clustering model of MBDIR SS data was of particular importance.

$$V_{u,i}=\frac{D_i^-}{D_i^++D_i^-},\overline{V_{.j}}=\frac{R_i^+}{R_i^++R_i^-} \tag{18}$$

An adaptive fusion cluster processing model of MBDIRs was developed. In addition, to increase the degree of MBDIR sharing, FS and FM of MBDIRs were performed using an association statistical FD approach [15]. CC was utilized to retrieve the association rule distribution parameter set *Y* of MBDIR information in compliance with association rule requirements. Moreover, fuzzy C-means clustering center vector $C(Y)$ was applied to derive the similarity distribution mapping function of MBDIR data in the setting of a CC environment.

$$Sim(X,Y) = Cos(X,Y) = \frac{C(X)\cdot C(Y)}{|C(X)|\cdot|C(Y)|} \tag{19}$$

A database for managing information storage center databases for MBDIRs had been established, and a grid block fusion method was used for clustering MBDIRs within the database. The adaptive update formula for MBDIR SS was as follows.

$$R_d^i(t+1) = \min\{R_s, \max\{0, R_d^i(t) + \beta(n_t - |N_i(t)|)\}\} \tag{20}$$

$$N_i(t) = \{j : \| x_j(t) - x_i(t) \| < R_d^i ; l_i(t) < l_j(t)\} \tag{21}$$

Based on the FD classification model, the adaptive scheduling of MBDIR sharing was obtained as below.

$$x_i(t) = x_i(t-1) + s\left(\frac{x_j(t-1) - x_i(t-1)}{\| x_j(t-1) - x_i(t-1) \|}\right) \tag{22}$$

The distributed database of MBDIR sharing was designed using an autoregressive moving average model. Under the standard normal distribution and CC technology, the cluster statistical characteristic of MBDIR sharing was expressed as follows.

$$p(Q_s) = \frac{1}{\sqrt{2\pi}\sigma_s}\exp\left[-\frac{\left(Q_s - \langle Q_s\rangle\right)^2}{2\sigma_s^{\,2}}\right] \tag{23}$$

$$\int_{-\infty}^{\infty} p(Q_s)\,dQ_s = 1 \tag{24}$$

The data sharing process was performed according to the optimized classification model of MBDIRs sharing, which included the construction of probability confidence intervals and rejection intervals to enable the effective management of data sharing and classification through the integration of CC technology. The information sharing flow chart was shown in Figure 4.

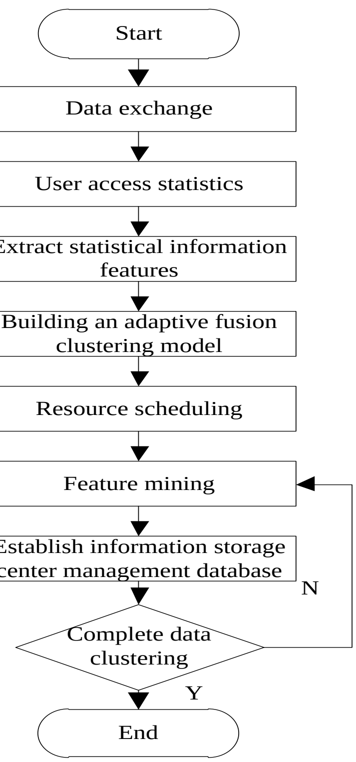

Figure 4. The flow chart of information sharing.

To evaluate the effectiveness of this methodology in facilitating MBDIR SS, a series of experimental analyses were conducted using Matlab simulation software (MathWorks, Natick, Massachusetts, USA). The algorithmic design of the MBDIR sharing algorithm was developed. The marine resource data selected for this study were located at latitudes of about -5° to -10° (south latitude) and longitudes of about 140° to 150° (east longitude). $B = 1000$ Hz was the first check

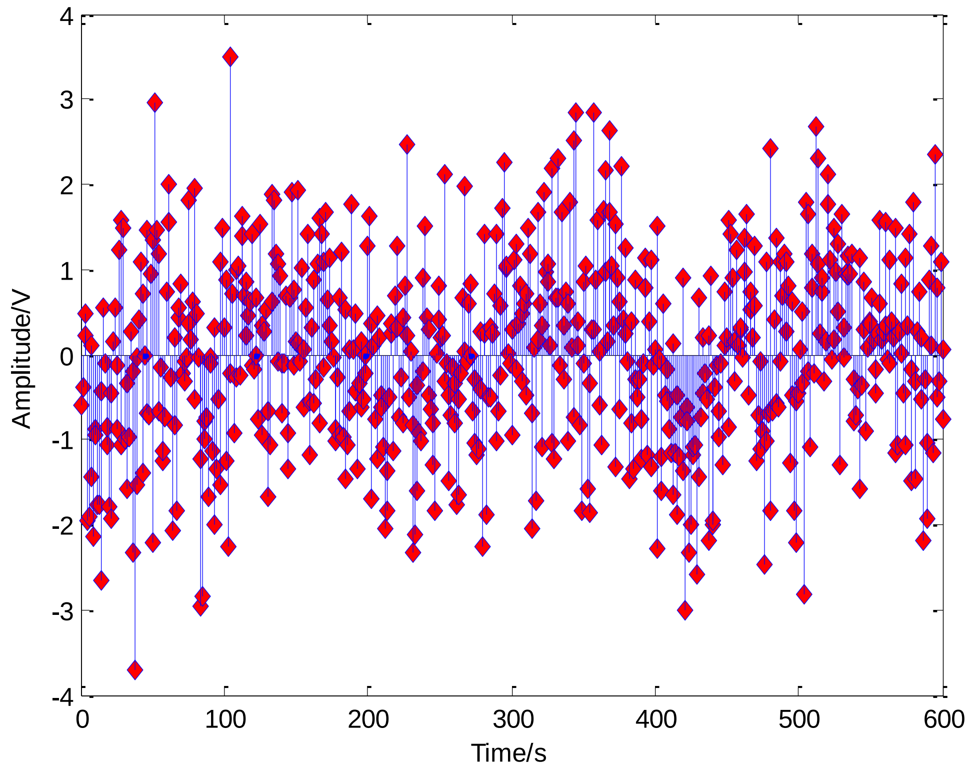

Figure 5. Big data distribution of MBDIRs.

frequency for MBDIR sharing BD. The MBDIR correlation rule was 400, the feature space's information embedding dimension was m = 40, the BIR's sampling time delay was D = 30 ms, the MBDIR adaptive scheduling weight was 0.9, and the fuzzy correlation coefficient was $K = 1.6, 1, 0.75, 0.35, 0.2, 0.1$. The MBD information sharing performance test was described as follows.

$$RMSE(\bar{x}_k) = \sqrt{\frac{1}{N_{MC}} \sum_{i=1}^{N_{MC}} (x_k^i - \bar{x}_k)^2} \quad (25)$$

where N_{MC} was the MBDIR samples. x_k^i was the original sample value of MBDIR sharing. and $\bar{x}_k$ represented the mean of MBDIR sharing.

Verification of proposed system

To fully verify the comprehensiveness and effectiveness of the design system in this study, the efficiency of resource sharing, the security of resource sharing, and the accuracy of resource recommendation were selected as comparative indicators. The respective results were obtained and evaluated through the comparative analysis of the proposed system with reference systems designed by Jiang *et al*. and Zhang *et al*. [5, 6].

Results

The dataset of MBDIRs obtained through the original MBDIR BD distribution model was employed as the basis for calculating the FS and FM of MBDIRs, which was achieved by using the association statistical FD method to facilitate the establishment of an information storage center management database for MBDIRs (Figure 5). The results showed that MBDIRs shared by using this method had better clustering and improved level of sharing (Figure 6). The comparative results of information recommendation error rates of different methods showed that, before 40 iterations, the proposed system did not have any noticeable advantages over the reference systems. However, after reaching 40 iterations, the error rate of resource push was significantly lower than that of the previous reported reference systems, indicating that the proposed system exhibited a high degree of accuracy in resource push and could ensure users access to more reliable overall information (Figure 7).

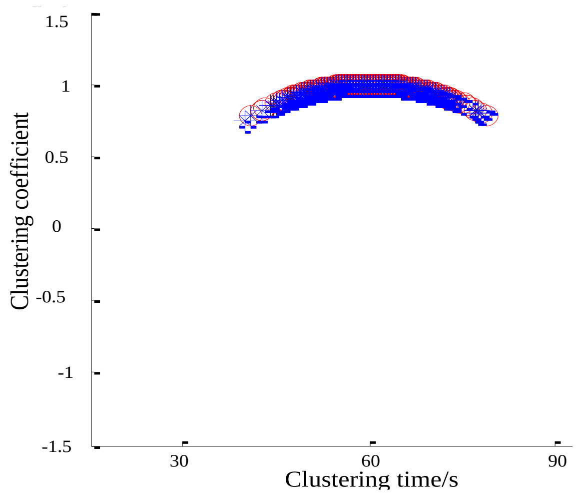

Figure 6. Clustering results of MBDIRs.

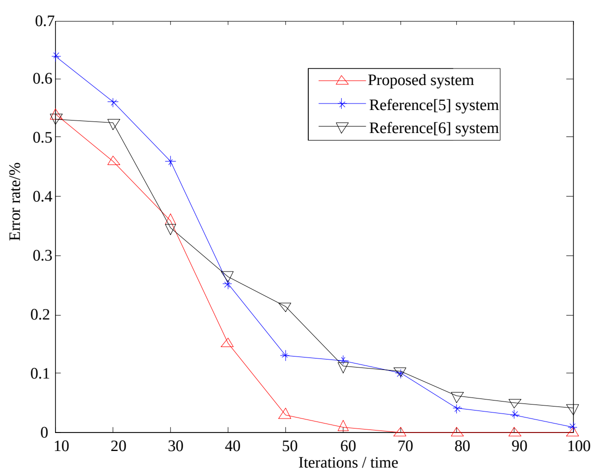

Figure 7. Comparison of information recommendation error rates of different methods.

The comparative results of the resource push efficiency of different methods demonstrated that all three compared systems showed a trend of initial increase followed by a decline. However, the resource sharing efficiency of the proposed system was higher than that of the other two reference systems with a maximum value of nearly 75% (Figure 8). Since an adaptive hierarchical planning model of BIR information was constructed based on the method of feature analysis and modeling in the design process of this system, the efficiency of this proposed system was also investigated. The system conjunct with statistical feature distribution was used to classify and fuse the dataset of BIR information, thereby reducing the time required for resource sharing.

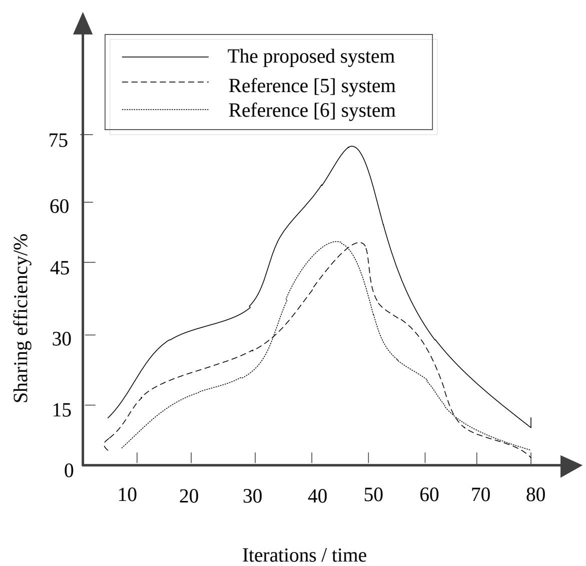

Figure 8. Comparison of resource sharing efficiency of different systems.

The safety factor of shared information was used as the comparative index for comparative verification to further confirm the efficacy of the proposed system. The results showed that the resource sharing security factor in this system was consistently higher than that observed in the reference systems, which indicated that users could use the MBDIRs in the sharing system with a reasonable level of security (Figure 9). This proposed system could effectively guarantee the security of user information, reduce network risk, and have higher applicability.

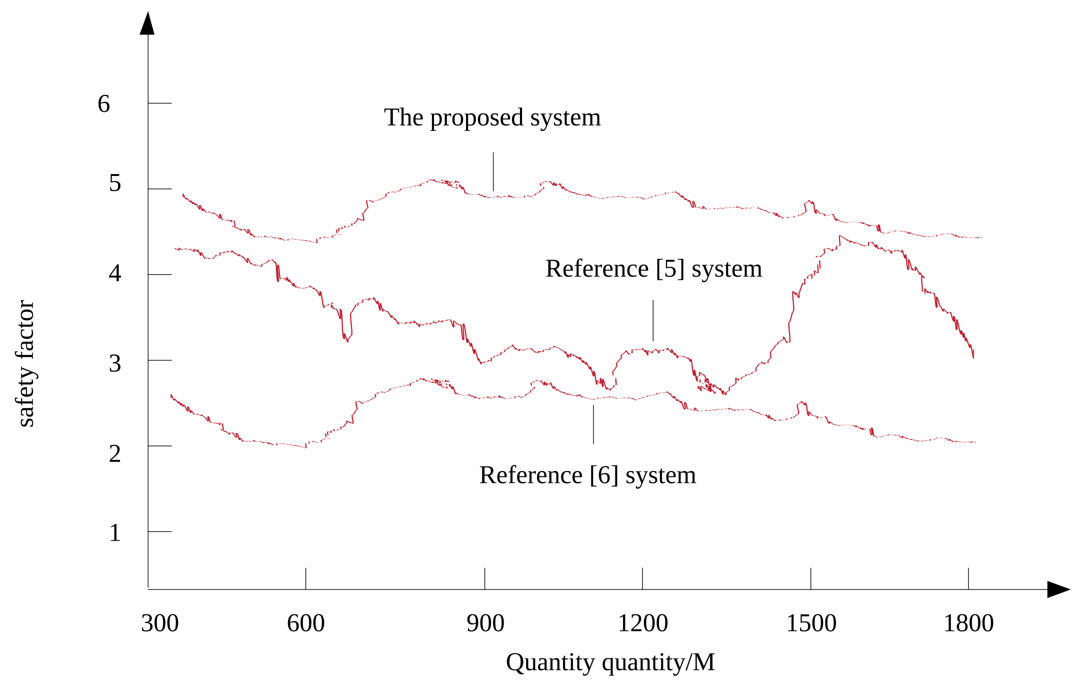

Figure 9. Comparison of safety factors of resource sharing under different methods.

Discussion

MBDIRs are constantly changing. Nowadays, most information resources are acquired by information resource managers who store information statically in a particular information resource storage device. The Internet Web interface is used by users to obtain information. However, this form is not sufficient to provide users with comprehensive information. The limited scope in available information resources, less innovative contents in the service, and extremely low efficiency of the service ultimately lead to user fatigue. Considering these issues, this study proposed an adaptive FC processing model of MBDIRs under the aegis of CC technology. The correlation statistical FD method was applied to facilitate the FC, thereby enabling the planning and mining of MBDIRs characteristics. Furthermore, a management database was established to store the MBDIRs information, and the grid block fusion method was used to cluster the MBDIRs in the database, thereby facilitating the sharing of marine resources. The results showed that the system users could access marine information resources more efficiently with high security factors, which confirmed that the proposed system had high applicability. In a CC environment, the optimization of MBDIRs management design involved the extraction of MBDIRs BD distribution characteristics, which was achieved by combining the MBDIRs management and sharing design with the association feature information detection and fuzzy cluster analysis method. Those approaches were based on the CC technology MBDIRs sharing system design method. The statistical information features of MBDIRs were extracted using the CC method, and an adaptive fusion cluster processing model of MBDIRs was constructed. The FD method was used to perform the FS and FM of MBDIRs, and an information storage center management database of MBDIRs was established. The gridding block fusion method was used to cluster the MBDIRs in the database. The results showed that the method exhibited superior performance and lower error rates in sharing and classifying MBD information. This proposed system could provide a more comprehensive information resource retrieval, which had certain requirements for the accuracy of information resources. Users should be able to get all the retrieval results of the required information through the port, reflecting the comprehensive and diverse information resources of the distributed virtual organization.

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