Future Generation Computer Systems 128 (2022) 443–450

Contents lists available at ScienceDirect

Future Generation Computer Systems

journal homepage: www.elsevier.com/locate/fgcs

Application of new digital signal processing technology based on distributed cloud computing in electronic information engineering

Hu Sheng *, Xiaodong Qi

School of Electrical and Information Engineering, Dalian Jiaotong University, Dalian 116028, China

ARTICLE INFO

Article history:
Received 18 May 2021
Received in revised form 11 October 2021
Accepted 26 October 2021
Available online 29 October 2021

Keywords:
Electronic information engineering
Distributed cloud computing
Digital signal processing
Proportional integral derivative control

ABSTRACT

The traditional digital signal processing technology in electronic information engineering has many issues, such as redundant data, low data utilization and so on. To end these issues, this paper proposed a new digital signal processing technology based on distributed cloud computing in electronic information engineering. From the data collection, data analysis, data classification, data mining, effective information storage and other aspects of conventional digital signal, through relying on distributed cloud computing method and intelligent gradient tracking algorithms to achieve efficient processing of digital signal, Proportional Integral Derivative (PID) control strategy is used to evaluate the intelligence degree of each link in the digital signal processing technology. This method can realize the adaptive regulation of data collection and storage in the process of digital signal processing, and realize diversified analysis and intelligent matching. Through the distributed cloud computing to achieve the rapid control of the system storage module, so that the database can improve the work efficiency, reduce the power consumption cost of the system in the process of data operation, and improve the efficiency of digital signal processing. The experimental results show that the digital signal processing system based on distributed cloud computing and intelligent gradient tracking algorithms has the advantages of high computing efficiency, high accuracy and good stability.

1. Introduction

At present, most of the electronic information engineering related enterprises have problems of low efficiency in the process of collecting and storing digital signal data generated daily. The main reason is that the underlying calculation methods and calculation strategies are difficult to achieve major breakthroughs [1]. With the development of intelligent technology, digital signal processing technology and distributed cloud computing technology have also been rapidly developed and constructed, and in the processing of massive digital signal data, the advantages of distributed cloud computing have become more obvious. They also provide opportunities to improve the big data collection and storage technology. Efficiency and effective data extraction have become important indicators for judging the advanced level of big data analysis systems [2]. Therefore, how to establish an efficient and intelligent digital signal processing system through distributed cloud computing technology has become an important development in the future [3].

Based on this above background, this paper combines practical applications to deal with the problems of redundant data and low data utilization in traditional digital signal processing technology in electronic information engineering. It studies digital signal processing based on distributed cloud computing and Proportional Integral Derivative (PID) control strategies. This work is mainly divided into three parts. The first part introduces the status of research on digital signal related data collection, processing and storage technology and distributed cloud computing. The second part builds a digital signal processing system based on distributed cloud computing based on the commonly used big data processing and storage technology, combined with random matrix, and through PID control strategy, builds a digital signal processing technology system and influences its efficiency. The third part tests the practical application effect of the digital signal processing system constructed in this paper, evaluates the efficiency and reliability of the system through different industry data, and draws conclusions and analyzes the shortcomings.

Compared with the problem of low database utilization in digital signal processing in traditional electronic information engineering, the innovation of this paper is to make full use of each relevant data information source and characteristic information in the database to realize the unification of the data collection system management, using PID control factors to quantitatively describe the degree of similarity between comparison columns (different types of data sets) and reference columns (standard

* Corresponding author.
E-mail address: hu.sheng@djtu.edu.cn (H. Sheng).

https://doi.org/10.1016/j.future.2021.10.032

valid data sets known or through screening rules) and the degree of agreement with expected indicators (potentially valid data), to complete the ranking of the degree of influence on the efficiency of the digital signal processing system with quantitative indicators, which can efficiently achieve optimized control of different digital signal processing processes through different control methods, and is verified by its application in electronic information engineering.

2. Related work

Johnston, et al. have made in-depth innovations from the level of digital signal processing methods, hoping for new breakthroughs [4]. Up to now, many industries produce a large amount of digital signal data every day. How to extract, collect and store effective data information through differentiated processing of digital signals in these redundant data volumes has become the current issue [5]. From the perspective of data information theory, Demir, et al. proposed that attention should be paid to the development of online cloud database network groups, to strengthen the construction and management of effective data collection station systems, and to enhance the awareness and attention of the underlying technology of distributed cloud computing. The ability of relevant engineers to study the architecture of enterprise digital signal processing systems should be improved [6]. Castanheira, et al. found that most digital signal processing systems still follow the traditional stack-based thinking in control methods, ignoring innovations in intelligent perception methods [7]. Blinder, et al. used the basic data acquisition, storage, and applied different data as the main functions of the digital signal-related data collection and control system, and the efficiency in high-precision control and data collaboration is very low [8]. Yadav, et al. combined power generation control theory, PID intelligent control system and other related theories to improve the digital signal processing technology commonly used in power stations, and constructed a particle swarm distributed computing algorithm based on traditional power generation control systems [9]. Muñoz, et al. used the theory of the underlying technical rules of cloud computing to explain the theoretical feasibility and practical significance of digital signal processing in the electronic information process industry, and through design experiments proved that the improved algorithm has better data processing efficiency [10]. Based on the functional theory and the characteristics of data collection stations, Zhang, et al. proposed a hierarchical calculation method, through the research and analysis of the structural disparity of the data information vector direction and vector length generated in different data collection processes [11]. In order to improve the computational efficiency of big data collection and storage technology, as well as the stability and security of the overall system in the calculation process, Boriga, et al. proposed a new digital signal processing system based on hyperchaotic mapping [12]. Wübben, et al. found that cloud computing technology has obvious advantages in processing digital signals, and proposed a digital signal processing system based on cloud computing systems, and verified the effectiveness of the system through experiments [13]. Sana, et al. found that in the process of processing related digital signals in the field of electronic information engineering, conventional methods have large data errors and instability, so they proposed a digital signal processing method based on the total variation method. Experimental results show that this method can effectively improve the processing speed and accuracy of digital signals [14].

In summary, it can be seen that the current digital signal-related data collection and storage system has the issues with high data redundancy and low calculation efficiency in the process of processing the data source [15]. Most of the existing digital signal processing methods do not involve intelligent algorithms combined with distributed cloud computing technology, and there are few innovative methods from the perspective of improving database utilization [16]. On the other hand, although a lot of basic researches in digital signal processing technology have been done, there are relatively few results in the integrated system of big data collection and storage, and there is no construction of a robust digital signal processing model [17]. Therefore, it is very important to carry out the application research of digital signal processing technology based on distributed cloud computing strategy in electronic information engineering.

3. Framework of digital signal processing system based on distributed cloud computing

3.1. Application foundation of distributed cloud computing in digital signal processing

Cloud computing is a new innovation in the information age after the Internet and computer. Cloud computing is a big leap in the information age [18]. Generally speaking, although cloud computing has many meanings, generally speaking, the basic meaning of cloud computing is consistent, that is, cloud computing has strong scalability and needs, and can provide users with a new experience [19]. The conventional method of distributed cloud computing is shown in Fig. 1. The core of cloud computing is to coordinate a lot of computer resources together. Therefore, users can obtain unlimited resources through the network, and the resources obtained are not limited by time and space [20]. Distributed cloud computing is different from conventional algorithms, and it is a better multi resource control and computing strategy. At present, cloud computing technology has been well applied in many engineering fields, such as traditional industrial production, electronic information engineering, control engineering, Internet of things control, traffic data analysis, image processing and precision control of national defense aerospace equipment [21]. At present, most of the cloud computing is in the Internet industry related to digital signal processing. In the efficient collaborative processing system for multi-user massive data, most of the Internet business companies are based on distributed cloud computing technology [22]. The purpose of distributed cloud computing is to provide effective approximate algorithm and optimal computing strategy for high-dimensional problems with large amount of data, and improve the optimization efficiency of the overall system and the utilization of storage resources [23]. On the other hand, the digital signal processing problem in big data analysis, not only integrates the methods and skills of combinatorics, distributed cloud computing, linear programming and algorithm theory, but also realizes the point-to-point solution strategy through cloud computing technology in the whole chain from data source to problem solution, Therefore, the application of distributed cloud computing to digital signal processing in electronic information engineering has obvious advantages in processing speed, data storage and feature analysis.

3.2. Construction of digital signal processing system framework

In the process of constructing the digital signal processing system based on distributed cloud computing, the distributed computing factor based on local adaptive is selected, four characteristic parameters related to the efficiency of big data processing and effective data storage are selected, and a high efficiency and high intelligence digital signal processing system are designed. The system can realize the unified management of massive data sources.

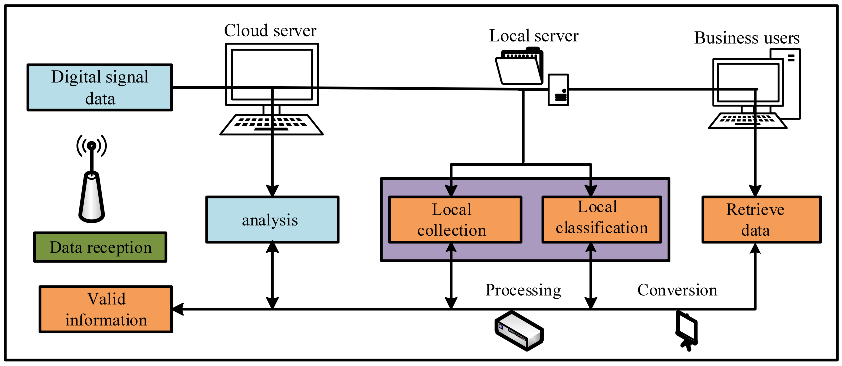


Fig. 1. The conventional approach to distributed cloud computing.

Firstly, according to the solving objectives and screening rules in the process of distributed cloud computing, the local differences between dynamic digital signal related data are analyzed, and then the PID control algorithm is used for intelligent regulation to realize the feedback regulation and intelligent control of digital signal processing system.

Secondly, after the completion of the above links, according to the collection process of big data resources, the vector difference, matrix difference and other different characteristic description values of different data eigenvalues and structural characteristics of the data itself are applied to the intelligent optimization processing and deep data information mining process based on distributed cloud computing, so as to realize the analysis of different data source information Hierarchical division and precise control. For example, if digital signal data can be divided into 34 data sets after analysis and processing, the data processing process of distributed cloud computing is shown in Fig. 2.

Finally, through the distributed cloud computing in the digital signal processing system of different digital signal data analysis, redundant data elimination, effective information extraction, data classification and storage strategy, so as to realize the massive digital signal data according to the degree of similarity to carry on the high classification, realize the collection of different data, information mining and feature extraction. When the effective information is accidentally removed or the invalid information is stored in the cloud system, the PID control strategy will be used to realize the regulation of data analysis and storage system according to the known processing requirements, so as to complete the functions of massive data collection, feature analysis, data classification, effective information extraction, multi data collaborative analysis and digital signal processing. The integral frame structure is shown in Fig. 3.

3.3. The working process of massive digital signal processing in digital signal processing system

In this digital signal processing system, the service types of distributed cloud computing can be divided into three categories, namely infrastructure as a service (IAAs), platform as a service (PAAS) and software as a service (SaaS) [23]. These three kinds of cloud computing services are sometimes called cloud computing stack, because they build the stack and they are located on top of each other. Therefore, enterprises can choose the appropriate service type among the three methods according to their existing digital signal processing system conditions and the needs of data processing in enterprise business. Taking the digital signal in the field of electronic information engineering as an example, its basic working process is as follows:

In the first step, in the process of big data analysis and effective digital signal processing, it is found that in the working process of conventional data analysis system, due to the setting deviation of dynamic control link, there are problems of poor system response and robustness in the process of data collection and storage, Combined with the control information fusion strategy based on the traditional data collection and digital signal analysis, in the process of distributed cloud computing, the wavelet neural network control algorithm is used for reference, and the random data eigenvector generated in the cloud database of big data analysis and storage system is taken as the core, through hierarchical closed-loop regulation, the problem of slow response in the process of digital signal collection and storage is solved.

In the second step, in order to solve the problems of low cooperation efficiency and slow data query speed in the process of collecting, processing and classifying massive digital signal data in distributed cloud computing, this study combines the digital signal processing ideas based on neural network algorithm and particle swarm optimization algorithm, and simulates the "multiple neural node calculation rules" in the process of "neural network" modeling and rendering, the efficiency evaluation basis of digital signal processing rules is constructed, and the effectiveness of the method is tested by simulation. The results show that the formulation of the strategy can effectively improve the collaborative work efficiency of cloud computing in the process of massive data collection and storage, and can effectively solve the computational complexity problem of cloud computing in the process of big data collection and storage.

In the third step, when the digital signal processing system analyzes different data sets, its data discrimination rules will attribute the unknown data information to the same data cluster group according to the corresponding eigenvalues. When the data eigenvalues of any two data cluster groups are different, it means that the characteristic information of the two types of data is greatly different, At this time, PID control strategy will play a role, the two types of data will be automatically classified, automatically adjusted to steady state, until the next group of data into the system, and compared with the next data eigenvalue. The simulation results are shown in Fig. 4.

It can be seen from Fig. 4 that in the above three sets of data, as the number of data analysis increases, the corresponding analysis factors change laws differently. Among them, the two sets of data show a gradual increase and then gradually decrease to 0. As a result, the upward trend and downward trend are similar. This is because for different data types, when the data characteristic values of any two data cluster groups are not the same, when the PID strategy is used for analysis, the corresponding data operation returns some information. The times are different, so the quantitative values corresponding to the analysis factors are different.

When distributed cloud computing is used to analyze and solve massive data sets, the selection of feature vector y is limited

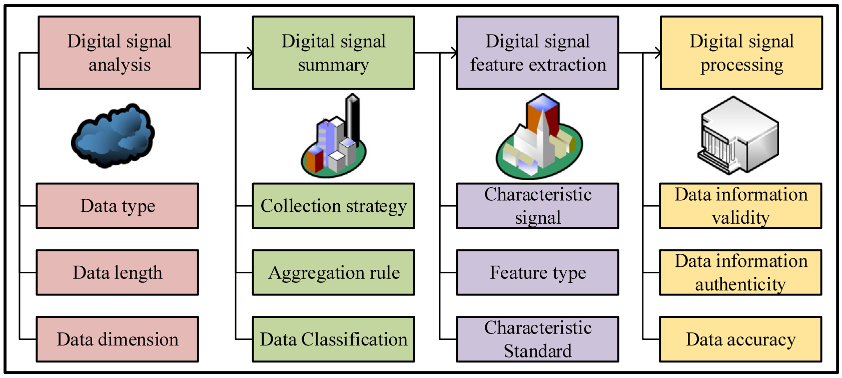


Fig. 2. Distributed cloud computing's data processing process.

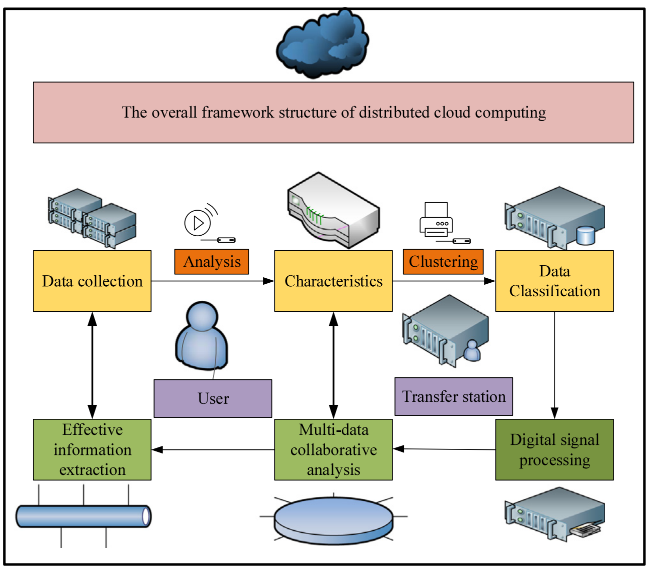


Fig. 3. The overall framework structure of distributed cloud computing.

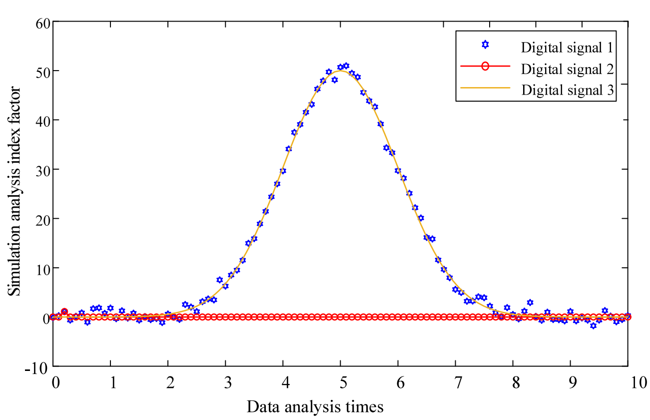


Fig. 4. Simulation analysis results under this model.

by stability, and its y size depends on the size of $|\lambda|$, the basic selection strategies are as follows:

$$y_{n+1} = y_n + \frac{f(x_n, y_n)}{h} \tag{1}$$

Where y is the eigenvector and $f(x_n, y_n)$ is the discriminant function. h is the characteristic factor, h should satisfy $|1 + h\lambda| < 1$, then y is absolutely stable, so the equation is derived:

$$\frac{dy}{dx} = -2\frac{y + x - 1}{x + 1} \tag{2}$$

There must be $h < 1$. The equation is transformed to get the result:

$$\frac{dy}{dx} = -200\frac{y + y^2 - x}{x^2 + x + 1} \tag{3}$$

The selected h must be very small to meet the $h < 1/100$, in order to ensure the absolute stability requirements.

For initial value problems of nonlinear ordinary differential equations:

$$\frac{dy}{dx} = \frac{f(x, y)}{f'(x - 1, y - 1)} \tag{4}$$

$$y(a) = \frac{y_0}{f'(x - 1, y - 1)} \tag{5}$$

If the initial value problem is stable, that is $\frac{\partial x}{\partial y} < 0$. When Euler method is used for numerical solution, h should satisfy $\left|1 + \frac{\partial f}{\partial y}h\right| < 1$, if $M = \max\left|\frac{\partial f}{\partial y}\right|$, h should satisfy $h < \frac{2}{M}$.

Next, in the process of collecting big data, the differential evolution strategy of distributed cloud computing will first randomly select these three individuals with different characteristics when it carries out local analysis operation inside the data set. Among them, different data types will be obtained under different collection strategies. In order to extract the features of different types of data and analyze the effective data, it is necessary to carry out local correlation test and non local test on these data. In the process of data collection, two-phase calculation method can be used, as shown in formula (7), where j_{rand} is represented by a random integer between 0 and N, and CR represents the data feature operator.

$$x_{ij} = x_j^l + rand(0, 1)\left(x_j^u - x_j^l\right)(i = 1, 2, \ldots, NP, j \approx 1, 2, \ldots, D) \tag{6}$$

$$u_{i,j,G+1} = \begin{cases} v_{i,j,G+1}, if\ \left(rand_j(0, 1) <= CR, or, j = j_{rand}\right) \\ x_{i,j,G+1}, else \end{cases} \tag{7}$$

The whole process of simulation results is shown in Fig. 5.

It can be seen from Fig. 5 that for the three different types of signal data sets, as the number of data feature analysis increases, the corresponding quantitative indicators of the signal analysis results show a gradually increasing law, but for different signals, the change trend of the data group is different. This is because in the process of digital signal processing in distributed cloud computing, due to the setting deviation of the dynamic control link, there are different degrees in the process of analyzing the characteristics of the digital signal.

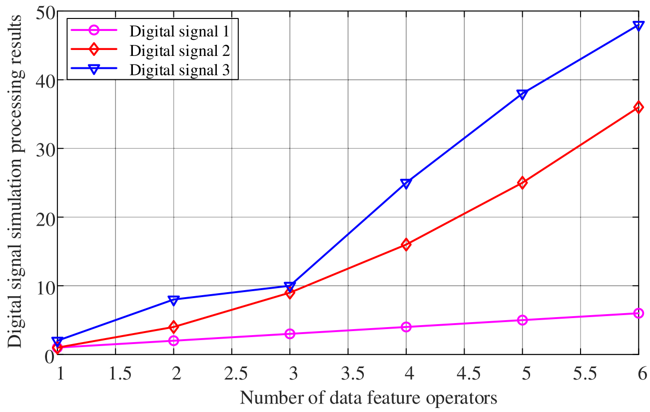


Fig. 5. Overall calculation simulation results.

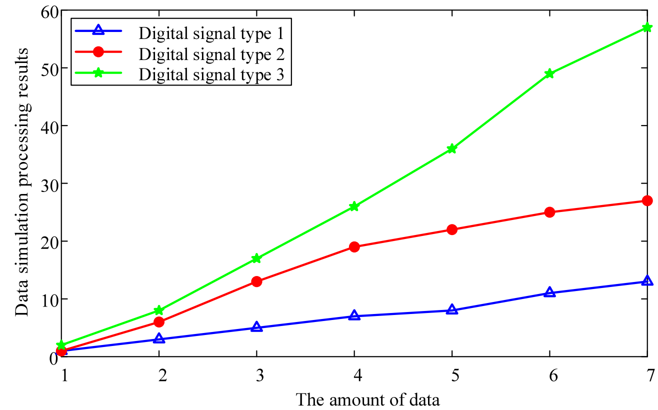


Fig. 6. Simulation results of valid data and information in digital signals.

3.4. Implementation steps of effective information analysis and cloud processing in digital signal

In this research, in order to better quantify the effectiveness and feasibility of the digital signal processing model proposed by this research based on distributed cloud computing, it is necessary to make application condition assumptions for the digital signal processing model proposed by this research, and then combine The expected final goal is to perform feedback-style quantitative characterization and disturbance error analysis, so as to realize the high-efficiency and intelligent processing of adaptive digital signals based on application condition assumptions. The hypothesis set by this research is that the dimensions of all collected electronic information are the same (the highest dimension does not exceed 10 dimensions), and the selected quantitative evaluation standards are consistent with the mainstream evaluation standards in the current research, including the degree of error analysis and corresponding speed, calculation time, etc.

First, the effective information collection strategy should be determined. In the process of digital signal data analysis and processing by distributed cloud computing, the distributed computing rules used in this paper are sparse processing for different data sources in big data. By using Gaussian random matrix, the information represented by multiple data in each digital signal set source is matrix operated to realize the feature extraction of effective information. Then, it is stored in a matrix far less than the original data. The corresponding vector data is iteratively processed, and the vector represented by a steady-state data collection rule is used as the basic criterion. The minimum vector corresponding to data representativeness and characteristic analysis matrix is selected as the basis of secondary control judgment (for data with high similarity in data types, the vector represented by it can be approximately converted to the corresponding numerical level, and the corresponding numerical level can be directly judged). In this way, the time required for the collection process of data from different sources is greatly reduced, and it greatly improves the extraction efficiency and calculation efficiency of the effective data and information in the digital signal. The simulation results are shown in Fig. 6.

Next, the effective data in the digital signal is classified. In the process of classifying different data, in order to evaluate the best classification processing scheme under the distributed cloud computing mode, the distributed cloud computing to convert the data of different digital signal types will be used. The optimal value index in this process can classify and evaluate the classification efficiency and control error rate of different data collection and storage processes, and then perform secondary operation on the feature vector of the core database commonly used by the automatic classification module in this digital signal processing system through the distributed cloud computing to achieve the third feedback control and update of the classified data information, so as to ensure the accurate classification of the data processing process in the working process of the digital signal processing system based on the distributed cloud computing method. The data analysis and processing results are shown in Fig. 7. It can be seen from Fig. 7 that with the increase of the number of simulations, the three sets of data all show the same change law, that is, they all show the gradual increase law of the linear function type.

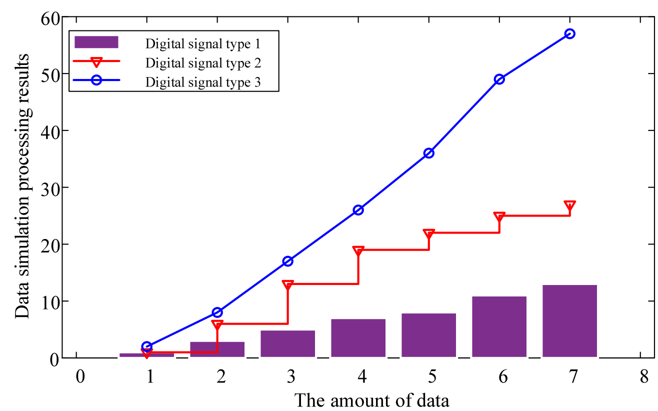


Fig. 7. Simulation analysis results of accurate classification processing.

Third, the effective data is stored in the cloud. In this digital signal processing system, when distributed cloud computing technology is facing a variety of data, it will first process the data source closest to it. After processing the cloud storage, distributed cloud computing technology has begun to play its role, so as to play the function of computing while storing, so that the digital signal processing system can be used in the process of working. The data collection and storage functions are relatively independent. When several times of this cycle work, the PID control strategy of the digital signal processing system will make the optimal storage scheme according to the control state of all data, and automatically store according to the guidance of the scheme.

Finally, the biggest feature and advantage of the digital signal processing system based on distributed cloud computing algorithm described in this paper is that the low correlation between data will not lead to the inefficiency of the whole system operation in the process of processing the massive data of different

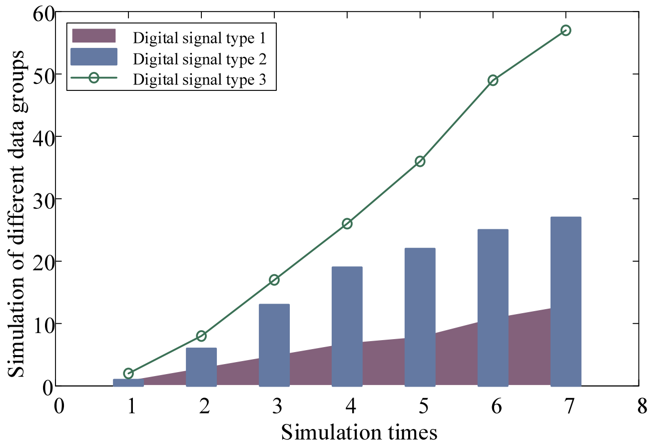


Fig. 8. Simulation results for different data groups.

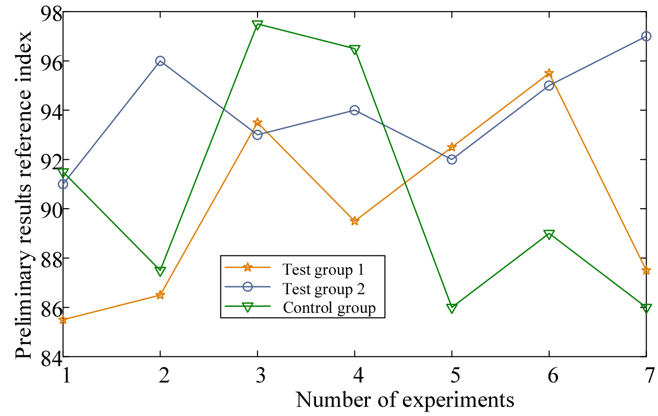


Fig. 9. Experimental process of system model.

sources, but can be analyzed through the data analysis of digital signals. The relative local independent division of labor of collecting and storing two functions can realize efficient operation, and can maximize the utilization of hardware resources (such as cpu/gpu), and can be controlled by secondary cross control according to different external features (such as data type, data feature vector, data length information, etc.). In this way, the central collection rules scheme of each data group can be gradually obtained, and the second data group can be collected and guided by the standard collection scheme, and the effective collection of different data groups can be realized. The simulation results are shown in Fig. 8. It can be seen from Fig. 8 that with the increase of the number of simulations, the three sets of data all show the same change law, that is, they all show the gradual increase law of the linear function type. This is also in line with the theoretical basis of this research, so it also proves the reliability of the simulation results from the side, and the errors are controlled within the effective range.

4. Experimental design and result analysis of digital signal processing system

4.1. The experimental design process of digital signal processing system

In order to verify the feasibility and advantages of the digital signal processing technology, the system needs to be self-checked before the experiment. The digital signal processing system based on distributed cloud computing is built with the traditional PID closed-loop control technology, distributed cloud computing idea, state intelligent discrimination model and database storage technology as the core. It can be used as the central evaluation basis according to the different characteristics of digital signal data from different sources and the differences of different data in the cloud storage process. To collect, analyze, extract and store data directionally, build a digital signal processing system with short time and high accuracy, and realize real data collection, utilization and storage, it has good reliability and feasibility. In order to verify the practicability of the system, the preliminary simulation and actual experiments are conducted. In terms of the parameter setting involved in the experiment process, this study combined the type, quantity, target extraction rate and minimum error requirements of the data volume in the experiment process to set the parameters separately, such as the maximum single cycle set. The amount of processed data is 5000, the minimum number of loop analysis is 4, the minimum data extraction rate is 2500/time, and the error is set to not higher than 3%. In order to ensure the fairness of different data analysis methods during the experiment, this experiment uses the same experimental data processed by different data processing methods, and the hardware equipment used is also the same. The indicators obtained are averages obtained after 10 experiments.

In the process of experiment, when analyzing the characteristic information of big data, the digital signal processing system described in this paper can quickly collect, analyze, extract, transform and store massive data (more than 100000 digital signal data samples) in the cloud, further get the characteristic analysis and cloud records of different types of data, so as to substantially improve the operation efficiency of distributed cloud computing in the process of processing big data, and realize the multiple analysis and utilization of different data sources. In this way, in the follow-up big data analysis and processing system, a high-precision and efficient result can be achieved, so as to achieve the accurate distribution of each digital signal data and demand side under the digital signal processing system, and improve the overall work efficiency of related enterprises in the field of electronic information engineering in the daily operation process. The preliminary experimental results of the digital signal processing system model are shown in Fig. 9. It can be seen from Fig. 9 that the experimental results in the two experimental groups have a certain degree of correlation. They both become larger, then smaller, and then larger, but both remain within a relatively fixed range of variation. The control group first became smaller, then larger, then smaller, and then increased slightly, that is, showing a "jumping" change rule. Therefore, the results of this experiment show that the data analysis method used in this study is very effective.

It can be seen from Fig. 9 that in the experimental groups and the control group, as the number of experiments increases, the corresponding experimental quantitative evaluation result factors show different changes, and the evaluation result factors in the experimental group are less stable. The stability of the results of the control group is poor. This is because the control group does not use the algorithm model proposed in this study. There are more disturbing factors in the process of analyzing digital signals, so the results are relatively stable.

4.2. Experimental results and analysis of digital signal processing system

The efficiency improvement of the system is analyzed by observing three groups of experimental processes processed by the system and three groups of traditional conventional digital

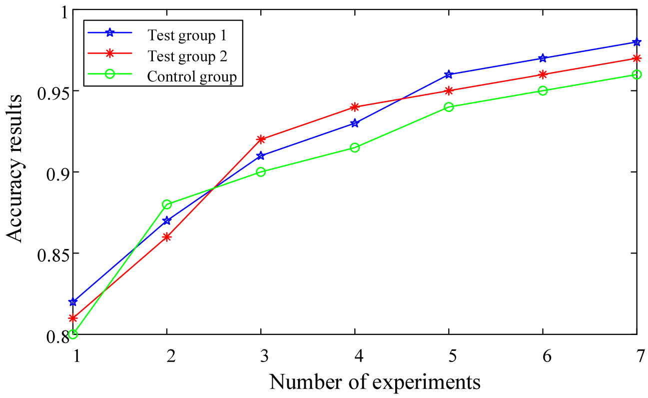


Fig. 10. The accuracy results with the number of experiments.

Table 1
Accuracy results of the experiment.

Experimental fit	1	2	3	4	5	6	7
Test group 1	0.97	0.92	0.94	0.96	0.93	0.95	0.98
Test group 2	0.98	0.96	0.95	0.94	0.95	0.93	0.96
Control group	0.88	0.89	0.91	0.91	0.90	0.92	0.91

signal processing systems under the digital signal processing system. The results of transition probability matrix involved in the distributed calculation process of three groups of experimental data (more than 100000 data) in this model are shown in Fig. 10.

The accuracy results are shown in Table 1.

According to the results in Fig. 10 and the data in Table 1, it can be seen that compared with the three groups of big data processed by the traditional data processing system, the digital signal processing system based on distributed cloud computing has greatly improved in collection speed, feature extraction efficiency, storage speed and response time, which can meet the daily needs of enterprise operation. In terms of collection speed, the digital signal processing system based on distributed cloud computing has lower technical complexity, higher collection speed of effective data, and lower difficulty in condition tracking. The above results show that the digital signal processing system based on distributed cloud computing can improve the operation efficiency in the process of digital signal processing through distributed cloud computing method and PID control strategy, which will be of great use to the enterprises involved in cloud computing and big data, it can also effectively reduce the cost of data development and utilization in the field of electronic information engineering.

5. Conclusion

The common digital signal processing methods have the issues of poor collection effect and slow storage speed. To end these issues, this paper proposed a new digital signal processing system based on distributed cloud computing and intelligent gradient tracking algorithms. This paper selects four characteristic parameters related to the efficiency of digital signal processing and effective data analysis, and designs a digital signal processing system with high efficiency and high intelligence. The system can realize the unified management of massive data sources, and realize the analysis of local differences between dynamic data according to the solving objectives and screening rules in the process of distributed cloud computing, Then intelligent gradient tracking algorithms is used for intelligent regulation to realize feedback regulation and intelligent control of digital signal processing system. Finally, the experimental results show that the digital signal processing system based on distributed cloud computing and intelligent gradient tracking algorithms has the advantages of high collection speed, fast storage speed and fast response, which can play an effective role in the development and utilization of digital signal data in the field of electronic information engineering. However, this study only considers the analysis speed and processing efficiency, and does not consider the security optimization in the process of data processing, so it can be further optimized.

CRediT authorship contribution statement

Hu Sheng: Revise the manuscript, Reply to review comments, Submission of amendments. **Xiaodong Qi:** Revise the manuscript, Reply to review comments.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

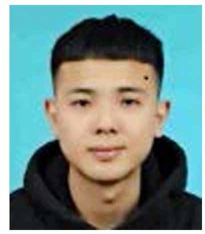
The study was supported by "National Natural Science Foundation of China (Grant No. 61671105)", "Natural science research project of Liaoning Provincial Department of Education, China (Grant No. JDL2019014)".

References

[1] L. Yan, P. Wang, J. Sun, et al., Simulation of tree point cloud based on the ray- tracing algorithm and three-dimensional tree model, Biosyst. Eng. (2020) 200.
[2] C. Li, J. Tang, Y. Luo, Multi-queue scheduling of heterogeneous jobs in hybrid geo-distributed cloud environment, J. Supercomput. 74 (10) (2018) 5263–5292.
[3] Muhammad Habib ur Rehman, Ejaz Ahmed, Ibrar Yaqoob, et al., Big data analytics in industrial IoT using a concentric computing model, IEEE Commun. Mag. 56 (2) (2018) 37–43.
[4] M. Johnston, E. Modiano, Wireless scheduling with delayed CSI: When distributed outperforms centralized, IEEE Trans. Mob. Comput. 17 (11) (2018) 2703–2715.
[5] H. Chen, W.P. Zhu, W. Liu, et al., RARE-based localization for mixed near-field and far-field rectilinear sources, Digit. Signal Process. 85 (2019) 54–61.
[6] Ö.T. Demir, T.E. Tuncer, Improved ADMM-based algorithms for multi-group multicasting in large-scale antenna systems with extension to hybrid beamforming, Digit. Signal Process. 93 (2019) 43–57.
[7] D. Castanheira, G. Barb, A. Silva, et al., A multi-user linear equalizer for uplink broadband millimeter wave massive MIMO, Digit. Signal Process. 92 (2019) 62–72.
[8] D. Blinder, A. Ahar, S. Bettens, et al., Signal processing challenges for digital holographic video display systems, Signal Process., Image Commun. 70 (2019) 114–130.
[9] I.C. Yadav, S. Shahnawazuddin, G. Pradhan, Addressing noise and pitch sensitivity of speech recognition system through variational mode decomposition based spectral smoothing, Digit. Signal Process. 86 (2019) 55–64.
[10] R. Muñoz, R. Vilalta, N. Yoshikane, et al., Integration of IoT, transport SDN, and edge/cloud computing for dynamic distribution of IoT analytics and efficient use of network resources, J. Lightwave Technol. 36 (7) (2018) 1420–1428.
[11] W. Zhang, Z. Zhang, H.C. Chao, Cooperative fog computing for dealing with big data in the internet of vehicles: Architecture and hierarchical resource management, IEEE Commun. Mag. 55 (12) (2017) 60–67.
[12] R. Boriga, A.C. Dăscălescu, I. Priescu, A new hyperchaotic map and its application in an image encryption scheme, Signal Process., Image Commun. 29 (8) (2014) 887–901.
[13] D. Wübben, P. Rost, J. Bartelt, et al., Benefits and impact of cloud computing on 5G signal processing, IEEE Signal Process. Mag. 31 (6) (2014) 35–44.
[14] P. Sana Ee, P. Moallem, F. Razzazi, A structural refinement method based on image gradient for improving performance of noise-restoration stage in decision based filters, Digit. Signal Process. 75 (2018) 242–254.

[15] Y. He, J. Guo, X. Zheng, From surveillance to digital twin: Challenges and recent advances of signal processing for industrial internet of things, IEEE Signal Process. Mag. 35 (5) (2018) 120–129.
[16] Sahil Kansal, Harish Kumar, Sakshi Kaushal, et al., Genetic algorithm-based cost minimization pricing model for on-demand IaaS cloud service, J. Supercomput. (2) (2018) 1–26.
[17] M. Shi, J. Liu, Functional and contextual attention-based LSTM for service recommendation in mashup creation, IEEE Trans. Parallel Distrib. Syst. 30 (5) (2018) 1077–1090.
[18] Jalal Khamse-Ashari, Ioannis Lambadaris, George Kesidis, et al., An efficient and fair multi-resource allocation mechanism for heterogeneous servers, IEEE Trans. Parallel Distrib. Syst. 29 (12) (2018) 2686–2699.
[19] J. Ren, Y. Guo, D. Zhang, et al., Distributed and efficient object detection in edge computing: Challenges and solutions, IEEE Network 32 (6) (2018) 137–143.
[20] C. Qiu, H. Shen, K. Chen, An energy-efficient and distributed cooperation mechanism for k-coverage hole detection and healing in WSNs, IEEE Trans. Mob. Comput. 2 (32) (2018) 1–9.
[21] F. Tang, H. Zhang, L. Fu, et al., Distributed stable routing with adaptive power control for multi-flow and multi-hop mobile cognitive networks, IEEE Trans. Mob. Comput. 18 (12) (2018) 2829–2841.
[22] D. He, Y. Qiao, S. Chan, et al., Flight security and safety of drones in airborne fog computing systems, IEEE Commun. Mag. 56 (5) (2018) 66–71.
[23] M.A. Rahman, M.S. Hossain, E. Hassanain, et al., Semantic multimedia fog computing and IoT environment: sustainability perspective, IEEE Commun. Mag. 56 (5) (2018) 80–87.

Hu Sheng, Doctor, Associate Professor. Graduated from the Dalian University of Technology in 2011. Worked in Dalian Jiaotong University. He research interests include random signal processing, modern communication, and intelligent control.



Xiaodong Qi, Graduate students in Dalian Jiaotong University, Electronic and Communication Engineering. He research interests include signal and information processing.