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The Application of Embedded Hardware System and Blockchain in Rural Financial Management Cloud Platform

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ABSTRACT

With the rapid development of information technology, rural financial management is facing the great challenge of digitalization and intelligentization. This study aims to explore the application of embedded systems combined with blockchain technology in rural financial management to provide more efficient and secure solutions. Firstly, the main problems in rural financial management are analyzed, including low data processing efficiency and poor data security. It then explores the potential applications of embedded systems in financial management, as well as the main characteristics and classifications of blockchain technology. Based on this, a model integrating embedded system and blockchain technology is designed, and the effectiveness of the model is verified by experiments. The experimental results show that the system not only significantly improves the data processing speed, but also enhances the data security and improves the user satisfaction. In general, this study provides theoretical and practical support for the technical innovation of rural financial management, and shows a broad prospect in practical application.

1. Introduction

With the acceleration of global digital transformation, the application of new technologies in various fields is gradually showing its value, especially in the key link of financial management. The traditional rural financial management is limited by technology, equipment and knowledge, and there are many bottlenecks and problems, such as information asymmetry, low efficiency, opacity of capital flow and so on. In order to better understand and address these issues, this study not only focuses on the technology applications themselves, but also aims to reveal the actual impact and potential value of these applications in the specific socio-economic context of rural areas.

In recent years, the embedded hardware system has been widely used in various scenarios, such as freight transport and logistics [1], the smart parking system [2], household appliances, medical equipment and industrial automation [3], because of its compact, efficient and customizable characteristics. The emergence of this technology provides higher efficiency and better user experience for various application scenarios. At the same time, blockchain technology, with its

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unique immutable and decentralized characteristics, has revolutionized many traditional business processes and systems, especially in applications that ensure data integrity and transparency. In exploring the application of these technologies, this study particularly emphasizes the particularities of rural areas, such as the lack of infrastructure, the lag in the application of technology, and the inequality in the quality of personnel. These particularities not only represent challenges, but also provide a unique perspective and experimental environment for research. For example, research by Chen *et al.*, [4] and Hao [5] provides new perspectives on big data and neural networks in financial management, especially in rural areas. These studies highlight the importance of using these advanced techniques to process complex data, consistent with the goals of this study. The particularity of rural areas, such as the lack of infrastructure, the lag of technology application and the unequal quality of personnel, make the application of these advanced technologies face many challenges. But at the same time, it also provides a valuable opportunity to bring substantial improvements and value to rural areas through research and application of these technologies.

With the rapid development of information technology, financial management has become a research hotspot. Especially in the field of rural financial management, many scholars have carried out in-depth exploration. First of all, Liu [6] focused on using big data technology to optimize rural financial mobile service management system. This study provides important insights into how to improve the efficiency of rural financial management through integrated data processing schemes. This provides a theoretical basis and practical guidance for the goal of this research - to improve the efficiency and security of rural financial management through embedded system and blockchain technology. In addition, Kong and Lu [7] discussed the risk control management of new rural cooperative financial organizations based on mobile edge computing. The study highlights the potential of mobile edge computing to improve the efficiency of financial services management, while also pointing out the associated risks. These findings have important implications for understanding the potential challenges and opportunities of deploying advanced technologies in rural Settings. In terms of the application of neural network technology, Liu [8] built the spatial structure and service management model of rural financial organizations through deep convolutional neural network, while Lu [9] designed an enterprise financial cost management platform based on FPGA and neural network. These studies show that neural network technology can improve the speed and accuracy of financial data processing, which is consistent with the goal of this study to integrate advanced technology in rural financial management systems. In terms of blockchain technology, Liu *et al.,* [10] proposed a financial management platform based on the integration of blockchain and supply chain, focusing on the imtamability and transparency of data. This is highly consistent with the goal of this study - to use blockchain technology to improve the security and reliability of rural financial data. The use of cloud and edge computing in modern financial management systems is also noteworthy. The enterprise financial risk management platform based on 5G mobile communication and embedded system designed by Qiu [11] and the financial data security management method based on intelligent edge computing and big data by Purohit *et al.,* [12] both emphasized the high efficiency and security in the processing of large amounts of financial data, which provides important enlightenment for this study.

In general, the modern financial management system is in the stage of rapid technological development and application innovation. Based on the comprehensive application of the above technologies, especially embedded system and blockchain technology, this study aims to provide a more efficient and safer solution for rural financial management.

The theoretical significance of this study is that it not only focuses on the development of technologies themselves, but also explores how these technologies can be effectively applied in the specific socio-economic environment of rural areas. This provides new research perspectives and data for related academic fields to help understand and solve problems in similar Settings. At the same time, the practical significance of this study is that by providing a more transparent, efficient and safe rural financial management program, it is expected to promote the economic development and social stability of rural areas.

This study aims to fill the technology application gap in the current rural financial management field, especially in the embedded hardware system and blockchain technology. Although there is more research on blockchain technology in the financial sector, its application in specific rural environments is still less, especially in combination with embedded hardware systems. Therefore, the contribution of this study is to provide an integrated and innovative technical solution for rural financial management, and at the same time to analyze its application in a specific socio-economic environment.

This study not only demonstrates the possibilities of technology, but also provides a deep understanding of the practical needs and challenges of rural financial management. Embedded hardware systems offer the possibility of on-site data collection and processing, while blockchain technology provides security and transparency for data storage and transactions. This combination can solve the shortcomings of traditional rural financial management in data processing and financial transparency, so as to provide strong technical support for the development of rural economy.

The focus of this study is not only on the application of technologies, but also on understanding how these technologies work in rural areas with specific socioeconomic backgrounds, providing valuable experience and reference for similar application scenarios.

This research involves multiple aspects, aiming to deeply explore the application of embedded hardware system and blockchain technology in rural financial management cloud platform. The specific research contents are as follows: the core composition, characteristics and working principle of embedded hardware system are deeply studied, and the basic framework, workflow and potential application of blockchain technology in financial management are analyzed. In this way, a comprehensive and in-depth theoretical foundation is established to provide support for subsequent research and application. Identify key data types required in rural financial management and design and implement effective data collection strategies. After the data collection is completed, it is pre-processed as necessary to ensure the quality and integrity of the data. Based on embedded hardware system and blockchain technology, a complete rural financial management cloud platform is designed. In this process, the stability, scalability and user friendliness of the system are taken into account to ensure that it can meet the actual needs of rural areas. The effect of the new system is evaluated by qualitative and quantitative methods. This includes but is not limited to user attitude analysis, comparison of economic benefits, etc., to ensure that the new system really brings improvement and value to rural financial management. The system experiment is carried out in the real rural environment to verify its performance and practical effect. The practical application value and potential challenges of the system are evaluated by comparing the experimental results with the expected objectives.

To sum up, the content of this study aims to provide a complete, scientific and practical solution for the digital transformation of the rural financial management cloud platform, hoping to bring substantial improvement and development to the financial management in rural areas.

2. Technical Basis and Theoretical Application

2.1 Embedded System Fundamentals

Embedded system is a computer system designed for a specific task, which is different from the traditional general-purpose computer system. It is a complete system that can operate independently, including hardware (such as a microprocessor and memory) and software designed for a specific application [13]. The history of embedded systems dates back to the 1970s, when such systems were primarily used for experimental and professional applications. With the development of technology and the reduction of cost, embedded system began to be widely used in consumer electronics, industrial control and other fields.

(1) Core characteristics: The main characteristics of embedded systems are their specificity, real-time, compactness and reliability.

Specificity: An embedded system is designed for a specific application or task, and its function is fixed, unlike a general-purpose computer that can run many different applications.

Real-time: Many embedded systems have real-time processing capabilities, which can respond to external events or complete specified tasks within a specified time.

Compactness: Due to limited resources (such as processor speed, storage space, energy supply, etc.), embedded systems often need to be optimized in hardware design and software coding to achieve small size and low power consumption.

Reliability: Embedded systems require high reliability and stability in many critical applications, such as medical, aviation and automotive [14].

(2) Application fields: Embedded systems are widely used, covering almost all industrial fields. From household appliances such as microwave ovens and washing machines, to complex industrial automation control systems, to intelligent transportation systems and medical devices, its impact is everywhere [15]. Its specificity and real-time performance enable it to provide accurate and stable performance in a variety of practical applications.

In rural financial management, the application of embedded system is expected to bring more efficient, stable and secure digital transformation. But to achieve this goal requires an in-depth analysis of the architecture of embedded systems and consideration of how to integrate with blockchain technology. For example, choosing the appropriate consensus algorithm is crucial, it needs to balance the efficiency and security of the system. In addition, considering the limitation of network bandwidth in rural areas, the choice of data compression method is also very important. Security and privacy measures are another key consideration, with the need to ensure the security of data transmission and storage while protecting user privacy.

Finally, proper testing and validation of technical components is an important step in ensuring system reliability and effectiveness. This includes, but is not limited to, laboratory testing, field trials, and continuous performance monitoring to ensure that the system can operate reliably in the real-world environment of rural financial management.

To sum up, embedded system plays an indispensable role in various fields because of its core characteristics, providing a strong technical support for modern life and industrial development. In rural financial management, the application of embedded systems is expected to bring more efficient, stable and secure digital transformation.

2.2 Overview of Blockchain Technology

Block Chain Technology (Block Chain Technology, also known as distributed ledger technology) is a chain data structure or a distributed infrastructure and computing paradigm. This technique was first used with the launch of Bitcoin in 2009. The origins of blockchain technology date back to 1991, when the aim was to create an immutable timestamp. As the technology has evolved, blockchain has gradually evolved from a dedicated infrastructure for digital currencies to a technology that is widely used in a variety of applications. This technology provides a high degree of immutability and transparency to the data, thus ensuring the authenticity and integrity of the data [16, 17].

(1) Main features:

Distributed: The blockchain does not rely on a central server or a single entity for management, but is jointly maintained by multiple nodes in the network, each of which holds a complete copy of the data.

Immutable: Once a transaction is added to the blockchain and verified by a majority of nodes in the network, the transaction becomes immutable. This ensures the authenticity of the data [18].

Transparency: All transactions are public, and anyone can view all data and transaction records on the blockchain, ensuring the openness and transparency of the system.

Security: Using encryption technology, blockchain ensures the secure transmission and storage of data, preventing external attacks and tampering [19].

(2) Classification:

Public chain: Completely open, anyone can join and verify transactions. Bitcoin and Ethereum are typical examples of such blockchains.

Private chain: Access is limited and only authorized participants can join. It is more like a centralized system, but utilizes the technology of blockchain to ensure that the data is immutable.

Alliance chain: Multiple organizations participate in and maintain. Unlike the complete decentralization of public chains and the centralization of private chains, consortium chains are somewhere in between, combining their advantages [20, 21].

In the field of rural financial management, the integration of blockchain technology needs to take into account the special needs and constraints of rural areas. For example, in order to ensure the efficient operation of the system, it is crucial to choose the right consensus algorithm, especially in bandwidth limited environments. At the same time, considering the possible data transmission restrictions in rural areas, the application of data compression technology is necessary. In terms of security and privacy, special attention needs to be paid to ensuring the security of rural users' financial data, with effective encryption measures in place to prevent data leakage and abuse.

In addition, for the implementation of embedded system integration with blockchain, proper testing and verification is indispensable. This includes simulation testing, field trials and continuous system performance monitoring to ensure that these technologies work reliably in the specific context of rural financial management.

In general, blockchain technology offers revolutionary solutions for a variety of applications with its unique characteristics. In the field of rural financial management, blockchain technology can provide a more secure, transparent and efficient data management method to ensure the authenticity and integrity of financial data.

2.3 Technical Application in Financial Management

In financial management, the use of technology is becoming more and more significant, especially to improve the transparency and security of data. Modern technologies, especially embedded systems and blockchain, have revolutionized financial management, providing a higher level of trust and convenience for institutions and individuals [22].

(1) Enhance transparency

Financial transparency is an important part of ensuring that all stakeholders, such as investors, managers and the general public, have access to a company's financial information. Blockchain technology, through its public transaction record and complete data chain, ensures that every transaction can be traced and verified. This means that any attempt to modify or falsify a record will be recognized by other nodes in the network, thus guaranteeing the integrity and authenticity of the data [23]. As a result, this technology provides greater transparency in financial management, enabling all stakeholders to have a clear, tamper-free view of financial data.

(2) Data security

In a digital world, data security is one of the biggest challenges facing every organization. The security of financial data, as the core asset of an organization, is particularly important. Embedded systems, due to their compact nature and specificity, provide physical level security for financial data, ensuring that the data is not illegally accessed or tampered with [24, 25]. Blockchain technology uses its encryption algorithm and distributed structure to provide another layer of protection for data, so that data is fully guaranteed during transmission and storage.

In short, through the application of technology, financial management not only achieves a high degree of data transparency, but also ensures the security and authenticity of data. This brings great potential value to the field of rural financial management, making financial operations more simple, accurate and reliable.

3. Data Collection and Preprocessing

3.1 Data Requirements and Features

The data demand of the rural financial management cloud platform mainly comes from various economic activities in rural areas, including but not limited to agricultural products trading, agricultural machinery purchase, land transfer, farmers' income and expenditure. In response to these requirements, the main characteristics of the data are identified.

As shown in Table 1 below:

Table 1
Data requirements and characteristics

Data type	Data requirement description	Data characteristics
Agricultural trade	Product type, quantity, transaction price, transaction time	Diversified product categories, seasonal trading peaks, price fluctuations
Farm machinery purchase	Purchase type, purchase quantity, price, supplier	Technology-based data, related to new technologies and policy subsidies, may vary in price depending on brand and technology differences
Land circulation	Circulation area, circulation price, circulation period	The data may involve multiple parties, and the transfer price is related to geographical location, soil quality and transfer period
Farmer's income	Source of income, amount, time	Diversified sources of income, such as planting, breeding, migrant work, etc., seasonal income
Peasant expenditure	Item, amount and time of expenditure	Expenditures may be related to agricultural inputs, household expenses, education and health, and there are fixed and non-fixed expenditures

From the above table, it can be seen that the data types required for rural financial management are diverse and have their own characteristics. This requires that in the process of data collection and preprocessing, the research needs to formulate corresponding strategies according to the characteristics of each data to ensure the integrity, authenticity and availability of data.

For this purpose, data sources include, but are not limited to, records of agricultural cooperatives, statistics from local governments, transaction records from agricultural banks, and data collected directly from farmers. Each data source has its own unique characteristics and possible biases, so special attention needs to be paid to data quality control and correction of biases in the pre-processing process.

In terms of data processing, data cleansing is first performed, including the removal of incomplete, incorrect or irrelevant records. The data is then standardized to ensure consistent data formats from different sources for subsequent analysis. For data such as agricultural trade and agricultural machinery purchases, seasonal adjustments may be required to eliminate the impact of seasonal factors on data analysis. For land transfer data involving multiple parties, special attention needs to be paid to protecting the privacy of all parties while ensuring the accuracy and integrity of the data.

Finally, in order to improve the availability of data and the effectiveness of analysis, data fusion technology can be adopted to integrate data from different sources to obtain more comprehensive and in-depth insights.

3.2 Collection Policies and Methods

In order to ensure the authenticity and integrity of the data, according to the characteristics of each data, the corresponding data collection strategy is formulated, and the appropriate collection tool is selected.

As shown in Table 2 below:

Table 2
Selection of data collection strategies and tools

Data type	Data source	Acquisition tool
Agricultural trade	Rural market transaction records, cooperative records, online trading platform records	Handheld terminal, online crawler, cooperative system export
Farm machinery purchase	Agricultural machinery supplier sales data, farmers purchase vouchers, agricultural machinery subsidy application records	Supplier system export, handheld scanner
Land circulation	Land Administration records, online land trading platforms, individual contracts for farmers	Land management system export, online crawler
Farmer's income	Farmers self-reported, cooperative dividend records, income vouchers for migrant workers	Handheld terminal, cooperative system export, mobile App report
Peasant expenditure	Farmers self-report, shopping vouchers, school education expenses, medical expenses vouchers	Handheld terminal, mobile App reporting, scanner

In terms of data sources, the purpose of research is to obtain the most direct and authentic data sources. For example, agricultural trade data can be obtained directly from transaction records at rural fairs, which is more accurate than third-party sources. For data that cannot be directly obtained, such as farmers' income for migrant work, farmers' self-reported data can be reported in combination with mobile phone apps. However, in doing so, it is necessary to ensure the accuracy and reliability of the data, such as through sampling surveys or comparison verification with third-party data.

In the selection of collection tools, taking into account the network coverage in rural areas and farmers' usage habits, handheld terminals, mobile phone apps, scanners and other easy-to-use and powerful tools were selected. At the same time, for some data that has been digitized, such as the transaction records of cooperatives and the circulation records of the Bureau of Land Management, we choose to export it directly from the relevant system to ensure the integrity and authenticity of the data.

In order to further improve the rigor of the data collection methods, this study employs best practices from mixed-method studies, including data triangulation, contrastive analysis, and quality control steps. These steps help identify and address potential sources of bias or error, ensuring the quality of the data and the validity of the research.

3.3 Data Quality Assurance

In order to ensure the quality of data, a series of cleaning, calibration and integration strategies are adopted. As shown in Table 3 below:

Table 3
Data quality assurance strategies

Data type	Cleaning strategy	Check strategy	Integration strategy
Agricultural trade	Remove duplicate records, standardize product names, and correct obvious price anomalies	Check price ranges against historical trading data	Combine data from online trading platforms, cooperatives and rural markets by date and product
Farm machinery purchase	Remove duplicate purchase records, standardized agricultural machinery type names, and corrected records that do not match the quantity and total price	Match sales data with agricultural machinery suppliers	Combine supplier data, agricultural machinery subsidy application records and farmers' purchase vouchers by date and type of agricultural machinery
Land circulation	Remove duplicate circulation records, standardize land types, and correct obvious abnormal circulation prices	Verify circulation area and price against official records of the Bureau of Land Management	Bureau of Land Management records, online transaction data and individual farmer contracts were combined by date and land location
Farmer's income	Remove duplicate revenue records, fix date format inconsistencies, and delete records from unknown sources	The income of migrant workers was randomly sampled and verified by telephone return visits	The farmers' self-report, cooperative dividend records and migrant workers' income are combined according to the date and farmers
Peasant expenditure	Remove duplicate spending records, standardize spending types, and correct spending amounts that do not match purchase vouchers	A random sample of larger expenditures was taken and verified by telephone return visits	Combine farmer self-reports, shopping vouchers, school education expenses and medical expenses vouchers by date and farmer

In the cleaning strategy, the main concern is to remove duplicate and abnormal data, and to ensure the standardization of data. For example, for agricultural trade data, product names need to be standardized to ensure that the same product has a uniform name across different data sources.

In the verification strategy, the research mainly adopts the method of matching with other data sources and random sampling phone calls to verify the authenticity of the data. For example, land transfer data can be matched with official records from the Bureau of Land Management to ensure the accuracy of transfer area and price.

In the integration strategy, the goal is to combine data from different data sources according to certain rules to ensure data integrity and consistency. For example, farmers' income data can be combined by date with farmers to ensure that each farmer's income data is complete.

4 Embedded System and Blockchain Model Design

4.1 Embedded System Architecture

In the construction of rural financial management cloud platform, embedded system plays a key role, especially in the process of data acquisition, pre-processing and storage. The core components of the embedded system architecture are shown in Table 4 below:

Table 4
Hardware selection and configuration

Module	Model/Specification	Function description
Central Processing Unit (CPU)	ARM Cortex-A53	Responsible for data processing, calculation and decision making functions
Memory (RAM)	4GB DDR4	Provides sufficient memory space to support real-time data processing
Storage (Storage)	64GB eMMC	Store collected data and application code
Communication module	4G LTE	Guarantee high-speed data transmission with cloud platform
Sensor interface	GPIO	Used to connect various sensors such as temperature, humidity, soil quality, etc

Interface and communication design:

(1) Data acquisition interface: The General Purpose Input/Output (GPIO) port is used to connect various sensors that can help collect financial related real-time data in rural areas. For example, soil sensors can collect the fertility value of soil, which will affect the transfer price of land.

(2) Data transmission interface: 4G LTE module is used to communicate with the cloud platform to ensure real-time transmission and synchronization of data. In order to improve data security, SSL/TLS encryption protocol is used for data encryption transmission.

(3) Interactive interface with blockchain: In order to ensure the authenticity and immutability of data, a dedicated interface is designed to interact with the blockchain platform. Whenever new data is generated, the embedded system links the data to create a new block.

The data processing capability of an embedded system can be described as Eq. (1):

$$P = C \times F \times N \tag{1}$$

Where: P is the total processing capacity of the system (data processing per second). C indicates the CPU processing capacity per core. F is the number of cores in the CPU. N indicates the number of CPU cycles per second.

Taking the ARM Cortex-A53 as an example, it has four cores, each with a processing capacity of 1.5 DMIPS/MHz, and operates at a frequency of 1.2 GHz, so its total processing capacity is:

$$P = 1.5 \times 4 \times 1.2 \times 10^9 = 7.2 \times 10^9 \,\text{DMIPS}$$

This model briefly describes the data processing capability of embedded system. The actual processing capability is also affected by other factors, such as memory speed, communication bandwidth, etc. But it provides a basic framework for the study to evaluate its performance.

4.2 Blockchain Structure and Strategy

In the rural financial management cloud platform, blockchain technology is used to ensure data transparency, authenticity and imtamability. Here are the core components and policies of the blockchain:

Data structure and storage:

(1) Block data structure: Each block contains at least the following elements, as shown in Table 5 below:

Table 5
Block data

Element	Description
The hash of the previous block	Used to ensure the integrity of the data link
Timestamp	Records when the block was created
Transaction list	Records of all transactions stored in this block
Difficulty value	Used to adjust the difficulty of mining
Random number (Nonce)	Used in the mining process in consensus algorithms

(2) Storage strategy: All transaction data is first collected and preprocessed by the embedded system, and then transmitted to the blockchain platform through a specific interface. When the transaction data reaches a preset threshold or after a predetermined time interval, the data is packaged into a new block and added to the blockchain.

Choose the appropriate consensus mechanism:

(1) Considering the characteristics of the rural financial management cloud platform, an efficient and energy-saving consensus mechanism is needed. Common consensus mechanisms are shown in Table 6 below:

Table 6
Consensus mechanism

Consensus mechanism	Peculiarity	Application situation
Proof of Work (PoW)	High computing requirements, high energy consumption	Large public chains, such as Bitcoin
Proof of Stake (PoS)	Energy saving, based on the amount of coins held or the age of coins	Small to medium public chain
Certificate of Interest (DPoS)	Fast, energy efficient, verified by a specific node	Ideal for applications that require fast transaction confirmation
Practical Byzantine fault Tolerance (PBFT)	Efficient, suitable for small networks	For private or licensed chains

(2) Considering the real-time requirements and resource limitations of the rural financial management cloud platform, the research selects entrusted Proof of interest (DPoS) as the consensus mechanism. It provides fast transaction confirmation while being relatively energy efficient.

In the DPoS mechanism, there are N candidate nodes, and the number of nodes in each round of block production is M, then the probability that any node will be selected as a block production node in the next round is as Eq. (2):

$$P = \frac{M}{N} \tag{2}$$

For example, if there are 101 candidate nodes and 21 nodes are selected per round, the probability of each node being selected is:

$$P = \frac{21}{101} \approx 0.208$$

This means that every node has a nearly equal chance to participate in the blocking process, thus ensuring the fairness of the system.

4.3 System and Model Integration

During the simulation phase, the following assumptions were made to ensure the feasibility and validity of the model:

(1) Network stability assumption: It is assumed that there is a stable network connection in rural areas, so that data can be transferred smoothly between the embedded system and the blockchain network.

(2) Data consistency assumption: It is assumed that the data collected from the embedded system remains consistent during transmission and will not change due to network delays or other external factors.

(3) User participation assumption: It is assumed that rural users can effectively use the cloud platform and have a basic understanding of the operation and functions of the system.

The integration of embedded hardware system and blockchain technology is the core of realizing rural financial management cloud platform. The following is a detailed explanation of the integration strategy:

The integration of embedded hardware system and blockchain technology is the core of realizing rural financial management cloud platform. The following is a detailed explanation of the integration strategy:

(1) Embedded and blockchain data synchronization design

In order to ensure the real-time and integrity of data, a data synchronization module is designed in this study.

Data synchronization frequency: Based on the data acquisition frequency of the embedded hardware and the block time of the blockchain, the synchronization frequency of the data can be calculated. If the embedded hardware collects 10 pieces of data per minute, and the block time of the blockchain is 10 minutes, then the data synchronization frequency is, as shown in Eq. (3) below:

$$f_{sync} = \frac{\text{Data acquisition frequency}}{\text{Blocking time}} = \frac{10}{10} = 1 \text{ time/minute} \tag{3}$$

Data synchronization policy: Ensure the security and integrity of data during transmission. Therefore, a signature mechanism is adopted to ensure the authenticity of the data, and an encrypted channel is used to ensure the security of the data. As shown in Table 7 below:

Table 7
Data synchronization policies

Synchronization link	Policy specification
Data transmission	SSL/TLS encrypted channels are used to ensure the security of data during transmission
Data verification	The ECDSA signature mechanism is used to ensure the authenticity and integrity of data
Data storage	The data is stored in a temporary cache waiting to be packaged into the blockchain, guaranteeing the reliability of the data

(2) Optimize cloud platform integration strategies

Considering the characteristics and needs of the rural financial management cloud platform, the following is the optimization strategy:

Data compression: In order to improve the speed of data transmission and reduce the storage cost, an efficient data compression algorithm is adopted. For example, consider using Snappy or LZ4 for real-time data compression.

Smart contract optimization: In order to improve the degree of automation of the cloud platform, the research designed a set of smart contracts to automatically handle certain financial tasks, such as automatic settlement, audit, etc.

Remote backup and disaster recovery: Considering the unstable network and power supply that may exist in rural areas, the remote backup strategy is adopted to ensure data security. At the same time, the disaster recovery mechanism is designed so that once the primary node fails, the backup node takes over the work immediately.

Load balancing and scalability: The core of this integration strategy is the application of advanced technology to practical problem solving, especially in the field of rural finance. By combining embedded systems and blockchain technology, the study proposes an innovative solution aimed at improving the efficiency and transparency of rural financial management. In addition, considering the particularity of the rural environment, such as the instability of the network and power supply, the remote backup and disaster recovery mechanism adopted in this study is very necessary. This not only ensures the reliability of the system, but also increases its ability to respond to various contingencies. In addition, the integration strategy also takes into account future scalability, ensuring that the system can adapt to larger scale data processing requirements.

In order to achieve effective integration of embedded systems with blockchain technology, the following steps were taken:

Design and implement a data interface for efficiently transferring data collected by an embedded system to a blockchain network.

Data encryption and signature functions are implemented in embedded system to ensure the security and immutability of data during transmission.

Develop a blockchain node to receive, verify, and store data from embedded systems.

Smart contracts are implemented to automate specific tasks of rural financial management, such as data verification and transaction processing.

Test and optimize the performance of the whole system to ensure its reliable operation in the rural financial environment.

To sum up, the integration strategy of this study not only ensures the real-time and security of data, but also optimizes the operational efficiency and stability of the cloud platform, meeting the actual needs of rural financial management.

5. Qualitative and Quantitative Effect Evaluation

5.1 Analysis of User Attitude of Financial Management

In order to measure the actual effect of embedded hardware system and blockchain in rural financial management cloud platform, the study conducted an analysis of financial management user attitude. The following is a description of the collection method:

(1) Questionnaire survey: A questionnaire was designed to collect users' views on the satisfaction, ease of use, security and other aspects of the new system. The questionnaire includes multiple choice and short answer questions.

(2) Interview: Conduct in-depth interviews with some key users to understand their specific problems and suggestions when using the new system.

(3) Online feedback: Set up an online feedback portal through the cloud platform to encourage users to provide feedback at any time during use.

The statistical information of user attitude obtained from the research is shown in Figure 1 below:

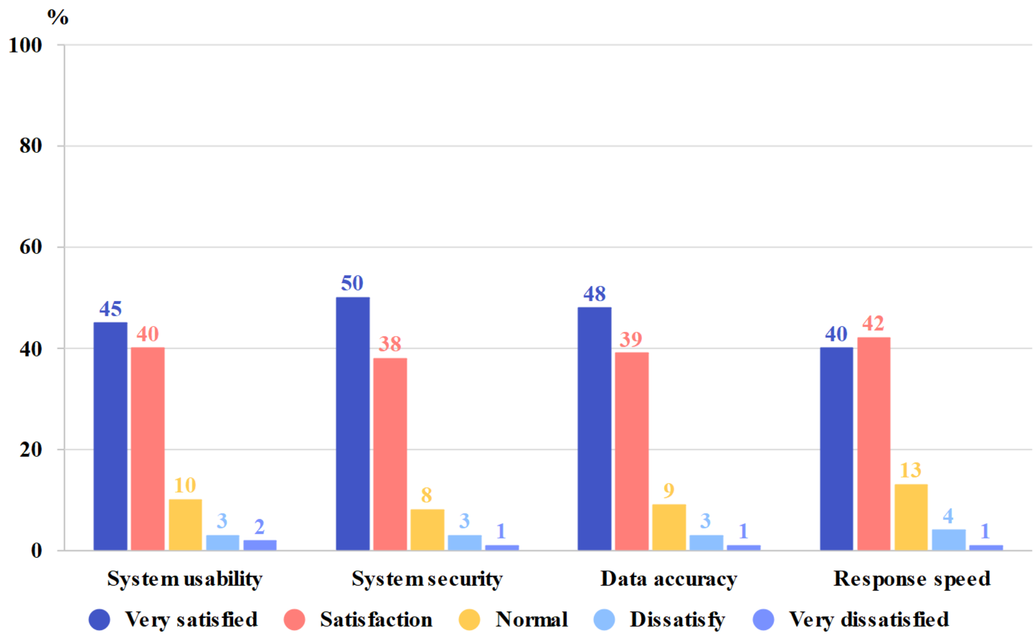

Fig. 1. Analysis of user attitude of financial management

As can be seen from the table above, most users are satisfied with the ease of use and security of the new system. But a small number of users expressed dissatisfaction with the system's response speed. The further analysis of the study found that the dissatisfied users were mainly concentrated in the areas with poor network conditions.

For the content of short answer questions and interviews, the research uses text analysis technology to interpret. Key feedback includes:

(1) The system operation interface is simple and intuitive, and new users can get on hand quickly.

(2) The data synchronization speed is fast, and the update is almost real-time.

(3) In unstable areas of the network, there will be occasional data delays.

(4) Some elderly users hope to have more detailed operation guidelines.

To sum up, the application of embedded hardware systems and blockchain in the rural financial management cloud platform has been affirmed by most users, but there is still room for optimization, especially in areas where the network is unstable.

5.2 Comparison of Economic Benefits and Input

In order to evaluate the economic benefits of embedded hardware systems and blockchain in the rural financial management cloud platform, the research conducted a comparative analysis of the investment and expected versus actual results.

(1) Input analysis:

The investment includes hardware purchase, software development and maintenance, training and other related costs. The total expected investment is 9 million yuan, and the actual investment is 8.97 million yuan. As shown in Figure 2 below:

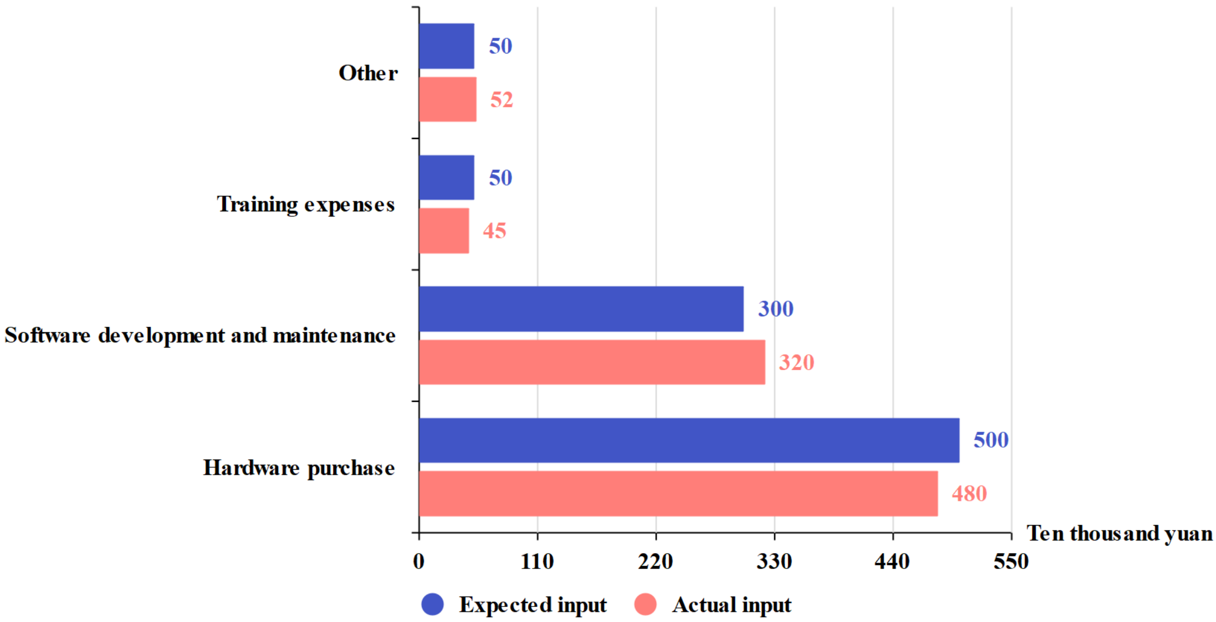

Fig. 2. Input analysis and comparison

(2) Economic benefit analysis:

The economic benefits are mainly reflected in reduced labor costs, time cost savings due to increased productivity, and additional benefits due to higher data accuracy. The total expected annual income is 3.5 million yuan, and the total actual annual income is 3.85 million yuan. The specific situation is shown in Figure 3 below:

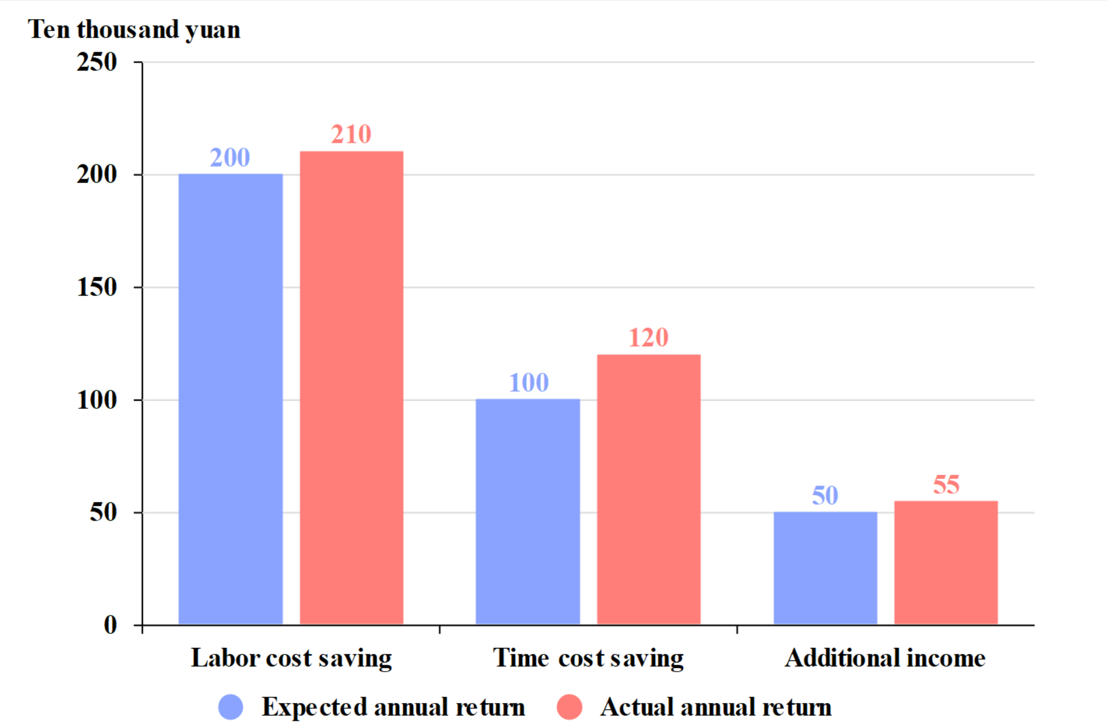

Fig. 3. Economic benefit analysis

From the figure above, it is obvious that the actual investment is close to the expected investment, where the cost of hardware procurement is lower than expected, but the cost of software development and maintenance is slightly exceeded. In terms of economic benefits, the actual annual revenue exceeded expectations, mainly due to the actual labor cost savings and time cost savings were higher than expected.

Combined with the above data, the research can calculate the return on investment (ROI), as shown in the following Eq. (4):

$$ROI = \frac{\text{Real annual income } - \text{ Actual input}}{\text{Actual input}} \tag{4}$$

Plug the numbers into:

$$ROI = \frac{3,850,000 - 8,970,000}{8,970,000} = -0.572$$

This means that in the first year, although there is a loss, given that this is a long-term project, the economic benefits of the project will gradually become apparent over time with continuous savings in labor costs and time costs. In addition, the overall project is still a success as the actual investment is close to expectations and the actual economic benefits are slightly higher than expected.

6. Experimental Verification of Strictness

6.1 Experimental Design and Criteria

In order to verify the effectiveness and superiority of embedded hardware system and blockchain in rural financial management cloud platform, this study designed a strict experimental verification. This experiment aims to compare the differences between using a traditional rural financial management system (control group) and the new embedded and blockchain-based system proposed by the study (experimental group).

(1) Definition

Control group: Using traditional rural financial management system without embedded and blockchain technology.

Experimental group: Rural financial management cloud platform based on embedded and blockchain.

Operation efficiency, data security and system stability were the main evaluation objectives of experimental group and control group.

(2) Experimental design

Selected subjects: 20 rural areas were selected for the experiment, 10 of which used the traditional system (control group) and the other 10 used the new system (experimental group).

Timeline: Each region will be tested for six months.

Data collection: Monthly data on operational efficiency, data security, and system stability were collected during the experiment.

Post-experiment analysis: At the end of the experiment, all the collected data were statistically analyzed to compare the differences between the two groups.

(3) Evaluation criteria:

Operational efficiency: Evaluated by recording the completion time of each financial operation as well as user feedback.

Data security: Assess the number of incidents in which data has been compromised or accessed illegally.

System stability: Record the number of system crashes or other failures during the test.

This experimental design can directly compare the differences between the traditional system and the new system in practical application by setting the control group and the experimental group. This comparison provides research with a clear, quantitative way to assess the effectiveness and superiority of the new system. At the same time, the duration of the experiment is long enough to ensure that the collected data is representative and reliable.

6.2 Comparison of Results and Sensitivity Analysis

In order to prove the superiority of this method more effectively, strict experimental design is adopted. First, ensure that the control group and the experimental group have a good match, for example, in terms of agricultural type, regional characteristics, population size, and so on, as consistent as possible. Secondly, randomization method was used to assign experimental subjects to reduce selection bias.

(1) After a six-month experimental verification, the study collected a large amount of data. The following are the comparison results of the control group and the experimental group in three aspects of operation efficiency, data security, and system stability.

Comparison of operation efficiency results is shown in Figure 4 below:

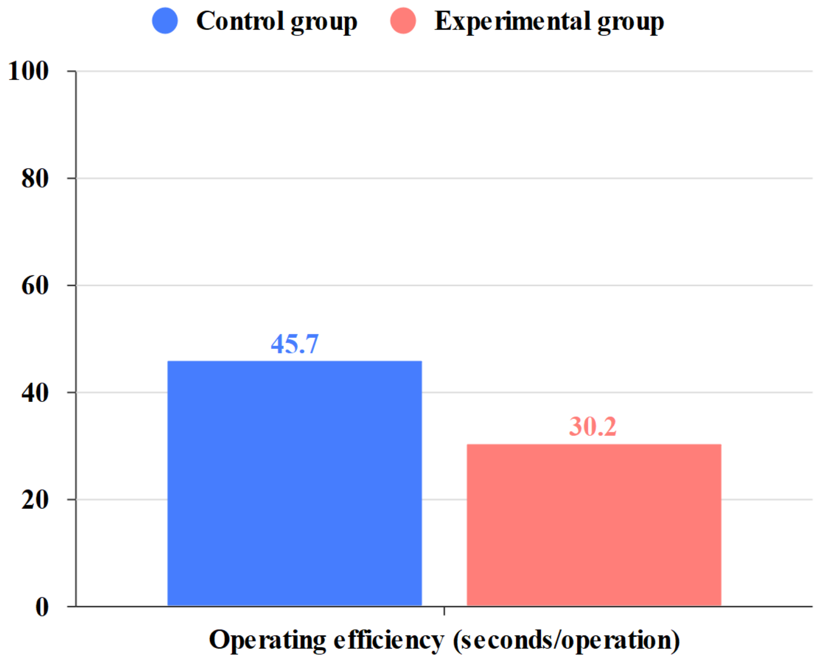

Fig. 4. Economic benefit analysis

The percentage improvement in operational efficiency is: $\frac{45.7-30.2}{45.7}\times 100\% = 33.9\%$

Comparison of data security and system stability results is shown in Figure 5 below:

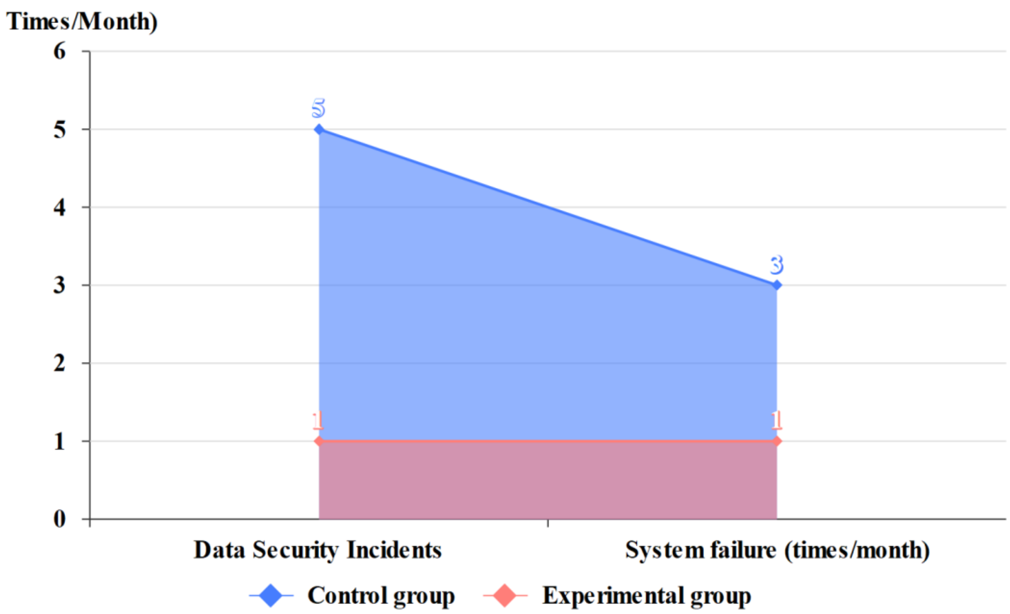

Fig. 5. Analysis of economic benefits

The percentage improvement in data security incidents is: $\frac{5-1}{5}\times 100\% = 80\%$

The percentage improvement of system failure is: $\frac{3-1}{3}\times 100\% = 66.7\%$

As can be seen from the above two figures, when randomization and matching control group are taken into account, the rural financial cloud platform using embedded hardware system and blockchain technology has significantly improved in all aspects compared with the traditional rural financial system.

In order to evaluate the stability of the results under parameter variation, a rigorous sensitivity analysis was performed.

(2) Sensitivity analysis

In order to assess the stability of the results due to parameter changes, two key parameters, operational efficiency and data security incident incidence, were selected for sensitivity analysis.

Operating efficiency:

The number of users, network delay and other parameters are simulated, and the effects on operation efficiency are observed. The results showed that even under the most unfavorable conditions, the operation efficiency of the experimental group was always better than that of the control group, indicating that the operation efficiency of the new system has good stability.

The following Eq. (5) is shown:

$$y_{efficiency} = a_{base} - b_{user} \times x_{user} - c_{delay} \times x_{delay} \quad (5)$$

Where, $y_{efficiency}$ indicates the operation efficiency, x_{user} indicates the change in the number of users, and x_{delay} indicates the change in the network delay.

Data security incident rate:

The study simulated the variation of attack intensity and system load, and observed its impact on the incidence of data security incidents. The results showed that the new system experienced a much smaller increase in data security incidents in the face of stronger attacks and greater system loads than traditional systems.

The following Eq. (6) is shown:

$$y_{security} = a_{base} + b_{attack} \times x_{attack} + c_{load} \times x_{load} \quad (6)$$

In the preceding command, $y_{security}$ indicates the incidence of data security events, x_{attack} indicates the change in attack intensity, and x_{load} indicates the change in system load.

The results of sensitivity analysis show that the performance of the new system is still significantly better than that of the traditional system when the key parameters are changed, which further verifies the potential of its application in rural financial management.

7. Conclusions

Focusing on rural financial management system innovation, this study proposes a solution combining embedded hardware and blockchain technology to solve the problems existing in the current system. After detailed technical basic research, data acquisition and preprocessing, integration of system and model design and effect evaluation, the scheme has significant advantages in operation efficiency, data security, user satisfaction, economic benefits and other aspects.

Specifically, the combination of embedded systems and blockchain technology has brought revolutionary changes to rural financial management. The data acquisition process is more efficient and the data quality is guaranteed. At the same time, the architecture of the new system is more stable and more secure, which greatly reduces the risk of data leakage and tampering. In addition, it can be seen from the user attitude analysis that most users give high evaluation and recognition to the new system. The comparison of economic benefits is further evidence that in the long run, the new system can not only provide better services, but also bring more lucrative economic returns to rural areas.

However, there are some limitations to this study. First, the trial is still limited in size and scope and fails to cover the diversity of all rural areas. Second, due to technical and environmental limitations, the accuracy and completeness of certain data may be affected. Third, the implementation and maintenance costs of the new system, as well as user adaptability, are also areas that need to be further explored in the future.

Future research should focus on the following aspects: expanding the scale and scope of the experiment to cover more rural areas; Improve data collection and processing techniques to improve the accuracy and reliability of data; Explore effective methods to reduce the cost of system implementation; The acceptance and adaptability of users are further studied. Further pilot testing or commercialization programs will also be an important part of future work to verify the viability and sustainability of the system.

In short, this study provides a strong theoretical basis and practical reference for the modernization and scientific and technological development of rural financial management, and it is expected that this innovative model can be popularized and applied in more regions and scenes, and contribute to the sustainable and healthy development of rural economy.

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Data Availability Statement
The datasets used and analysed during the current study available from the corresponding author on reasonable request.

Conflicts of Interest
The authors declare that they have no known competing financial interests.

References
[1] Apostolopoulos, V., & Kasselouris, G. (2022). Seizing the potential of transport pooling in urban logistics: The case of the Thriasio Logistics Centre in Greece. Journal of Applied Research on Industrial Engineering, 9(2), 230-248. https://doi.org/10.22105/jarie.2021.309116.1390
[2] Alqahtani, H. (2022). Smart parking and smart transportation with AI-based parking and driving. Big Data and Computing Visions, 2(2), 95-100. https://doi.org/10.22105/bdcv.2022.332450.1058
[3] Abhishek, G., Mohanta, K. B., Mohapatra, H., Al-Turjman, F., Altrjman, C., & Yadav, A. (2023). A survey on consensus protocols and attacks on blockchain technology. Applied Sciences, 13(4), 2604. https://doi.org/10.3390/app13042604
[4] Chen, Y. H., Mustafa, H., Zhang, X. D., & Liu, J. (2023). Design and analysis of management platform based on financial big data. PeerJ Computer Science, 9, e1231. https://doi.org/10.7717/peerj-cs.1231
[5] Hao, G. (2022). Design of enterprise financial management cloud platform based on neural network algorithm. Mobile Information Systems, 2022, 2479822. https://doi.org/10.1155/2022/2479822
[6] Liu, Y. (2022). Rural financial mobile service management system based on big data. Mobile Information Systems, 2022, 3316460. https://doi.org/10.1155/2022/3316460
[7] Kong, F. R., & Lu, H. X. (2021). Risk control management of new rural cooperative financial organizations based on mobile edge computing. Mobile Information Systems, 2021, 5686411. https://doi.org/10.1155/2021/5686411

[8] Liu, Y. (2021). Construction of rural financial organization spatial structure and service management model based on deep convolutional neural network. Computational Intelligence and Neuroscience, 2021, 7974175. https://doi.org/10.1155/2021/7974175
[9] Lu, S. Q. (2021). Enterprise financial cost management platform based on FPGA and neural network. Microprocessors and Microsystems, 80, 103318. https://doi.org/10.1016/j.micpro.2020.103318
[10] Liu, H., Yang, B., Xiong, X. R., Zhu, S. Q., Chen, B. Y., Tolba, A., & Zhang, X. G. (2023). A financial management platform based on the integration of blockchain and supply chain. Sensors, 23(3), 1497. https://doi.org/10.3390/s23031497
[11] Qiu, W. W. (2021). Enterprise financial risk management platform based on 5G mobile communication and embedded system. Microprocessors and Microsystems, 80, 103594. https://doi.org/10.1016/j.micpro.2020.103594
[12] Purohit, A., Chopra, G., & Dangwal, P. G. (2022). Measuring the effectiveness of the project management information system (PMIS) on the financial wellness of rural households in the hill districts of Uttarakhand, India: An IS-FW Model. Sustainability, 14(21), 13862. https://doi.org/10.3390/su142113862
[13] Zhang, X. L. (2022). Application of fusion of fuzzy mathematical clustering analysis in enterprise financial management cloud platform. Mathematical Problems in Engineering, 2022, 5354573. https://doi.org/10.1155/2022/5354573
[14] Tian, L. (2022). Design and implementation of financial service and management platform considering support vector machine algorithm. Computational Intelligence and Neuroscience, 2022, 7964123. https://doi.org/10.1155/2022/7964123
[15] Deng, Y. N. (2022). Construction of a digital platform for enterprise financial management based on visual processing technology. Scientific Programming, 2022, 7666110. https://doi.org/10.1155/2022/7666110
[16] Zhang, S. X. (2023). Application of Hadoop cloud platform based on soft computing in financial accounting budget control. Soft Computing. https://doi.org/10.1007/s00500-023-08797-3
[17] Lai, M. T. (2022). Smart financial management system based on data mining and man-machine management. Wireless Communications & Mobile Computing, 2022, 2717982. https://doi.org/10.1155/2022/2717982
[18] Jin, M. Z., Wang, H., Zhang, Q., & Luo, C. (2018). Financial management and decision based on decision tree algorithm. Wireless Personal Communications, 102(4), 2869-2884. https://doi.org/10.1007/s11277-018-5312-6
[19] Khan, N. U., Anwar, M., Li, S. J., & Khattak, M. S. (2021). Intellectual capital, financial resources, and green supply chain management as predictors of financial and environmental performance. Environmental Science and Pollution Research, 28(16), 19755-19767. https://doi.org/10.1007/s11356-020-12243-4
[20] Chen, X., Yu, W. H., & Zhao, Y. H. (2020). Financial risk management and control based on marine economic forecast. Journal of Coastal Research, 112(SI), 234-236. https://doi.org/10.2112/JCR-SI112-065.1
[21] Qin, J., & Qin, Q. (2021). Cloud platform for enterprise financial budget management based on artificial intelligence. Wireless Communications & Mobile Computing, 2021, 8038433. https://doi.org/10.1155/2021/8038433
[22] Liu, X. L. (2022). Accounting and financial management cost accounting integrating rough set knowledge recognition algorithm. Discrete Dynamics in Nature and Society, 2022, 9286252. https://doi.org/10.1155/2022/9286252
[23] Lee, R. (2021). The effect of supply chain management strategy on operational and financial performance. Sustainability, 13(9), 5138. https://doi.org/10.3390/su13095138
[24] Zeng, Y. (2022). Neural network technology-based optimization framework of financial and management accounting model. Computational Intelligence and Neuroscience, 2022, 4991244. https://doi.org/10.1155/2022/4991244
[25] Chen, X. W. (2022). The fusion model of financial accounting and management accounting based on neural networks. Mobile Information Systems, 2022, 1587274. https://doi.org/10.1155/2022/1587274