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Analysis of the Accessibility of Rural Digital Financial Services Using Machine Learning Algorithms

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Abstract The introduction of machine learning algorithms provides a new perspective and tool for the accessibility analysis of rural digital financial services. By optimizing resource allocation, improving service efficiency, and enhancing user satisfaction, machine learning can significantly improve the coverage and quality of financial services in rural areas. However, in current research and practice, the application of machine learning algorithms in rural digital financial services has not received sufficient attention, resulting in low resource utilization and insufficient service efficiency. This paper applies Linear Discriminant Analysis (LDA) in machine learning algorithms to the field of rural digital financial services and analyzes its support for the development of the real economy. Through testing rural financial institutions in different regions, it is found that the digital financial service model optimized by machine learning algorithms can significantly improve resource utilization, promote the sustainable development of the financial ecology, and effectively improve user satisfaction scores. The experimental results show that the application of machine learning algorithms has increased user satisfaction by 6.6% and significantly improved the ecological and environmental protection index and efficiency of financial services.

Index Terms Digital Financial Services, Ecological Construction, Industrial Ecology, LDA

I. Introduction

Digital financial services refer to new financial services created by combining traditional financial services and products with the Internet with the help of information technology and tools and equipment, with the Internet and mobile Internet as the main selling points. It focuses on financial services and products, and its source is closely related to the network activities of capital. It is very important to let digital finance play its own benefits to help the economy grow naturally and increase the momentum of economic growth.

Many scholars have studied digital financial services: Abounabhan M studied rural residents' views on digital financial services and determined which factors might enhance or hinder their adoption. The survey results showed that the lack of liquidity of agents and the implicit costs imposed by agents on consumers hindered the adoption of digital financial services [1]. Mu H L explored the rationale for a new tax on digital financial services and its likely impact to help governments and other parties involved develop policies that best met their competitive needs [2]. From the aspects of infrastructure construction, market opening, new area development, etc., Bailur S pointed out that the digital financial data foundation was weak, the transformation speed of traditional financial institutions was slow, and the digital financial supervision was insufficient [3]. Kulkarni L worked on the development of the foundations of digital transformation and ensures its stability, so as to study the conceptual basis of thermal markets and to define the priorities of their growth on the basis of the digitalization of services and secure a midterm period of growth and stability [4]. Chikomba A described that digital financial services were promoting financial inclusion and improving financial health through digital technology. There was an urgent need to raise citizens' awareness of the basic knowledge of digital financial services, especially in rural and semi urban areas [5]. However, most of these studies focus on the application of traditional methods and lack exploration of the potential of emerging technologies in rural digital financial services.

As society continues to develop, people's demand for financial services is becoming increasingly diversified, especially in rural areas. How to improve the accessibility of digital financial services through technological innovation has become an urgent problem to be solved. As a powerful data analysis tool, machine learning algorithms can optimize the resource allocation and decision-making process of financial services through deep mining and pattern recognition of multi-dimensional data. Khan M S explored the effect of modern modern finance on energy and energy performance, and showed that digital finance significantly improved energy and environmental performance, which remained strong after a series of tests. The green innovation was the route of transmission through which digital finance influences energy and energy performance [6]. Wang D sought to use digital finance to solve the obstacles faced by traditional finance in supporting these innovations. By using panel data from listed companies and cities, he analyzed the impact of digital finance on green technology innovation and found that the development of digital finance had a greater positive effect on small enterprises' green technology innovation [7]. Thompson studied the impact of numerical finance on green growth empirically using a fixed effects approach. The results of the analysis of dissimilarity showed that digital finance had a greater impact on green growth in midwestern cities and minor towns [8]. Olowu G systematically discussed the concepts of legal ecology and legal ecology, the components of legal ecology and its evaluation index system, and also analyzed the current situation of legal ecology in cities and suggestions for improvement [9]. Zhou X proposed countermeasures for optimizing the region's financial economy from the perspective of ecology, and local governments should strengthen their leadership in optimizing the financial ecology [10]. The above research has analyzed the green ecological finance, but there are still some problems.

The ecological development of digital financial services is of vital importance. This paper integrates the ecological construction of green industries into digital financial services, aiming to promote their sustainable development, and verifies their actual effects through accessibility analysis. In terms of methods, this paper uses LDA to conduct an in-depth study of rural digital financial services. By performing multidimensional feature analysis on the data of different rural financial institutions, linear discriminant analysis can effectively distinguish and optimize financial service models, thereby improving resource utilization, ecological and environmental protection index, and financial efficiency. The experimental results show that the digital financial service model combined with linear discriminant analysis not only significantly improves user satisfaction, but also provides a scientific basis and technical support for the sustainable development of rural finance.

II. Role of Green Ecological Construction in Digital Financial Services

(1) The embodiment of digital finance serving the development of real economy

1) Digital finance increases the financing channels of the real economy

Small businesses have difficulty reaching the credit limits of traditional financial institutions due to their small size and insufficient deposits. Digital finance can provide customers with appropriate financial services without asset collateral and effectively solve financial problems for a long time.

2) Digital finance reduces the cost of real economy to obtain financial services

Digital finance uses mobile Internet, cloud computing, big data and other technologies to overcome the limitations of time and space and achieve the effect of streamlining human resources, compressing teams and simplifying processes. Based on data insight, changes in customers' financial needs and risks are discovered in time to improve the efficiency of financial resource allocation and reduce credit risk and financial service costs [11].

3) Digital finance brings new business models to the development of the real economy

The emergence of electronic payment has solved the payment problem in e-commerce transactions and promoted the online business to become the largest online shopping website. Many sellers have started to own their own online stores, and their profits even exceed those of physical stores.

(2) Green financial service model

In view of the new characteristics of green financial service analysis service, that is, multidimensional data set optimization, time optimization, data mining optimization and other problems, a four tier big data analysis service model with user needs as the main body is proposed. The model develops a set of appropriate analysis functions according to each user's needs, and can provide analysis results in a timely manner. It can adequate to respond to the customization, sophisticated and adaptation of the user's needs at the moment, and finally supply the user with an exact analysis solution. The green financial service model is shown in Figure 1.

As shown in Figure 1, the mathematical model of financial analysis services is divided into four stages. Among them, the hierarchical representation of user requirements: There are many users, and the analysis requirements of each user are divided into various categories. The matching relationship with the next level is the analysis requirements of each user by function. There are two levels of service level. Among them, the functions in the analysis function combination layer can have many different individual functions, and the functions in the atomic function layer can complete an independent function [12].

(3) Key technology analysis

Based on the architectural analysis of the above system, this paper carries out in-depth study of the technical content of the present analysis service system. The implementation of financial services must solve the problems of user management, service management, demand management, and construction management decision-making. The specific core technology architecture analysis is shown in Figure 2.

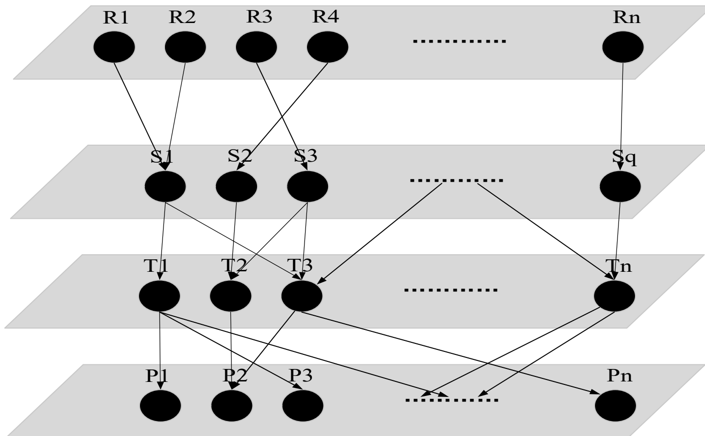

Figure 1: Green financial services model

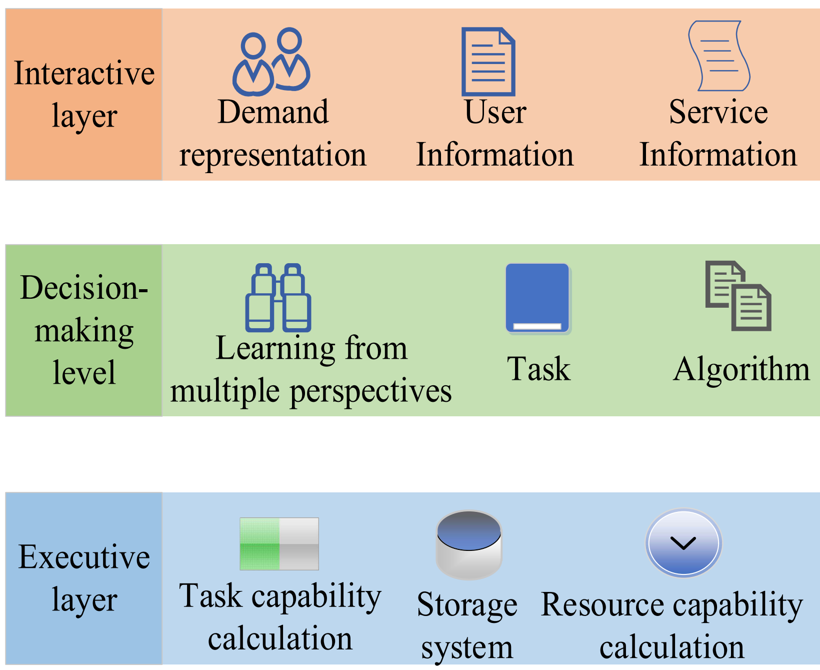

Figure 2: Key technical analysis

As shown in Figure 2, the underlying technologies are grouped in three main areas: the interaction floor, the decision floor, and the delivery floor. The need to automate the volume and timing of service delivery requires the support of technologies such as machine learning and analytical algorithms. The executor tier must count the workload and estimate the resource consumption based on the workload calculation plan determined by workload scheduling in order to assign tasks appropriately. By depending on the amount of collected data stored, a number of data used by the interactivity and decision layers are stored in the file system and then processed based on the decision and implementation [13]. This layer is saved in a database in storage in mind and can be adjusted to the processing, generating small amounts of data with high real-time requirements.

(4) System service architecture

The general structure of the platform refers to the model, the point of view and the coordinator together, which allows to index the input, handling and output functions in a logical pictorial environment. Among them, the call model displays the request selection service, and displays the analysis result as it is. The system result of the system service is shown in Figure 3.

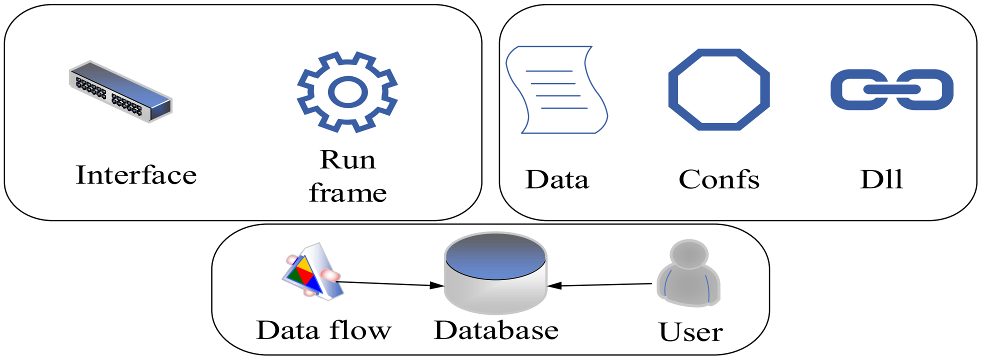

Figure 3: System services architecture

The green financial services analysis framework is developed to monetize system services through applications. The layer of providing services first interprets and carries out data analysis treatment flows. The main functionality of the system is based on three basic layers of services: administrative layer, visiting layer, and durable layer. The operator calls the interface of the service layer and responds to user demands. The application allows users to present and submit several tasks in a single multi-user and multitasking manner and can run multiple tasks in the background.

III. Combination of Digital Financial Evaluation Services for Multi Perspective Learning

Traditional analysis services aim to improve the service value. They only describe the data from one perspective, and then learn the classics in the portfolio to obtain the effective value of the portfolio. They provide users with more portfolio related analysis functions and ensure high-value aggregate analysis results, so as to help users make decisions [14], [15].

(1) Overview of multi perspective learning theory

In real life, the same object can be described from many different angles or in different ways, that is, the data obtained can be represented by many features, so the features of the object can also be represented by different feature sets from different angles. It has been shown that such data is called multi view data, and the research on multi view data can be called multi view learning.

Multi view learning focuses on the data representation of multidimensional features in machine learning. To a large extent, the introduction of this machine learning is due to the fact that the data features generated by practical applications are no longer unique, that is, data has useful applications, and it can be described with different features or different perspectives. In addition, for multi view learning, it is worth mentioning that when a feature is unavailable, the use of artificial features can also be considered to improve performance. Therefore, a broader multi perspective learning world is a promising research topic.

In the research process of multifaceted learning, canonical correlation analysis and cooperative learning are the most typical technologies. These theories and methods are mainly used to study their scientific characteristics in the later development of various theories, which not only explains their successful process, but also can be applied to other machine learning fields.

By studying correlation from multiple angles, a method combining canonical correlation analysis and linear discriminant analysis is proposed. First, the correlation of multidimensional indicators of financial stock characteristics is studied, and then the joint training classifier is used to predict market changes. In other words, the combination is completed by learning the compatibility of the data set provided by a single function, and then it analyzes the accuracy of the analysis results provided by the combination function.

(2) Multi perspective learning method

The traditional way to deal with multi view data is to analyze the characteristics of each view of multi view data independently, while a group of different views describing the same object have internal relations. Therefore, by analyzing the relationship between different opinions and combinations, the prediction classification of common opinions is created to provide the analysis results of the joint intelligence analysis function to help users make decisions [16].

The basic idea of linear discriminant analysis is to form an optimal discriminant vector space from high-dimensional data samples, which is used to separate two or more categories of objects or events, and find the optimal prediction space, so that it has multiple class attributes that can be used[17], [18]. The design of this space provides the minimum intersection, so it is the best separation. It is an effective tracking classification method, which can not only minimize the space occupied by verification samples of the same structure, but also maximize the distance of samples of different structures, so as to achieve the maximum classification category [19], [20].

A data array $M \in R^{x \times y}$ is given. Among them, each column of data contains a type of attribute data. It is assumed that $M = [m_1, m_2, ..., m_y] = [M_1, M_2, ..., M_k]$. Among them, $m_j \in R^x (1 \le j \le y)$ represents a data type, so y refers to the total number of samples and k refers to the total number of categories. At the same time, $M_i \in R^{x \times y_i}$ represents all sampling units in category i; y_i represents the number of data in the unit; $\sum_{i=1}^{k} y_i = y$ represents the reference. In addition, S_b represents the inter class hash matrix; S_w represents the intra class hash matrix; S_t represents the global hash matrix; q_i represents the sample mean of class i; q represents the overall mean sample.

According to the above symbol description, the average value of the population sample is obtained:

$$q = \frac{1}{y} \sum_{i=1}^{k} M_i \tag{1}$$

Similarly, the sample mean of class i can be obtained:

$$q_i = \frac{1}{y_i} \sum_{m=M_i} m \tag{2}$$

According to the definition of overall hash matrix, inter class hash and intra class hash matrix, the following formula can be obtained:

$$S_t = \frac{1}{y} \sum_{j=1}^{y} (m_j - q)(m_j - q)^T \tag{3}$$

$$S_b = \frac{1}{y} \sum_{i=1}^{k} m_i (q_i - q)(q_i - q)^T \tag{4}$$

$$S_w = \frac{1}{y} \sum_{i=1}^{k} \sum_{m \in M_i} (m - q_i)(m - q_i)^T \tag{5}$$

$$F(w) = \frac{w^T S_b w}{w^T S_w w} \tag{6}$$

$$F(w) = \frac{w^T S_b w}{w^T S_t w} \tag{7}$$

Among them, w refers to the column vector with any dimension y, and Fisher discriminant analysis is used to select the vector prediction point that can maximize the result value of $F(w)$. Through analysis and investigation, it is found that the eigenvector corresponding to the maximum eigenvalue in matrix $S_w^{-1} S_b$ or $S_t^{-1} S_b$ is the best prediction point w. Finally, according to the classification prediction function $n = w^T m - w^T q$, when q>0, it belongs to category 1, otherwise it belongs to category 2.

Under the LDA method, the accessibility of digital financial services in rural areas can be modeled through multiple characteristic indicators, such as network coverage, mobile phone penetration, financial knowledge level, income level, etc. LDA uses samples of these known categories to find an optimal linear combination to effectively distinguish different regions.

Through dimensionality reduction processing, LDA not only reduces the interference of complex features on the analysis model, but also maximizes the differences between categories, thereby improving the accuracy of identifying the level of accessibility of rural financial services. This method can help policymakers or financial institutions clearly identify areas with weak services and formulate more targeted digital financial promotion strategies.

Overall, linear discriminant analysis provides a statistical tool that takes into account both explanatory and classification accuracy for the study of rural digital financial accessibility, so that complex and multi-dimensional data can be transformed into intuitive and operational decision-making basis.

IV. Evaluation on the Accessibility of Digital Financial Services for Industrial Ecological Construction

In order to analyze the impact of machine learning algorithms on the accessibility of rural digital financial services, four banks in a rural area were randomly selected for research, and they were named Bank A, Bank B, Bank C and

Bank D. Among them, Bank A and Bank B adopted the traditional rural digital financial service model, while Bank C and Bank D introduced a digital financial service model optimized based on the LDA algorithm. By conducting resource utilization tests, ecological and environmental protection index tests, financial efficiency tests, and user satisfaction tests on these four banks, the effect of the LDA algorithm in improving the accessibility of rural digital financial services was evaluated. The test period is 4 weeks, and the results are recorded once a week to observe the differences between different service models and analyze their impacts. The specific data are shown in Table 1.

Table 1: Bank specific data sheet

	Service type
Bank A	Internet payment; Mobile payment; Online bankin; Financial services
Bank B	Internet payment; Mobile payment; Online bankin; Financial services;Online fund
Bank C	Internet payment; Mobile payment; Online bankin
Bank D	nternet payment; Mobile payment; Online bankin;Online fund

(1) Resource utilization test

Reasonable utilization of resources can reduce the use of resources and ensure the sustainable development of the industry. Four banks were tested for resource utilization to observe how the digital financial service model of ecological construction of green industry has improved compared with the traditional digital financial service model. The experimental test was recorded and the results were analyzed, as shown in Figure 4.

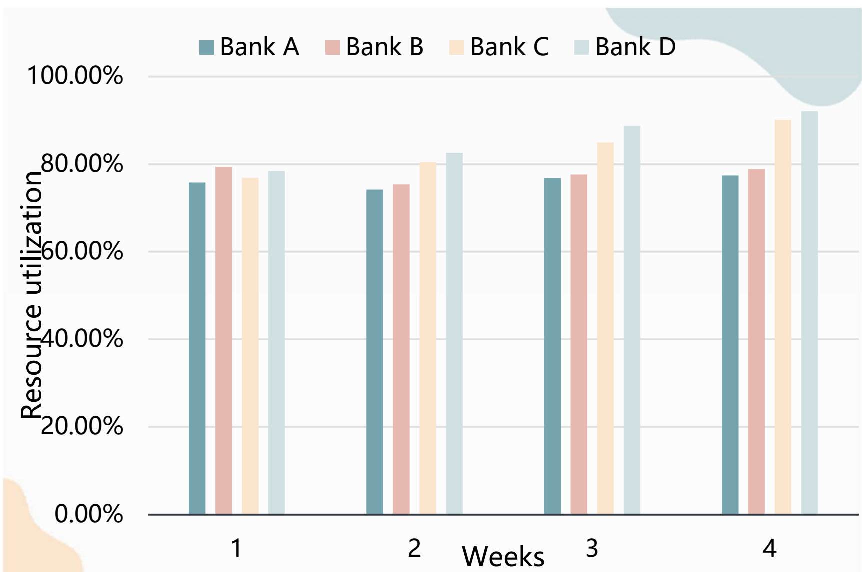

Figure 4: Resource utilization test

It can be seen from Figure 4 that the initial resource utilization rates of the four banks are similar. After four weeks of experimental testing, the resource utilization rates of Bank C and Bank D are far higher than that of Bank A and Bank B. Among them, the resource utilization rate of Bank A decreased in the second week and increased in the third and fourth weeks. The resource utilization rate of Bank B decreased in the second week and increased in the third and fourth weeks. The resource utilization rate of Bank C and Bank D increased in the second, third and fourth weeks. The resource utilization ratio of Bank C increased from 76.9% to 90.1%, and the resource utilization ratio increased by 13.2%. The resource utilization ratio of Bank D increased from 78.4% to 92.1%, and the resource utilization ratio increased by 13.7%. To sum up, the digital financial service model of ecological construction of green industry can improve the utilization rate of resources and ensure the sustainable development of the industry.

(2) Ecological and environmental protection index test

In the continuous development of the industry, special attention should be paid to ecological environmental protection. The four banks are tested on the ecological environmental protection index to observe the differences in the test results of the four banks. The results are recorded and analyzed, as shown in Figure 5.

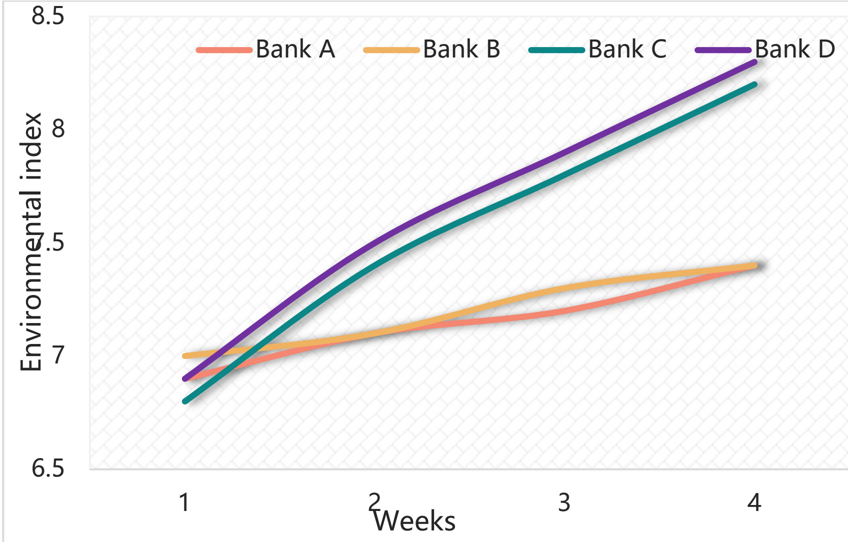

Figure 5: Ecological environmental protection index test

It can be seen from Figure 5 that, through experimental tests, the ecological environmental protection indexes of the four banks are showing an upward trend. The rising trend of the ecological environmental protection index of Bank A and Bank B is relatively slow, while the rising trend of the ecological environmental protection index of Bank C and Bank D is relatively fast. Among them, the ecological environmental protection index of Bank A increased from 6.9 to 7.4, and the ecological environmental protection index increased by 0.5. The ecological environmental protection index of Bank B increased from 7 to 7.4, and the ecological environmental protection index increased by 0.4. The ecological environmental protection index of Bank C rose from 6.8 to 8.2, and the ecological environmental protection index rose by 1.4. The ecological environmental protection index of Bank D rose from 6.9 to 8.3, and the ecological environmental protection index rose by 1.4. To sum up, the digital financial service model of ecological construction of green industry can improve the ecological environmental protection index more than the traditional digital financial service model.

(3) Financial effectiveness test

Financial efficiency refers to the liquidity and value-added of finance. The financial efficiency test can well observe the trend of digital financial services. The financial efficiency test is conducted on four banks to observe the differences in the financial efficiency of the four banks' digital financial services. The results are recorded and analyzed as shown in Figure 6.

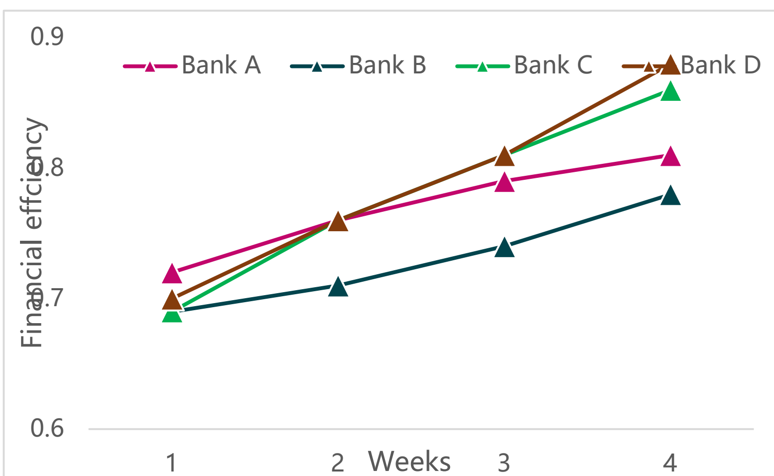

Figure 6: Financial performance test

It can be seen from Figure 6 that the financial efficiency of the four banks is on the rise. The rising trend of financial efficiency of Bank A and Bank B is relatively slow, while that of Bank C and Bank D is relatively fast. The financial efficiency of Bank A increased from 0.72 to 0.81, and the financial efficiency increased by 0.09. The financial efficiency of Bank B increased from 0.69 to 0.78, and the financial efficiency increased by 0.09. The financial efficiency of Bank C increased from 0.69 to 0.86, and the financial efficiency increased by 0.17. Among them, the financial efficiency of Bank D increased from 0.7 to 0.88, and the financial efficiency increased by 0.18.

(4) User satisfaction test

User satisfaction refers to the recognition of financial services and five users are randomly selected from four banks to conduct satisfaction test. The test method is questionnaire survey and the full score of the questionnaire is 10. The user satisfaction test results of four banks are recorded and the impact of ecological construction of green industry on user satisfaction is analyzed. The results are recorded and analyzed. The results are shown in Figure 7.

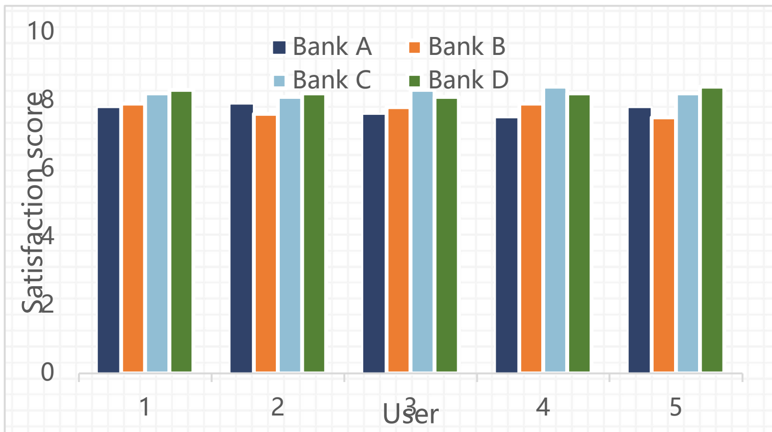

Figure 7: User satisfaction test

As can be seen from Figure 7, the customer satisfaction scores of Bank C and Bank D are higher than that of Bank A and Bank B. Among them, the average user satisfaction score of Bank A is 7.72; the average customer satisfaction score of Bank B is 7.74; the average customer satisfaction score of Bank C is 8.24; the average user satisfaction score of Bank D is 8.24. To sum up, the average satisfaction score of bank users who adopt the traditional digital financial service mode is 7.73, and the average satisfaction score of bank users who adopt the green industrial ecological construction digital financial service mode is 8.24. The application of ecological construction of green industry has improved the user satisfaction score by 6.6%.

In order to comprehensively evaluate the application effect of linear discriminant analysis in rural digital financial services, this paper conducts multi-dimensional tests on the four selected banks. By analyzing key indicators such as service coverage, transaction convenience score, risk control capability index, and inclusive finance index, the purpose is to compare the differences between the traditional model and the digital financial service model based on LDA. The results are shown in Table 2:

Table 2: Financial accessibility analysis

Bank	Service coverage (%)	Transaction convenience score	Risk Control Ability Index (0-1)	Financial inclusion index (0-100)	Comprehensive accessibility score (0-100)
Bank A	68.3	6.9	0.74	56.2	62.8
Bank B	70.4	7.1	0.72	58.5	64.1
Bank C	85.7	8.3	0.86	78.9	86.4
Bank D	87.2	8.5	0.88	80.3	88.7

Through a multi-dimensional analysis of the accessibility of financial services of the four banks, the results show that the green industry ecological construction model based on LDA optimization is superior to the traditional model in terms of service coverage, transaction convenience, risk control ability and inclusive financial level. This not only significantly improves the accessibility of rural digital financial services, but also provides a practical basis for the application of machine learning algorithms in financial services.

V. Conclusions

With the continuous development of information technology, the application of digital financial services in rural areas is becoming more and more extensive, but its accessibility is still a key challenge that needs to be solved. This paper introduces the LDA algorithm to conduct an in-depth analysis of the accessibility of rural digital financial services, and combines it with the green industry ecological construction model to verify its significant effect in improving service accessibility. Through multi-dimensional testing of four banks, it is found that Bank C and Bank D, which adopt the green digital financial service model based on LDA optimization, are significantly better than Bank A and Bank B with traditional models in terms of service coverage, transaction convenience, risk control ability and inclusive finance index. Especially in terms of user satisfaction, the application of the green model has increased the user satisfaction score by 6.6%, further proving its important role in improving the accessibility of rural financial services.

The research results show that machine learning algorithms can effectively mine and analyze multidimensional data characteristics, optimize the resource allocation and decision-making process of rural digital financial services, and thus improve the overall service efficiency. In addition, the combination of green industry ecological construction and digital financial services can not only improve resource utilization and ecological environmental protection levels, but also enhance the inclusiveness and sustainability of financial services. These findings provide new ideas and technical support for promoting the high-quality development of rural finance. Future research can further explore the application of other machine learning methods in rural financial services to achieve wider financial inclusion and higher service accessibility.

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Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

Conflicts of Interest

These are no potential competing interests in our paper. And all authors have seen the manuscript and approved to submit to your journal. We confirm that the content of the manuscript has not been published or submitted for publication elsewhere.

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