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Smart Platform for Matching and Optimizing Barter Using Artificial Intelligence and Blockchain

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Monitoring transaction histories and the flow of commodities is complicated with increasing transaction risks and disputes. Although a variety of technological solutions are available in the market, they often operate in isolation, lacking effective integration. In addition, the traditional barter trade model, with its inefficiency, lack of transparency, and security risks, hinders the efficient development of trade. Therefore, a smart barter platform is required to create a system where multiple technologies, such as artificial intelligence, blockchain, near-field communication, and IoT, are integrated to enhance transaction efficiency and user experience. In this study, we developed deep learning and machine learning algorithms for the smart barter platform, which accurately identify market demand, optimize supply chains, and predict demand trends. Blockchain technology was employed to ensure the transparency, security, and traceability of transactions. The core function of the developed smart barter platform is to accurately predict and intelligently match market supply and demand while ensuring transaction transparency and temporality through blockchain technology. E-commerce platform companies confirmed the advantages of the smart barter platform in improving transaction success rates and transaction security. The companies using the developed AI and blockchain increased the successful search rate for merchandise by 15.5%. The developed innovative technological solution for smart barter transactions is a new business model for the digital economy.

1. Introduction

Global trade activities have thrived within the rapidly advancing digital economy, driven by significant growth and potential through the adoption of emerging information technologies, especially AI. Amid the trend, the Information Technology Agreement (ITA) of the World Trade Organization (WTO) has been instrumental in fostering the growth of information technology (IT) trade. Eighty-two countries involved in the global trade of IT products have embraced ITA,

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which promotes the use of IT in industries and advocates for the elimination of tariffs on IT products.(1)

The application of AI in barter systems has revolutionized global trade. AI is utilized to manage warehouses, forecast demand, and improve the efficiency of just-in-time manufacturing.(2) Particularly in the North American market governed by the U.S.-Mexico-Canada Agreement, the importance of leveraging technology in fulfilling trade agreements and promoting free trade at the border is highlighted.(3) In the European Union (EU) market, AI-driven consumer services are provided to personalize transactions at scale to connect EU consumers with globally operating businesses.(4)

Blockchain technology has the potential solution to address challenges in trade finance.(5) Global trade risk management has been conducted to facilitate trade in control processes.(6) Blockchain technology, as an effective technological tool, provides targeted proposals for trade settlement by enhancing the trade structure and improving global competitiveness.(7) Blockchain technology in trade finance promotes economic diversification, such as in Qatar.(8) Presently, blockchain technology is used to ensure automated, efficient, and secure trade processes.(9)

However, the implementation of IT solutions, including AI and blockchain in barter transactions, relies on global agreements such as ITA, and there are concerns about data security and privacy. These factors highlight the efficiency, security, and compliance with trade regulations in barter transactions. Therefore, the IT solutions used in global trade improve the efficiency of barter transactions and significantly affect the related decision-making process. However, IT usage still requires in-depth research to address the challenges posed by the evolving trade industry and varying needs.

In this study, we developed a digital token based on blockchain technology (YiCoin) to facilitate trading on e-commerce platforms. YiCoin is created by the pledge method and cash recharge methods to ensure the transparency, security, and traceability of transactions. To create YiCoin, we developed an algorithm for the smart barter platform to match and recommend transactions using blockchain, near-field communication (NFC), and the IoT technology. The architecture of the platform was designed for IoT blockchain-based barter transactions and their management. The developed platform was validated for its performance by comparing it with that of existing solutions. The efficiency, transparency, and feasibility of the smart barter platform were evaluated, and challenges such as management complexity, compliance issues, and the impact of data quality on the platform were discussed along with them.

Note that these three major challenges are not isolated but interact with each other, amplifying the risks for smart barter platforms. As emphasized in interdisciplinary research literature references, poor data quality directly increases management complexity—for example, if IoT-collected product data are incomplete, technical teams must allocate additional resources to verify data accuracy before integrating it into the blockchain ledger, thereby extending maintenance cycles. Simultaneously, compliance requirements may further constrain data management: regions enforcing stringent data privacy laws may restrict the types of user transaction data that can be stored or utilized for algorithmic recommendations. This, in turn, reduces the scale of the dataset available to matching algorithms and amplifies the impact of existing data quality issues. This interdependence underscores the necessity for a holistic solution that addresses all three challenges simultaneously, rather than treating them as separate, independent problems.

This article is structured as follows. In Sect. 2, the literature review results on the essential technologies and algorithms of the smart barter platform are presented. Then, in Sect. 3, we describe the design, key technologies, and algorithms of the smart barter platform. In Sect. 4, we present the system design, architecture, and user interface (UI) of the platform and its implementation. In Sect. 5, we verify the platform performance and compare it with that of existing solutions. In Sect. 6, we analyze the results and explore the impact of the practice and policy on the system implementation. In Sect. 7, we conclude this study and review the limitations of the system development and usage.

2. Literature Review

2.1 AI and blockchain in trade

AI is used to reduce costs and improve productivity in automated production and logistics management. AI also helps companies develop and manufacture customized products and services to meet personalized needs.[10] AI has been applied to supply chain management and market forecasting and has contributed to the development of global trade. Companies can manage the supply chain and logistics efficiently with AI,[11] as the efficiency and accuracy in data processing and analysis are significantly enhanced. By accurately identifying market demand, optimizing the supply chain, and predicting demand trends, companies can better grasp market opportunities, improve decision-making efficiency, reduce risks caused by demand fluctuations, and thus improve transaction efficiency.[12] AI has been changing the business model of global trade. However, there are concerns about the regulation of AI in trade and e-commerce agreements of WTO. Companies must protect their trade secrets as AI evolves to prevent any potential disclosure and its consequences.[13]

Blockchain technology has proven its value in global trade but presents the risk of demand volatility. Companies can trade more efficiently by reducing delivery lead times and transportation costs when using blockchain and smart contracts.[14] Such advantages are also observed in credit and financial markets.[15] H. Wang et al. developed a blockchain maturity model to evaluate the effectiveness of blockchain technology in the agricultural supply chain, emphasizing the need for technology application.[16] T. Teo evaluated the user acceptance and experience of the mobile automatic identification system in the technology acceptance model and DeLone and McLean information system. He recommended improving the user experience.[17]F. Lamberti et al. explored how to apply augmented reality technologies in education, highlighting their benefits for increasing learning motivation.[18] L. Kobayashi et al. reviewed the implementation of multi-source information fusion in the rough set theory.[19] H. C. Koh et al improved the Apriori algorithm for data mining to enhance the efficiency and convenience of using the copyright management system for books.[20] L. Dijkstra et al summarized how blockchain technology has been utilized in the food and agriculture industry and emphasized the importance of forming a consortium to use it. Blockchain technology simplifies the transaction process, eliminates the need for a trusted third party, and enhances the transparency and security of transactions.[21]

2.2 Algorithm of barter platform

Various algorithms have been developed and implemented on barter platforms to enhance their functionality and efficiency. The algorithms are used to balance the trade-offs between exploration and development to maximize access to functionality.[(22)] Ren and Bao reviewed human–computer interaction and intelligent robots in systems.[(23)] Van Luc *et al.* developed a fast binary field multiplication algorithm for hardware platforms.[(12)] Yan *et al.* proposed a new matrix factorization algorithm for collaborative filtering.[(24)] Mladenov and Nooshabadi compared the hardware efficiency of the secure hash (SHA) algorithm on different field-programmable gate array platforms.[(25)] B. Liu B et al. compared the hardware efficiency of the secure hash (SHA) algorithm on different field-programmable gate array platforms.[(26)] Zhang and Cao improved a container scheduling algorithm using big data applications.[(27)] Zhou developed an intelligent education system based on deep learning.[(28)] Wu *et al.* designed a resource recommendation algorithm for online English learning systems,[(29)] and Xiong *et al.* developed a modification-free steganography algorithm for an online English learning system by designing a universal servo control algorithm verification system.[(30)]

Algorithmic bias detection and mitigation are crucial to address biases due to various data sources.[(31)] Digital neuromorphic processors such as the SENECA core are used to run integrated algorithms on a single platform.[(32)] Optimizing algorithms on the Trade Desk platform enables the determination of user value to solve complex problems. The Trade Desk's Kokai platform adopts deep learning algorithms.[(33)] Algorithms automate trading at high speed and frequency. However, ethical considerations must be considered on platforms such as Facebook. Therefore, responsible algorithmic design is critical for privacy protection.[(34)] On the MT4 platform, trading algorithms are coded especially for stocks and commodities.[(35)] Companies, including Apple, are developing display image processing algorithms in their platform architecture.[(36)] The Federal Trade Commission emphasizes the responsible use of AI and algorithms to ensure fairness and ethics in automated decision-making.[(37)]

Human–computer interaction, binary domain multiplication, collaborative filtering algorithms, security hash algorithms, container scheduling mechanisms, intelligent education systems, steganography, and servo control algorithms are designed and used on barter platforms. On the basis of the principles of existing algorithms, the functions of the barter platform are optimized to improve user experience and system efficiency. The evolving IT has simplified, accelerated, and improved the efficiency of trade processes and influenced consumer behavior and market trends. However, the application of a single technology in smart trade has challenges such as a lack of diverse algorithms and the vulnerability of security, which deteriorates transaction security and barter trade efficiency.

Therefore, more research is required to utilize AI to develop algorithms for smart trade and integrate diverse algorithms for increased trading efficiency, data security, and ethics. In this study, we developed a smart barter platform that integrates AI and blockchain technologies and evaluated its effectiveness in enhancing the success rate and transaction security to fill the gaps of existing research.

3. Background Knowledge

3.1 Blockchain and YiCoin

Despite extensive research on algorithms for human–computer interaction, binary domain multiplication, collaborative filtering algorithms, the hardware-level implementation of security hash algorithms, container scheduling mechanisms, intelligent education systems, steganography, and servo control algorithms, there is still a need for research on its development for barter platforms. On the basis of existing algorithms, we developed an algorithm for a barter platform to enhance user experience and system efficiency. To simplify and improve the efficiency of trade processes, consumer behavior and market trends must be analyzed. However, challenges, including the lack of effective algorithms and vulnerability, undermine transaction security. Therefore, it is necessary to study how to integrate different technologies to enhance trading efficiency and data security, solve legal ethics issues, and promote the usage of related algorithms. In this study, we integrated a company-level transaction algorithm and blockchain technologies for a smart barter platform to enhance the success rate of transactions and ensure transaction security.

YiCoin was designed to support interactive, decentralized storage systems at a massive scale. It was developed on the basis of blockchain technology to facilitate barter transactions on e-commerce platforms. YiCoin is used for operations including account redirection, storage access, and NFT minting without smart contracts for users to easily exchange value directly. It rewards storage providers, validators, and contract executors for creating a decentralized economy where services can be exchanged for YiCoin. Transactions through YiCoin are stored off-chain as receipt fragments to provide barter-style exchanges of data or services without clogging the blockchain. Created through pledges and cash recharges, it ensures transaction transparency, security, and traceability. It serves as a medium of exchange, reducing reliance on traditional financial systems and enhancing transaction efficiency and security through smart contracts. YiCoin is in a conceptual or experimental phase to realize decentralized storage and off-chain transactions, but it supports yottabyte-scale data and flexible operations without smart contracts.[38]

3.2 NFC and YiCoin

P. Van Luc et al. designed a cloud-edge computing power trading framework using NFC and its mobile communication terminals and functions. (12) J. Mao et al. introduced AI and NFC to global trade NFC utilizes the spatial coupling of radio frequency signals for noncontact information transfer. It is developed on the basis of 13.56 MHz noncontact technology and is compatible with the ISO14443 standard. It is a short-range wireless technology that enables two electronic devices to communicate when they are within a few centimeters of each other, and it is based on radio-frequency identification (RFID) and operates at a frequency of 13.56 MHz. It enables exchanging data at short distances between different electronic devices. Data are read from a passive NFC tag through a process called inductive coupling. The NFC reader with a coil generates an electromagnetic field by absorbing energy through the modulation of the electromagnetic field and the generation of an induced current to power the tag's microchip. Then, the microchip transmits stored data.[39] The reader then decodes and interprets the tag's data. NFC is used with a broader bandwidth and consumes less energy than RFID (Table 1).

NFC Forum Types 2 and 5 tags are widely used for product authentication, supply chain management, and inventory tracking. NFC Forum Type 2 tags are based on the ISO/IEC 14443-3A standard, whereas NFC Forum Type 5 tags are based on the ISO/IEC 15693 standard. They are standard industrial applications for logistics and asset tracking because they have a longer communication range than other NFC types.

NFC Forum Type 2 tags are fabricated using a small IC chip, such as the NXP NTAG® NFC Tag Integrated Circuit Series, which is bonded to a thin and flexible antenna made of copper or aluminum. This assembly is mounted onto a plastic or paper substrate, that is, a sticker or label. The tag is then attached to items. NFC Forum Type 5 tags are manufactured using chips that comply with the ISO/IEC 15693 standard, including the NXP ICODE NFC/RFID Tag IC Series or STMicroelectronics ST25DV-I2C Dynamic NFC Tag Series. The tags feature larger antennas to support longer read ranges and are often embedded into durable materials, such as hard plastic casings or rugged labels. The fabrication process includes bonding the chip to the antenna, encapsulating it for protection, and encoding it with relevant data for industrial or commercial use. Their compatibility with NFC and RFID readers makes them versatile for hybrid systems.[40]

We combined NFC with YiCoin to develop an inventory management model with the process related to YiCoin transactions as follows (Fig. 1). YiCoin is integrated with NFC tags that are attached to goods to store basic item information. The information stored in the NFC tags is used for the real-time tracking of item transportation as well as for bartering through the YiCoin platform.

Step 1: System initialization
1) NFC tags are attached to each inventory item to store basic information about the item.
2) NFC readers and sensors are configured and deployed to cover all inventory areas.
3) The YiCoin platform is integrated with NFC platforms through the transaction algorithm using blockchain technology for smart matching and transaction recording.

Table 1
Technical specifications of NFC and RFID.

Specification	NFC	RFID
Transmission distance	10–20 cm	Dozens of meters
Operation	Advanced smartphone-compatible structure	Traditional for logistics, tracking, etc.
Security	Shorter transmission distances for secure and reliable information exchange	Low
Mode of communication	Two-way communication	One-way communication
Advantage	Fast, reliable, and simple	Wide range of applications and long transmission distances

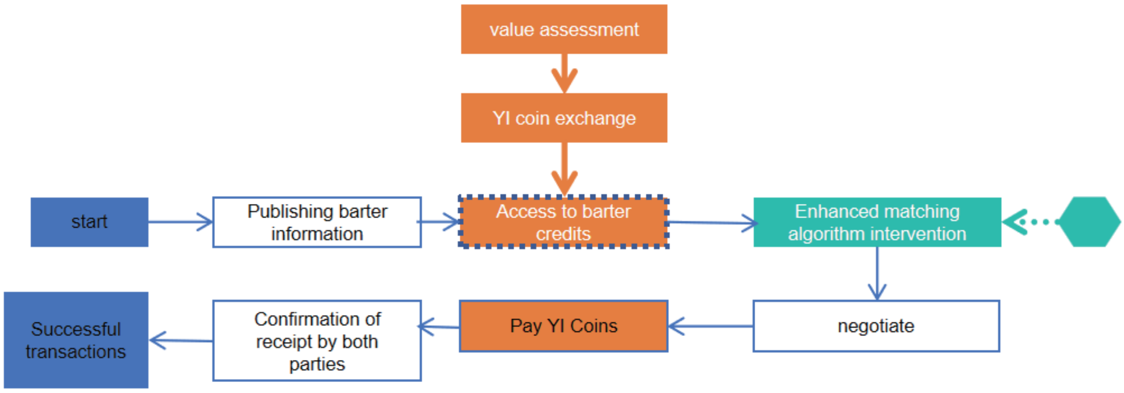

Fig. 1. (Color online) Transaction flow based on blockchain and YiCoins.

Step 2: Inventory management
1) The collected data from NFC tags of the newly stocked items are input into the system and associated with the YiCoin platform for item registration.
2) Item locations are confirmed to ensure that they are in the correct storage location.
3) Through data synchronization, the inventory data, including information on the number and location of items, are automatically updated.

Step 3: Real-time inventory tracking
1) When the item is transferred, the NFC reader automatically reads the NFC tag and updates the inventory status on the YiCoin platform.
2) For inventory monitoring, the inventory status is displayed in real time, providing a real-time view of inventory levels.

Step 4: Automated trading
1) Through devices (e.g., smartphones) that read data in the NFC tag and transmit them to the YiCoin platform, the transaction process is initiated to select products.
2) Transactions are automatically processed on the platforms, including price calculations and inventory updates.
3) After the transaction is completed, a transaction confirmation message is sent to the trading partners.

Step 5: Data collection and analysis
1) Detailed information about the item is collected through NFC tags.
2) The transaction algorithm analyzes the collected data and provides recommendations for inventory optimization.
3) The inventory management strategy is adjusted on the basis of analysis results.

Step 6: Security management

1) For encrypted communication, the Advanced Encryption Standard is used to secure transactions and data transmission. It is most widely used in NFC applications and is ideal for protecting data, such as product identifications, timestamps, and locations.
2) The platform implements access control to ensure that only authorized users can access sensitive information for access control.

Step 7: Smart barter platform

1) For intelligent matching, the transaction algorithm analyzes user demand and inventory and intelligently recommends matching barter deals.
2) According to the trading rules and user behavior, the system automatically generates YiCoins.
3) Users can trade with YiCoins, and blockchain technology ensures the transparency and security of transactions.

3.3 Transaction algorithms

The developed algorithm of the smart barter platform in this study is an enhanced solution to provide matching-recommended transactions. AI and blockchain technologies are integrated into the algorithm to enhance the efficiency and security of the transaction. The transaction algorithm analyzes the historical transaction data and behavioral patterns of a user for accurate matching between supply and demand. Such a smart matching algorithm significantly reduces the time and cost of finding an appropriate trading partner.

The enhanced matching recommendation module of the developed platform, powered by AI data analytics, was designed to intelligently screen and recommend merchandise or services. A user's needs can be satisfied on the basis of the in-depth analysis results of the user's historical transactions, behavior, preferences, and other data. The module enables higher degree of personalization and accuracy, which are essential in increasing user satisfaction and transaction success rates. The transaction algorithm analyzes users' transaction history, browsing behavior, and preferences to provide personalized recommendations, significantly improving search efficiency for merchandise. Personalized recommendations help users quickly find desired items, real-time recommendations update results based on user behavior changes, and diverse recommendations offer a variety of product choices. Users on the YUNSHANYI, RUISUOSI, and LEYI platforms felt that such improvements increased their search rate by 15 to 30%, which needs precise validation through further research. However, the system with the algorithm proved its advantages in improving transaction efficiency and security, reducing transaction costs, and providing effective personalized recommendations through empirical data. These advantages improve user experience and help companies create new market opportunities and enhance resource utilization efficiency, thereby adding value to their business.

The platform utilizes algorithms for collaborative filtering, content recommendation, and tag-based recommendation to intelligently match users' needs to merchandise. Such algorithms account for the user's characteristics and combine the attributes and features of the merchandise or services. The enhanced matching recommendation module utilizes advanced self-learning and optimization. As users' transaction behavior and preferences evolve, the module updates its recommendation algorithm accordingly to maintain timely and accurate recommendations. On the basis of continuous feedback and learning, the module provides continuously improved recommendations for customized and accurate service. The user's contextual information, including time, location, social connections, and other data, is also used to further improve the relevance and usefulness of recommendations. For example, at specific time and location, the module suggests relevant merchandise or services on the basis of the user's information needs.

3.3.1 Personalized recommendation algorithm

Y. Xiong et al. developed an application of collaborative filtering on Internet education and validated its effectiveness in an online English recommendation system.[30] In a user-item matrix R, user-based synergy overdrive is calculated using Eq. (1). For user i interest in item j, the level of interest is estimated using the weighted average of other users' ratings for similar items.

$$\hat{R}_{ij} = \frac{\sum_{k \neq i} sim(i,k) \times R_{kj}}{\sum_{k \neq i} sim(i,k)} \tag{1}$$

Here, $sim(i, k)$ denotes the similarity of user i and k, and R_{ij} denotes the degree to which user i is interested in item j.

For item-based collaborative filtering, object j at the level of interest of user i is estimated using the weighted average of the users' ratings of similar items.

$$\hat{R}_{ij} = \frac{\sum_{l \neq j} sim(j,l) \times R_{il}}{\sum_{l \neq j} sim(j,l)} \tag{2}$$

Here, $sim(j, l)$ denotes the similarity of items j and l.

3.3.2 Real-time recommendation

Van Luc *et al.* stated that item-based collaborative filtering has higher scalability and efficiency with large-scale datasets.[12] For real-time recommendations, online learning algorithms are used. In the algorithms, model parameters are updated as soon as user behavior is identified. A simple real-time recommendation algorithm calculated online gradients using Eq. (3).

$$\theta_{t+1} = \theta_t - \eta \nabla L(y_t, \hat{y}_t) \tag{3}$$

Here, θ_t denotes the value of the model parameter at time t, η denotes the learning rate, $L(y_t, \hat{y}_t)$ denotes the loss function, y_t denotes the actual observed user behavior, and $\hat{y}_t$ denotes the model's prediction of user behavior.

3.3.3 Diversity recommendation

Zhang and Cao explored the advantages and disadvantages of similarity metrics when using a cosine similarity-based recommendation algorithm with multiple datasets.(27) An equation was created to optimize an objective function for the relevance and diversity of recommendations. A simple objective function for recommendations was defined as follows.

$$\max \sum_{j=1}^{N} \left(r_j \times \lambda + \left(1 - r_j\right) \times \mu \right) \tag{4}$$

Here, r_j indicates whether item j is recommended or not, and λ and μ denote the weights of relevance and diversity, respectively. Equation (3) is used for linear and integer programming in recommendation algorithms.

3.3.4 Comparison of algorithms

The comparison of the three recommendation algorithms is presented in Table 2. Although the traditional recommendation algorithm is most widely used in recommending commodity trade, it relies too much on users' historical data, resulting in an inability to adapt to changes in user preferences or capture new popular trends in a timely manner. Transparency cannot be ensured in recommending items, making it difficult for users to understand the logic behind it. Also, if there are biases in the input data, the algorithm unintentionally amplifies the biases and provides biased recommendation results.

3.3.5 Enhanced recommendation algorithm

We modified the recommendation algorithm, considering user feedback to enhance its performance and user satisfaction. The enhanced recommendation algorithm uses personalized,

Table 2
Comparison of three recommendation algorithm models.

Recommendation algorithms	Descriptive	Arithmetic
Personalized recommendations	Based on the user's historical transaction data, browsing behavior, interest preferences. and other information, using enhanced matching recommendation algorithms to recommend products that meet the user's needs.	Personalized recommendations = f(historical transaction data, browsing behavior, interest preferences)
Real-time recommendations	Real-time monitoring of user trading behavior and preference changes to update recommendation results and improve user trading experience.	Real-time recommendations = g(trading behavior, preference changes)
Diversity recommendations	Combining the commodity information and user data on the blockchain, it recommends a diverse selection of commodities to meet the different needs and preferences of users.	Diversified recommendations = h(product information, user data)

real-time, and diverse recommendations and fuses the results of these three recommendation algorithms by using weighted fusion. AI data analytics is used to improve the accuracy and effectiveness of the recommendation system.

We assigned weights to personalized recommendations R_1, real-time recommendations R_2, and multiple recommendations R_3. By assigning the weights w_1, w_2, and w_3, the integrated recommendation R is obtained using Eq. (5).

$$R = w_1 \times R_1 + w_2 \times R_2 + w_3 \times R_3 \tag{5}$$

The score of the personalized recommendation R_1 = 4, the score of the real-time recommendation R_2 = 3, and the score of the diversified recommendation R_3 = 5. w_1 = 0.4, w_2 = 0.3, and w_3 = 0.3 were assigned to each score. Substituting these values into Eq. (5), the combined recommendation result R is obtained using Eq. (6).

$$R = 0.4 \times 4 + 0.3 \times 3 + 0.3 \times 5 = 1.6 + 0.9 + 1.5 = 4.0 \tag{6}$$

The integrated recommendation was adjusted again with its weights, resulting in a composite recommendation score of 4.0, which reflected user needs and preferences better (Fig. 2).

The integrated recommendation algorithm is continuously optimized to improve recommendation accuracy and performance. For the optimization, the model structure, parameters, and features are also optimized iteratively. On the basis of the results, deep reinforcement learning and meta-learning techniques are utilized to automatically learn and adapt to changes in user behavior and preferences.

4. System Architecture

4.1 Barter transactions based on IoT and blockchain

The barter trade based on blockchain technology is classified into no barter intervention and barter intervention modes depending on the degree of barter intervention. No barter intervention

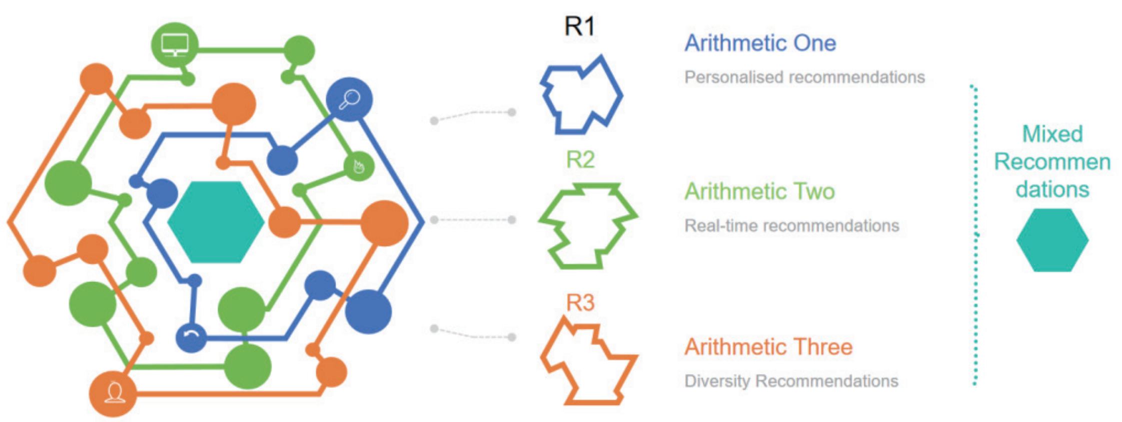

Fig. 2. (Color online) Transaction algorithm of barter system.

refers to the completion of transactions directly through the platform's aggregation, based on equal-value barter and unequal-value barter. In equal-value barter, both a buyer and a seller (traders) exchange the equal value of an item and the exact matched information on the transaction. In unequal-value barter, a rolling difference exists, but the information is exchanged between the traders. Time nodes for the settlement or completion of the transaction are recorded in the form of "barter" to realize the elimination of debt.

The barter intervention mode consists of indirect barter and differential barter modes. In the indirect barter mode, a company uses the raw materials as collateral. The platform issues property rights to record the ownership of the warehoused merchandise. The pledges are received as a standard warehouse receipt on the e-commerce platform. The platform issues an equal amount of YiCoins to the value of the pledged objects. The pledgee uses YiCoins to select commodities. In the unequal-value barter mode, companies obtain YiCoins through cash recharge to purchase merchandise on the platform, utilizing the platform's resources. To enhance the credit in barter transactions, the deposit needs to be made in advance to mitigate credit risks associated with the absence of cash usage. After the transaction is completed, the e-commerce platform refunds the deposit to protect the rights and interests of traders.

4.2 Barter transaction management model

NFC tags are widely used in barter transactions, and their applications were studied extensively, mainly on data management and challenges in transactions using them.[41] Deep learning is used for the evaluation of NFC's potential in decentralized finance.[42] NFC is used as an identifier of digital assets, including cryptocurrencies or tokenized assets, and each asset is assigned an NFC tag for its transactions and management on the blockchain. NFC tags are also used for security verification. Traders in a transaction scan the tag using an NFC-enabled device to validate the authenticity and ownership of the asset and ensure the legitimacy of the transaction. When NFC tags are used with smart contracts, transactions are executed automatically. For example, when scanning an NFC tag, a smart contract is automatically created. NFC tags are important in managing storage. An NFC tag is used as an identifier for transaction records and to securely store data, including batch information and production dates. The data are encrypted and stored on the blockchain to ensure data security and prevent fraud.

On the barter platform, the enhanced recommendation system in this study provides personalized recommendations to find the merchandise of interest faster on the basis of users' historical transaction records and preference information. The entire transaction process is conducted on the blockchain for transparent transactions and trust, the efficient issuance and management of barter, and the fast storage of the information on traders in the transaction process, transaction items, and the time of the transaction. The decentralized nature of blockchain allows the platform to be secure and risk-resistant, providing reliable protection for transactions (Fig. 3). The exchange patterns and recommendations for the IoT blockchain in different tasks are presented in Table 3.

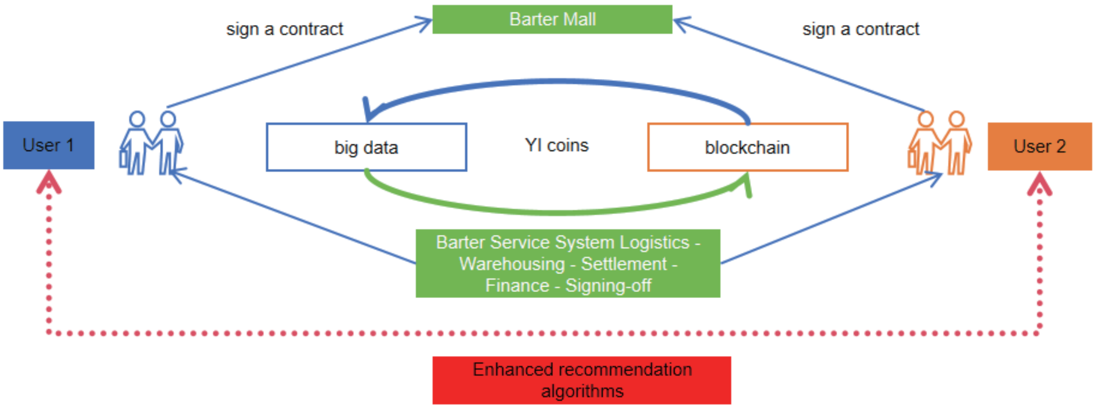

Fig. 3. (Color online) Barter transaction on blockchain and IoT.

Table 3
Barter patterns and recommendations for blockchain and IoT in different tasks.

Working session	Recommendations for use
Warehouse management link	Manage inventory using NFC tags or IoT devices and record product in and out in real time on the blockchain.
	Provide real-time inventory monitoring to ensure accurate and reliable inventory information.
	Enhance supply chain visibility and enable treasurers to quickly locate and manage inventory.
Logistics link	Use NFC tags or IoT devices to track the location and status of merchandise, recorded in real time on the blockchain.
	Verify the authenticity of merchandise by scanning NFC tags to ensure safe and fast deliveries.
	Provide transparency and visibility into the logistics process, helping logisticians optimize routing and transportation arrangements.

5. Platform Testing

E-commerce has been widely used globally, with numerous companies engaged, such as Alibaba and Jingdong. We applied the smart barter platform to YUNSHANYI, RUISUOSI, and LEYI, which are three integrated Internet platforms for online, offline, and cross-border barter trade built under the B2B2M business model and achieving intelligent resource allocation through blockchain technology, and managed their barter transactions for one year. The developed platform was tested on YUNSHANYI, RUISUOSI, and LEYI from January 1 to March 31, 2024. The number of transactions was 486. We deleted abnormal and invalid data to finally obtain 427 valid transactions (Fig. 4).

First, the effectiveness of the algorithm was tested by randomly collecting 10 transactions using the enhanced recommendation algorithm. The algorithm assigned a score to each transaction as follows.

1) Weight vector $w = \left[w_1, w_2, w_3\right]$.
2) The score vectors for the three recommender systems are $\mathbb{R}_1$, $\mathbb{R}_2$, and $\mathbb{R}_3$.

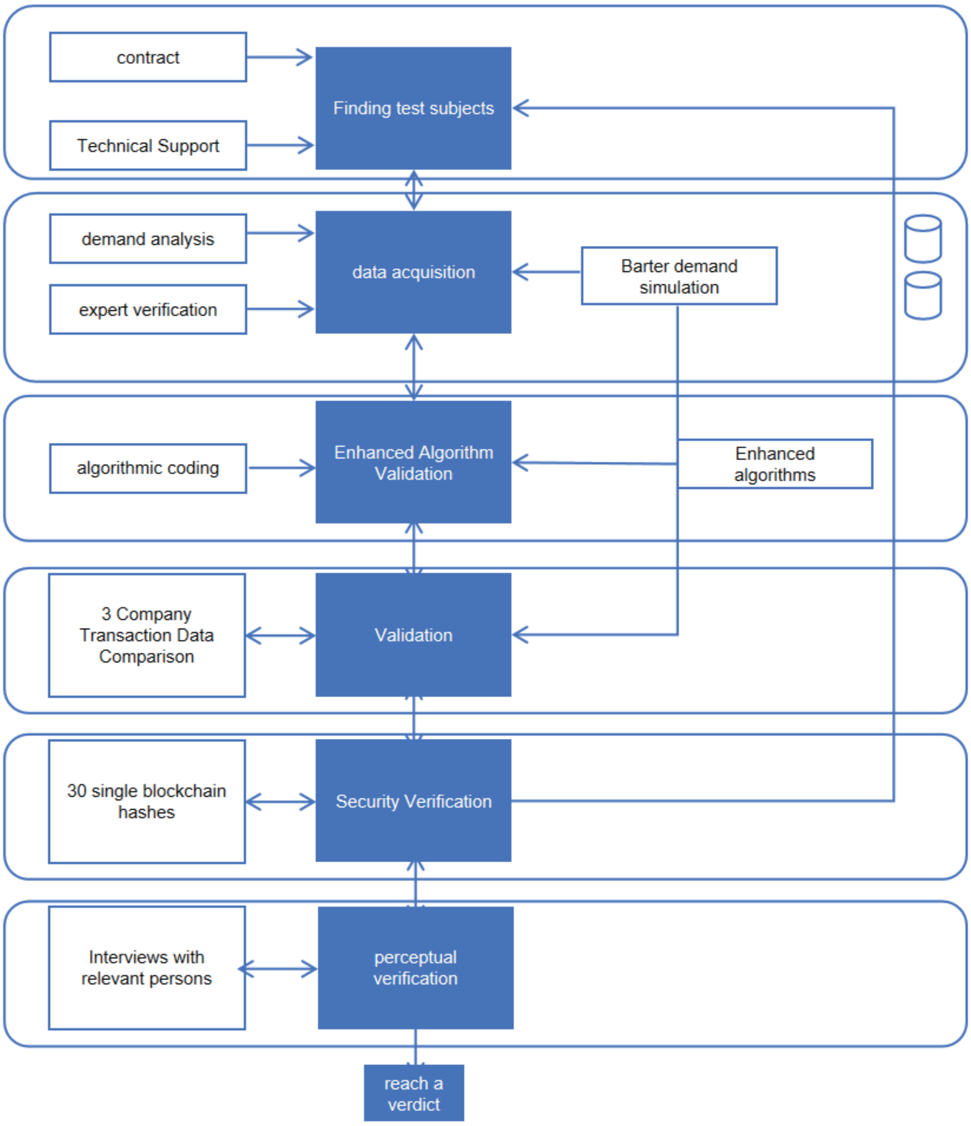

Fig. 4. (Color online) Testing developed platform based on YUNSHANYI, RUISUOSI, and LEYI.

Each vector contained 10 elements corresponding to the scores of 10 transactions. For 10 matches, we created a 10 × 3 score matrix S and a 1 × 10 weighted row vector. With the enhanced recommendation algorithm, the recommendation score matrix S was established as Eq. (7).

$$S = \begin{bmatrix} \square_{1,1} & \square_{1,2} & \cdots & \square_{1,10} \\ \square_{2,1} & \square_{2,2} & \cdots & \square_{2,10} \\ \square_{3,1} & \square_{3,2} & \cdots & \square_{3,10} \end{bmatrix}_{10\times 3} \quad (7)$$

The validation results are shown in Table 4.

Table 4
Weights and scores of enhanced recommendation algorithm of smart barter platform.

Transaction n	w_1	w_2	w_3	R_1	R_2	R_3	R
1	0.215031008	0.482733338	0.455815726	9.667218093	2.285200201	1.4124805	3.825724798
2	0.415322054	0.281333662	0.377121362	9.120691406	4.730917022	4.979800668	6.996979716
3	0.263590769	0.371028254	0.356202726	7.216347506	4.723518937	8.190323611	6.572137164
4	0.453206962	0.329053361	0.497707911	8.159206759	4.319609058	2.09709334	6.162931127
5	0.476186914	0.141169873	0.36228232	1.221523161	2.37200273	6.048531854	3.107804819
6	0.1182226	0.459929988	0.383412187	5.30016374	2.249254571	2.858782507	2.757190818
7	0.311242195	0.198435094	0.31762641	7.826135838	3.097306895	2.147784852	3.732631274
8	0.456967618	0.116823813	0.337656808	2.947671423	5.193662052	7.779770779	4.580626364
9	0.320574006	0.231168288	0.215663895	3.863629069	3.393753763	9.055408232	3.976031903
10	0.282645894	0.48180146	0.158845459	3.084632068	8.720449438	4.370164983	5.767564719

The test results showed that the enhanced recommendation algorithm provided accurate personalized recommendations with high efficiency and rapidity, even on a large dataset, and presented its robustness, adaptability, and versatility. It continuously conducted model tuning and cross-validation and provided real-time feedback based on feature engineering to ensure the quality of recommendations and user satisfaction. The algorithm can be used for personalized recommendations, trend forecasting, inventory management, and risk management to enable efficient decisions and satisfying experiences. To verify the effect of the smart barter platform, we compared the test results with the transaction data of YUNSHANYI, RUISUOSI, and LEYI. Thirty randomly selected transactions were compared, and the results proved the effectiveness of the developed platform in barter transactions with improved security. Interviews were conducted with representatives from YUNSHANYI, RUISUOSI, and LEYI to understand user experience and satisfaction with the platform and YiCoins as a digital token, and the platform's impact on enhancing transaction success rates.

6. Results

6.1 Successful transactions

For the 427 valid transactions, the success rate was 27.5%. The smart barter platforms significantly improved the success rate by an average of 15.5%. The developed recommendation algorithm on the platform analyzed large amounts of data to identify user demand and supply and accurately matched traders. Such precise matching reduced the time and effort to search and filter merchandise. The developed platform provided personalized trading recommendations based on a user's trading history, preferences, and behavioral patterns, and helped the user identify plausible trading opportunities, thereby increasing the likelihood of a trade. AI technology was used to suggest merchandise prices by analyzing market data. The results can be used to create competitive pricing strategies and increase the attractiveness of the transaction. Through credit assessment and risk management, and by analyzing a user's historical transaction data, ratings, and other relevant information, fraud can be avoided, as the platform provides reliable credit scores of users for making informed decisions. The platform consistently incorporated user experiences into the transaction process to provide intelligent customer service support. These improvements enhance user satisfaction, user trust, and loyalty for successful transactions. The effectiveness of AI-enhanced recommendations was demonstrated on smart barter platforms, highlighting their value in optimizing transactions.

6.2 Blockchain technology in barter transactions

We predicted blockchain hash values for 30 randomly selected transactions on the platform (Fig. 5 and Table 5). By applying blockchain technology, we calculated blockchain hash values for the real-time tracking and verification of the merchandise. The values were used to enhance the transparency and traceability of the merchandise to ensure the security of transactions.

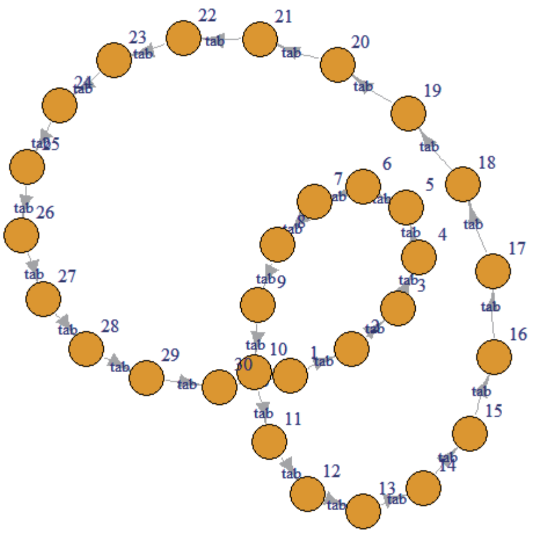

Fig. 5. (Color online) Matching and trade on developed smart barter platform.

Table 5
Blockchain hash values in transaction.

Transaction number	Hash value	State
Tagged 1	96494c50ad1700a62f687a9bcd95606f3833505f63616ef128ea153411836cd7	Shipment
Tagged 2	93b9b12fd147084d61564eadc879328c775c104895e387e6bc662582bf299795	In transit
Tagged 3	a83d3e57fc81b5cad01a9f73055c4f753732b8bcb099e9ce3b2e34403433fbe8	Signed
Tagged 4	b4961e6421772fd68c3f7981d68d97c0e9b8bec5b310d07a8458a32f6baa58cc	Pending
Tagged 5	d285e9a64cc5d8bc943fa8606697964839ee27e48f31910f10844afba52d3871	Shipment
Tagged 6	70d7a6ed937f65f751220f02210dcda1516434d716ca947cc8f9fdc0831675cc	In transit
Tagged 7	0a8321992fa64a63c6e35b29376ce52de5861cc583047a9f64c083fecee8c9f1	Signed
Tagged 8	32bed0817b53d24cd4844f0cd297f9c77e9120a99d25c867861d3818b66a362e	Processing
Tagged 9	9c896a3769250fcab6d1dd35941ed743cade9adc0ec76ab3ad3bb58a6d11cb7e	Shipment
...	...	...
Tagged 26	5a5418cfe52b21a11cef5647b47dc37480736281b20b85bccc7d30789cbb641b	In transit
Tagged 27	7ca06b0db162b1a403930d93619720bcdcbcf8d2c1cfe5a92ba9f5bcd005c20c	Signed
Tagged 28	766f98065463a79df8e996848463c6c9a6458d8d688f9fef5c17dfbfee9a0f60	Processing
Tagged 29	464799475e718e7a729dbc967417de1ee650d6182f0dbe53d47ea429ac600854	Shipment
Tagged 30	07ff0304b48482be2964f43a05c12502dfb68c667257abbaf0c401e57f74a94f	In transit

By integrating blockchain technology into the platform, the states of merchandise in logistics were verified and tracked, being coded as "shipment", "in transit", "signed", "pending", and "processing" on the basis of unique blockchain hash values. Transparency and traceability in logistics were ensured with effective risk management and dispute settlement. The platform enhances supply chain transparency, end-consumer trust, and data security, and provides a safe, efficient, and reliable transaction. The platform also demonstrates the following advantages of the blockchain in transactions.

First, the decentralized nature of the blockchain enables the distributed storage of barter transaction data, minimizing the risk of data leakage while improving reliability and stability. Second, the blockchain's inerrancy ensures the security of transaction records, as it is impossible to alter the stored data on the blockchain. Each block of data is linked to the previous block, forming a continuous chain, thus guaranteeing the integrity and authenticity of the data. Such characteristics of the blockchain prevent fraud and tampering in barter transactions. In addition, consensus mechanisms such as proof of work or proof of stake also ensure the security and consistency of the blockchain based on the agreements of using nodes by all users. Public and private key encryption and smart contracts enhance the security of transactions. Public-private key encryption ensures the confidentiality of data transmission and storage, while smart contracts automate the execution of transaction conditions without human intervention and errors.

With blockchain technology, the security, integrity, and authenticity of transaction data are enhanced considerably, and risks in trade and transactions are mitigated, providing safer and more reliable barter transactions.

6.3 Recommendation and efficiency enhancements in smart barter platforms

We interviewed the nine representatives of YUNSHANYI, RUISUOSI, and LEYI to investigate the recommendation efficiency, timeliness, fairness, system compatibility, and ability to personalize services of the smart barter platform (Table 6). The representatives pointed out the need for flexibility for personalized services. Three of them stated that existing barter systems have time-consuming problems in the process of warehousing and shelving, which directly affects the delivery time of merchandise. Five representatives indicated that the existing

Table 6
Information on interviewers.

Interviewer number	Responsibility	Gender	Position	Years in service
1	Barterer	Female	Marketing manager	4
2		Male	Engineer	2
3		Male	Manager	3
4		Male	Deputy general manager	5
5		Male	Logistics manager	3
6		Male	Deputy general manager	4
7		Female	Deputy director	5
8	Product specialist	Male	Storage technology	3
9		Male	Barter trading process design	2

systems provide only simple recommendations that do not provide enough information on identifying and responding to personalized needs. Eight representatives agreed that AI and blockchain technologies must be introduced to significantly improve the efficiency of warehousing and shelving, reduce delayed transactions, and enhance the transparency and security of transactions. They mentioned that such enhancements improve the compatibility and trust of the system and the operation and management of barter platforms to adapt to market dynamics, improve customer satisfaction and loyalty, and strengthen market competitiveness and brand recognition.

The smart barter platform in this study significantly improves the efficiency and security of transactions. The flexibility of the platform can be ensured by integrating technological innovation and addressing the limitations of traditional barter platforms. The developed platform in this study accurately predicts market demand and trends, thereby optimizing supply chain management by using deep learning and machine learning algorithms. By integrating blockchain technology into the platform, the transparency, security, and traceability of transactions are enabled. The effectiveness of the smart barter platform was validated on existing e-commerce platforms of YUNSHANYI, RUISUOSI, and LEYI, which are three trading platforms used in Jinan, Shandong Province, China, with an increased success rate of transactions by 15.5% compared with their previous technology.

7. Conclusions

The smart barter platform integrated with AI and blockchain technologies provides a new solution for barter and trade. Its effectiveness and feasibility were verified on existing e-commerce platforms. The AI-enhanced recommendation algorithm enabled successful barter transactions. The developed platform increased the search rate for merchandise by an average of 15.5%, according to the users, which needs further validation. Blockchain technology applied to logistics management enabled the real-time tracking and verification of merchandise in logistics, thus improving transparency and traceability and ensuring the security of barter transactions. The representatives who used the developed platform on their e-commerce platforms confirmed the efficiency of warehousing and shelving, reduced delays, and ensured the transparency and security of transactions with compatibility. Such advantages enhance the operation and management of the platform to adapt to market dynamics and improve customer satisfaction and loyalty. Consequently, the market competitiveness and brand recognition of the company can be increased. Besides improved efficiency and transparency in transactions, accurate recommendations were provided by maintaining data quality and optimizing user experience.

The platform might cause complexity in management and compliance challenges, such as cross-border tax issues. Therefore, the platform needs to be refined continuously by data acquisition and algorithm optimization. A robust credit system is also necessary to reduce transaction risks. The functions and performance of the platform need to be improved in expanded application scenarios for diversified and convenient transaction services. At the same time, user data privacy protection and transaction security must be ensured to create a more secure and reliable trading environment than at present. Then, the presently developed platform can be used more effectively to promote the use of AI in global trade.

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