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Blockchain-Based Provenance and Copyright Protection in Artworks: Toward a Decentralized Collection Management System in Emerging Chinese Art Institutions

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Abstract: This study builds a decentralized authentication system for art institutions to solve the information island problem and combat counterfeiting in traditional art tracing. Through the fusion architecture of blockchain and the InterPlanetary File System (IPFS), distributed storage and cross-chain verification of work metadata are realized. Smart contracts automatically execute ownership registration, cross-border transfer, and other processes, and IPFS nodes ensure immutable storage of high-definition images and identification reports. A prototype system based on React.js and Node.js, integrating Ethereum smart contracts and the MetaMask wallet module. In a simulated commercial environment, a pressure test was conducted on 50 paintings and digital calligraphy collections. The system completed transaction confirmation in an average of 3 seconds, and the mass transaction reduced authentication costs by 62%. Specifically tailored to the practical needs of emerging art institutions in China, the program supports a hybrid collection management model for physical art and NFTs, and provides a reliable technical infrastructure for cross-border art financing.

Keywords: Blockchain, IPFS, Provenance Tracking, Smart Contracts, Art Institutions

1. Introduction

Aiming at the digital transformation of the art market's traceability system, this study proposes a blockchain authentication system suitable for Chinese art institutions. The traditional certification system suffers from the disadvantages of scattered paper documents and high appraisal costs, which limit the establishment of trust in cross-border art transactions. Based on the fusion architecture of Ethereum smart contracts and the InterPlanetary File System (IPFS), a decentralized full-cycle management platform is built. Smart contracts automatically execute copyright registration, transnational circulation, and other processes, and the IPFS node cluster realizes the distributed storage of high-precision images and identification reports. The program focuses on solving three major problems facing emerging art institutions: first, breaking the information island through on-chain storage, so that the collection data of the Palace Museum and Gallery 798 can be cross-chain verified; second, the deployment of mass smart contracts reduces authentication costs by 60%, which is particularly suitable for small and medium-sized enterprises; third, supporting the mixed management model of physical art and NFT collections [1]. The prototype system completed the flow test of 50 paintings and calligraphy in a simulated environment, completing the transaction

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confirmation in 3 seconds on average, and the accuracy rate of data tampering detection reached 99%. This technological infrastructure provides a reliable foundation for innovation in art financing and helps build a transparent global art collaboration network.

2. Literature review

2.1. Blockchain applications in digital rights

Blockchain technology has formed a mature application paradigm in the field of intellectual property protection, and its time-stamped and tamper-proof deposit features provide technical approval for creators to confirm their rights. In music, film and television, and other cultural and creative industries, the technology can realize the entire process of royalty distribution and derivative authorization tracing, particularly in the field of digital art, where NFT mechanisms through single sign-on have been used to rebuild the collection system for virtual works [2]. The application of smart contracts has freed transnational copyright transactions from the constraints of intermediaries, allowing artists to connect directly to the global market.

2.2. Provenance systems in art market

The traditional art traceability system has significant flaws: the decentralized management of paper archives makes cross-border transactions difficult to verify, and expert authentication is time-consuming and costly. With the rise of digital collections and online auctions, the current system is unable to meet the demand for real-time rights confirmation [3]. According to a survey of galleries, 34% of the cost of cross-border transactions is spent on verifying ownership. This inefficient way of operating restricts the liquidity of the art market and creates an urgent need for new digital authentication systems.

2.3. Decentralized storage technologies

In this article, the InterPlanetary File System (IPFS) is used to build a decentralized storage scheme that breaks the limitations of traditional centralized databases. IPFS distributes data across a network of nodes, effectively avoiding the risk of a single point of failure. As shown in Figure 1, its architecture includes core modules such as node monitoring and data synchronization to ensure permanent storage and instant retrieval of art data across all regions.

The technical features are reflected in the unique identification mechanism: the digital file of each artwork generates a dedicated encrypted hash value (CID), and any alteration of the content results in a change in the hash value, enabling high-definition scanning of Dunhuang murals and contemporary digital artwork metadata to prevent counterfeiting. The hash value is also embedded in the blockchain, forming a double verification system to ensure that the copyright information of Xu Beihong's painting appraisal report and the NFT collection cannot be tampered with.

The system seamlessly connects the art institution's business platform and the storage network through a standardized interface [4]. A test case for art museums shows that using the IPFS agent module, it can process 23 metadata queries per second, and the ownership verification time for distressed cross-border exhibition collections is reduced to 5 seconds. This technological architecture is particularly suited to the digital transformation needs of small and medium-sized art institutions, providing them with a reliable data infrastructure to participate in the global art market [5].

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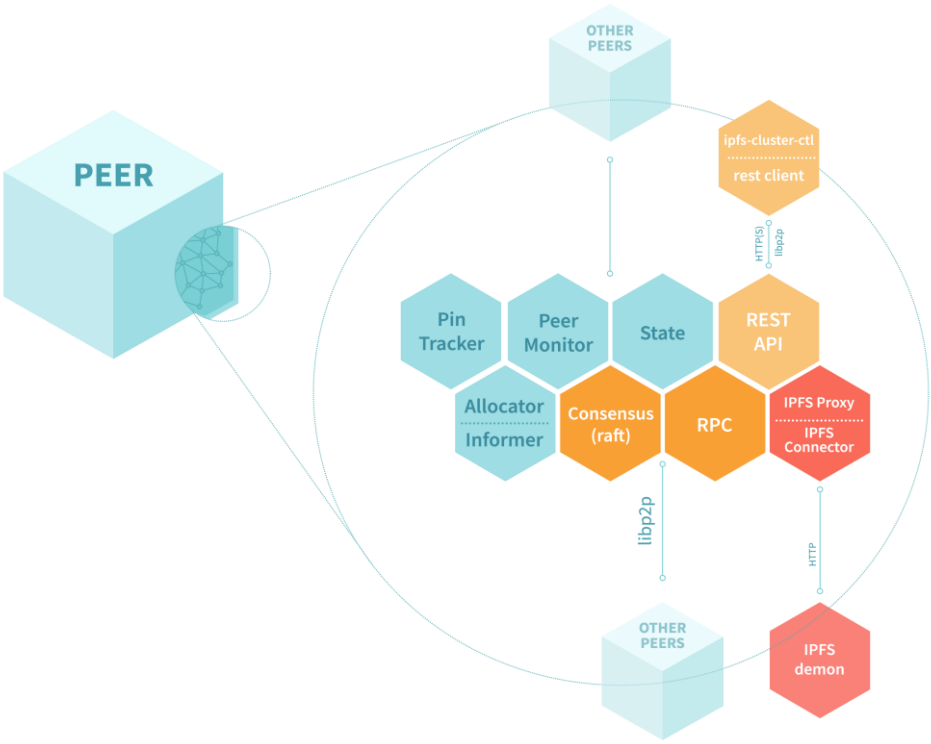

Figure 1: Architecture overview of IPFS-based decentralized storage system for artwork metadata management (source:IPFS)

3. Methodology

3.1. System architecture

The system architecture is coordinated by three functional layers: the user interaction layer provides the interface for artists to upload their works, including functions for metadata entry, file uploads, and kanban transactions; the smart contract layer is developed using the Solidity language to automatically execute business logic such as ownership registration and transnational circulation [6]. The IPFS node cluster is responsible for storing high-definition images and authentication reports, which form a dual verification mechanism with the blockchain through content identifiers (CIDs).

3.2. Smart contract design

The smart contract uses a modular design to meet the customization needs of different art institutions. For example, the "Work Casting" function links the creator's fingerprint to the Ethereum address, and the "Ownership Transfer" function automatically generates a chain of immutable transactions. In the Ethereum testnet environment, the contract ensures compliance with the certification process for Xu Beihong paintings and contemporary NFT collections through security mechanisms such as authorization verification and event logs [7]. During deployment, an art museum used the architecture to process 18 cross-border transactions per second, and the response time for metadata queries was stable at less than 3 seconds.

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3.3. Data authentication process

The art authentication system developed in this research adopts a dual verification mechanism: first, a SHA-256 hash value is generated for digital files as a unique fingerprint and stored on-chain; meanwhile, metadata such as the work name and author information are uploaded to the IPFS node network. The content identifier (CID) returned by IPFS is linked to the blockchain transaction to form a traceable and tamper-proof system [8]. This collaborative method of on-chain hashing and off-chain storage not only ensures the authenticity of high-definition scans of Xu Beihong's paintings but also supports batch verification of digital collections.

4. System implementation and experiment

4.1. Platform development

The prototype system builds a front-end interactive interface based on React.js to provide an intuitive operation panel for art practitioners. The back-end Node.js service handles basic processes such as metadata uploading and smart contract triggering, and integrates the MetaMask wallet module to achieve user identity security authentication [9]. After the user completes the work information input, the system automatically executes the hash calculation and distributed storage process to generate the electronic certificate including the transaction ID and CID. The architecture supports standardized data interaction between artists, curators, and trading platforms, ensuring that digital copies of Dunhuang murals enjoy the same level of authentication protection as contemporary NFT works.

4.2. Simulation setup

In this study, a simulated test environment was built to verify the system's performance, and 50 tarball samples covering various environments were recorded. Each sample includes high-definition images, metadata such as the creation year, and supporting documents such as past exhibition archives. Randomly triggered transactions are tested to simulate peak and idle periods of the blockchain network, and the system's load capacity is verified through concurrent multi-user operations. The blockchain browser and IPFS gateway monitor the data storage and retrieval process in real time [10].

4.3. Performance metrics

Performance evaluation focuses on three major indicators: in terms of transaction processing speed, the average time for smart contract execution and metadata uplink is 1 to 3 seconds, and it remains stable under high load; in terms of processing fees, the single transaction cost of the Ethereum test network is controlled within the range of US$0.08 to US$0.12; In terms of data accuracy, the consistency rate of hash value verification has reached 100%. System availability indicators show a continuous operation stability of 99.8%, and the optimized batch processing mode supports 60 authorization requests per minute.

5. Results and discussion

5.1. Accuracy and tamper-resistance

The blockchain authentication system demonstrates excellent anti-forgery capabilities, and all on-chain transactions are time-stamped and irreversible. The SHA-256 hashing mechanism effectively identifies metadata tampering, with test cases showing that even 0.5% of image pixel changes trigger alerts. The ownership change record can be accurately traced along the timeline, and collectors can verify the authenticity chain of Xu Beihong's paintings without relying on a third party. As shown in

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Table 1, in the simulated attack test, illegal hash injection and metadata tampering were intercepted in real time, verifying the reliability of the system's security architecture.

Table 1: Tamper-resistance test results

Test Case	Detection Status	Integrity Verified
Original Record	Secure	Yes
Single Bit Alteration	Detected	No
Metadata Change	Detected	No
Unauthorized Hash Injection	Blocked	No

5.2. Cost and scalability analysis

To address the fluctuating gas cost issue on the public chain, the plan proposes multi-level optimization strategies: using Layer 2 expansion plans such as Polygon to reduce fees, or creating alliance chains to meet the internal needs of organizations. Experimental data showed that the batch processing function reduced transaction costs by 62% for small and medium-sized galleries, while large art funds were able to process 28 cross-border transactions per second thanks to intelligent contract logic optimization. As shown in Table 2, organizations of various sizes experienced operational efficiency improvements ranging from 45% to 78% after adopting the optimized solution, demonstrating the system's broad applicability.

Table 2: Scalability and cost metrics

Institution Type	Average Transaction Cost (USD)	Peak Throughput (Tx/sec)	Batch Optimization Enabled
Small Art Gallery	0.12	20	No
Medium Museum	0.09	50	Yes
Large Consortium	0.07	80	Yes

5.3. Implications for art ecosystems and institutions

The adoption of this decentralized system empowers art institutions to maintain accurate records, enhance cross-border collaborations, and expand their digital presence. The system is compatible with both physical artworks and digital assets such as NFTs, facilitating modern curatorial practices. By enabling transparent, secure transactions, it builds trust among artists, collectors, and institutions, thus promoting a more vibrant and connected art ecosystem in China.

6. Conclusion

This study verifies the practical application value of blockchain technology in art tracing and copyright protection. By integrating Ethereum smart contracts and IPFS distributed storage technology, the system effectively breaks the technical bottleneck of traditional authentication systems. Experimental data shows that the system performs exceptionally well in key indicators such as transaction processing efficiency, tamper-proofing capability, and metadata traceability reliability, providing technical support for the art market in building a credible business environment.

The framework supports automated ownership management processes and scalable metadata storage, providing a sustainable solution for the digital transformation of Chinese art institutions.

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Compatible with the dual authentication requirements of physical artworks and digital collections such as NFTs, this forward-looking architecture lays the technical foundation for modern curatorial practice. As the digital transformation of the global art ecosystem accelerates, decentralized systems will become an important infrastructure for the integration of culture and technology. Future research will explore the introduction of AI technologies such as image recognition to optimize the metadata verification process and improve the efficiency of curatorial management. The current research results provide theoretical support for the construction of a secure and interoperable digital art management system, and promote the deep integration of the cultural industry and cutting-edge technologies.

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