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A Blockchain-Based Cryptographic Framework for Secure, Private, and Traceable Digital Art Copyright Management

Jiang Lv
https://orcid.org/0009-0001-7426-424X
Beijing Institute of Fashion Technology, China

Jiuru Lin
https://orcid.org/0009-0005-5854-0602
Beijing Institute of Fashion Technology, China
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ABSTRACT

Digital art growth brings copyright challenges: slow verification, tampering risks, and privacy leaks. This study proposes a blockchain-based cryptographic framework for secure, private, and traceable management. The layered design uses AES for content encryption, ECC for key security, and blockchain for immutable metadata storage, ensuring integrity and authenticity. Smart contracts enable automated access control with pseudonymized identities to protect user privacy. Tested on 2D, 3D, and dynamic artworks, the system outperforms traditional DRM: verification latency drops over 50%, tamper detection exceeds 95%, and CPU/memory usage stays low. It supports scalable, real-time operations and provides an auditable, trust-aware environment for content lifecycle management. Though interoperability and new formats remain challenges, the framework meets technical, organizational, and regulatory needs in information security. This work advances integrated, privacy-preserving solutions for sustainable digital rights ecosystems.

KEYWORDS

Digital Art Copyright Protection, Blockchain Technology, Cryptographic Graphics Technology, Layered Protection. Collaborative Verification

INTRODUCTION

In recent years, with the rapid development of emerging digital technologies such as artificial intelligence, blockchain, and big data, digital art has gradually become the core component of cultural and creative industries (Malik et al., 2023; Patrickson, 2021). Compared with traditional art forms, digital works of art bring greater convenience and reproducibility to the process of creation and communication (Dhaenens & Truyen, 2024). Although this advancement has effectively promoted innovation and prosperity in the art industry, it has also produced a series of practical problems, namely, difficulty in defining copyright ownership, repeated infringements, and a complicated and expensive process of obtaining evidence in legal disputes (Savelyev, 2018). Traditional centralized copyright protection mechanisms, such as relying on an official registration system combined with

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digital watermarking, has exposed obvious limitations in practical application (Liu et al., 2025). When this kind of scheme encounters judicial disputes, its legal effect is often easily questioned. Although digital watermarking technology can trace the source of works to a certain extent, it may damage the image quality of high-resolution digital works of art; digital watermarks are also easy to remove and tamper with (Begum & Uddin, 2020; Zhang et al., 2024).

Consequently, copyright protection systems relying solely on traditional methods have been difficult to adapt to the increasingly diversified and complicated development needs of the current digital art ecology. In this context, blockchain technology has been widely studied by academic and industrial circles because of its core technical characteristics of decentralization, non-tampering, and traceability (Lina & Yongzhong, 2025). Previous studies have confirmed that a copyright protection scheme based on blockchain can automatically record the creation timestamp and author identity information of works with the help of smart contracts; these functions significantly improve the efficiency and transparency of ownership verification; At the same time, the application of blockchain in digital cultural heritage management and digital art trading scenarios has also been proved to effectively enhance the credibility of copyright information (Vacchio & Bifulco, 2022). However, it should be pointed out that most of the existing related research focuses on ownership authentication and traceability at the metadata level and that there are still obvious shortcomings regarding security protection of the ontology content of artistic works.

On the other hand, cryptographics techniques play a crucial role in securing digital content (Chaudhari et al., 2023). Algorithms such as advanced encryption standard(AES), rivest-shamir-adleman (RSA), and elliptic curve cryptography (ECC) effectively prevent unauthorized access, leakage, and tampering during data transmission and storage (Ramakrishna & Shaik, 2025). Among these, the ECC algorithm is especially suitable for resource-constrained application environments because of its strong security performance under conditions of short key length (Pandey & Bhushan, 2024). However, this kind of technology also has limitations: Relying solely on encryption means, it is incapable of managing the whole life cycle of copyright, especially in the aspects of tracing the distribution path of works, the transaction history, and ownership transfer and storage.

Therefore, the core challenge of digital art copyright protection lies in how to balance the dual needs of content security and reliable and efficient traceability of copyright information (Qureshi & Megías Jiménez, 2021). Current approaches often represent a mere layering of blockchain and encryption technologies, lacking deep integration, leading to notable deficits in performance, key management, and cross-platform compatibility. To bridge this technical gap, this paper proposes an innovative framework based on the core principle of "layered protection and collaborative verification," which organically integrates blockchain technology and encrypted image technology and thus integrates the system. This method has the capacity not only to realize the credible traceability of copyright metadata in the whole process, but also to ensure the overall security protection of digital artworks, thus finally providing a more stable and efficient comprehensive solution for digital art copyright protection.

LITERATURE REVIEW

Progress in Research on Blockchain in Digital Copyright Protection

In recent years, the field of research on blockchain applications in digital copyright protection has grown. Kurniawan et al. (2025) showed that blockchain's decentralization and transparency can effectively enhance the efficiency of copyright registration and royalty distribution, enabling automated and trustworthy identification and circulation of digital art rights. However, other studies have pointed out that existing blockchain systems based on Ethereum or Hyperledger Fabric often face performance deficits and insufficient scalability under conditions of large-scale user access (Xiao et al., 2023). Meanwhile, the rise of non-fungible tokens (NFTs) has introduced a new way to express ownership in digital art, with NFTs' recording a work's uniqueness via on-chain identifiers (Wu et al., 2023). Yet