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A multi-agent framework for verifiable AIGC licensing in digital ecosystems

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ABSTRACT

The emergence of AI-generated content (AIGC) presents intricate difficulties concerning authorship, ownership, and validation of digital assets. These difficulties reveal a significant deficiency in existing governance frameworks, especially regarding the licensing and traceability of synthetic media. This study introduces a modular, multi-agent framework (MAG-AIGC) that utilizes Retrieval-Augmented Generation (RAG) and blockchain technologies to automate content registration, license interpretation, and provenance verification. The suggested architecture was formulated using the Design Science Research (DSR) approach and assessed over 30 relevant AIGC-licensing scenarios. Experimental findings indicate that the system attains up to 90% accuracy in licensing compliance detection, concurrently ensuring minimal latency and transaction costs. In addition to its technological contributions, the framework enhances trust, transparency, and accountability within the emerging AIGC ecosystem, providing actionable insights for regulators, creators, and platform developers to implement verifiable digital governance mechanisms and ensure reliability in AIGC-based commerce.

Dijital ekosistemlerde doğrulanabilir AIGC lisanslaması için çoklu ajan çerçevesi

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ÖZ

Yapay zekâ tarafından üretilen içeriklerin (AIGC) ortaya çıkışı, dijital varlıkların yazarlığı, mülkiyeti ve doğrulanması açısından karmaşık sorunlar doğurmuştur. Bu sorunlar, özellikle sentetik medyanın lisanslanması ve izlenebilirliği konusunda mevcut yönetişim çerçevelerinde önemli bir yetersizliği açığa çıkarmaktadır. Bu çalışma,

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içerik kaydını, lisans yorumlamasını ve köken doğrulamasını otomatikleştirmek için bilgiye dayalı üretim (Retrieval-Augmented Generation, RAG) ve blok zinciri teknolojilerini kullanan modüler, çoklu aracılı bir çerçeve (MAG-AIGC) önermektedir. Önerilen mimari, Tasarım Bilimi Araştırması (Design Science Research, DSR) yaklaşımıyla geliştirilmiş ve 30'dan fazla AIGC lisanslama senaryosu üzerinde değerlendirilmiştir. Deneysel bulgular, sistemin lisans uyumluluğu tespitinde %90'a varan doğruluk oranına ulaştığını ve aynı anda düşük gecikme süresi ile işlem maliyeti sağladığını göstermektedir. Teknolojik katkılarının ötesinde, bu çerçeve gelişmekte olan AIGC ekosisteminde güveni, şeffaflığı ve hesap verebilirliği artırmakta, düzenleyiciler, içerik üreticileri ve platform geliştiricileri için doğrulanabilir dijital yönetişim mekanizmalarının uygulanması ve AIGC tabanlı ticarette güvenilirliğin sağlanması adına uygulanabilir içgörüler sunmaktadır.

Anahtar Kelimeler: yapay zekâ, yapay zekâ tarafından üretilen içerik, blok zinciri, çoklu ajan sistemleri, dijital varlıklar

1. Introduction

The swift advancement of Artificial Intelligence (AI) is profoundly altering the domain of digital content creation, with AI-generated content (AIGC) rapidly emerging as a transformative influence across various sectors, including the burgeoning virtual environments like the Metaverse (Huynh-The et al., 2023). AIGC, encompassing text, imagery, audio, and various digital media generated by AI systems (Mezzi et al., 2025), presents unparalleled prospects for innovation and economic advancement. However, the remarkable ease and scale at which AIGC can be produced generate substantial governance complexities. Ambiguities related to authorship attribution, content ownership, and permissible use create substantial uncertainties, undermining trust and presenting significant barriers to a flourishing digital marketplace for AIGC (Luo et al., 2024; Wang et al., 2023).

Although current technologies tackle particular aspects of these challenges, a holistic and automated solution is still unattained. Blockchain technology, particularly through Non-Fungible Tokens (NFTs), has been utilized to securely represent unique digital assets (Ko et al., 2023). Simultaneously, multiple AI governance frameworks are developing to tackle the wider societal implications of AI utilization (Chaffer, 2025). Despite these advancements, there is a clear absence of an integrated approach that automates the initial governance steps, particularly the nuanced decisions required for AIGC licensing. Current blockchain-based systems generally necessitate significant manual intervention, whereas autonomous licensing through Large Language Models (LLMs) is still an emerging field of study.

This research presents the Multi-Agent Governance Framework for AIGC (MAG-AIGC), a blockchain-based architecture that utilizes Retrieval-Augmented Generation (RAG) techniques to facilitate automated and context-aware licensing decisions, thereby addressing significant gaps in the field. The modular multi-agent design of MAG-AIGC effectively captures creator intent, autonomously selects suitable licenses using advanced LLMs, and securely records these decisions on the blockchain through NFTs. This research aims to empirically evaluate the feasibility, efficiency, and practical effectiveness of the MAG-AIGC prototype using a rigorous Design Science Research methodology.

This study is significant for its potential to create a transparent and reliable governance infrastructure, thereby reducing information asymmetries among creators, users, and digital platforms. MAG-AIGC seeks to minimize governance overhead and verification costs associated with managing AIGC assets by establishing clear, immutable records of initial licensing terms (Zhang et al., 2025). This research presents four key contributions: (i) the design of a modular, multi-agent governance architecture; (ii) the integration of an advanced RAG pipeline for automating license selection through AI; (iii) an empirical evaluation of the accuracy, operational performance, and cost-efficiency of the proposed solution; and (iv) the demonstration of a practical, automated, and verifiable initial governance framework aimed at enhancing integration and trust in AIGC within the digital economy.

2. Literature review

Effective governance of AIGC necessitates strong technological foundations capable of managing complex information, ensuring reliable record-keeping, and navigating intricate rights landscapes. This review integrates literature from two primary areas: the foundational technologies facilitating digital asset governance and the commercialization challenges and licensing intricacies posed by AIGC.

2.1. Foundational technologies for digital asset governance

The governance of digital assets in modern ecosystems depends on the integration of advanced information processing systems and reliable, transparent record-keeping methods. Addressing the informational complexities of AIGC rights necessitates intelligent processing that is both powerful and reliable. Retrieval-Augmented Generation (RAG) presents a promising solution to this challenge (Miao et al., 2024). Standard Large Language Models (LLMs) exhibit a tendency to produce "hallucinations," which are outputs that appear plausible yet are factually incorrect. This presents a considerable risk in the context of legal and commercial stipulations (Ray, 2023). The RAG technique addresses this issue by initially retrieving a relevant subset of information from a comprehensive knowledge base, such as a collection of license policies. This process allows the LLM to reason solely over the retrieved data, thus ensuring that its output is grounded in verifiable context (Fan et al., 2024). This paradigm extends to agentic systems that utilize LLMs as the reasoning core for autonomous agents, enabling them to perform complex tasks such as planning, tool use, and interaction with external systems like blockchain (Cao et al., 2025; Singh et al., 2025).

Effective digital asset governance fundamentally relies on establishing trust in the integrity of assets and their associated records, a principle examined in transaction cost economics (Chaffer, 2025). Blockchain technology presents a robust solution through a secure and tamper-resistant digital ledger. Its fundamental characteristics, decentralization, immutability, and transparency, effectively tackle significant challenges in managing AIGC (Nakamoto, 2008; Salah et al., 2019). Recording claims and initial licensing terms provided by creators on a blockchain offers verifiable evidence of these parameters, which is essential for future transactions (Chohan, 2021). NFTs serve as unique digital certificates for AIGC assets (Hammi et al., 2023), while self-executing smart contracts facilitate automated agreements, including royalty distributions and usage restrictions (Khan et al., 2021; Liu et al., 2024). Efficient management of large files is achieved through systems such as the InterPlanetary File System (IPFS), which stores AIGC off-chain. An immutable Content Identifier (CID) is recorded on-chain, thereby ensuring data integrity and persistence (Daniel and Tschorsch, 2022; Xu et al., 2025; Zhang et al., 2024).

2.2. AIGC: commercialization barriers and licensing

The emergence of advanced AIGC represents a significant change in content creation, while also presenting new challenges for its effective incorporation into commercial systems. The AI-driven creation process introduces a "governance bottleneck" due to inherent uncertainties (Wang et al., 2023). Identifying a singular "creator" of AIGC presents challenges, as contributions are often shared among model developers, users, and data owners, resulting in a "attribution gap" (Mezzi et al., 2025). Moreover, existing copyright laws, based on human authorship, create legal uncertainty that may hinder trade and licensing (Foo et al., 2025; Karandikar et al., 2021). This requires technical systems that can document and uphold contractually established initial rights, ensuring operational certainty despite evolving legal frameworks (Hammi et al., 2023). The challenges highlight the essential requirement for a specialized governance framework to convert AIGC into a more consistently tradable asset class.

Emerging digital ecosystems, particularly those conceptualized within the Metaverse, are expected to be significantly populated by AIGC, with blockchain considered a fundamental infrastructure for ensuring verifiable ownership and facilitating transparent interactions (Hanneke et al., 2025; Yang et al., 2024). A notable advancement in these ecosystems is the anticipated emergence of AI agents as active economic entities, capable of autonomously generating and trading AIGC (Karim et al., 2025). The concept of a "agent-to-agent economy" requires governance frameworks capable of effectively managing autonomous transactions, especially concerning the intellectual property rights of

the assets exchanged by these agents (Kaal, 2025; Ouyang et al., 2022; Wang et al., 2019).

Concurrent with these technical advancements, recent policy and legal frameworks highlight the importance of verifiable governance for AIGC systems. The EU AI Act (2024) and the U.S. AI Accountability Policy Framework (2024) highlight the importance of traceable model behavior, data provenance, and auditable decision-making in establishing trustworthy AI ecosystems. The China Generative AI Service Regulation (2023) mandates that AIGC platforms provide transparent content labeling and verifiable data sources. These initiatives collectively illustrate a global trend toward responsible autonomy, wherein AI systems are required to function independently while maintaining external verifiability.

The MAG-AIGC framework supports the regulatory vision by integrating license traceability and provenance data onto a blockchain layer, thereby converting legal compliance requirements into enforceable governance mechanisms.

2.3. Synthesizing the literature and identifying the research gap

The prior study emphasizes notable progress in technology pertinent to digital asset governance. Agentic systems utilizing LLMs have potential for automated decision-making (Fan et al., 2024), whereas blockchain provides reliable frameworks for overseeing digital asset transactions (Nakamoto, 2008). Nonetheless, although helpful frameworks exist to handle facets of the AIGC lifecycle, a significant deficiency remains in the comprehensive integration of various technologies for the preliminary governance of AIGC.

Current research, for example, emphasizes securing LLM lifecycles (Luo et al., 2024), establishing platforms for AIGC trading (Truong et al., 2024), or formulating protocols for ownership protection (Xu et al., 2025), yet fails to incorporate a modular, multi-agent architecture with LLM-driven, context-aware decision-making for the essential initial phase of licensing and registration. The comparative analysis of selected AIGC governance-related frameworks presented in Table 1.

Table 1

Comparative analysis of selected AIGC governance-related frameworks

Feature / Framework	Proposed MAG-AIGC	BC4LLM (Luo et al., 2024)	MetaTrade (Truong et al., 2024)	Proof-of-AIGC (Liu et al., 2024)	Trustworthy AIGC Gov. (Yang et al., 2024)
Primary Focus	Initial Governance, Automated Licensing via RAG	Secure LLM lifecycle	Secure Trading in Metaverse	Secure lifecycle management	Regulatory Compliance
Autonomy in Initial Governance	High (Agent-driven)	Medium (Securing LLM processes)	High (Smart contract)	Medium (Protocol- based)	Medium (Mechanism-based)
AIGC-Specific Initial Licensing	Advanced AI-driven license selection	Data right confirmation for corpus	License-based AIGC trading	AIGC registration for ownership; Proof-of-AIGC for copyright	Blockchain AIGC owner ID & assurance
Verifiability Mechanism	NFT-based ERC-721 with Metadata CID	On-chain DID records for AIGC ID	Blockchain records (IPFS URL & hash of AIGC)	On-chain transaction with AIGC hash & metadata	On-chain transaction records for the owner ID

Feature / Framework	Proposed MAG-AIGC	BC4LLM (Luo et al., 2024)	MetaTrade (Truong et al., 2024)	Proof-of-AIGC (Liu et al., 2024)	Trustworthy AIGC Gov. (Yang et al., 2024)
Intelligent Policy Interpretation for Licensing	Yes (via RAG for initial license selection)	No (Focus on LLM lifecycle)	No (Focus on transaction protocols)	No (Protocol & mechanism-driven)	No (Focus on regulatory mechanisms)

Table 1 presents a structural comparison of current AIGC governance frameworks, while a more detailed functional distinction elucidates the uniqueness of the proposed MAG-AIGC. Previous frameworks, such as BC4LLM (Luo et al., 2024), concentrate on trust assurance and lifecycle security for large language models, neglecting the initial rights registration and autonomous licensing phase. Trustworthy AIGC Governance (Yang et al., 2024) highlights the importance of regulatory compliance mechanisms and on-chain traceability; however, it does not incorporate an agent-driven interpretive component that can translate creator intent into executable licensing decisions.

In contrast, MAG-AIGC integrates these dimensions by combining a RAG-enhanced Policy Agent for intelligent license interpretation with a blockchain-anchored verification layer, effectively bridging the gap between semantic understanding and verifiable governance execution. The dual-layer approach distinguishes MAG-AIGC from previous architectures that address these functions separately, establishing it as a crucial advancement toward fully autonomous AIGC governance systems.

This research addresses a specific architectural and functional gap. The MAG-AIGC presents a pipeline of specialized agents, featuring a dedicated Policy Agent that autonomously interprets creator intent to implement a verifiable, on-chain license. This process establishes a foundation of trust for all subsequent interactions involving the AIGC asset (Lin et al., 2023; Tanriverdi, 2024).

The literature indicates that although blockchain and multi-agent systems offer robust technical foundations for digital asset governance, their incorporation into a comprehensive automated framework for AIGC has not been thoroughly investigated. This section outlines the systematic approach taken to address the identified gap using a structured Design Science Research methodology.

3. Methodology and framework prototype

This study utilizes a Design Science Research (DSR) methodology to tackle the identified governance challenges, as it is effective for the creation and assessment of innovative IT artifacts aimed at resolving recognized organizational issues (Hevner et al., 2004; Peffers et al., 2007). This research adheres to the Design Science Research (DSR) cycle, commencing with problem identification and concluding with the design, development, and evaluation of the primary artifact: the MAG-AIGC, which is presented as a functional prototype. The aim is to automate and ensure verifiability of essential governance tasks for AIGC, which includes registering content with details provided by the creator and enabling an AI-driven process for selecting a suitable initial license. We evaluated practical performance and cost by employing the Sepolia Ethereum testnet and implementing the ERC-721 NFT standard to represent unique AIGC assets and their governance records.

This study maintains methodological transparency by adhering to the six canonical stages of the DSR process as outlined by Hevner et al. (2004) and Peffers et al. (2007):

(1) Problem Identification: delineating the absence of verifiable governance in AIGC

(2) Objective Definition: establishing automation and verification as the main design objectives.

(3) Design and Development: constructing the MAG-AIGC prototype as a modular, multi-agent system that integrates RAG and blockchain components.

(4) Demonstration: validation of the framework through 30 representative AIGC licensing scenarios.

(5) Evaluation: involves assessing the system's performance regarding accuracy, latency, and

cost-efficiency.

(6) Communication: involves the dissemination of research outcomes via publication and the open-access release of datasets and code.

Table 2 presents a summary of the instantiation of each DSR phase in this research.

Table 2

Mapping of Design Science Research (DSR) phases to MAG-AIGC development process

DSR Stage	Implementation in MAG-AIGC
Problem Identification	Governance gap in AIGC licensing and rights management
Objective Definition	Automation and verifiable on-chain licensing
Design & Development	Multi-agent, blockchain-integrated architecture
Demonstration	30 scenario-based prototype evaluations
Evaluation	Accuracy, latency, cost, and verifiability metrics
Communication	Publication of code, dataset, and empirical results

3.1. MAG-AIGC framework architecture

The MAG-AIGC prototype is designed as a modular pipeline consisting of three specialized, autonomous agents, which are coordinated by a central orchestrator. This design delineates responsibilities to improve robustness and maintainability, establishing a sequential workflow in which each agent executes a specific task prior to transferring its structured output to the subsequent agent. Figure 1 illustrates the high-level architecture.

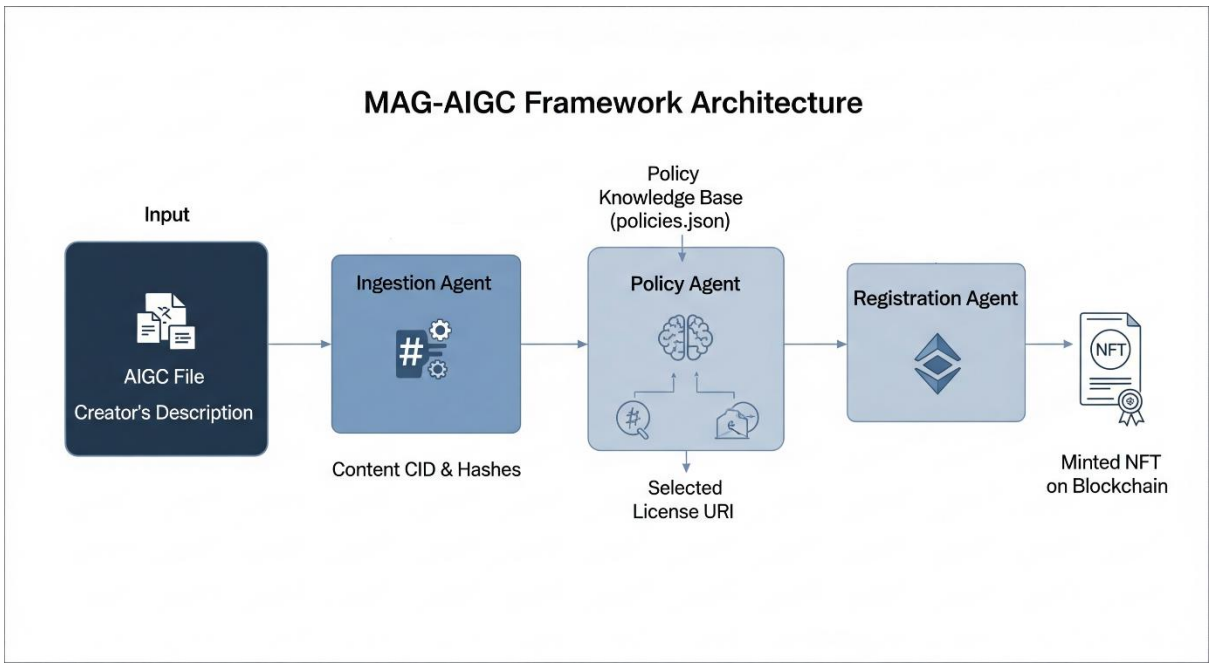

Figure 1. High-level multi-agent architecture

An Orchestrator oversees the comprehensive process, including the loading of evaluation scenarios, the initialization of shared components such as the LLM and blockchain connection, and the management of data flow among agents. The workflow initiates with the Ingestion Agent, which analyzes the raw AIGC file by calculating cryptographic hashes (SHA-256 and pHash) to ensure integrity and subsequently packages the content into a Content Addressable Archive (CAR) file for upload to IPFS. The output, which includes the file's immutable CID and hashes, is subsequently forwarded to the Policy Agent.

The Policy Agent serves as the central intelligent component of the licensing process. The process utilizes a two-stage Retrieval-Augmented Generation (RAG) method to identify the most suitable license according to the creator's textual description. The retrieval stage employs a sentence-transformer model to identify the ten most semantically relevant policies from a curated knowledge base (policies.json). During the selection stage, a prompt is formulated that includes the creator's description alongside a curated list of candidate policies. This prompt instructs an LLM (qwen2.5:14b-instruct-q5_K_M) to function as an intellectual property expert and identify the most suitable license.

The Registration Agent generates the on-chain record. A final JSON metadata file is compiled, which includes the asset's name, description, creator's wallet address, selected license URI, and integrity hashes. The metadata is uploaded to IPFS, resulting in the generation of a metadata CID. The agent initiates a blockchain transaction by invoking the safeMintWithCARCID function of the AIGCRegistry smart contract to mint an ERC-721 NFT. This establishes a permanent connection between the creator's wallet, the asset's metadata, and the immutable AIGC package, as illustrated in the workflow diagram (Figure 2).

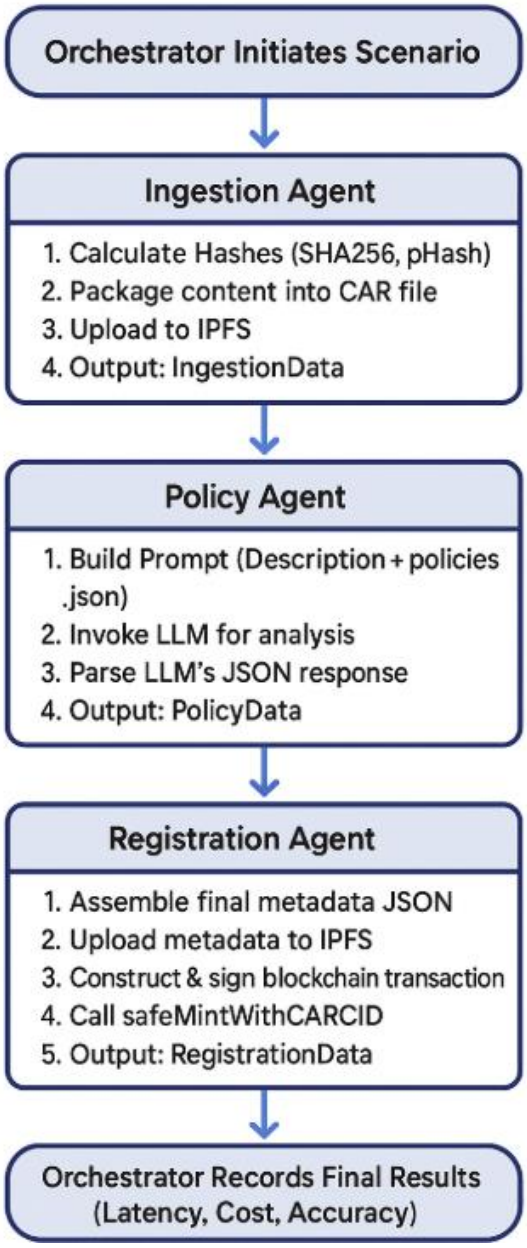

Figure 2. Detailed workflow diagram

3.2. Evaluation plan

The assessment of the MAG-AIGC prototype concentrated on its practicality and efficacy within a realistic operational framework. A synthetic dataset and a corresponding policy knowledge base were systematically developed to establish a robust and representative testbed, informed by a comprehensive analysis of the current AIGC licensing landscape.

The 30 evaluation scenarios were selected using a systematic sampling process to ensure representativeness and methodological rigor, based on current AIGC application domains. Candidate cases were sourced from three main content categories: creative works (art, music, text), software artifacts (code, models, utilities), and virtual assets (3D models, game items, metaverse property). Each category was populated based on common licensing intentions identified from public AIGC marketplaces, Creative Commons repositories, and AI content projects on GitHub.

The stratified selection process facilitated diversity in semantic complexity and licensing intent, allowing for the framework's evaluation under varied, realistic usage conditions. To enhance the assessment of generalizability, ambiguous or borderline scenarios, such as overlapping commercial and non-commercial use clauses, were intentionally incorporated.

The evaluation encompassed not only technical validation but also ethical and user-centric considerations. Each scenario was analyzed for potential misuse, bias, or fairness issues in automated license recommendation, with the findings contributing to the discourse on responsible deployment in Section 4.4. This multi-dimensional approach enhances the interpretive reliability of the Policy Agent and the external validity of the overall framework.

The policy knowledge base, comprising 19 representative license policies, was developed to reflect the intricate and diverse ecosystem of AIGC governance. The policies were selected purposefully to encompass the main categories of licenses utilized for digital and AI-generated assets. This encompasses traditional permissive and copyleft open-source software licenses, the diverse array of Creative Commons licenses tailored for creative works (e.g., CC BY, CC BY-NC-ND) (Creative Commons, 2023), as well as innovative, AI-specific frameworks including use-restricted licenses and platform-centric community licenses. The diversity guarantees that the Policy Agent's knowledge base encompasses a broad range of options, accurately representing the complexity of the decision space and offering a thorough evaluation of the RAG system's selection ability.

A synthetic dataset comprising 30 unique evaluation scenarios was developed. Each scenario was designed to reflect a typical and practical application of AIGC in digital content management, including the licensing of digital art for video games, the release of AI-generated code snippets, and the distribution of AI-assisted music tracks (Cao et al., 2025). Each scenario pairs a description of an AIGC asset with a natural language expression of the creator's licensing intent, such as "People can use this for personal projects, but not for commercial use." Credit should be provided, along with a corresponding ground-truth expected license URI. This design evaluates the framework's fundamental value proposition: its capacity to accurately interpret nuanced human intent and translate it into a standardized, formal policy. The scenarios were deliberately constructed with differing degrees of semantic complexity and potential ambiguity to comprehensively evaluate the LLM's reasoning and interpretative abilities.

A baseline comparison for AIGC registration was established by documenting the time and potential errors associated with a manual process that included file uploads, metadata creation, and the use of a web interface to mint an NFT. Metrics were collected for each of the 30 scenarios to evaluate the prototype. (i) Effectiveness is assessed through the accuracy metrics of the Policy Agent's license selection, including F1-Score, Precision, and Recall, in comparison to the ground truth; (ii) Performance is evaluated based on the average end-to-end processing latency; (iii) Cost-Efficiency is determined by the gas fees incurred on the Sepolia testnet; and (iv) Verifiability involves a qualitative evaluation of the integrity of the on-chain record. Appendix A and Appendix B provide a comprehensive overview of the scenarios and policies utilized in the evaluation.

The MAG-AIGC framework implements the DSR process by integrating design rigor with empirical validation. The subsequent section outlines the evaluation results and provides a detailed discussion of the empirical findings.

4. Results and discussion

This section delineates the empirical results from the assessment of the MAG-AIGC prototype and examines their ramifications. The assessment, performed on a varied dataset of 30 unique situations, concentrated on the framework's efficacy in license selection, its performance regarding latency and cost, the verifiability of its on-chain records, and the wider implications for practical and responsible implementation.

4.1. Effectiveness in license selection

The principal criterion for effectiveness was the Policy Agent's capacity to precisely choose an initial license utilizing its RAG architecture. This study specifically concentrated on open-source Large Language Models (LLMs) that are operable locally. This methodology presents numerous unique benefits for a verifiable governance framework: it guarantees data privacy by interpreting creator intent independently of third-party APIs; it affords increased control and customization for subsequent endeavors, including domain-specific fine-tuning (Dettmers et al., 2023; Qwen Team, 2024); and it improves the scientific reproducibility of outcomes by employing a specific, versioned model.

Upon assessing other notable open-source models, the qwen2.5:14b-instruct-q5_K_M model proved to be the most efficient for this particular task. It attained an overall accuracy of 90%, accurately recognizing the anticipated license in 27 out of 30 test situations (F1-Score: 0.90). This exceptional accuracy illustrates the feasibility of employing a RAG-based agent for this complex governance assignment. In contrast, alternative models exhibited inferior performance under same settings, with llama3.1:8b-instruct-q6_K attaining 73.3% accuracy and deepseek-coder:6.7b achieving 50%, highlighting the essential significance of the LLM's foundational reasoning capabilities inside the RAG pipeline. The performance outcomes summary is given in Appendix C.

A study of the three erroneous scenarios highlights difficulties in semantic interpretation. The model encountered difficulties in differentiating between two analogous licenses for "non-exclusive commercial use," misinterpreted a "no derivatives" stipulation, and was unable to associate a "sound effect" with a license intended for "royalty-free music/sound." A 90% accuracy rate is encouraging for low-stakes applications or as a recommendation tool; however, it underscores the necessity for a human-in-the-loop (HITL) validation mechanism to assess low-confidence selections prior to on-chain registration in legally binding or high-value commercial transactions. The RAG architecture, by offering a rationale for each decision, is ideally equipped to support this review process.

4.2. Performance: latency and cost-efficiency

The prototype demonstrated high efficiency. The average end-to-end processing time for the MAG-AIGC pipeline, from initiation to blockchain confirmation, was 22.22 seconds on average. Figure 3 details the end-to-end latency in seconds for each of the 30 evaluation scenarios. The minimal latency indicates that the framework can facilitate near real-time registration processes, an essential characteristic for platforms requiring large-scale onboarding of AIGC assets. The automated framework provides substantial improvements in speed and reliability compared to a manual baseline method, which is anticipated to require several minutes per asset and has a high likelihood of error.

In terms of cost, the safeMintWithCARCID function consumed a consistent 155,074 gas per transaction on the Sepolia testnet. This translates to a negligible on-chain cost, emulating the economics of an L2 scaling solution. The low and predictable costs indicate that the framework is economically viable for large-scale AIGC registration, removing cost as a barrier to creating verifiable on-chain records for digital assets in digital content management.

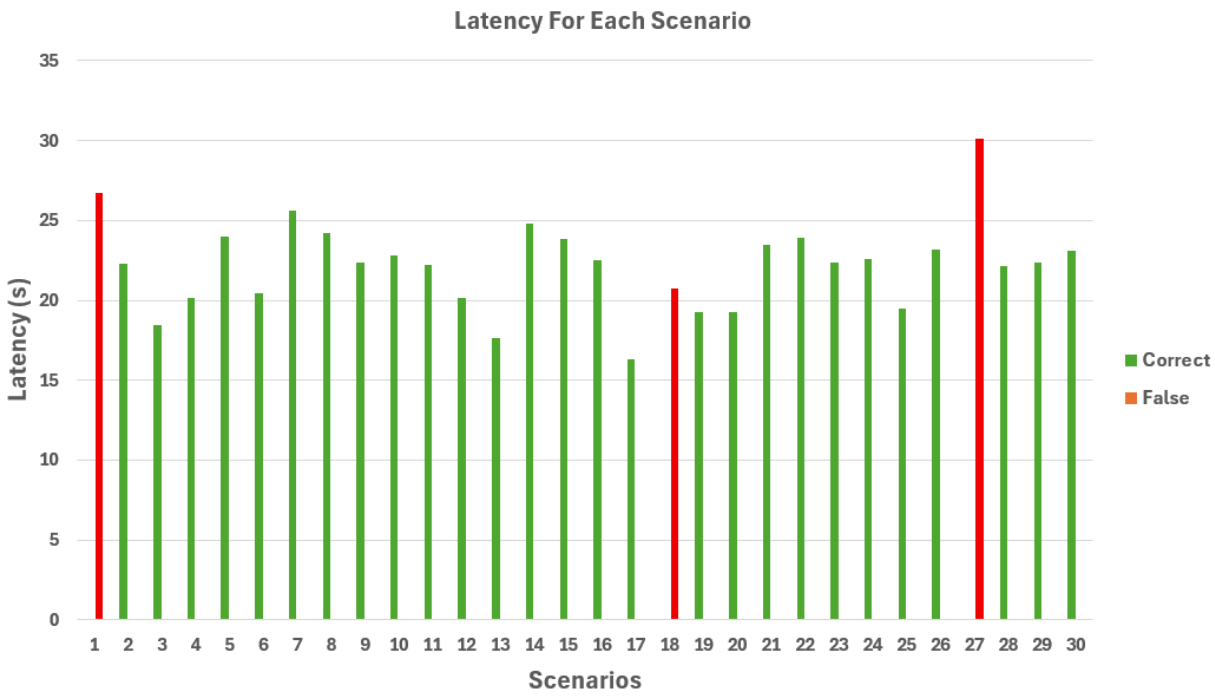

Figure 3. Per-scenario latency and accuracy

4.3. Verifiability and data integrity

For all 30 scenarios, irrespective of the license selection accuracy, the framework successfully executed the technical workflow of generating and recording verifiable data. In every case, the on-chain NFT record provided an immutable and correct link to the corresponding off-chain metadata and AIGC content package stored on IPFS. This confirms the robustness of the framework's core data integrity mechanisms, which are essential for building trust. By creating a verifiable link between a creator-provided wallet, asset metadata, and the content itself, the system provides a foundational "source of truth" that can be referenced in subsequent commercial transactions.

4.4. Implications for responsible AI and practical deployment

The effective automation of AIGC registration presents significant practical and ethical implications. The framework's dependence on information supplied by creators allows a hostile actor to register unauthorized or unlawful content. Consequently, effective implementation in a real-world operational setting would require the incorporation of mitigation methods, such AI-driven content filtering tools or verifications against established copyright databases before registration. The equity of the Policy Agent is fundamentally reliant on the selected policies. JSON knowledge repository. This knowledge base necessitates stringent governance to avert systemic bias, encompassing audits and transparent curation guidelines to guarantee equitable outcomes for creators.

From a deployment standpoint, interoperability is essential for AIGC assets to be effective across diverse platforms. The implementation of universal standards such as IPFS and ERC-721 establishes a robust foundation. The agent pipeline could be provided as an API service for connection with AIGC generation tools or digital asset management platforms. This would enable platforms to implement their distinct terms of service by offering tailored, version-controlled policy modules for the Policy Agent. It is essential to specify that the "creator wallet address" documented on the NFT denotes the blockchain address submitted by the entity asserting creation during registration. This wording sets expectations and appropriately indicates that the framework documents a provable assertion, rather than a legally determined reality of ownership, in accordance with the current directives from regulatory authorities such as the U.S. Copyright Office.

The empirical findings validate the technical integrity of the proposed architecture and illustrate its wider significance within digital governance ecosystems. Integrating verifiable licensing procedures within a blockchain framework actualizes essential principles of trust, transparency, and accountability highlighted by contemporary policy frameworks. Moreover, the robust correlation between model accuracy and regulatory goals indicates that MAG-AIGC can function as a basic prototype for compliance-oriented AIGC systems. Based on these findings, the next part presents overarching conclusions, delineates practical consequences, and emphasizes significant avenues for further research.

5. Conclusion and future work

This study examined the significant governance issue of creating verifiable initial records for AIGC. We presented and empirically validated the MAG-AIGC, an integrated architecture designed to automate the initial governance tasks for AIGC. The evaluation indicated that a multi-agent system, utilizing a RAG-based LLM, can effectively package AIGC for verifiable storage, achieve an initial license selection accuracy of up to 90%, and immutably record the results on-chain with low latency and minimal cost. The findings confirm that the MAG-AIGC offers a practical and precise technical basis for the establishment of the initial layer of AIGC governance, which is essential for its reliable incorporation into the wider digital economy.

The findings present multiple practical implications for digital marketplace operators. The framework offers a scalable approach to diminish operational friction and ambiguity in the onboarding of AIGC, which may lead to reduced transaction costs and enhanced market liquidity. Platform managers may modify the modular policy knowledge base of the framework to implement their particular terms of service. Additionally, the verifiable on-chain records can improve user trust and establish a fundamental basis for dispute resolution. This research presents a technical pathway for policy designers to implement transparency and record-keeping obligations, as outlined in emerging regulatory frameworks such as the EU AI Act.

This study confirms the viability of the core concepts; however, its limitations indicate significant directions for future research. The evaluation utilized a limited dataset comprising 30 scenarios and 19 policies; expanding this into a large-scale public benchmark represents a critical subsequent step. Moreover, although 90% accuracy is substantial, applications involving legal sensitivity require near-perfect performance. Future research should concentrate on optimizing the leading LLM using an extensive, domain-specific dataset of licensing scenarios to enhance accuracy. To mitigate the residual risk of error, a crucial advancement will be the establishment of an HITL system designed to identify low-confidence decisions for expert evaluation. In live operational environments, it is advisable to implement the Policy Agent not as a fully autonomous decision-maker, but rather as a strong recommendation engine that identifies selections requiring mandatory human verification, particularly in scenarios involving high asset value or legal complexity. Enhancing the on-chain autonomy and security of agents through the utilization of emerging standards such as ERC-4337 Account Abstraction represents a promising direction. This research aims to develop a comprehensive solution that is crucial for realizing the complete commercial and creative potential of AIGC within the digital economy.

This study proposes a cohesive and verifiable governance framework for AI-generated content (AIGC), addressing the intersection of technological automation and legal accountability. The proposed MAG-AIGC model integrates multi-agent reasoning, blockchain-based traceability, and the Design Science Research (DSR) methodology, offering conceptual clarity and operational feasibility for future AIGC ecosystems.

The framework not only offers technical advancements but also represents a significant policy innovation by implementing emerging regulatory principles, including responsible autonomy and transparent provenance. This provides a scalable basis for developing compliance-ready, ethically aligned AIGC platforms, a focus that future research may enhance through longitudinal user evaluations and cross-jurisdictional policy simulations. MAG-AIGC enhances the scientific discussion surrounding trustworthy AI and provides a viable approach to verifiable digital governance in the context of generative intelligence.

Author statement

Research and publication ethics statement

This study has been prepared in accordance with the ethical principles of scientific research and publication.

Approval of the ethics board

Ethics committee approval is not required for this study.

Author contribution

This study has one author.

Conflict of interest

There is no conflict of interest arising from the study for the authors or third parties.

Declaration of support

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Appendixes

Appendix A: Evaluation Scenarios

The following table details the 30 scenarios used to evaluate the Policy Agent's effectiveness. Each scenario includes a creator's intent (Description) and the ground-truth license URI expected as the correct output.

Scenario ID	File Name	Description	Expected License URI
SCENARIO-001	art_quantum_leap.jpg	I want a standard commercial license for my 3D model.	standard-commercial-v1
SCENARIO-002	model_forest_spirit.glb	This is an open source texture pack, people just need to credit me.	cc-by-4.0
SCENARIO-003	docs_chimera.txt	This artwork is proprietary and confidential, no one can use it.	all-rights-reserved-v1
SCENARIO-004	kit_open_arch.zip	Releasing this code into the public domain. Do whatever you want with it.	cc0-1.0
SCENARIO-005	music_cyber_dreams.mp3	People can use this for personal projects, but not for commercial use. Please give credit.	cc-by-nc-4.0
SCENARIO-006	item_phoenix_blade.glb	This is a unique 1-of-1 NFT. The owner gets full commercial rights.	unique-collectible-commercial-owner-v1
SCENARIO-007	code_sky_shader.txt	This is a software library. Any derivatives must use the same copyleft license.	gpl-3.0
SCENARIO-008	photo_graduation.jpg	This avatar is for my personal use only. No one else can use or sell it.	personal-use-only-v1

SCENARIO-009	logos_innovate_corp.zip	I am selling the exclusive commercial rights to this digital painting.	exclusive-commercial-transfer-v1
SCENARIO-010	paper_ai_ethics.pdf	Free to share, but non-commercial use only and no changes allowed. Credit required.	cc-by-nc-nd-4.0
SCENARIO-011	art_community_character.jpg	Anyone can use this, even commercially, but they cannot modify it. Credit me.	cc-by-nd-4.0
SCENARIO-012	texture_ancient_map.png	This is open source. All derivative works must be shared under the same terms. Credit is needed.	cc-by-sa-4.0
SCENARIO-013	audio_jingle.mp3	This is a royalty-free music track for use in any commercial project.	nonexclusive-royaltyfree-music-v1
SCENARIO-014	model_spaceship_cockpit.glb	This photo is for use in news articles only. Not for advertising.	editorial-use-only-v1
SCENARIO-015	lib_ai_governance.zip	This is a permissive open source software script. Just include the copyright notice.	MIT
SCENARIO-016	story_lonely_robot.txt	A plot of virtual land with building restrictions set by the platform.	virtual-land-use-restricted-v1
SCENARIO-017	deed_virtual_land.pdf	A game asset that can only be used within the 'Metropolis World' game.	platform-exclusive-asset-v1
SCENARIO-018	ad_holo_billboard.glb	For a non-commercial educational project. Others can adapt it if they also share non-commercially.	cc-by-nc-sa-4.0
SCENARIO-019	art_final_concept.jpg	My company's logo. For use in promotional materials about our brand only.	trademark-use-only-v1
SCENARIO-020	music_exclusive_beat.mp3	A commercial license that is not exclusive. I can sell this to multiple people.	nonexclusive-commercial-v1
SCENARIO-021	pack_voxel_assets.zip	The most permissive open license. People can use my work for anything, just attribute it to me.	cc-by-4.0
SCENARIO-022	lib_procedural_gen.zip	A code snippet for a game. It's copyleft, so any game using it	gpl-3.0

		must also be open source under the same license.	
SCENARIO-023	print_limited_edition.png	This digital fashion item is for personal, non-profit use only. Not for resale.	personal-use-only-v1
SCENARIO-024	kit_game_ui.zip	I want to put this meme into the public. No rights reserved.	cc0-1.0
SCENARIO-025	video_corporate_training.mp4	I'm transferring all commercial rights of this jingle to the buyer. It will be theirs exclusively.	exclusive-commercial-transfer-v1
SCENARIO-026	kit_dungeon_modular_v2.zip	A 3D model of a real-world car for an educational documentary. Not for use in a commercial game.	editorial-use-only-v1
SCENARIO-027	sfx_city_ambience.mp3	A sound effect for a game. Non-exclusive and royalty-free for unlimited commercial projects.	nonexclusive-royaltyfree-music-v1
SCENARIO-028	text_blog_post.txt	A software utility licensed under MIT.	MIT
SCENARIO-029	logo_open_source.svg	A unique piece of generative art where the NFT holder has the exclusive right to monetize it.	unique-collectible-commercial-owner-v1
SCENARIO-030	art_genesis_block.png	This is a texture for a 3D model. It can be used commercially, but any modifications must be shared under the same license.	cc-by-sa-4.0

Appendix B: Policy Knowledge Base

The policies.json file contained 19 distinct license policies that the Policy Agent used as its knowledge base for the RAG-based selection process.

Policy ID	Description
standard-commercial-v1	A standard commercial license for general marketplace assets. It grants non-exclusive rights to use the asset in commercial projects.
cc-by-4.0	Creative Commons Attribution 4.0. Allows sharing and adaptation for any purpose, including commercial, with attribution.
all-rights-reserved-v1	Highly restrictive and proprietary. No use, distribution, or modification is permitted without explicit permission.

cc0-1.0	Creative Commons Zero (Public Domain). Waives all copyright, allowing free use for any purpose without attribution.
cc-by-nc-4.0	Creative Commons Attribution-NonCommercial 4.0. Allows sharing and adaptation for non-commercial purposes only, with attribution.
unique-collectible-commercial-owner-v1	For a unique digital collectible (NFT). The owner is granted full and exclusive commercial rights to use and monetize it.
gpl-3.0	GNU General Public License v3.0. A strong 'copyleft' license for software; derivatives must also be licensed under GPL.
personal-use-only-v1	Strictly for personal, non-commercial use. The asset cannot be sold, re-distributed, or used for monetary gain.
exclusive-commercial-transfer-v1	A full and exclusive transfer of commercial rights. The original creator cannot use the asset commercially after transfer.
cc-by-nc-nd-4.0	Creative Commons Attribution-NonCommercial-NoDerivatives 4.0. Allows sharing for non-commercial purposes, but cannot be modified.
cc-by-nd-4.0	Creative Commons Attribution-NoDerivatives 4.0. Allows redistribution (commercial/non-commercial) but must be passed along unchanged.
cc-by-sa-4.0	Creative Commons Attribution-ShareAlike 4.0. A 'copyleft' license; derivatives must be licensed under the same terms.
nonexclusive-royaltyfree-music-v1	A non-exclusive, royalty-free license for music/sound effects for unlimited commercial projects after a one-time fee.
editorial-use-only-v1	Restricts asset use to editorial purposes (e.g., news articles, journalism). Cannot be used for commercial or promotional purposes.
MIT	A permissive open-source software license allowing broad use, including in proprietary software, with inclusion of the notice.
virtual-land-use-restricted-v1	Governs the use of virtual land on a specific platform, subject to platform restrictions and terms of service.
platform-exclusive-asset-v1	Restricts the use of an asset to a single, specific platform, game, or virtual environment.

cc-by-nc-sa-4.0	Creative Commons Attribution-NonCommercial-ShareAlike 4.0. Allows non-commercial remixing; derivatives must be under identical terms.
trademark-use-only-v1	For brand assets (logos, trademarks). Use is restricted to promoting the associated brand or product.

Appendix C: Detailed Evaluation Results

The following table presents the complete results for each of the 30 scenarios evaluated with the qwen2.5:14b-instruct-q5_K_M model.

Scenario ID	Selected License	Expected License	Correct?	Latency (s)	Gas Used
SCENARIO-001	nonexclusive-commercial-v1	standard-commercial-v1	FALSE	26.73	155074
SCENARIO-002	cc-by-4.0	cc-by-4.0	TRUE	22.33	155074
SCENARIO-003	all-rights-reserved-v1	all-rights-reserved-v1	TRUE	18.49	155074
SCENARIO-004	cc0-1.0	cc0-1.0	TRUE	20.12	155074
SCENARIO-005	cc-by-nc-4.0	cc-by-nc-4.0	TRUE	23.99	155074
SCENARIO-006	unique-collectible-commercial-owner-v1	unique-collectible-commercial-owner-v1	TRUE	20.44	155074
SCENARIO-007	gpl-3.0	gpl-3.0	TRUE	25.63	155074
SCENARIO-008	personal-use-only-v1	personal-use-only-v1	TRUE	24.19	155074
SCENARIO-009	exclusive-commercial-transfer-v1	exclusive-commercial-transfer-v1	TRUE	22.39	155074
SCENARIO-010	cc-by-nc-nd-4.0	cc-by-nc-nd-4.0	TRUE	22.79	155074
SCENARIO-011	cc-by-nd-4.0	cc-by-nd-4.0	TRUE	22.22	155074
SCENARIO-012	cc-by-sa-4.0	cc-by-sa-4.0	TRUE	20.12	155074

SCENARIO-013	nonexclusive-royaltyfree-music-v1	nonexclusive-royaltyfree-music-v1	TRUE	17.62	155074
SCENARIO-014	editorial-use-only-v1	editorial-use-only-v1	TRUE	24.84	155074
SCENARIO-015	MIT	MIT	TRUE	23.84	155074
SCENARIO-016	virtual-land-use-restricted-v1	virtual-land-use-restricted-v1	TRUE	22.54	155074
SCENARIO-017	platform-exclusive-asset-v1	platform-exclusive-asset-v1	TRUE	16.29	155074
SCENARIO-018	cc-by-nc-sa-4.0	cc-by-nc-sa-4.0	TRUE	20.78	155074
SCENARIO-019	cc-by-sa-4.0	trademark-use-only-v1	FALSE	19.25	155074
SCENARIO-020	nonexclusive-commercial-v1	nonexclusive-commercial-v1	TRUE	19.27	155074
SCENARIO-021	cc-by-4.0	cc-by-4.0	TRUE	23.51	155074
SCENARIO-022	gpl-3.0	gpl-3.0	TRUE	23.94	155074
SCENARIO-023	personal-use-only-v1	personal-use-only-v1	TRUE	22.40	155074
SCENARIO-024	cc0-1.0	cc0-1.0	TRUE	22.62	155074
SCENARIO-025	exclusive-commercial-transfer-v1	exclusive-commercial-transfer-v1	TRUE	19.48	155074
SCENARIO-026	editorial-use-only-v1	editorial-use-only-v1	TRUE	23.18	155074
SCENARIO-027	standard-commercial-v1	nonexclusive-royaltyfree-music-v1	FALSE	30.10	155074
SCENARIO-028	MIT	MIT	TRUE	22.15	155074

SCENARIO-029	unique-collectible-commercial-owner-v1	unique-collectible-commercial-owner-v1	TRUE	22.35	155074
SCENARIO-030	cc-by-sa-4.0	cc-by-sa-4.0	TRUE	23.08	155074