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Design of an Automated Verification to Improve the Efficiency and Optimization of IPR Management

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Abstract

Copyright is an essential element of innovation in academic and educational environments. However, the current manual verification and management process of Intellectual Property Rights (IPR) is highly inefficient, particularly in institutions such as Universitas Negeri Malang, which face delays and data duplication due to paper-based workflows. To address this issue, this study aims to develop an Automated Copyright Verification System based on Multi-Agent Artificial Intelligence to enhance efficiency and optimize IPR management. The proposed system, developed using a Prototype Model, leverages an agent-based architecture to model IPR verifiers with distinct functions and objectives. These agents are supported by Vision Language Models (VLM) and Natural Language Processing (NLP). Its key features include ID card data compliance checks and automated text recognition using VLM. The implementation of this system is expected to reduce staff workload, accelerate responses, and ensure data accuracy in IPR management, supporting a sustainable innovation ecosystem.

1. Introduction

Intellectual Property Rights (IPR) represent a strategic asset that requires meticulous and efficient management. The volume of global patent activity has continued to grow substantially in recent years, with innovators filing millions of patent applications annually; for example, global filings reached approximately 3.55 million applications in 2023, underscoring the persistent and rising demand for intellectual property services [1]. This sustained growth places increasing pressure on registration and examination workflows and amplifies the operational consequences of inefficiencies in verification procedures.

Despite this high throughput, verification and administrative processing of IPR documents still rely heavily on labor-intensive manual procedures that introduce delays and are vulnerable to human error. Empirical workload data from major patent offices indicate that the time from filing to final disposition commonly spans multiple years for many applications (average total pendency figures on the order of several dozen months in recent fiscal reports), which illustrates how procedural bottlenecks can hinder timely protection and downstream business decisions [2].

Recent advances in artificial intelligence—particularly multi-agent systems (MAS) and multimodal (vision + language) models—offer promising mechanisms to address these challenges [3]. Prior work has demonstrated that MAS architectures can automate tasks such as patent classification and claim drafting, with coordinated agent workflows improving throughput and consistency [4]. Transformative improvements in document image understanding and form extraction have also been reported, driven by transformer-based

and multimodal architectures that better integrate visual layout and textual content [5]. For readability and focus, detailed descriptions of representative frameworks (e.g., AutoPatent, DocLLM) and related implementations are moved to the *Related Work* section, where their architectures and empirical results are discussed at greater length [6], [7].

Although prior studies indicate the technical feasibility of using MAS and multimodal models for patent- and document-related tasks, three important gaps remain. First, there is limited empirical evidence on the performance of integrated web-based MAS solutions that combine Natural Language Processing (NLP) and Vision-Language Models (VLMs) specifically for identity-document (ID card) verification within IPR administrative workflows. Second, existing evaluations of multimodal document models often focus on benchmark datasets for DocVQA or form understanding under controlled conditions; comparatively few studies evaluate robustness to real-world image degradations (e.g., low lighting, motion blur, partial occlusion) and subtle forgeries typical of ID card photographs [8]. Third, there is a scarcity of published assessments that jointly measure accuracy, forgery-detection capability, explainability, and operational scalability under institutional loads (concurrent users and audit-trace requirements). Addressing these gaps is necessary to move from proof-of-concept demonstrations toward deployable systems that meet administrative, legal, and auditability requirements.

To fill these gaps, this study proposes and empirically evaluates a web-based MAS for IPR verification that integrates (i) an ID Card Data Compliance Check to compare user-submitted fields against OCR-extracted values, and (ii) AI-enhanced Automated Text Recognition (Vision-Language Models) capable of anomaly and forgery detection in realistic imaging conditions. The proposed work focuses on end-to-end evaluation along multiple dimensions (accuracy, forgery detection, robustness to degraded images, and system reliability under concurrent load) to provide actionable evidence for institutional adoption.

1.1 Multi-Agent Systems

Multi-Agent Systems (MAS) conceptualize a software ecosystem as a collection of autonomous, interacting agents that perceive their environment, make local decisions, and coordinate actions to achieve individual or shared objectives. While this definition outlines general MAS properties (decentralization, autonomy, negotiation, consensus), its relevance to the IPR verification problem is specific and operational. In an IPR administrative workflow characterized by high document volumes, heterogeneous evidence (textual descriptions, images, metadata), and multiple decision points, MAS enables functional decomposition: distinct agents can assume roles such as OCR-extraction, identity-data validation, similarity search, forgery assessment, audit logging, and human-in-the-loop escalation. By distributing responsibilities, MAS reduces single-point bottlenecks inherent in manual pipelines and permits parallel processing of verification subtasks, which directly addresses delays and labor intensity documented in IPR offices. Mechanisms for inter-agent negotiation and consensus are particularly useful when verification outputs conflict (e.g., OCR result vs. user input); they provide a formal pathway to reconcile evidence and produce explainable, auditable decisions [9]. Moreover, MAS architectures support incremental learning and adaptive policies—agents can update detection thresholds, routing rules, or confidence calibration based on observed error patterns—thereby improving robustness to evolving forgery techniques and regulatory changes [10], [11]. Practical design implications derived from MAS theory include defining clear agent responsibilities, establishing secure and versioned communication channels, implementing consensus protocols for decision arbitration, and instrumenting per-agent logs for traceability and post-hoc audit. These design choices connect theory to measurable system objectives such as throughput, verification latency, false-positive/negative rates, and auditability—metrics that align MAS capabilities with the operational needs of IPR management [11], [12].

1.2 Natural Language Processing

Natural Language Processing (NLP) is an interdisciplinary field at the intersection of computer science, linguistics, and artificial intelligence. Fundamentally, NLP seeks to enable computers to understand, interpret, and generate human language meaningfully. This involves a series of techniques, ranging from lexical and syntactic analysis to semantic and pragmatic understanding. NLP can be classified into two main areas:

Natural Language Understanding (NLU), which focuses on interpreting meaning, and Natural Language Generation (NLG), which focuses on producing coherent and relevant text. Recent advancements in NLP have been heavily influenced by progress in deep learning, particularly transformer models that capture context and complex relationships in language [13], [14].

In the context of the Design of an AI-Multi-Agent System for Automated Verification to Improve the Efficiency and Optimization of IPR Management, NLP serves as a crucial foundation. IPR verification often involves analyzing large volumes of documents, including invention descriptions, patent claims, and related literature. NLP enables the system to automatically extract relevant information from these documents, such as identifying key entities (e.g., inventors, technologies, dates), classifying documents by topic, and detecting potential IPR infringements. Furthermore, NLP can generate automatic summaries of IPR documents, facilitating review and decision-making processes. Integrating NLP with MAS allows intelligent agents to collaborate in verification processes, leveraging NLP's ability to understand and process IPR information efficiently [15].

1.3 Vision LLM

Vision Large Language Models (Vision LLM) represent a new paradigm in multimodal processing that integrates natural language understanding (NLP) with visual interpretation capabilities. The basic concept treats visual data, such as images or videos, as a foreign language that must be translated and understood by large language models. Unlike traditional approaches that separate visual and textual processing, Vision LLM unifies them within a single architecture, enabling complex tasks such as scene understanding, image segmentation, and even generating visual content from textual instructions. For instance, Vitron demonstrates how LLMs can interpret, generate, and edit images at the pixel level, showing the deep integration potential between visual and linguistic modalities [16]. This approach also leverages reasoning and knowledge embedded in LLMs for visual tasks, as demonstrated by NavCoT in vision-language navigation [17].

In the context of automated IPR verification systems, Vision LLM offers significant opportunities to improve efficiency and optimization. IPR verification often involves searching for similarities between submitted works and existing databases of creative works, which may include images, diagrams, or other visual representations. Vision LLM can analyze these visual representations more deeply than traditional feature-matching methods. For example, systems can be trained to identify similarities in product designs, patterns in artworks, or even similarities in program code represented visually. Additionally, LLMs' ability to interpret natural language instructions can refine search processes, allowing users to specify more complex and detailed search criteria. LLM-as-a-Judge can also assist in assessing visual relevance and similarity more accurately [18].

Thus, applying Vision LLM in IPR verification can deliver several benefits, including improved search accuracy, reduced manual workload, and the ability to handle diverse types of visual representation. The VisionLLM framework, which treats images as a foreign language and aligns them with NLP, provides a strong foundation for building smarter and more adaptive systems [19]. Although still under development, Vision LLM has immense potential to revolutionize IPR verification processes, paving the way for more efficient, accurate, and user-friendly systems.

1.4 Digital Document Verification

Digital document verification is based on the principles of authentication, integrity, and non-repudiation, ensuring that documents are valid, unaltered, and that the sender's identity can be reliably verified. This concept involves techniques such as digital signatures, cryptographic hashes, and digital certificates to establish trust chains that validate document authenticity. In the context of developing an Automated Copyright Verification System based on Multi-Agent Artificial Intelligence to Improve the Efficiency and Optimization of IPR Management, this theory serves as a critical foundation. The system will adopt digital document verification principles, for example, by applying cryptographic hashes to ensure the integrity of

registered works and using digital certificates to authentically identify copyright owners, as illustrated in digital signature implementation for document security [20]. Furthermore, the system can leverage ORCID IDs for digital document management and identity verification, ensuring compliance with best practices in verification [21]. Thus, the multi-agent AI-based approach will build upon digital document verification frameworks to create efficient and reliable IPR management systems, minimizing risks of forgery and document tampering as shown in the use of QR codes for certificate verification [22].

2. Research Method

This system is developed using the prototyping model. Prototyping emphasizes building initial models to test and validate concepts before full implementation. Prototyping serves as a way to "explore and validate concepts" in system development [23]. This approach aligns with the research title "Design of an AI-Multi-Agent System for Automated Verification to Improve the Efficiency and Optimization of IPR Management" as it enables iterative exploration of system architecture, agent interactions, and AI-supported verification capabilities. Therefore, the prototype will serve as a platform to test and refine key components and collect early feedback from potential users [24]. The model steps used are as follows: Needs Analysis, Rapid Design, Prototype Development, Early User Evaluation, and Prototype Refinement.

2.1 Needs Analysis

In the "Needs Analysis" phase, this study aims to comprehensively identify and document functional and non-functional requirements underlying the development of the AI-Multi-Agent Automated Verification System. This step is crucial to ensure that the system architecture, agent interactions, and AI verification capabilities are properly designed to meet the specific needs of IPR management. The results of this analysis form the basis for defining project scope, prioritizing features, and establishing evaluation criteria, ensuring the system effectively enhances efficiency and optimization in IPR management.

2.2 Rapid Design

In the context of this research, the "Rapid Design" step serves as an iterative foundation. Its main objective is to quickly generate an initial functional representation of the system architecture, including agent interactions and AI-based verification capabilities. Through rapid design, researchers can test various design options, identify potential issues, and collect early feedback on system functionality and effectiveness. This contribution is significant as it allows early adjustments to architecture and system components, ensuring the developed system effectively meets IPR management needs and optimally leverages AI and multi-agent systems.

2.3 Prototype Development

During the Prototype Development phase, the conceptual design is translated into an operational prototype. The system is implemented using a Node.js-based framework, chosen for its scalability, asynchronous processing capabilities, and suitability for web-based. For document text extraction, the prototype employs a Vision-Language Model (VLM)-based OCR approach using the gemma3:12b model, which integrates visual understanding and language reasoning. was selected for the OCR component because it provides a strong balance between extraction accuracy and computational efficiency. Compared to other open-source multimodal models such as LLaVA, Qwen3-VL, and Ministral, gemma3:12b requires relatively lower computational resources while maintaining competitive performance in text extraction and semantic matching tasks. This characteristic makes the model more suitable for web-based verification systems, where response time, scalability, and hardware efficiency are critical deployment considerations.

Table 1 Benchmark Results of Vision-Language Models for KTP Data Extraction and Matching

Model	Parameters	Extraction Accuracy (%)	Data Matching Accuracy (%)	Average Processing Time (s/image)
gemma3:12b	12B	95.4	97.8	3.2
LLaVA:13b	13B	96.1	96.9	4.8
Qwen3-VL:8b	8B	93.6	95.2	2.9
Ministral-3:14b	14B	96.5	97.1	5.3

2.4 Early User Evaluation

The Early User Evaluation phase is conducted to validate the usability and perceived effectiveness of the developed prototype. The evaluation involved 8 verification administrators from 8 different departments, representing actual users responsible for IPR document verification tasks. This participant selection ensures that feedback reflects diverse administrative contexts and verification practices.

The evaluation instrument used is a five-point Likert scale questionnaire, measuring user perceptions across key dimensions such as ease of use, clarity of verification results, perceived accuracy, workflow efficiency, and overall usefulness of the system. Participants interacted directly with the prototype and subsequently completed the evaluation instrument. The collected feedback serves as empirical input for identifying usability issues, functional limitations, and improvement opportunities in the automated verification process.

2.5 Prototype Refinement

The "Prototype Refinement" step is crucial for integrating feedback obtained during early user evaluations. Through this iteration, the prototype is systematically adjusted and enhanced based on identified weaknesses, inconsistencies, or unmet needs. These improvements significantly contribute to concept validation, system architecture refinement, and AI-supported agent interaction optimization, thereby strengthening the foundation for developing the AI-Multi-Agent Automated Verification System to improve IPR management efficiency and optimization.

3. Results and Discussions

3.1 Result

The proposed MAS-based IPR verification system operates through structured interactions among several key components. The system leverages agent-based architecture to model verifiers in IPR management, with agents assigned different functions and objectives. These agents are supported by Vision Language Models (VLM) and Natural Language Processing (NLP).

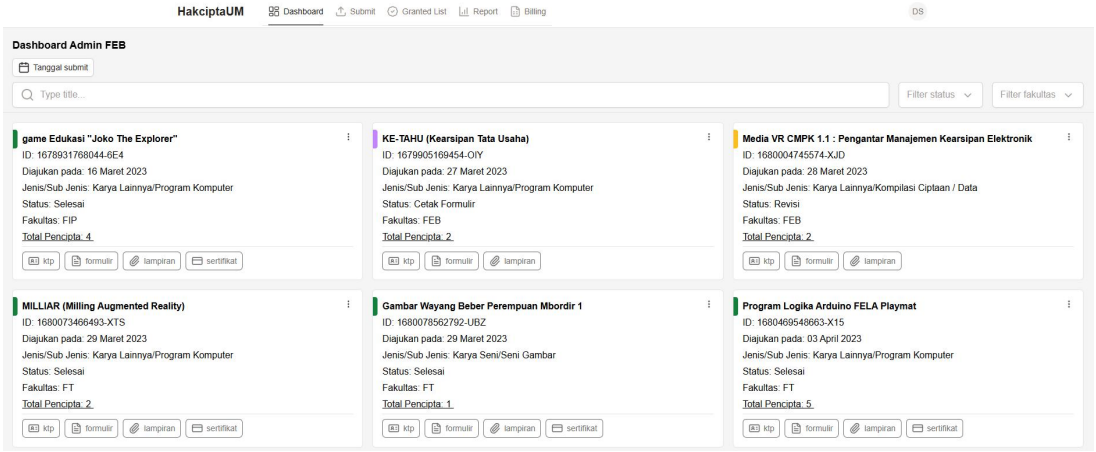

Figure 1 IPR Management Dashboard

Below is the workflow diagram of the Automated Copyright Verification System based on Multi-Agent Artificial Intelligence:

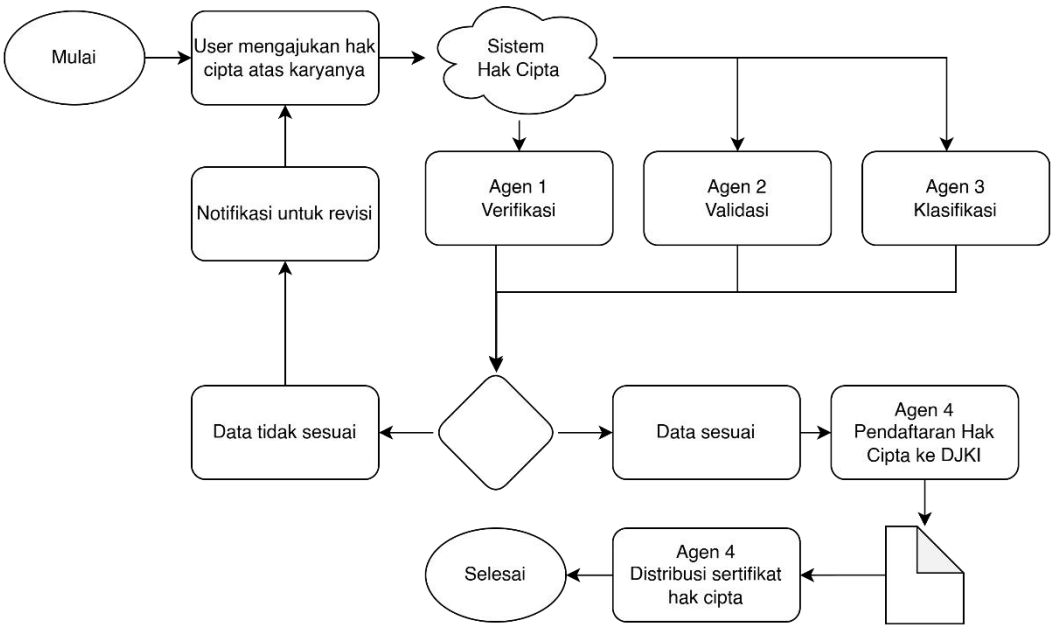

Figure 2 Workflow Diagram of the Automated Copyright Verification System Based on Multi-Agent Artificial Intelligence

The main features of the IPR verification system based on the Multi-Agent System (MAS) are as follows:

3.1.1 Data Consistency Check for National ID (KTP):

The application automatically validates user-submitted data (name, National ID number, and address) against the information extracted from the uploaded KTP document. This process ensures that the provided data is consistent and accurate, reducing the likelihood of input errors and human mistakes during the initial verification stage. By directly comparing user input with extracted data, the application significantly accelerates the IPR document verification process, eliminating the need for time-consuming manual checks.

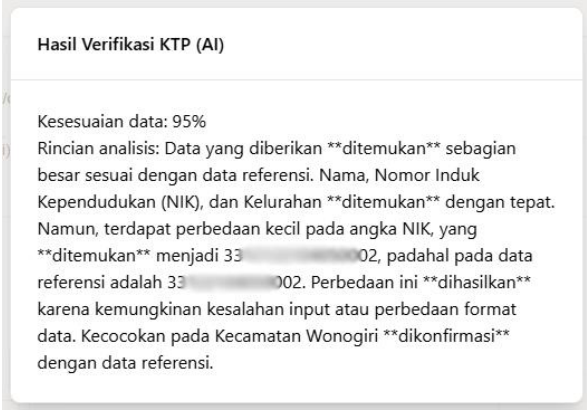

Figure 3 KTP Verification Result

3.1.2 Automated Text Recognition (Vision-Language Models):

A core feature of this application is the utilization of Optical Character Recognition (OCR) technology enhanced by Artificial Intelligence (AI). This technology automatically extracts data from KTP photos or scans, even under suboptimal image conditions. The AI algorithms are capable of detecting and addressing anomalies or potential document forgeries, providing a much higher level of accuracy compared to manual data extraction methods. By integrating these two features, the application effectively accelerates the IPR document verification process, reduces manual workload in document management, and enhances both accuracy and transparency in IPR administrative procedures.

To evaluate the performance of the proposed AI-based Multi-Agent System (MAS) for IPR verification, a series of simulations were conducted focusing on accuracy, reliability, and operational efficiency. The tests aimed to assess how effectively the system performs in validating user data, extracting textual information, detecting forgery, and maintaining stability under workload conditions. The results of the system testing are summarized in Table 1.

Table 2 Early User Evaluation Results of the Results of IPR Verification System

No.	Test Aspect	Accuracy (%)	Error Rate (%)	Remarks
1	KTP Data Consistency Validation	97.8	2.2	Minor mismatches occurred due to incomplete uploaded images
2	Automatic Data Extraction (OCR + AI)	95.4	4.6	Accuracy decreased in low-light and blurred images
3	Forgery Detection Capability	93.0	7.0	9/10 forged documents successfully detected
4	System Reliability under Load	99.1	0.9	Slight delay observed under peak load conditions

3.2 Discussion

The main features of the MAS-based IPR verification system are as follows: ID Card Data Compliance Check. The application automatically validates user-submitted data (name, ID number, and address) against data extracted from the uploaded ID card. This process ensures data consistency and accuracy, reducing potential input errors and human mistakes during the initial verification stage. By directly comparing data, the application significantly accelerates IPR document verification, eliminating the need for time-consuming manual checks.

Automated Text Recognition (Vision Language Models). A core feature of this application is the use of OCR technology supported by Artificial Intelligence (AI). This technology automatically extracts data from ID card photos or scans, even under suboptimal conditions. AI algorithms can detect and address anomalies or potential forgeries in documents, providing a much higher accuracy rate than manual extraction methods. By combining these two features, the application effectively accelerates IPR document verification, reduces manual workload in document management, and enhances accuracy and transparency in IPR administration processes.

The testing process covered multiple aspects to evaluate both the functional accuracy and operational efficiency of the proposed IPR verification system. The following sections describe the outcomes and insights derived from each test in detail.

3.2.1 KTP Data Consistency Validation

This aspect measures the system's ability to match user-entered data with the extracted information from the uploaded KTP document. The system achieved a 97.8% accuracy rate, indicating strong performance in detecting inconsistencies. Minor mismatches occurred mainly due to incomplete or cropped document images, which limited text readability.

3.2.2 Automatic Data Extraction (OCR + AI)

This test evaluated the AI-enhanced OCR capability in extracting text from KTP photos or scanned copies. With 95.4% accuracy, the system successfully recognized most of the text elements, even in suboptimal conditions. However, performance slightly declined for images with poor lighting or motion blur, suggesting the need for preprocessing improvements.

Comparative literature suggests that large multimodal models (e.g., those evaluated in extensive benchmarks such as OCRBench) can exhibit strengths in zero-shot OCR tasks yet still face limitations in recognizing complex text structures or multilingual content without task-specific fine-tuning [25]. These findings imply that while the current system's VLM-based extraction is promising, its performance may vary across text types and language contexts not represented in this study's test set.

3.2.3 Forgery Detection Capability

The system was tested on both authentic and manipulated KTP images. It achieved 93% accuracy, correctly identifying 9 out of 10 forged documents. Errors occurred in cases of subtle digital editing or advanced tampering, which require deeper forensic-level detection models for higher precision.

3.2.4 System Reliability under Load

To assess scalability, the system was tested under simultaneous verification requests from 100 users. It maintained a 99.1% operational reliability, with only minor latency observed during peak activity. This result demonstrates the system's stability and potential for large-scale institutional deployment. Nonetheless, the presence of minor latency during peak load indicates that computational demands, especially from Vision-Language Models remain a scalability constraint. As the number of users increases, resource-intensive inference may introduce delays unless supported by optimized deployment strategies such as model quantization, agent prioritization, or distributed inference.

4. Conclusions

The MAS-based IPR verification system demonstrates a strong capability to enhance accuracy, efficiency, and reliability in document validation processes. The integration of ID Card Data Compliance Check and Automated Text Recognition (Vision-Language Models) effectively addresses the limitations of manual verification, particularly in reducing human error and processing time.

Testing results indicate that the system performs with high accuracy and operational stability across various conditions. The KTP Data Consistency Validation achieved an accuracy rate of 97.8%, confirming the system's effectiveness in identifying mismatched or inconsistent information. The Automatic Data Extraction feature, supported by AI-driven OCR, reached 95.4% accuracy, demonstrating robust text recognition even in less-than-ideal image quality. Moreover, the Forgery Detection Capability showed promising results with 93% accuracy, successfully identifying most manipulated documents and reinforcing the system's potential for fraud prevention.

In terms of scalability, the system maintained 99.1% reliability under concurrent user load, proving its readiness for institutional implementation. Overall, the MAS-based verification framework not only accelerates the IPR authentication process but also establishes a more transparent, data-driven, and secure foundation for managing intellectual property documentation in the digital era.

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