Decentralized Intellectual Property (IP) Protection Platform with AI-Powered Similarity Detection

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***Abstract*— The digital revolution has resulted in a surge of intellectual property (IP) across textual, visual, and multimedia formats, exposing content creators to increasing risks of plagiarism and unauthorized usage. Centralized IP protection systems are often slow, jurisdiction-bound, and incapable of detecting semantically or visually similar content that has been paraphrased, translated, or remixed. This research proposes a decentralized IP protection platform that integrates AI-powered semantic and multimedia similarity detection with blockchain-based ownership verification and metadata storage. Our methodology includes transformer-based vision-language models for video analysis, Sentence-BERT and FAISS indexing for semantic similarity checking, and federated learning for privacy-preserving, real-time model adaptability. Experimental results demonstrate the system's ability to detect IP infringement across modalities with high precision, while leveraging Ethereum smart contracts and IPFS for secure, transparent content registration. The platform not only improves the speed and accuracy of IP registration but also ensures verifiable authorship and supports dynamic content adaptation in decentralized environments. This research contributes a modular, multimodal, and scalable solution for modern IP governance.**

Keywords—Intellectual property protection, semantic similarity detection, video similarity checking, decentralized storage, blockchain, federated learning, IPFS, smart contracts, transformer models.

I. INTRODUCTION

A. Background Information

The digital transformation of creative, scientific, and technical domains has led to an unprecedented increase in intellectual property (IP) assets. From academic research to multimedia content, these digital assets are often vulnerable to plagiarism, unauthorized usage, and infringement due to weaknesses in existing centralized IP protection mechanisms. Traditional IP registries suffer from bottlenecks, delayed verification processes, and a lack of transparency and interoperability between jurisdictions. Moreover, their reliance on manual checks and keyword-based search mechanisms is insufficient to counter modern infringement tactics such as paraphrasing, rewording, and multimedia remixing.

Recent advancements in blockchain technology offer a compelling foundation for overcoming these limitations. The decentralized, immutable, and transparent nature of blockchain enables tamper-proof registration and traceable ownership verification. When combined with artificial intelligence (AI), particularly in the form of semantic similarity detection and machine learning (ML), it becomes possible to automate infringement detection, context-aware IP discovery, and secure metadata management across modalities. As highlighted in global IP trend reports and recent academic works [8][9][19][21], the integration of AI and blockchain marks a transformative evolution in digital IP governance, enabling smarter, scalable, and cross-border IP protection systems.

B. Statement of the Problem

Despite technological advancements, current IP protection frameworks remain fragmented, centralized, and reactive rather than proactive. They lack the ability to detect semantically similar content that has been paraphrased, translated, or slightly altered. Furthermore, centralized IP databases are prone to single points of failure and do not offer verifiable, tamper-proof ownership proof. Infringement detection is also modality-limited, often restricted to text-based search and incapable of handling multimedia content like images and videos.

There is an urgent need for a unified platform that not only registers IP securely but also proactively monitors for semantic similarity across various content types. Additionally, it must provide global accessibility, decentralized consensus, and real-time ownership verification without the intervention of third-party authorities. These challenges underscore the need for a decentralized, AI-powered system that integrates semantic search capabilities, multimodal comparison, and blockchain-based metadata storage - a gap this research aims to fill.

C. Research Objectives

The primary objective of this research is to develop a decentralized, AI-powered platform for robust intellectual property (IP) protection across multiple modalities. The proposed system integrates semantic similarity detection mechanisms with blockchain-based metadata storage to provide real-time infringement detection, secure ownership verification, and decentralized content registration.

The platform architecture is modularized into four interdependent components.

- Textual Similarity Checker: This module aims to detect plagiarism, paraphrasing, and reworded content in books, articles, and academic manuscripts. By leveraging sentence embeddings and FAISS-based vector indexing, it enables fast, high-accuracy semantic comparison between newly submitted and existing texts.
- Related Patent Discovery: This component utilizes semantic search algorithms and pretrained transformer models to identify contextually related patents. It processes key sections such as title, abstract, and claims to retrieve and rank patents with overlapping or tangential innovation, thereby aiding novelty assessment and reducing research redundancy.
- Multimedia Similarity Detection: This module addresses the need for infringement detection in non-textual domains. It applies transformer-based vision-language models and temporal neural networks such as TimeSformer to evaluate video and image similarity across time and spatial features. This enables detection of unauthorized reuse or remixing of visual IP.
- Blockchain Integration: This layer ensures the secure, tamper-proof storage of intellectual property metadata. Smart contracts developed using Solidity and deployed via Hardhat on the Ethereum Sepolia test network facilitate decentralized CID registration of IPFS-hosted content, enabling immutable proof of ownership and traceability.

In addition to these core components, supporting objectives include implementing wallet-based user authentication via Moralis, facilitating real-time model adaptability through federated learning pipelines, and delivering an intuitive user interface for similarity result visualization, ownership tracking, and decentralized IP lifecycle management.

D. *Significance of the Research*

This research presents a unified and scalable solution to the emerging challenges of intellectual property (IP) infringement in the digital era. By integrating decentralized storage (IPFS), smart contracts, and AI-powered semantic similarity detection into a single platform, it facilitates verifiable authorship, continuous monitoring, and real-time infringement alerts. The system's multimodal capabilities—encompassing academic text, patents, images, and video content—allow it to be applied across diverse domains such as publishing, academia, research and development, and digital content creation.

The platform also fosters innovation by streamlining IP discovery and reducing redundant research through context-aware semantic retrieval. Its decentralized architecture minimizes reliance on jurisdiction-bound databases and ensures global accessibility. Moreover, the design aligns with key international standards including the TRIPS Agreement [12], the Berne Convention [11], and local regulations such as those governed by the National Intellectual Property Office of Sri Lanka [17]. By addressing foundational weaknesses in conventional IP protection systems, this research contributes to the global discourse on digital rights, decentralized governance, and equitable protection of creative and technological innovations.

II. Literature Review

Intellectual property (IP) protection has become a pressing concern in the digital age, where the creation and distribution of textual, visual, and multimedia content occur at unprecedented speed and scale. Traditional IP systems, governed by centralized authorities, face challenges such as manual verification, jurisdictional constraints, and limited capacity to detect semantic or multimedia-based infringement [8], [9]. These gaps have motivated the exploration of decentralized architectures and AI-powered detection mechanisms for robust and scalable IP governance.

A. *Significance and Related Work*

Blockchain's decentralized ledger capabilities offer immutable storage and smart contract automation for IP metadata and ownership verification [1], [3]. Studies such as Jiang et al. [20] and Wang et al. [21] have illustrated how blockchain enables copyright tracing and provenance in digital content, although without integrating semantic detection. Simultaneously, AI models such as Sentence-BERT, LaBSE, and FAISS-based retrieval systems have redefined semantic similarity detection in plagiarism and patent novelty analysis [19], [24]. However, these are predominantly applied to text.

In the multimedia domain, vision-language transformer models like TimeSformer [25] and ViT [26] have shown promise in encoding spatiotemporal representations, but their adoption in decentralized, real-time IP protection platforms remains minimal. Federated learning (FL) has also emerged as a method to enhance privacy in AI training by enabling client-side model updates [23], yet few systems incorporate FL for model personalization in the IP space.

B. *Research Gap*

Despite these advances, most existing solutions fall short in the following ways:

- They address either semantic similarity or ownership verification, but not both in an integrated system.
- Multimedia-based detection, especially for video content, is underrepresented in IP protection research.
- Continuous model learning for adaptation to new infringement techniques is rarely addressed in deployed solutions.
- Existing blockchain-backed systems often rely on user trust or centralized databases for actual content storage, rather than decentralized solutions like IPFS.

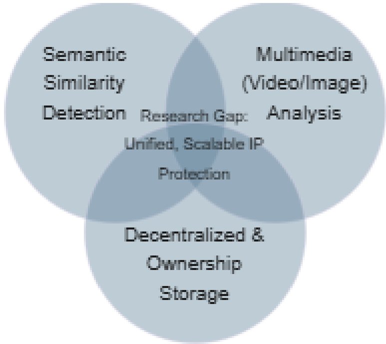

Figure 1: Research Gap

C. Gap Visualization

Table 1 presents a comparative analysis of popular tools versus our proposed platform. While some tools address content analysis, none offer a combined stack of AI, federated learning, blockchain registration, and multimodal IP coverage.

Table 1: Comparison of Features Across Existing Tools and Proposed System

Feature	System A	System B	System C	Proposed System
Text Similarity (Semantic)	Fully Supported	Fully Supported	Partially Supported	Fully Supported
Video/Image Similarity	Not Supported	Partially Supported	Not Supported	Fully Supported
Blockchain-Based Metadata Storage	Not Supported	Fully Supported	Partially Supported	Fully Supported
IPFS Decentralized File Hosting	Not Supported	Not Supported	Not Supported	Fully Supported
Federated Learning Support	Not Supported	Not Supported	Not Supported	Fully Supported
Smart Contract Ownership Traceability	Not Supported	Fully Supported	Not Supported	Fully Supported

D. Research Positioning

This review confirms the need for a holistic, decentralized IP protection system that supports semantic and multimedia similarity detection, continuous model adaptation, and tamper-proof ownership verification. Our system is uniquely positioned to fill this gap by combining:

- Multimodal AI models (text + video) for content similarity,
- IPFS + Ethereum for verifiable, decentralized storage,
- Smart contracts for ownership proof, and
- Federated Learning for adaptive, privacy-preserving model training.

These innovations build upon and extend the limitations of previous research, contributing a practical solution for modern, cross-border IP protection.

III. Methodology

A. System Overview

The proposed system employs a modular architecture that integrates decentralized technologies and AI-powered similarity detection to enhance the protection of intellectual property (IP). The methodology is structured into four key phases: requirement analysis, feasibility study, system implementation, and testing and evaluation. Each phase is designed to ensure that the platform is both functionally robust and practically deployable. The overall system architecture is illustrated in Fig. 2.

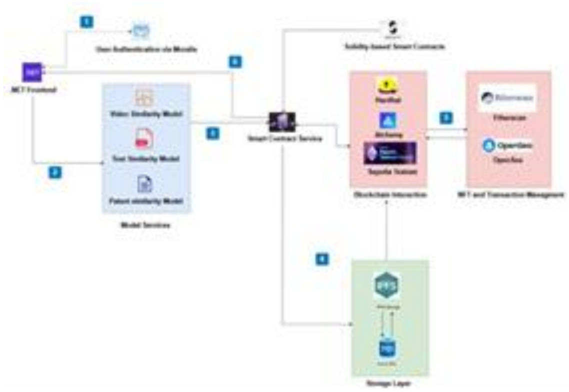

Figure 2: System Architecture of the Proposed Platform

B. System Implementation

The implementation of the system was conducted in modular layers, aligned with the architecture shown in Fig. 1.

1) Frontend Development: The user interface was built using ASP.NET MVC. Authentication was integrated via Moralis, enabling decentralized identity verification through MetaMask wallets. The frontend allowed users to upload content, initiate similarity checks, and manage IP registration actions.

2) Model Services: The backend AI layer included three major models: a video similarity model (using CLIP), a text similarity model (using SentenceTransformers), and a patent similarity model (leveraging FAISS and semantic embeddings). These services were exposed via RESTful endpoints developed in Flask or FastAPI.

3) Smart Contract Layer: Smart contracts were developed in Solidity using OpenZeppelin standards to ensure security and upgradeability. Functions such as IP asset registration, ownership lookup, and metadata retrieval were implemented. The contracts were compiled and deployed using Hardhat and tested on the Sepolia Ethereum Testnet via Alchemy.

4) Blockchain Interaction and NFT Layer: The system integrates tokenization of IP assets as NFTs. Each successful registration triggers a minting process, and metadata including IPFS hashes is linked to the NFT. Blockchain explorers such as Etherscan were used to track transactions, while OpenSea was optionally integrated for NFT visibility.

5) Storage Layer: Content is persistently stored in IPFS, with the returned CID referenced in smart contracts. Metadata such as title, owner, and similarity score are additionally stored in a local SQL database to enable faster query operations.

6) Integration Services: The integration layer serves as a bridge between the frontend, AI services, and blockchain layer. A smart contract service coordinates the workflow, ensuring that model outputs are passed to smart contracts only after novelty thresholds are met.

C. Related Patent Discovery

The Related Patent Discovery component aims to identify semantically similar prior art from large patent corpora using contextual embeddings, approximate vector search, and decentralized metadata recording. This methodology addresses the limitations of conventional keyword-based retrieval, which often fails to detect paraphrased or cross-lingual similarities [8], [9]. By combining natural language understanding with blockchain-based metadata verification, the system enhances both the accuracy and trustworthiness of the patent novelty evaluation process.

Patent data for this system was obtained from public repositories, including the United States Patent and Trademark Office (USPTO), the World Intellectual Property Organization (WIPO), and The Lens open patent database [8], [9]. The dataset comprised documents in PDF, JSON, and XML formats. For demonstration and evaluation, a filtered subset from the computer science and engineering domain was used to simulate realistic innovation submissions.

Each submitted document undergoes a multi-stage preprocessing pipeline. Text is extracted from native PDFs using PyMuPDF, while image-based or scanned documents are processed using Tesseract OCR [21]. Following this, the text is segmented into the title, abstract, and claims using a combination of regular expressions and structural layout analysis. These sections were selected based on their high semantic density and relevance to patent evaluation [22].

To obtain meaningful semantic representations, each section is passed through the Language-Agnostic BERT Sentence Embedding (LaBSE) model [19]. This model was selected for its multilingual robustness and its proven capability to capture contextual meaning in legal and technical texts. A final document vector is computed by applying a weighted aggregation of the three embeddings:

$$v_{\text{final}} = \alpha \cdot v_{\text{title}} + \beta \cdot v_{\text{abstract}} + \gamma \cdot v_{\text{claims}}$$

where the weights $\alpha = 0.2$, $\beta = 0.5$ and $\gamma = 0.3$ were empirically derived based on their relative semantic contributions.

The resulting document embeddings are indexed using Facebook AI Similarity Search (FAISS), a high-performance library optimized for approximate nearest neighbor (ANN) search in high-dimensional vector spaces [20]. Upon submission, the embedding of the new patent is compared with existing entries in the FAISS index using cosine similarity:

$$sim(v_a, v_b) = \frac{v_a . v_b}{\|v_a\| . \|v_b\|}$$

A similarity threshold of τ=0.75 is used to determine novelty. If no existing embedding exceeds this threshold, the patent is deemed novel and proceeds to registration. The top-k results are also returned and dynamically ranked using a feedback-based weighting mechanism that incorporates both semantic similarity and historical user interaction metrics, such as click rates and time-on-result [22].

To ensure tamper-proof and verifiable registration, the full patent document is uploaded to the InterPlanetary File System (IPFS) via Pinata, which generates a unique Content Identifier (CID) [18]. This CID is then immutably recorded on the Ethereum Sepolia Testnet using a Solidity smart contract deployed through the Hardhat framework [1], [3]. The smart contract maps each system-generated patent ID to its respective CID:

```
mapping(uint256 => string) public patentCID;
```

This mapping is accessed and updated through web3.py, enabling both metadata retrieval and on-chain registration of new patents [22]. This architecture guarantees that each patent is cryptographically verifiable and permanently accessible through IPFS.

To maintain indexing scalability and real-time responsiveness, all semantic embeddings are cached in `.npy` format, and the FAISS index is stored in `.index` format. Upon each successful registration, the new embedding is appended to the cache, and the index is updated without full recomputation.

The final results are delivered through a web-based interface, which displays the title, abstract, claims, and similarity score of each related patent. IPFS-linked CIDs are embedded as clickable URLs, allowing users to access the original documents. Long text sections are truncated with “Show More / Show Less” toggles for usability. A visual clustering interface using D3.js is also being developed to illustrate inter-patent relationships graphically.

Figure illustrates the complete pipeline of this component, from document ingestion and semantic embedding to decentralized storage and blockchain-based verification.

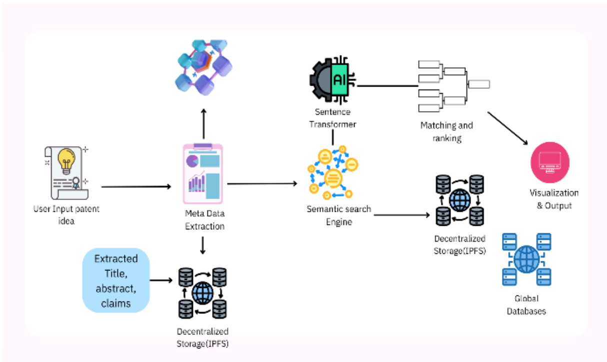

Figure 3. Related Patent Discovery Component Workflow

D. Overview of the Semantic Similarity Module

This section outlines the methodology adopted for Component 2 – Semantic Similarity Checking for Text-Based Creative Works, one of the three semantic similarity detection modules proposed in the decentralized intellectual property (IP) protection platform. This module is specifically designed to assess the novelty of books, novels, and other long-form text content using semantic embeddings and vector similarity techniques.

Unlike traditional keyword-matching systems, this component utilizes deep learning models to compute contextual embeddings, enabling detection of paraphrased or semantically similar works. It acts as a gatekeeper to determine whether a submitted document should be approved for decentralized registration on IPFS and Ethereum.

1) Task Design

The module architecture includes several core subtasks:

a) Dataset Acquisition and Preprocessing: Classical literary works from the Project Gutenberg corpus are downloaded using gutenbergpy. The dataset is cached in a local SQLite database for offline access.

b) Embedding and Indexing: Texts are extracted from selected Gutenberg book IDs. Using the sentence-transformers/all-MiniLM-L6-v2 model, each book is embedded into a 384-dimensional semantic vector. These vectors are normalized and stored in a FAISS index for similarity comparison.

c) Metadata Handling: For each embedded book, metadata including book_id, title, and author are stored in a parallel pdf_metadata.json file, allowing efficient retrieval and similarity match reporting.

d) Similarity Detection API: A Python Flask backend (app.py) provides two REST endpoints:

e) Check_similarity: accepts PDF input, extracts text with PyMuPDF, encodes it, and compares it with the FAISS index

f) Upload_and_train: accepts new user documents to be embedded and added to the index

g) Similarity Evaluation and Registration Control: A .NET API controller (PdfSimilarityApiController.cs) sends user-uploaded PDFs to the Flask server, retrieves similarity scores, and applies a threshold-based decision to either accept or reject the content for IPFS and blockchain registration.

2) AI Model and System Architecture

a) Semantic Embedding:

The all-MiniLM-L6-v2 SentenceTransformer model is used to convert input text into high-dimensional semantic vectors. The model is not fine-tuned but utilized in inference mode.

b) Vector Search:

FAISS (Facebook AI Similarity Search) provides a scalable mechanism to perform approximate nearest-neighbor (ANN) search for identifying similar documents.

c) Storage Architecture:

- Embeddings are stored in pdf_embeddings.index
- Metadata is recorded in pdf_metadata.json
- Reference books are selected from a subset of 3000 Gutenberg entries

3) Blockchain Integration:

Upon confirming semantic novelty, the document is uploaded to IPFS via Pinata. The resulting Content Identifier (CID) is stored on the Ethereum Sepolia blockchain using a Solidity smart contract. The smart contract maps patent/token IDs to their respective IPFS CIDs, providing immutable and decentralized ownership verification.

4) Scoring Logic

The semantic similarity score is computed using L2 distance between normalized embeddings:

$$\textbf{similarity} = 1 / (1 + \| \mathbf{v\_input} - \mathbf{v\_reference} \|)$$

A threshold of 0.6 is applied. If the similarity score exceeds this threshold, the document is considered not novel and is rejected from the IP registration process.

The top-3 most similar books are retrieved, and their metadata and scores are returned to the user for transparency.

5) Training and Validation

Although no additional fine-tuning is applied to the model, a training-like indexing process is conducted:

- ~3000 books are embedded from the Gutenberg dataset
- Embeddings and metadata are stored in FAISS and JSON formats respectively.
- The selection of book IDs is performed via an SQL query against the cached Gutenberg SQLite metadata.

Validation Method:

- Known plagiarized and novel content samples were tested against the index to empirically determine the optimal threshold
- Continuous learning is enabled via the /upload_and_train API, which allows embedding of user-provided texts to keep the index current

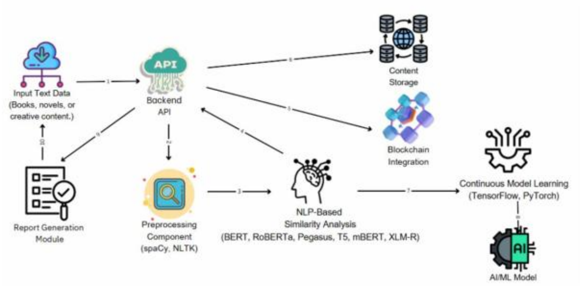

Figure 4: work flow

E. Video Similarity Checking Component

This component is designed to detect infringement in video-based intellectual property by leveraging temporal and spatial feature analysis through deep learning models. The system incorporates frame-level processing, embedding generation, similarity indexing, and decentralized storage to facilitate scalable and tamper-proof video IP protection.

1) Preprocessing and Feature Extraction

Submitted video files undergo preprocessing via FFmpeg to extract uniformly sampled frames. Frames are resized to 224x224 pixels and batched into segments. The extracted frame sequences are passed through a pretrained TimeSformer model [23], which generates spatiotemporal embeddings for each segment. These embeddings are then aggregated into a single video-level feature vector V video.

2) *Similarity Computation*

The generated vector V video is compared with existing entries in a FAISS index [19] using cosine similarity. If the top similarity score is below a predefined threshold au = 0.70, the video is considered novel and eligible for registration. Otherwise, the system flags the submission as potentially infringing and returns the matched result.

3) *Decentralized Storage on IPFS*

Novel video content is uploaded to the InterPlanetary File System (IPFS) via the Pinata API [18], ensuring content immutability and distributed accessibility. The system returns a unique Content Identifier (CID) that serves as the file's fingerprint.

4) *Smart Contract-Based Ownership Mapping*

The generated CID is stored on the Ethereum Sepolia blockchain [1], [3] using a Solidity smart contract. The contract maintains a mapping from a unique video ID to the CID, ensuring verifiable ownership:

```
mapping(uint256 => string) public videoCID;
```

This provides publicly auditable proof of ownership and timestamping.

5) *User Interface and Result Presentation*

The user-facing dashboard enables users to upload video files, visualize their similarity scores, and preview matched results through embedded IPFS video players. High-similarity results are displayed alongside the CID and matched timestamp. If no matches are found, the video is marked as original and is recorded as protected IP.

6) *Continuous Model Learning and Adaptation*

To enhance long-term adaptability, the system incorporates a federated learning architecture that supports continuous model improvement without centralized data pooling. The video encoder model (e.g., TimeSformer) is periodically fine-tuned using feedback from distributed nodes, where user devices contribute local training updates.

The system uses Federated Averaging (FedAvg) [23] to aggregate model updates securely. Only weight deltas are transmitted, preserving raw data privacy and ensuring compliance with GDPR and other IP regulations [23]. This approach enables personalization of detection thresholds and model behavior based on regional and domain-specific usage patterns.

To ensure traceability and reproducibility, each model version is hashed and stored on-chain using a Solidity mapping structure [24]:

```
mapping(uint256 => string) public modelHashByVersion;
```

This mapping provides an immutable audit trail of model updates and supports rollback if required.

By combining deep video similarity detection and federated learning, this integrated component addresses both accuracy and adaptability, ensuring relevance in dynamic IP infringement scenarios.

Together, these components form the intelligent backbone of the system's multimodal similarity engine, combining advanced AI with privacy-preserving decentralized infrastructure.

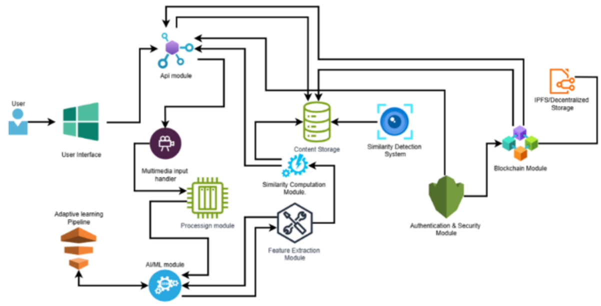

Figure 5: Video similarity checking component work flow

IV. CONCLUSION

This paper presented a decentralized AI driven framework for robust intellectual property (IP) protection across text, patent, and multimedia domains. By integrating semantic similarity detection with blockchain based metadata management, the system effectively identifies paraphrased, translated, and visually altered content. Core components including Sentence BERT with FAISS indexing, transformer based video encoders, and Ethereum smart contracts enable real time infringement detection and secure, tamper proof ownership registration via IPFS. The inclusion of federated learning further enhances adaptability while maintaining data privacy. Experimental validation confirmed the platform's accuracy and scalability. Future work will aim to expand multimodal support, enhance the model's efficiency under real world constraints, and incorporate feedback driven learning for continuous improvement.

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