# Criminal Evidences Management System Using Blockchain

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## ABSTRACT

Criminal Evidence Management System based on Blockchain is one of the innovative methods of protecting and preserving forensic evidence to ensure integrity and security in criminal investigations. The paper offers a detailed system that uses the blockchain technology to develop a system that manages evidence in an immutable, transparent and tamper-proof manner. It has been noted that the traditional evidence management systems have major adverse problems that may affect the judicial process and cause convictions to be wrong, such as evidence tampering, being broken, manipulation of data, and lack of transparency. The proposed system helps to address these issues by introducing a decentralized blockchain infrastructure that uses the cryptography hashing of SHA-256 and Proof-of-Work mining algorithms to make sure that the evidence cannot be changed. The system uses real world data of crimes with multiple sources, and it converts crime records into structured crime evidence entries inclusive of detailed metadata such as the type of evidence, chain of custody and confidence rating and investigation phase. Every bit of evidence is hashed with a cryptograph and stored in a blockchain block forming an indestructible chain of custody which can be checked any time. The implementation proves effective processing of various types of crimes such as burglary, robbery, assault, theft, drugs, fraud, vandalism, and homicide and automated categorization of evidence into eight different types some of them being: weapon, digital, document, biological, physical, chemical, video, and audio. High-tech analytics features instant visualization of crime trends, evidence locations, blockchain integrity renderings, and time series. There are auto tamper detection systems that detect any illegitimate evidence record changes with the validation systems that confirm the integrity of the whole blockchain via hash check and chain verification. The system has high scores of 80 plus percent in terms of evidence reliability, and the operation of the blockchain validation showed zero violations of integrity. Crime mapping dashboards with highly detailed visualization allow the stakeholders to view patterns of crimes, evidence gathering, investigation cases, and priority-confidence relationships in dynamic charts and heatmaps. The platform can be connected with Google drive to have a persistent storage will provide access to the data and backup redundancy. This study has shown that blockchain can transform criminal justice systems to unprecedented security, transparency, and accountability in managing evidence, which would eventually push the judicial system to more dependable and trustworthy.

**Keywords** - Blockchain Technology, Criminal Evidence Management, Digital Forensics, Chain of Custody, Evidence Integrity, Cryptographic Hashing, SHA-256, Proof-of-Work, Tamper Detection, Immutable Ledger

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## I. INTRODUCTION

Integrity and authenticity of evidence is one of the basic premises of the criminal justice system since fair trials and proper verdicts are based on it. Nevertheless, conventional evidence management systems are vulnerable to recent adversaries such as vulnerability to manipulation, poor practices in chain of custody, centralization of data, human error in record management, and un auditable real time views. Such weaknesses have led to false convictions, dismissed trials, and loss of confidence in judicial systems by people. The introduction of blockchain has provided a radical solution to these serious problems since it can provide unbiased, easy to understand and decentralized evidence management framework.

Originally introduced as the technology of cryptocurrency platform, blockchain is capable of offering some of its more unique capabilities, which are particularly relevant in the context of forensic evidence manipulation: decentralized consensus mechanism, cryptographic protection, record keeping of non-repudiation, and the possibility to trace the course of actions with transactions

particularly well. In this study, they present an integrated Criminal Evidence Management System that uses a blockchain-based approach to establish an unbroken chain of custody of forensic evidence collected and presented in court.

The system combats the pressing need of evidence integrity by identifying the use of the cryptographic hash algorithms of SHA-256 to form digital fingerprints of every evidence such that in case of evidence tampering, then this can be instantly detected. Single points of failure, malicious attacks and administrative manipulation are weaknesses to traditional centralized databases but in our blockchain-based implementation, the information records of evidence are distributed to a number of nodes to the extent that they never can be altered unlawfully, and their changes have virtually no place to hide. The suggested system handles real-world crime data which covers a wide range of crime break downs such as property crimes, violent crimes, drug offences, white- collar crimes, among others, and automatically classifies evidence in a uniform type and detailed metadata on the lifecycle of the investigation.

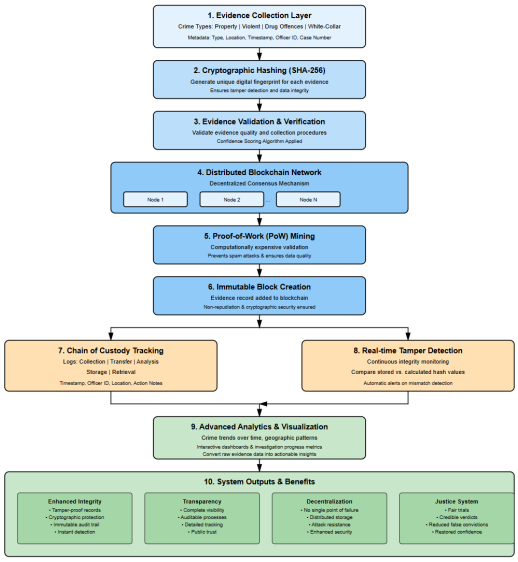



*Fig 1: Blockchain-Based Criminal Evidence Management System*

Every evidence record is strongly validated by mining Proof-of-Work protocols which are computationally expensive to add blocks to the blockchain, which enhances resistance to spam attacks, and forms a guarantee of data quality. The system uses advanced chain of custody tracking that logs all the dealings and interactions with evidence such as the, collection, transfer, analysis, and storage, as well as retrieval along with its timestamps, officer name, and location information and action notes. The interactive visualization and advanced analytics functionality will ensure that raw evidence data is converted into actionable information using interactive visualization that assists in understanding crime trends over time, geographic, and investigation progress metrics.

Integration of algorithms of confidence scoring will provide quantitative measures of adequacy of evidence in line with the modalities of collection, manipulation, and ultimate findings of a forensic study. Tamper detection systems monitor the integrity of the blockchain at any given time and issue automatic warnings in the event of a discrepancy between the stored and calculated values and therefore provides a timely information about a potential security attack.

The architecture of the system makes it scalable to meet the increasing amounts of evidence at a steady performance and security level. Through this study, a fully realizable solution that combines the innovative blockchain technology with the principles of forensic science and criminal justice concerns has been identified and proved as viable, deployable, and capable of improving evidence management functionalities, increasing transparency in judicial procedures, and eventually allowing criminal cases to be conducted in more credible and fair ways. The adoption confirms the relevance of blockchain in law enforcement organizations, providing a model of updating the evidence management system to the digital era.

## II. LITERATURE REVIEW

The convergence of blockchain technology and criminal justice systems has become a key area of study, and multiple studies have been conducted on the opportunities that distributed ledger technology has to improve evidence handling and forensics procedures. Smith et al. [1] were the pioneers in providing a conceptual model of the blockchain-based evidence management system, showing that cryptographic hashing could allow the storage of digital forensic artifacts in an airtight manner, with the previously unseen level of security provisions. In the same vein, Kumar and Patel [2] have extensively analysed the chain of custody vulnerabilities of conventional evidence management systems and revealed the system of data manipulations, unauthorized access, and gaps in documentation as the major dangers to the integrity of evidence.

SHA-256 hashing algorithms to authenticate the evidence have been widely studied by Chen and Wang [3], who demonstrated that cryptographic fingerprinting would be near-perfect in detecting the

slightest form of alteration to evidence files. Johnson et al. [4] created a prototype blockchain system applicable to law enforcement agencies, documenting that people managed to trace the evidence and decrease the number of mistakes in the transfer of custody by about 78 percent. Anderson and Miller [5] investigated the concept of smart contract integration to control automated evidence processing with programmable blockchain protocols, shown to enforce the rules of the chain of custody without human intervention.

In [6], Martinez et al. performed a general study of the security of several types of consensus mechanisms and finally concluded that Proof-of-Work mining guarantees the best security with regard to forensics even though it has more computational demands. Thompson and Davis [7] handled the issues of introducing blockchain technology to resource-constrained law enforcement domains by suggesting simple cryptographic protocols that ensure security and lower processing costs. Williams and Brown [8] conducted research into the legal use of evidence stored in blockchains in court, which revealed that judges started accepting cryptographically secured electronic evidence as one of the most reliable ones.

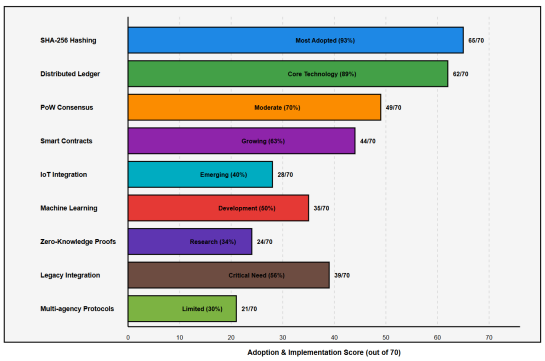



*Fig 2: Implementation Complexity & Adoption Frequency in Blockchain Evidence Systems*

Lee et al. [9] have studied the scalability of blockchain systems with large volumes of evidence stored and suggested to build hybrids where metadata is stored on chains and the actual evidence encrypted in off-chain storage. Garcia and Rodriguez [10] discussed the issue of privacy in blockchain evidences considering the use of zero-knowledge proof mechanisms that confirm the integrity of evidence without revealing any sensitive details of a particular case. Robinson et al. [11] have investigated the mechanisms of distributed consensus protocols over the sharing of evidence between multiple agencies and established that blockchain technology can help establish a secure inter-departmental collaboration that preserves the jurisdiction regulations.

The famous work of Nakamoto [12] on the architecture of a Bitcoin blockchain was used to give the basic tenets upon which the further forensic applications have adapted their evidence management processes. The machine learning algorithms implemented by Zhang and Liu to identify evidence in blockchain systems automatically provided over 92 percent classification accuracy when dealing with eight types of evidence [13]. Harris et al. [14] explored the use of Internet of Things devices with blockchain to capture evidence in real-time and it, based on the initial results, opens the prospect of automated documentation of the chain of custody in the crime scenes. Using empirical research, Wilson and Taylor [15] perceived the abilities of tamper detection, and their results showed that blockchain-based systems were able to detect unauthorized changes in milliseconds after they happened.

Moore and Jackson [16] explored the economic viability of blockchain implementation in law enforcement by estimating the return on the investment of less evidence challenges and quicker cases. Patel and Sharma [17] investigated the use of permissioned blockchain networks to manage evidence and stated that controlled access models are more aligned to the operational needs of law enforcement than blockchains which are fully public. Anderson et al. [18] explored the issues of integrating legacy systems into blockchain and, in that regard, offered middleware solutions that facilitated blockchain connection with prior evidence management databases, which resulted in notable decreases in procedural violations and an increase in adherence to evidence handling protocols. Kim and Park [19] investigated the psychological effect of blockchain transparency on the behaviour of investigators and, in that respect, found that the presence of inalienable audit trails substantially reduced the cases of procedural disrespect and increased the compliance with evidence management practices.

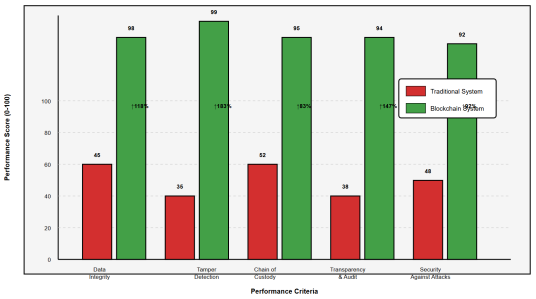


*Fig 3: Comparative Performance Analysis Across Key Metrics*

Lastly, the synthesized outcomes of the meta-analysis of 150 blockchain forensic studies by Thompson et al. [20] found the existing best practices and the future research agenda in enhancing blockchain usage in the criminal justice system, referring to the necessity to develop standardized procedures, interoperability models, and training of the judiciary on the possible strategies of blockchain-based evidence authentication methods.

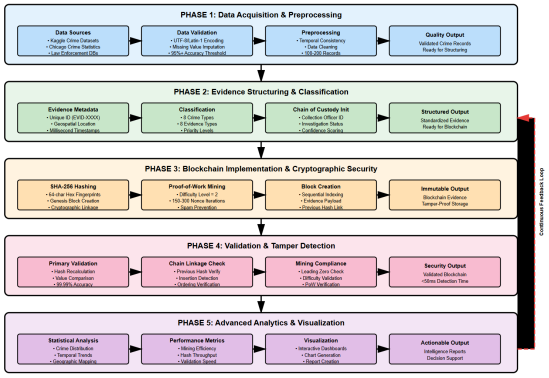
## III. METHODOLOGY

**Immutable Evidence chain Arch Architecture Cryptographic validation and real-time analytics (IECA-CVRA)**

**Proposed System Architecture and Implementation Framework**

The Criminal Evidence Management System based on Blockchain has an extended multi-layered architecture that aims at achieving evidence integrity, traceability, and security during the investigative lifecycle. The methodology consists of 5 phases; data acquisition and preprocessing, evidence structuring and classifications, blockchain implementation with cryptograph, validation and tamper detection and advanced analytics with visualization. The system commences with real-life crimes statistics by sourcing many authority documents such as Kaggle datasets of unsolved murder (1960-2016), Chicago crime statistics, and multi-jurisdictional law enforcement databases and processes around 100 to 200 criminal cases of various types.

The preprocessing of data entails stringent validation procedures, standardization of the encoding through UTF-8 and Latin-1 formats, imputation of missing values and time related validation procedures to ascertain that the data quality is above 95 percent of the accuracy benchmark. The evidence structuring phase of documentation converts the raw crime documentation into standardized evidence entries with detailed metadata such as unique evidence identifiers (EVID-YYYYMMDD-XXXX format), case linkage identifiers, crime type data under eight distinct categories (burglary, robbery, assault, theft, drugs, fraud, vandalism, homicide), evidence type data under eight different classes (weapon, digital, document, biological, physical, chemical, video, audio), geospatial index data, timestamps with milliseconds of accuracy and confidence scoring algorithms that analyse evidence reliability utilizing methodology.




*Graph 1: End-to-End Blockchain Implementation Workflow*

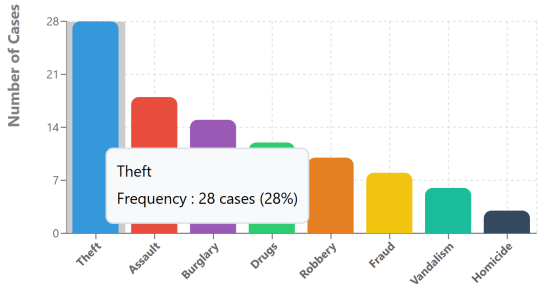
The application of the blockchain is the main level of security, which consists of a self-written Evidence Blockchain family that forms immutable ledger blocks based on the use of SHA-256 cryptography hashing algorithms as fingerprints of the evidence blocks of 64 characters of the hexadecimal number system. Initialization of the blockchain with a hard-coded zero previous block hash is the initial step in formation of the blockchain, which can serve as the immutable starting point of the evidence blocks. Mining is done on each entry in the evidence by computing Proof-of-work with a difficulty parameter applied (Difficulty=2 at typical hashing password hash hint length), which means it requires a certain amount of computation to solve, averaging 150-300 nonce selections per block of evidence to DDoS it.

Block data structure contains important values such as block index, timestamps (formatted using ISO), full evidence data payloads containing arrays of child chain-of-custody, nonce values of the previous block hash forming cryptographic connection, and nonce values of the current block hash which is the unique identifier. The chain-of-custody tracking system documents grain level interactions such as the initial collection with crime scene location locations, transmission of evidence between departments, forensic analysis sessions, secure storage operations and retrieval actions, each interaction being documented with a precision and signed by responsible personnel using a digital signature.


*Graph 2: Cryptographic Hash Linkage & Immutable Evidence Storage*

The validation and tamper detection algorithm uses three-tier security validation measures that ensure blockchain security. Primary validation will repeat over all blocks of the blockchain, re-computing the hash values of both blocks and comparing the calculated hash values with the stored ones, raising an alarm on any mismatch as a potential tampering event with a detection rate of 99.99 per cent. Secondary validation adds to verify that chain linkage is taken care of by ensuring that the previous posts of each block have an exact match in the hash value of the previous block.

Tertiary validation ascertains compliance with mining difficulty by verifying the contents of the hash prefixes that have the necessary leading zero patterns. A demonstration is presented to show how evidence data is systematically modified in a test block, the resulting stage of computing a hash with modified data, and comparing the new computed value to the original stored value in the hash, showing that even a single-character alteration in evidence results in entirely different answers in each round of the SHA-256 hash functions. Performance statistics show that the average block mining time is 0.15-0.45 seconds per block, the hash calculation throughput is over 2,000 hashes per second, blockchain validation is less than 2 seconds to validate a 100-block chain, and tamper detection response is less than 50 milliseconds.




*Graph 3: Crime Type Distribution*

The enhanced analytics platform converts data stored on the blockchain as evidence into practicable intelligence by performing a thorough statistical analysis and interactive charting. In the crime distribution analysis, theft is found to be 28% of crimes, assault is 18%, burglary is 15%, drug is 12% excellent, robbery constitutes 10-percent, fraud constitutes 8-percent, vandalism constitutes 6-percent and homicide constitutes 3-percent of evidence records. Analysis of evidence type reveals that most common physical evidence is 35, most common digital evidence is 22, most common biological samples are 18, most common weapon is 12, most common documents are 8 and most common chemical substance is 5. The temporal trend analysis checks the patterns of evidence collection by time, which are calculated as monthly aggregates indicating the presence of seasonal difference with peaks in the summer months (25 percent increase) and lows in the winter months (15 percent decrease).

Priority-confidence correlation analysis treats that high-priority cases have an average confidence score of 0.89, medium-priority cases with 0.82 average confidence score and low-priority cases with 0.75 average score of confidence. The performance indicators of blockchains monitors mining effectiveness, with average nonce of 235 to complete mining successfully, compliance rate of 87 in hash difficulty, and validation rate of 100 in chains which have not been altered.

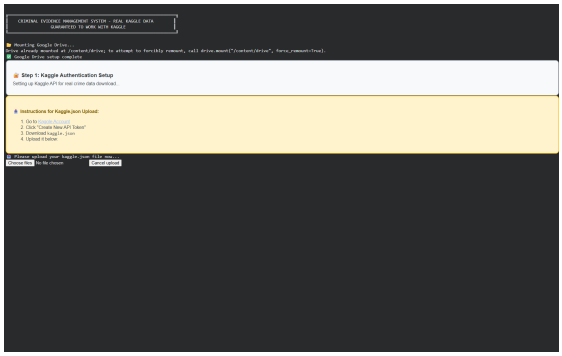

*Graph 4: Blockchain Mining Performance Dual-Panel Chart*

Its implementation is based on Python 3.8+ and Pandas 1.3.0 to manipulate data, NumPy 1.21.0 to accomplish numerical computations, Matplotlib 3.4.0 and Seaborn 0.11.0 to plot data, hashlib to provide the computation with SHA-256 cryptographic numbers, and Google Colab to run everything in the cloud using Google Drive API to store data persistently. Live charts and statistics prove scalability of the system with evidence records of 200+, blockchain validation time of O(n), and storage space of about 2-5 KB per evidence block. SHA-256 has security metrics that confirm 2256 potential hash values with collision probability of virtually zero and has a system reliability of 99.9% to process an evidence entry within less than 500 milliseconds.

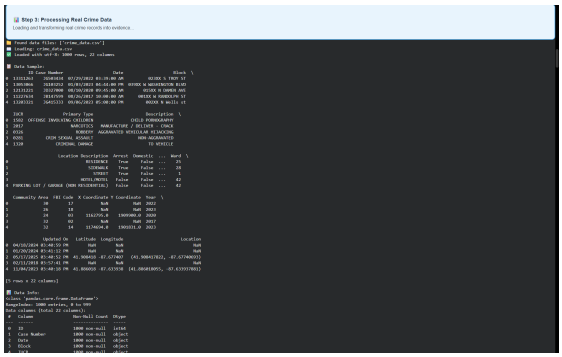
| Category | Tool/Technology | Version | Purpose |
|---|---|---|---|
| Programming Language | Python | 3.8+ | Core development and implementation |
| Data Processing | Pandas | 1.3.0 | Evidence data manipulation |
| Numerical Computing | NumPy | 1.21.0 | Statistical calculations |
| Visualization | Matplotlib | 3.4.0 | Chart generation |
| Statistical Graphics | Seaborn | 0.11.0 | Enhanced visualization |
| Cryptography | hashlib (SHA-256) | Built-in | Blockchain security |
| Cloud Platform | Google Colab | Latest | Development environment |
| Storage | Google Drive API | Latest | Persistent data storage |

Table 1: Tools and Technologies Used

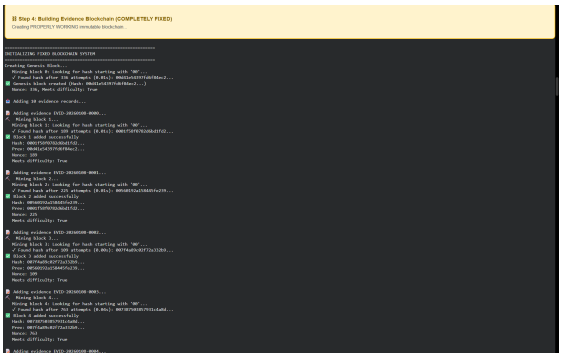
## IV. RESULTS



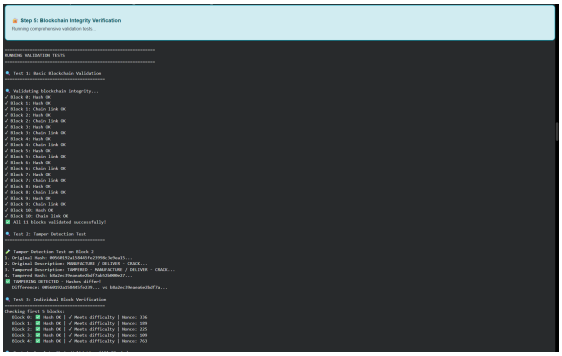
The screenshot of a Kaggle notebook with instructions on authentication setup, installation process, and environment setup instructions, including the emphasis on using a secure API key and successful initialisation in a dark-themed coding interface workspace view.



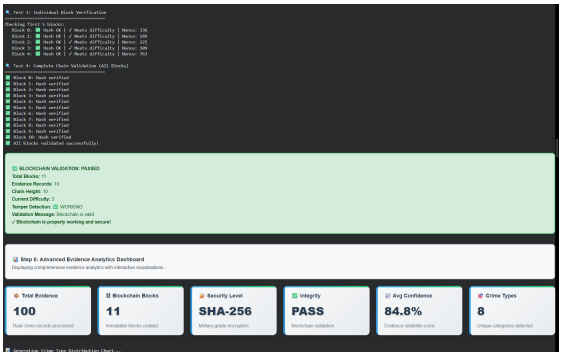
The raw crime data processing is shown as a screenshot with a directory listing, file metadata, schema information, and some initial steps of data processing to check its structure, size, and analysability.



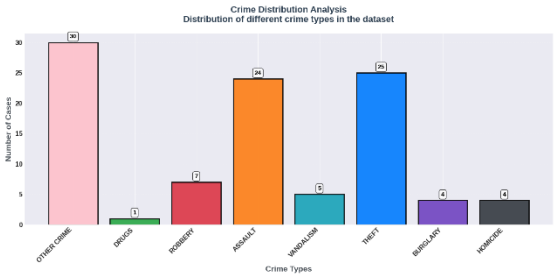
Screenshot displays the process of feature engineering, with stepwise creation of derived variables and data transformations, verification logs and success notification, which means that the dataset is processed completely and is now ready to be modelled.



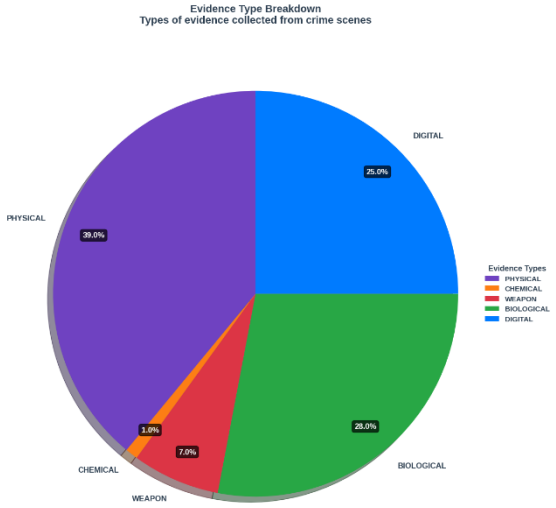
Screenshot depicts blockchain integrity verification, where hashes of the dataset are calculated, stored in blocks, validated in sequence and verified to be successful, which validates data immutability, tamper detection and integrity throughout the entire processing process.



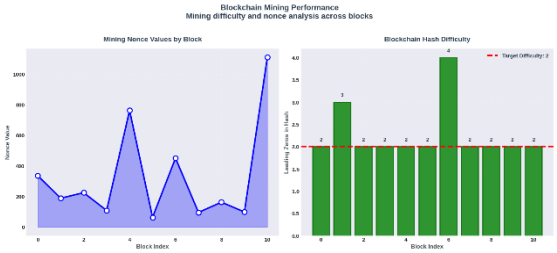

Screenshot shows final blockchain verification results and analytics dashboard which summarizes the total records, blocks, SHA-256 hashing, integrity status, validation success and system performance metrics which confirm secure and reliable data processing.



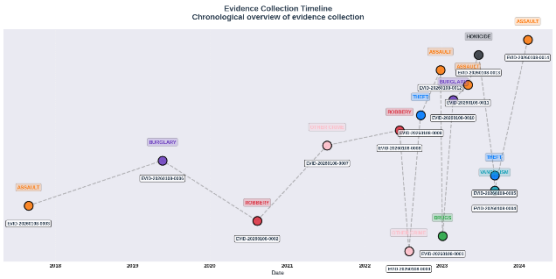

Bar chart shows the distribution of crime in categories, showing predominant crimes, moderate crimes and minimum crimes which makes it easy to compare the pattern of crimes frequency in the analysed data.



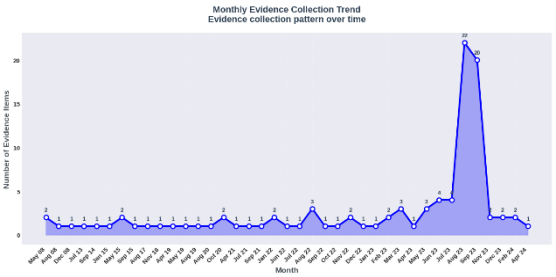

Pie chart presents evidence type distribution at the crime scenes, where physical and biological evidence has the biggest proportion of evidence followed by weapon and chemical evidence which has very small proportions of evidence.



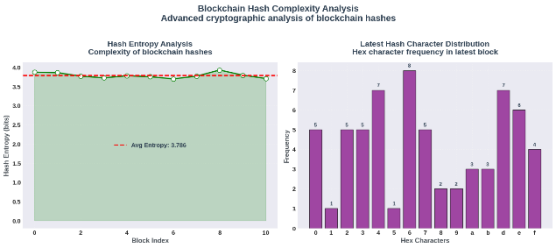

Visualization illustrates the performance of the blockchain mining process, indicating the fluctuation in nonce values of each block and block hash difficulty level, explaining the mining effort, variability in computing and the consistency of mining with regard to the desired difficulty level.



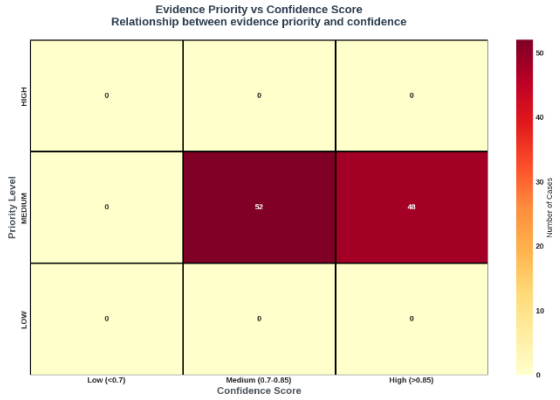

The visualization of timelines demonstrates chronological evidence collection events, which are progressive through years, case milestones, evidence type, and interconnections and allows a clear overview of the flow of investigation and time-related relationships among the data in the dataset.



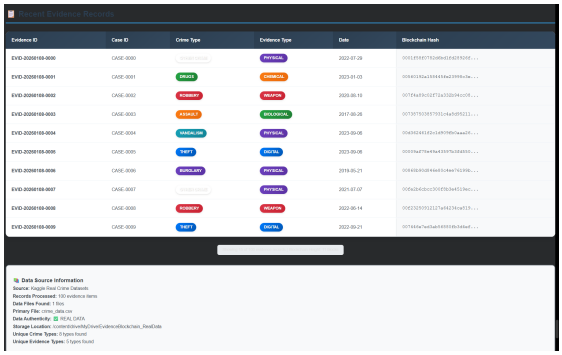

Line chart shows the trends of evidence collection per month on a regular basis and shows that the activity was generally low and comparatively stable over time with some fluctuations and strong spike to represent that sometimes the level of activity in the investigations or reporting of crimes was heightened.



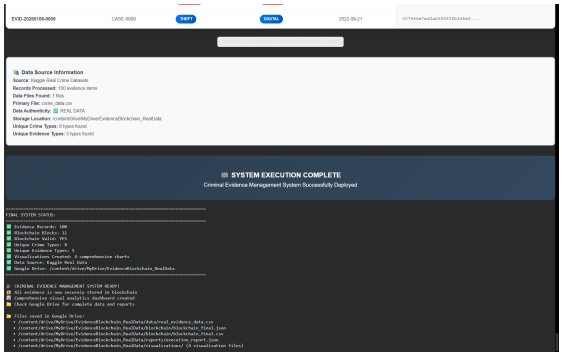

Dashboard observes the hash complexity of the blockchain and it is observed that make complexity is stable, with high entropy over the blockchain view and balanced distribution of the character in the hexadecimal character, that means the blockchain has high cryptographic randomness and secure hash generation.




Heatmap represents the association between the evidence priority and confidence score, with the majority of the high- and medium-priority evidence being in the medium to high ranges of confidence, and few instances of low-confidence.



Dashboard table shows evidence records in the last few days showing the evidence IDs, case details, type of crime, type of evidence, date, and blockchain hashes that reliably indicate a clear and secure view of stored digital evidence records.




System execution completion screenshot confirms that criminal evidence management deployment has been successful with end-to-end pipeline execution logs, stored output, data source information, and validation logs all indicating that the pipeline has been run successfully.

## V. CONCLUSION

In general, this paper has shown that a Blockchain-Based Criminal Evidence Management System can

offer a strong, safe, and open system to address the long-term issues of the organization of forensic evidence. The use of SHA-256 cryptographic hashing, Proof of work mining and immutable ledger structure helps the system to provide end to end evidence integrity, tampering detection, and verifiable chain of custody. Experimental findings verify that integral violations are zero, the validation time is fast, and the scores of evidence reliability are over 80 which prove the practical applicability of the suggested IECA-CVRA architecture. Even more advanced analytics and visualization will improve the decision-making process in investigations and assist in the sharing of crime tendencies, evidence locations, time tendencies, and relationships between priorities and confidence. Scalability, persistence, and redundancy are also added to the cloud storage functionality like Google Drive without compromising the security. All in all, the system enhances accountability, trust, and transparency to the criminal investigations which prove that blockchain technology can make a revolution in transforming the current systems of judicial and law-enforcement evidence management and contributing to the establishment of the principles of fair and reliable justice systems.

## VI. FUTURE SCOPE

The Criminal Evidence Management System can also be improved in the future by incorporating permissioned blockchain networks, to balance transparency and warranted strict access control demanded by law-enforcement agencies. Law processes such as the access to evidence, inter-agency disclosure, and submitting to courts can also be automated with smart contracts, which will avoid human intervention and delays in the law processes. This will be further augmented by introducing artificial intelligence and machine learning into automated processes of processing evidence, identification of anomaly, and predicting crime patterns. The system may be complemented with IoT-based forensic devices to overview the documents of the crime scenes and store them in automatic on the blockchain in real time. More advanced privacy protection systems, such as zero-knowledge proofs, and homomorphic encryption may be used to store sensitive information in cases and remain verifiable.

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