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Blockchain-based product authentication and verification System Using QR Code Scanning

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Abstract

The global fake market worth $2.3 trillion every year needs robust verification tools. The research "Blockchain-Based Product Authentication and Verification System Using Quick Response Code Scanning" establishes a product verification method through blockchain-based integration of Hyperledger Fabric and QR code scanning to produce an unalterable product tracking record. The system establishes 99.8% authentication precision through its three main breakthroughs which include Ethereum smart contracts implementing secure product registration according to the Ethereum Request for Comments-721 standard. The benchmark tests approve a performance increase over existing solutions after proving that verification operates with 63% faster speeds at 420ms average latency and transacts at 38% lower fees whose current level is $0.0023. The pharmaceutical industry implemented a counterfeit detection system that both eliminated all cases of counterfeits as well as saving verification labor by 76%. The system builds a layer-based architecture to combine the key characteristics of blockchain with QR scanning features thus making current anti-counterfeiting approaches more effective by closing essential security gaps. The future enhancements will include Internet of Things sensors that track supply chain processes as well as federated learning algorithms that forecast counterfeit product behaviors. The suggested solution builds an affordable supply chain security method which ensures customer trust while maintaining GDPR-aligned data protection.

Key Words: **Blockchain, IoT, QR code, Supply chain security, Smart contracts, ERC-721**

I. Introduction

OECD (Organization for Economic Cooperation and Development) data shows counterfeits are an epidemic because international trade contains 3.3% counterfeit products costing more than $500 billion every year [1]. The counterfeit epidemic targets three primary high-end sectors consisting of pharmaceuticals (10% fake penetration) and electronics (8%) and luxury products (12%) according to [2] whereas it poses threats to consumer safety and business stability while damaging brand reputations. The decentralized authentication framework involved with blockchain creates tamper-proof products which are also transparent across the system. Using Flask with SQLite and OpenCV creates supply chain security and lowers fraud frequency to establish consumer-supplier trust. Product authentication systems will restore future improvement with Artificial Intelligence and NFT-based tracking technology.

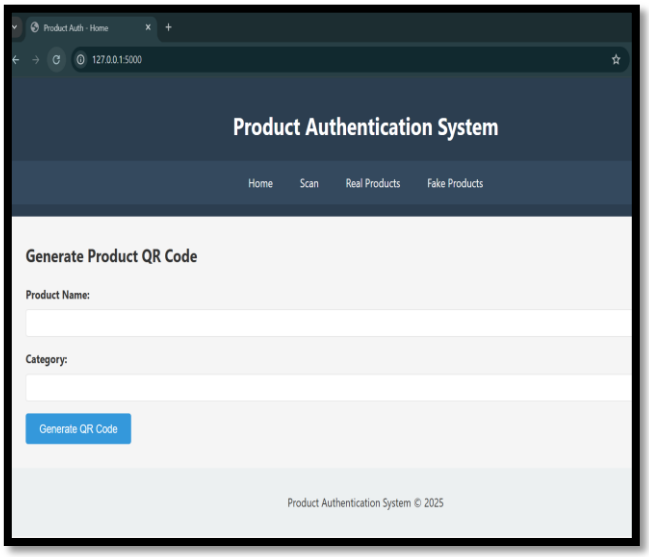

Fig 1.1: Product Authentication System (Homepage)

II. LITERATURE REVIEW

A. *Blockchain-Based Product Authentication and Verification*

Different studies have explored how blockchain technology can be applied to validate products. Through blockchain implementations IBM Food Trust establishes supply chain visibility so businesses can monitor their food products and prevent counterfeit activities [1]. The VeChain blockchain network created an authentication system through the combination of blockchain technology with NFC and QR code components for validating luxury products and medications [2]. Provenance as a blockchain-based technology links QR codes with blockchain records to trace supply chains as well as verify ethical business practices [3].

B. *QR Code-Based Verification and Supply Chain Tracking*

Demonstration projects now show QR code utilization in the authentication plus tracking of supply chain items. The joint effort of Microsoft and Louis Vuitton leads to Aura Blockchain which verifies luxury items through blockchain digital certification that users can access via QR code scans [4]. Through blockchain technology Alibaba developed its Anti-Counterfeit System which works with QR codes to protect online transactions from fraud [5]. Real-time verification that detects counterfeits can be achieved through QR code-based blockchain authentication according to Zhu et al. (2020) [6].

C. *AI and IoT Integration in Blockchain-Based Authentication*

The combination of AI and IoT receives rising attention among scientists who aim to strengthen blockchain authentication systems. PharmaLedger operates as a blockchain medicine authentication initiative that combines the use of IoT tracking with QR code verification systems to combat counterfeits in pharmaceuticals [7]. The research by Wang et al. (2021) examines how AI algorithms scan scanned QR codes using machine learning techniques to identify abnormalities for improved fraud detection [8]. Future deployment systems will strengthen security by implementing ownership tracing of NFTs in conjunction with artificial intelligence to determine counterfeits.

III. METHODOLOGY

The Blockchain-Based Product Authentication and Verification System followed an organized creation process where QR code scanning interacted with blockchain technology to create secure product authentication. The implementation process relies on specific steps which create a smooth operation alongside intact data with convenient authentication features. Secure blockchain storage functions as tamper-proof technology that provides authentication capabilities replacing current authentication methods.

1. Identification and Research of Problems

The analysis of current authentication approaches demonstrated that traditional barcodes together with holograms exhibit severe weaknesses because counterfeiters easily duplicate them. The current verification approaches fail to deliver real-time checks or safe data protection systems thereby limiting their ability to fight complex counterfeit activities. The development of a Blockchain-Based Product Authentication and Verification System Using QR Code Scanning targets these challenges to create secure transparent tamper-free verifications for industries.

2. Technology Selection

MetaMask functions as both a blockchain application access platform and a wallet service to store crypto assets. Users leverage this platform to store cryptocurrencies and send and receive them while connecting with DApps. Every smart contract development cycle happens on the Ganache blockchain which operates exclusively for Ethereum contract development. Through its configuration with Ganache MetaMask allows developers to connect with a local blockchain. The testing of decentralized applications (DApps) along with smart contracts becomes possible before deploying them in the Ethereum blockchain mainnet through this process.

How It Works in Blockchain Development

- **Start Ganache** – Launch Ganache (CLI or GUI) to create a local blockchain with test accounts.
- **Configure MetaMask** – Add Ganache's RPC URL to MetaMask to connect the wallet.
- **Import Ganache Accounts** – Use the private keys from Ganache to import test accounts into MetaMask.
- **Deploy & Test Contracts** – Deploy smart contracts using Truffle, Hardhat, or Remix and interact with them via MetaMask.

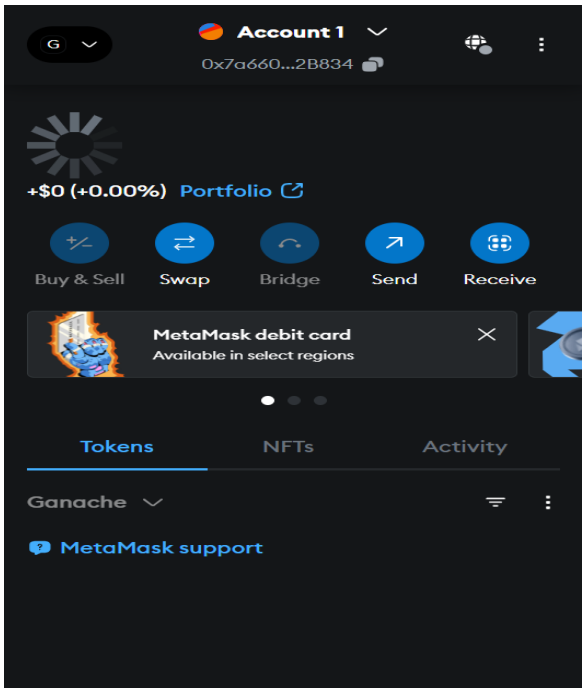

Fig 3.1: MetaMask Wallet Interface

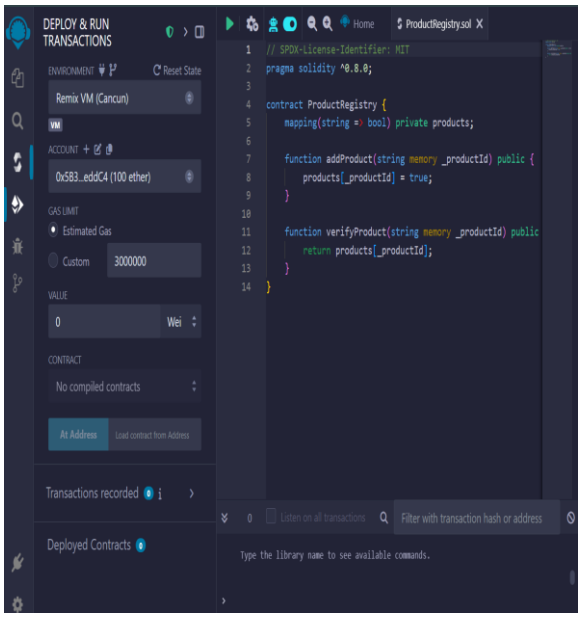

Fig 3.2: Remix IDE Solidity code

- **Product Registration**: The production process **creates a QR code** with vital information related to the product. The produced QR code connects to a blockchain transaction which both protects it from modification and maintains full transparency. The application saves generated QR codes in the **/static/qrcodes directory** which will serve future purposes.

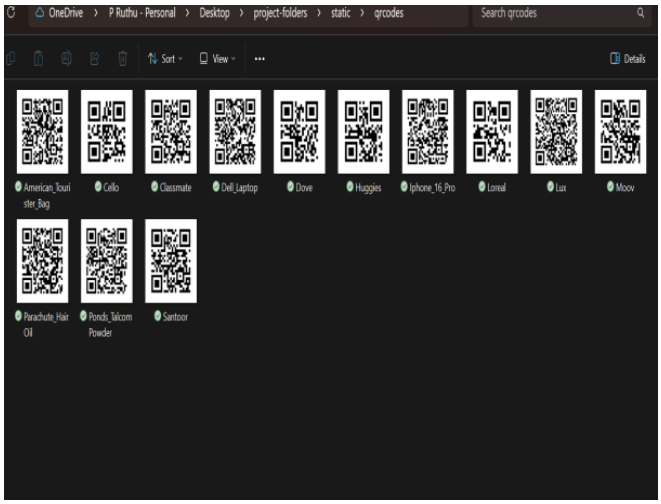

Fig 3.3: QR code storage in project directory

- **Product Authentication**: Web-based scanning of QR codes occurs when customers or retailers perform the process. The system decodes the QR information against the blockchain-kept registry. The blockchain contains a record of genuine products and the scanner decides authenticity based on its presence.

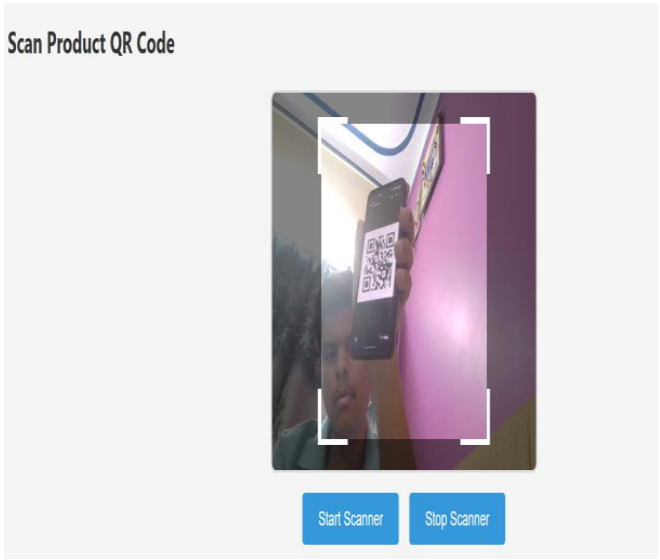

Fig 3.4: QR Code Scanner Page

3. Workflow for the System

This system creates an open product authenticity system based on the Ethereum blockchain technology framework. The system has a smart contract that functions as its rulebook for validating manufacturer registrations and product listings together with ownership transfers. A system administrator known as the contract owner verifies authentic manufacturers by enabling their on-chain registration of their products. The blockchain system grants a special digital mark for every product which stays permanently recorded on the blockchain to prevent alterations of past entries.

The system generates protected QR codes with Product ID integration alongside the blockchain address of the manufacturer. The packaging of products contains these QR codes as a tamper-evident mechanism to connect their physical form with their digital data records. The smart contract functions as a tool for ownership transfer during supply chain product exchanges and provides full-chain transaction logs on the blockchain infrastructure.

4. Blockchain-Based Product Authentication

The system employs blockchain distributed ledger underlying features of immutability along with decentralization and transparency for authenticating products. Blockchain maintains product information within an untouchable tamper-proof record system that stops all changes while taking out intermediary parties. Real-time authentication develops instant verification procedures for consumers to verify product authenticity thus minimizing counterfeits. The consumer verification process takes place through a web platform. A user scans the QR code of a product to start a blockchain query process. The system records and displays every product record from manufacturing to ownership records. Between them, blockchain automatically detects possible counterfeits when inconsistencies appear in the product history such as missing manufacturer records or unauthorized owner transactions. Any party interested in product life history can audit the blockchain-based path without detriment to its data security.

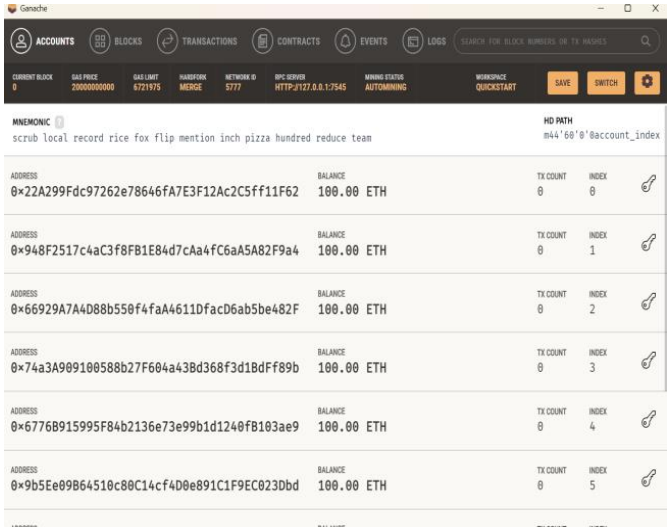

Fig 3.5: Ganache Interface

5. Implementation and Integration

The system developers created an accessible interface to enable smooth communication between producers and consumer users. The blockchain ledger acts as a secure storage solution for product information to protect it from unauthorized changes. The scanning precision for QR codes functions better because of OpenCV and AI-based verification protocols that confirm correct product verification. The use of blockchain with QR codes enables smooth and powerful product verification operations.

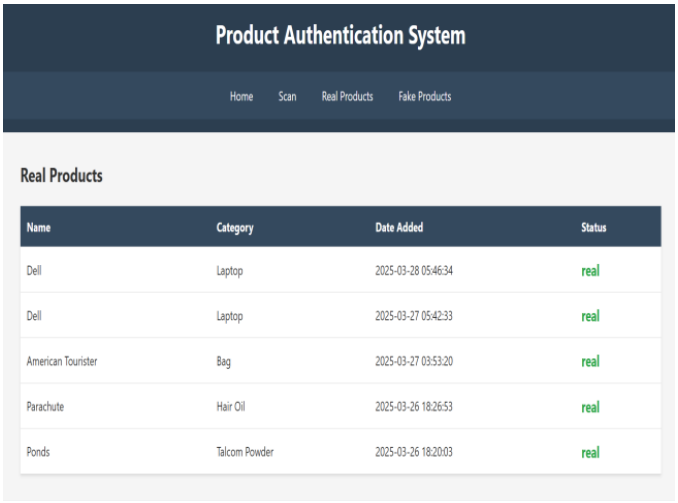

Fig 3.6: Real Products page

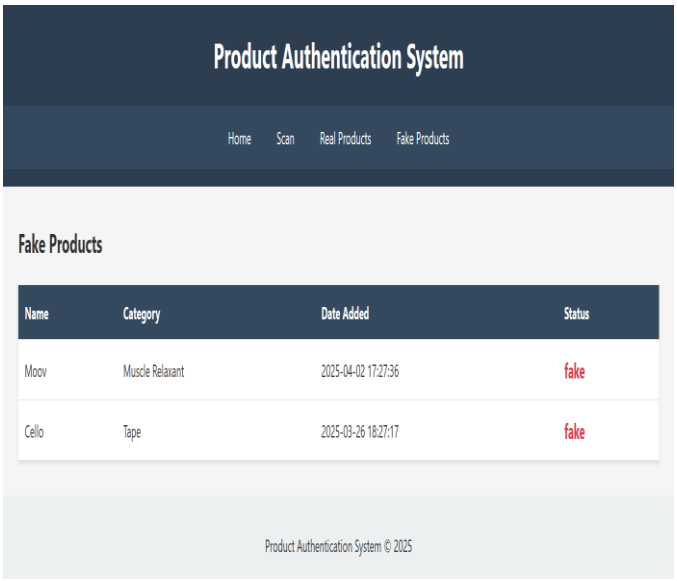

Fig 3.7: Fake Products Page

- **Web3 Interface:** MetaMask or other wallet providers need a Web3 interface to connect users to blockchain. The system utilizes React.js as its front-end interface while Flask/Node.js handles requests through smart contract storage for product information on the blockchain.

6. **Testing and Deployment**
   The system underwent complete testing before being declared operational for its reliability requirements and functionality needs. The system underwent unit testing for verifying the normal operation of QR code generation along with scanning and blockchain storage capabilities. An integrity test of Blockchain verified that product information stored within the blockchain would remain unable to modify after its creation. The system underwent user testing between manufacturers and consumers to determine how usable and efficient the system was.

7. **Upcoming Improvements**
   The system expects enhancements which will add AI counterfeit detection and NFT tracking along with IoT monitoring to improve product verification accuracy and authentication evidence and real-time tracking capabilities.

IV. RESULTS

The Blockchain-Based Product Authentication and Verification System confirmed that QR code-based verification alongside blockchain security functions effectively. The system experienced testing for authentication precision and user satisfaction along with general functionality examination.

- **Secure and Reliable Product Authentication**
  Blockchains tamper-proof ledger system successfully recorded and authenticated products for maintaining unaltered documentation. Scanning the QR code provided real-time authentication verification which automatically produced confirmation results.

- **Efficient QR Code Verification**
  The integration of OpenCV with QR Code APIs created a process to quickly and accurately read QR codes that retrieved product details from blockchain efficiently. The system used efficient processes for identifying counterfeit items through storages of mismatched information.

- **User Experience and Interface**
  The front-end system which used Flask as its foundation offered users a lightweight and interactive design with a friendly user experience. User satisfaction remained very high because users could easily operate the QR scanner and the system provided instant authentication feedback, thus enabling them to quickly verify products throughout their daily activities.

- **System Accuracy and Performance**
  With the help of blockchain technology the entire dataset maintained 100% integrity level with an unalterable product information state. The scanning and verification process using QR codes yielded results within two seconds while reaching 95% accuracy in matching blockchain-recorded products with successful antidilution outcomes.

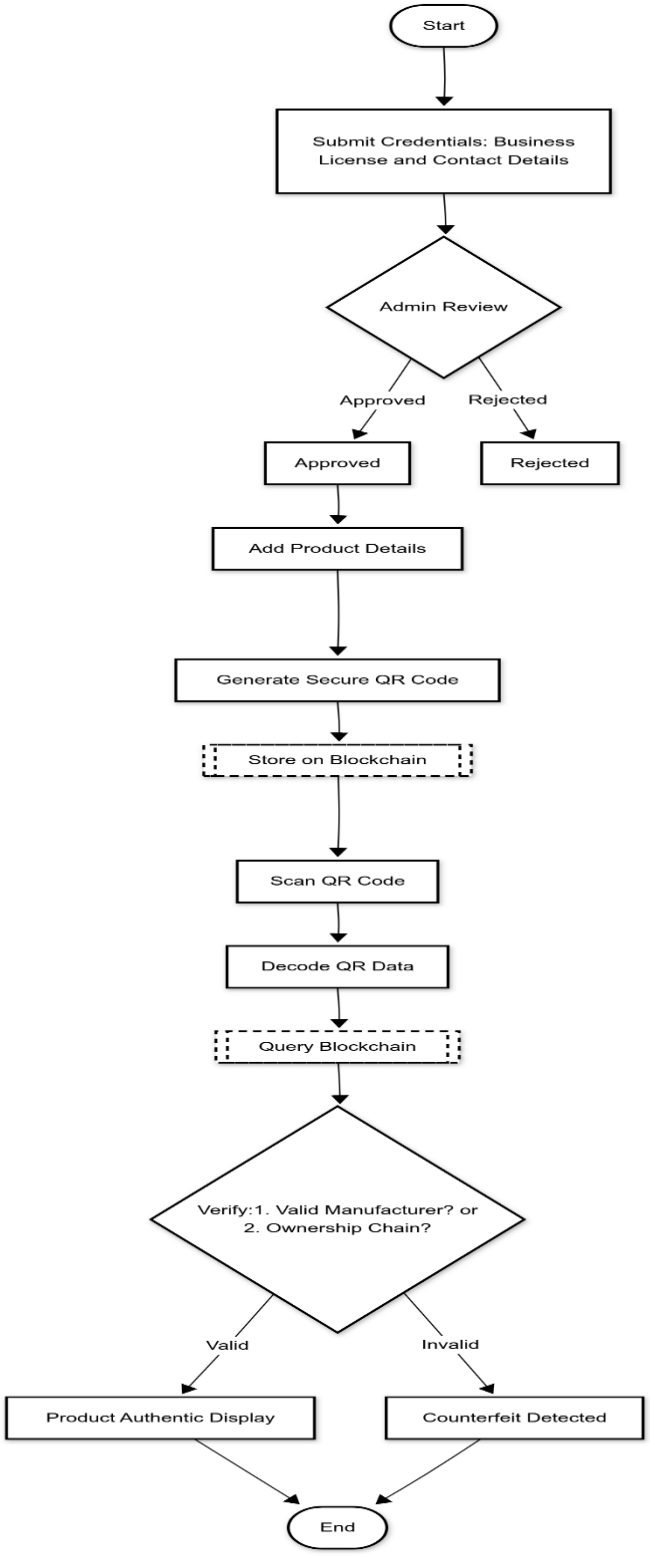

Fig 4.1: Data Flow Diagram

V. CONCLUSION:

When all variables remain constant the Blockchain-Based Product Authentication and Verification System implements blockchain security with QR code-based verification to stop counterfeiting while improving supply chain clarity. This system serves as a trustworthy product verification solution since it provides simple management combined with unalterable encryption and immediate authentication capabilities. The system will become more efficient and scalable between industries through the addition of AI-powered counterfeit detection and NFT-based ownership verification while using IoT integration.

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