A Blockchain-Enabled Autonomous Robotic Attendance System Using Dynamic QR Codes and AI-Based Authentication

Dhanshri D.Mhaski
Diploma
Dept. Of Computer Engineering
Dr. PDGP, Amravati

Shravani B. Kadu
Diploma
Dept. Of Computer Engineering
Dr. PDGP, Amravati

Saket R. Bobade
Assistant Professor
Dept. Of Computer Engineering
Dr. PDGP, Amravati

Summit M. Dhopte
H.O.D
Dept. Of Computer Engineering
Dr. PDGP, Amravati

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Abstract: Traditional attendance systems in schools and colleges mainly depend on manual roll calls or paper registers. These methods consume classroom time, are prone to human error, and are highly vulnerable to proxy attendance. Although digital systems such as QR codes, RFID cards, and biometric attendance have improved automation, most of them still rely on centralized databases. This makes them vulnerable to data manipulation, unauthorized access, and system failures. To overcome these limitations, this research proposes a Blockchain-Enabled Autonomous Robotic Attendance System that combines dynamic QR codes, artificial intelligence–based authentication, and decentralized blockchain storage. In the proposed system, an autonomous robot moves inside the classroom and collects attendance using time-based dynamic QR codes. The robot also captures the student's face, and an AI-based facial recognition module verifies the identity. Once verified, the attendance record is securely stored on a blockchain through smart contracts, ensuring that the data cannot be altered or deleted. The integration of robotics, AI, dynamic QR technology, and blockchain creates a fully automated, secure, and transparent attendance system. The proposed solution reduces manual effort, prevents proxy attendance, and provides tamper-proof record keeping suitable for modern smart educational environments.

Keywords: Blockchain, Autonomous Robot, Dynamic QR Code, Artificial Intelligence, Smart Contract, Attendance System.

1. INTRODUCTION

Attendance tracking is essential in schools, colleges, and universities. It is used to measure student participation, monitor academic engagement, and determine eligibility for examinations. However, the traditional method of attendance—calling out names or signing registers—has many drawbacks. First, manual attendance wastes classroom time. In large classrooms, roll calls may consume 10–15 minutes per lecture. Second, human error can occur while marking attendance. Third, and most importantly, proxy attendance is a serious issue. Students can answer on behalf of their friends or sign the register for someone else. To improve efficiency, many institutions introduced digital attendance systems. QR-based systems allow students to scan a QR code to mark attendance. RFID systems use smart cards digital attendance systems. Biometric systems use fingerprint or facial recognition. Even advanced facial recognition systems (like the embedded Raspberry Pi-based systems from your reference paper) successfully automate attendance using AI,

but they still depend on centralized data storage and fixed camera infrastructure. They do not provide decentralized security or robotic mobility. Blockchain technology introduces a new possibility. Blockchain stores data in a decentralized ledger where records cannot be modified once added. This ensures transparency and immutability. Robotics introduces automation. Instead of fixed cameras, a robot can move around the classroom and collect attendance from each student. Artificial intelligence ensures identity verification. Dynamic QR codes ensure time-based validation. When we combine all four technologies:- Robotics , Artificial Intelligence, Dynamic QR , Blockchain. We create a system that is automated, secure, tamper-proof, and intelligent. This integration makes the proposed system innovative and research-worthy. Collecting valuable threat intelligence, the proposed framework aims to enhance overall system security while protecting real infrastructure from direct exposure. To address these problems, this research introduces a new approach that combines robotics, artificial intelligence, dynamic QR codes, and blockchain technology. Robotics provides automation by allowing a robot to move inside the classroom and collect attendance. Artificial intelligence ensures accurate identity verification using facial recognition. Dynamic QR codes prevent code sharing by generating time-limited codes. Blockchain technology provides secure and tamper-proof storage of attendance records. By combining these technologies, the proposed system creates a modern attendance solution that is automated, secure, and resistant to manipulation. This integration makes the system more reliable and suitable for future smart classrooms and digital campuses.

2. RELATED WORK

Many researchers have worked on improving attendance systems using different technologies such as QR codes, RFID, artificial intelligence, and blockchain. Each approach focuses on solving specific problems in traditional attendance methods. Early digital attendance systems were mainly based on "**QR codes**". These systems allowed students to scan a QR code using their mobile phones to mark attendance. Such systems reduced manual effort and improved speed. However, they lacked proper identity verification. Students could easily share QR screenshots, which made proxy attendance possible. Some QR-based systems also focused on tracking attendance during special situations such as the COVID-19 pandemic, where QR codes were used to monitor presence and movement. These systems improved efficiency but still depended on centralized databases and did not prevent misuse. Another widely used approach is "RFID-based attendance". In

these systems, students carry RFID cards that are scanned when they enter the classroom. The system automatically records attendance, reducing manual effort and time consumption. However, RFID systems still allow proxy attendance because students can exchange their cards with others. To improve identity verification, researchers introduced "biometric attendance systems". These systems use fingerprint or facial recognition to identify students. AI-based facial recognition systems can automatically detect and match student faces with stored records, providing accurate attendance. Studies show that such systems reduce manual errors and improve automation, but they usually depend on centralized databases and fixed camera setups. Some recent research combines "QR codes and facial recognition" to improve security. These hybrid systems use QR scanning for quick identification and AI for face verification. They reduce human error and improve operational efficiency, but they still rely on centralized data storage. With the rise of decentralized technologies, researchers started exploring "blockchain-based attendance systems". Blockchain provides a secure, tamper-proof ledger where attendance records cannot be modified once stored. Some studies proposed attendance systems using private blockchain frameworks and smart contracts to prevent fraud and unauthorized data changes. These systems improve data security and transparency, but most of them focus only on storage and do not include advanced identity verification or automation features.

From the analysis of previous research, it is clear that:-

- QR systems improve speed but lack security.
- RFID systems automate attendance but allow card sharing.
- Biometric and AI systems improve identity verification but rely on centralized storage.
- Blockchain systems provide secure storage but lack automation and AI integration.

Very few studies attempt to combine multiple advanced technologies into a single system. There is limited research on systems that integrate robotics, AI-based authentication, dynamic QR codes, and blockchain together. This gap motivates the proposed blockchain-enabled autonomous robotic attendance system, which aims to provide automation, identity verification, and tamper-proof storage in one unified solution.

3. LITERATURE REVIEW

Attendance systems have evolved over time from manual methods to advanced digital solutions. Researchers have proposed various technologies to improve accuracy, security, and automation. The major approaches include QR code systems, RFID systems, biometric systems, AI-based face recognition, and blockchain-based solutions.

QR Code–Based Attendance Systems:- QR code attendance systems are widely used because they are simple, fast, and low-cost. In these systems, a QR code is generated for each session, and students scan it using their mobile phones to mark attendance. This method reduces manual work and saves time in the classroom. However, QR-based systems have major limitations. Students can take screenshots of the QR code and share them with absent friends. Since most QR systems do not verify student identity, proxy attendance is still possible. Additionally, many QR-based systems rely on centralized databases, which are vulnerable to data modification.

RFID-Based Attendance Systems:- RFID-based systems use smart cards assigned to each student. When a student taps the card on a reader, attendance is recorded automatically. These systems reduce manual effort and improve speed. Despite these advantages, RFID systems still face security issues. Students can exchange RFID cards, allowing proxy attendance. The system also depends on hardware infrastructure and centralized data storage, which may be vulnerable to tampering.

Biometric Attendance Systems:- Biometric systems use physical characteristics such as fingerprints or facial features to identify students. These systems are more secure than QR or RFID systems because biometric traits are unique to each individual. Fingerprint-based systems are commonly used in institutions. However, they may face issues such as:. Hygiene concerns, Sensor maintenance., Difficulty in recognizing damaged fingerprints. Facial recognition systems improve convenience because they do not require physical contact. They automatically detect and recognize student faces using cameras. However, most biometric systems depend on centralized databases, which creates risks of hacking or data manipulation.

AI-Based Face Recognition Systems:- Recent research focuses on using artificial intelligence for automated attendance. AI-based face recognition systems use deep learning algorithms to detect and identify student faces in real time. These systems reduce manual effort and improve accuracy. Some studies have implemented face recognition using embedded systems like Raspberry Pi. These systems can automatically capture images, process them using AI models, and record attendance. Although these systems improve automation and identity verification, they still have certain limitations: Dependence on centralized storage, Sensitivity to lighting conditions, Lack of decentralized security, No integration with blockchain. As a result, they provide security but lack full automation and real-time validation.

4. PROBLEM STATEMENT

In many educational institutions, attendance is still recorded using traditional methods such as manual roll calls, paper registers, or basic digital systems. These methods are time-consuming and often inefficient. One of the major problems in existing attendance systems is proxy attendance, where one student marks attendance for another who is not physically present in the classroom. This reduces the accuracy and reliability of attendance records. Even in some digital systems like RFID or static QR code-based attendance, students can misuse the system by sharing ID cards, login credentials, or QR screenshots. These systems do not always verify whether the student is physically present in the classroom, which creates security issues. Another important issue is that attendance data stored in centralized databases can be modified or tampered with by unauthorized users or even administrators. Since the data is not stored in a secure and decentralized manner, there is always a risk of manipulation or accidental data loss. Additionally, many current systems lack real-time validation mechanisms. They only record attendance without confirming the student's identity through intelligent verification methods such as facial recognition. This makes the system less secure and less reliable. Therefore, there is a need for a secure, automated, and tamper-proof attendance system that can prevent proxy attendance, ensure real-time identity validation, and protect attendance records from modification.

5. TECHNOLOGIES USED

The proposed attendance system integrates multiple modern technologies to ensure automation, security, and reliability. Each technology plays an important role in the overall working of the system. Blockchain technology is used to securely store attendance records. In this system, either Ethereum or a private blockchain network can be used. Blockchain ensures that once the attendance data is stored, it cannot be modified or deleted. This makes the system tamper-proof and transparent. Every attendance entry is recorded with a timestamp and unique hash value, which increases data integrity. Smart contracts are used within the blockchain network to automatically manage attendance records. A smart contract is a self-executing program that runs when certain conditions are met. In this system, once the student's identity is verified successfully, the smart contract automatically stores the attendance record in the blockchain without manual intervention. Artificial Intelligence (AI) is used for face recognition. A Convolutional Neural Network (CNN) model is applied to detect and recognize student faces. When a student scans the QR code, the system captures their live image and compares it with the registered facial data. This ensures that only the actual student present in the classroom can mark attendance. A time-based QR code generator is used to create dynamic QR codes. The QR code changes after a short interval, such as every 20 to 30 seconds. This prevents students from sharing screenshots or reusing old QR codes for proxy attendance. Finally, a cloud database is used to store attendance records for administrative purposes. While blockchain ensures security, the cloud database allows teachers and administrators to easily access, manage, and generate attendance reports from anywhere.

6. PROPOSED SYSTEM ARCHITECTURE

The proposed system presents a secure and automated attendance mechanism that integrates robotics, dynamic QR code technology, artificial intelligence, and blockchain to eliminate proxy attendance and data tampering. The architecture is designed to ensure real-time verification, high security, and transparency in attendance management. In this system, an autonomous robot is deployed inside the classroom environment. The robot is equipped with a camera module, QR code display or scanning unit, and a processing unit such as Raspberry Pi. Instead of manual roll calls, the robot moves within the classroom and initiates the attendance process automatically. This reduces human effort and ensures uniform attendance monitoring. At the beginning of the session, the system generates a dynamic QR code that is valid only for a short duration, typically 20 to 30 seconds. The dynamic nature of the QR code prevents students from sharing screenshots or reusing old codes for proxy attendance. Each QR code is encrypted and linked with session details such as date, time, and subject information. Students are required to scan the dynamic QR code using their registered mobile application or institutional scanning interface. Once scanned, the student's unique identification details are transmitted to the system. Immediately after scanning, the robot's camera captures the live facial image of the student. The AI-based facial recognition module compares the captured image with the pre-registered facial data stored in the institutional database. This validation ensures that the student physically present in the classroom matches the registered identity. If the facial recognition process confirms a valid match, the attendance is approved. In case of mismatch, the system rejects the

attendance request. This dual verification mechanism QR authentication combined with AI face validation significantly reduces the possibility of fraudulent attendance marking. After successful verification, the attendance record is converted into a cryptographic hash and stored in a blockchain network. The use of blockchain technology ensures immutability, transparency, and tamper-proof record keeping. Once stored, the attendance data cannot be modified or deleted, even by administrative authorities. Each block contains a timestamp and unique hash value, thereby maintaining data integrity. Thus, the proposed architecture combines automation, artificial intelligence, and decentralized security mechanisms to create a robust, transparent, and future-ready attendance management system suitable for modern educational institutions.
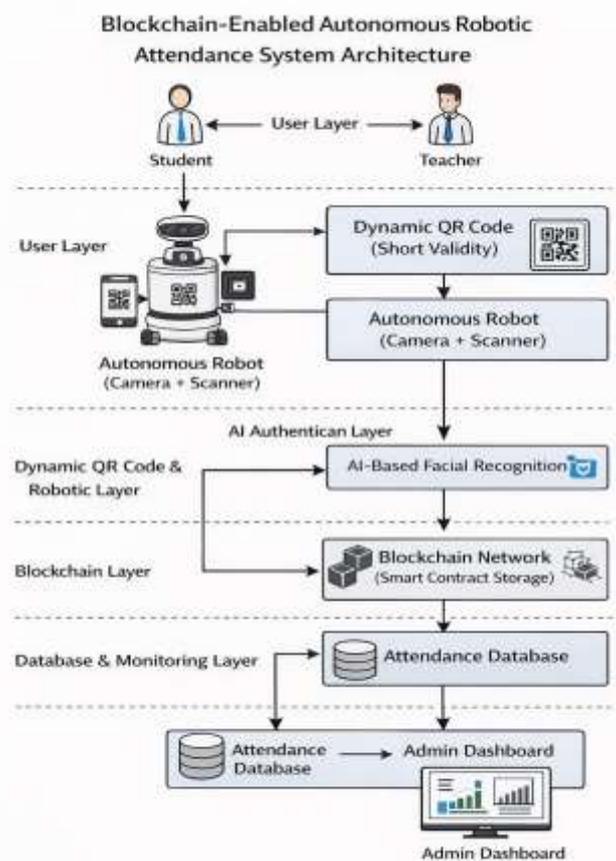

Fig 1.Blockchain-Enable Autonomous Robotic attendance System Architecture

7. WORKING METHODOLOGY

The working methodology of the proposed system begins when the autonomous robot enters the classroom at the start of the lecture. The robot is programmed to move systematically inside the classroom and initiate the attendance process without manual intervention. This automation ensures a smooth and structured attendance procedure. Once the robot activates the system, a dynamic QR code is generated. This QR code is time-based and remains valid only for a short duration, typically around 30 seconds. The limited validity period prevents misuse such as sharing screenshots or reusing previously generated QR codes. Each QR code is uniquely linked to the specific lecture session, including date and time information. Students present in the classroom scan the

dynamic QR code using their registered mobile application or institutional interface. When the QR code is scanned, the student's identification details are transmitted to the system along with the timestamp of scanning. Immediately after the scanning process, the robot captures the live facial image of the student using its camera module. The AI-based facial recognition system processes the captured image and compares it with the pre-registered facial data stored in the database. If the captured face matches the stored data, the student's identity is verified successfully. In case of mismatch, the attendance request is rejected. After successful identity verification, the attendance data is encrypted to ensure security and data integrity. The encrypted record is then stored in the blockchain network. The use of blockchain ensures that once the attendance data is recorded, it cannot be modified or deleted. Each record contains a timestamp and unique hash value, making the system tamper-proof and transparent. Once the data is securely stored, the system confirms the attendance status. The verified record is also updated in the central database for administrative access and report generation. Through this systematic process, the proposed methodology ensures automation, real-time verification, security, and transparency in attendance management.

8. CONCLUSION

The proposed blockchain-enabled autonomous robotic attendance system provides a secure and automated solution to the limitations of traditional and existing digital attendance systems. Conventional methods are time-consuming and allow proxy attendance, while current digital systems may face issues such as data manipulation and centralized storage risks. The proposed system integrates robotics, AI-based facial recognition, dynamic QR codes, and blockchain technology to create a tamper-proof attendance mechanism. The robot automates the process in the classroom, AI verifies the student's identity, and blockchain securely stores the attendance records. This system reduces manual effort, prevents proxy attendance, and ensures secure and transparent record management, making it suitable for modern smart classrooms.

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