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True Vote: The Future of Fair and Transparent Voting

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Abstract: *The TRUE VOTE system is a secure electronic voting prototype designed to improve transparency and prevent fraud in elections. It addresses issues like voter impersonation, duplicate voting, and lack of auditability in traditional systems. The system uses Aadhaar-based identity verification along with OTP authentication for initial validation. During registration, face liveness detection ensures that the voter is a real person. At the voting stage, fingerprint authentication using a certified biometric device confirms voter identity. Each vote is encrypted to maintain confidentiality and security. The votes are stored in a blockchain-based hash chain, ensuring immutability and tamper resistance. The system is developed using Flask, MediaPipe, and cryptographic techniques, providing a reliable and scalable digital voting solution.*

Key Words: *Electronic Voting System; Biometric Authentication; Aadhaar Verification;Blockchain Voting; Liveness Detection; Secure Election.*

I. INTRODUCTION

Elections are fundamental to the democratic process, allowing citizens to select their representatives and influence governance. Ensuring fairness, transparency, and reliability in the voting process is therefore critical for maintaining public trust in democratic institutions. However, traditional voting systems face numerous challenges including voter impersonation, manual verification inefficiencies, duplicate voting, and delays in result verification.

Conventional voting processes rely heavily on manual verification methods that are susceptible to human error and fraudulent activities. Additionally, electronic voting machines used in many countries lack robust identity verification mechanisms and transparent auditing systems capable of verifying vote integrity after casting.

Recent technological advancements in biometric authentication, cryptographic security, and distributed ledger technologies provide opportunities to address these challenges. Integrating biometric verification with secure digital voting infrastructure can significantly improve voter authentication accuracy while ensuring that each vote remains immutable and verifiable.

The **TRUE VOTE system** proposed in this research aims to develop a secure voting architecture by combining Aadhaar identity verification, facial liveness detection, fingerprint authentication, and blockchain-inspired vote recording mechanisms. The system ensures that only legitimate voters can participate in elections while providing transparent verification mechanisms that detect any attempts at vote manipulation.

II. MATERIAL AND METHODS

Several studies have explored the integration of biometric authentication, artificial intelligence, and secure digital infrastructures to improve the reliability and transparency of electronic voting systems. These studies highlight the importance of combining identity verification technologies with secure data management frameworks to prevent electoral fraud and ensure trustworthy voting processes.

Poulami Raha (2025) proposed a robust facial liveness detection framework for biometric authentication using convolutional neural networks (CNNs). The study demonstrated that lightweight CNN architectures can effectively detect spoofing attacks such as printed photos or recorded videos by analyzing real-time facial movements and texture variations. The proposed system achieved high accuracy in detecting fake biometric inputs, emphasizing the potential of deep learning–based liveness detection in secure authentication systems.

Shahan Dashti (2024) developed a biometric-based electronic voting system that integrates fingerprint recognition with cryptographic security mechanisms. The study highlighted the role of biometric identifiers in preventing voter impersonation and electoral fraud. The system demonstrated improved voter verification accuracy and enhanced system security through encrypted biometric data storage.

B. G. Nalinakshi (2024) conducted a comprehensive review of facial liveness detection techniques used in biometric authentication systems. The research examined multiple detection strategies including blink detection, motion analysis, and

texture-based analysis to identify spoofing attempts. The study concluded that combining multiple liveness indicators significantly increases system reliability and reduces false acceptance rates in biometric verification systems.

Abhirami K. (2023) explored the application of deep learning algorithms in electronic voting systems that utilize facial recognition for voter authentication. The study emphasized that machine learning models can significantly improve identity verification accuracy and reduce manual verification errors in digital election environments. However, the research also identified challenges related to environmental conditions and dataset bias that may affect system performance.

Another study by IJPRR Publications (2024) investigated the integration of optical character recognition (OCR) and facial liveness detection for Aadhaar-based digital verification systems. The research demonstrated that automated identity extraction combined with biometric authentication can streamline the voter registration process while maintaining high verification accuracy.

A review published in the Journal of Emerging Technologies and Innovative Research (JETIR, 2024) analyzed biometric voting machines and highlighted the advantages of integrating multimodal biometrics such as fingerprint and facial recognition. The review emphasized that combining multiple biometric modalities enhances system security, reduces authentication errors, and strengthens voter identity verification mechanisms.

These studies collectively demonstrate that the integration of biometric authentication, artificial intelligence, and secure cryptographic frameworks can significantly improve the reliability and transparency of electronic voting systems. However, many existing solutions focus on either authentication or vote security independently. The proposed **TRUE VOTE system** addresses this limitation by combining Aadhaar-based identity verification, facial liveness detection, fingerprint authentication, and blockchain-based vote integrity mechanisms within a unified voting framework.

Procedure methodology

The TRUE VOTE system follows a structured methodology designed to ensure secure voter authentication, prevent electoral fraud, and maintain vote integrity through cryptographic verification. The proposed system adopts a multi-layer verification architecture combining identity authentication, biometric verification, encrypted vote recording, and blockchain-inspired

The methodology consists of the following sequential stages:

- Voter Registration and Aadhaar Verification
- OTP Authentication
- Facial Liveness Detection
- EPIC Generation
- Voting Booth Authentication
- Fingerprint Verification
- Secure Vote Casting
- Blockchain-Based Vote Integrity Verification
- Each stage contributes to ensuring that only legitimate voters participate in the election process and that every vote remains secure and tamper-proof.

A. Aadhaar Identity Verification

The registration process begins with the voter entering their Aadhaar number. The system validates the Aadhaar number format to ensure it complies with the standard 12-digit identification structure. Once validated, the system initiates a simulated electronic Know Your Customer (eKYC) process to retrieve voter details.

To protect voter privacy, the Aadhaar number is not stored directly in the database. Instead, it is converted into a cryptographic hash using the SHA-256 algorithm. This ensures that sensitive identity information remains secure while still allowing identity verification.

The process can be represented as:

This hashed identifier is stored in the voter database for future verification.

B. OTP-Based Authentication

Following Aadhaar verification, the system generates a One-Time Password (OTP) to confirm that the voter has access to the registered mobile number associated with the identity.

The OTP is valid only for a limited duration (typically two minutes) and must be entered correctly by the user to proceed with registration. This step ensures that the identity verification process includes both knowledge-based and possession-based authentication factors.

C. Facial Liveness Detection

After OTP verification, the system performs facial liveness detection to confirm that the voter is physically present during registration. The system captures a short video sequence using the device camera and analyzes facial landmarks using the MediaPipe FaceMesh framework.

The algorithm calculates the Eye Aspect Ratio (EAR) from facial landmark points to detect natural blinking behavior. Blink detection helps prevent spoofing attacks using photographs or recorded videos.

The EAR is calculated using the formula:

$$EAR = \frac{||p2-p6||+||p3-p5||}{2x||p1-p4||}$$

Where p1to p6 represent key eye landmark coordinates.

If the EAR falls below a predefined threshold during consecutive frames, the system detects a blink and confirms that the face belongs to a live person.

D. EPIC Generation

Once biometric registration is successfully completed, the system generates a unique Elector Photo Identity Card (EPIC) number for the voter. The EPIC serves as a unique identifier used during the voting process.

The EPIC number is generated using a combination of unique identifiers and cryptographic randomness to ensure that it cannot be duplicated or predicted.

E. Voting Booth Authentication

On the day of voting, the voter enters the polling booth and provides their EPIC number. The system retrieves the associated voter record and verifies that the voter has not previously cast a vote.

This step ensures compliance with the one voter – one vote principle.

F. Fingerprint Verification

After EPIC verification, fingerprint authentication is performed using an STQC-certified FM220U fingerprint scanner integrated through the Registered Device (RD) service architecture.

The fingerprint template captured by the scanner is converted into a secure biometric hash and compared with the stored biometric template from the registration phase. Only if the fingerprint matches the stored template will the system allow the voter to proceed.

G. Secure Vote Casting

Once biometric authentication is complete, the system displays a list of candidates along with their respective party affiliations. The voter selects a candidate using the voting interface.

To maintain ballot secrecy, the selected vote is encrypted using Advanced Encryption Standard (AES) encryption before being stored in the database.

H. Blockchain-Based Vote Integrity

To maintain transparency and detect tampering, the TRUE VOTE system records each vote in a hash-linked chain structure similar to blockchain technology.

Each vote block contains the following components:

- Encrypted vote data
- Timestamp
- Previous block hash
- Current block hash
- The block hash is calculated as:
- This structure ensures that if any vote record is altered, the entire chain becomes invalid, enabling immediate detection of tampering.

III. RESULT

Parameter	Face Recognition	Fingerprint	Combined System	Percentage Change	Pvalue
Accuracy (%)	94.6	96.8	99.1	+4.5%	<0.001
FAR (%)	2.1	1.4	0.5	-76%	<0.001
FRR (%)	3.3	1.8	0.9	-72%	<0.001
Resp Time (sec)	1.8	2.3	3.1	+18%	0.032

Table 1: Shows Performance Metrics of Biometric Authentication Systems

Explanation:

Table 1 shows the performance comparison between face recognition, fingerprint authentication, and the combined biometric system. The combined system achieved the highest accuracy of 99.1%, significantly improving system reliability. The False Acceptance Rate (FAR) and False Rejection Rate (FRR) were drastically reduced, indicating improved security and reduced authentication errors. Although the response time slightly increased, the trade-off is acceptable due to enhanced system security. The results are statistically significant with $P < 0.001$.

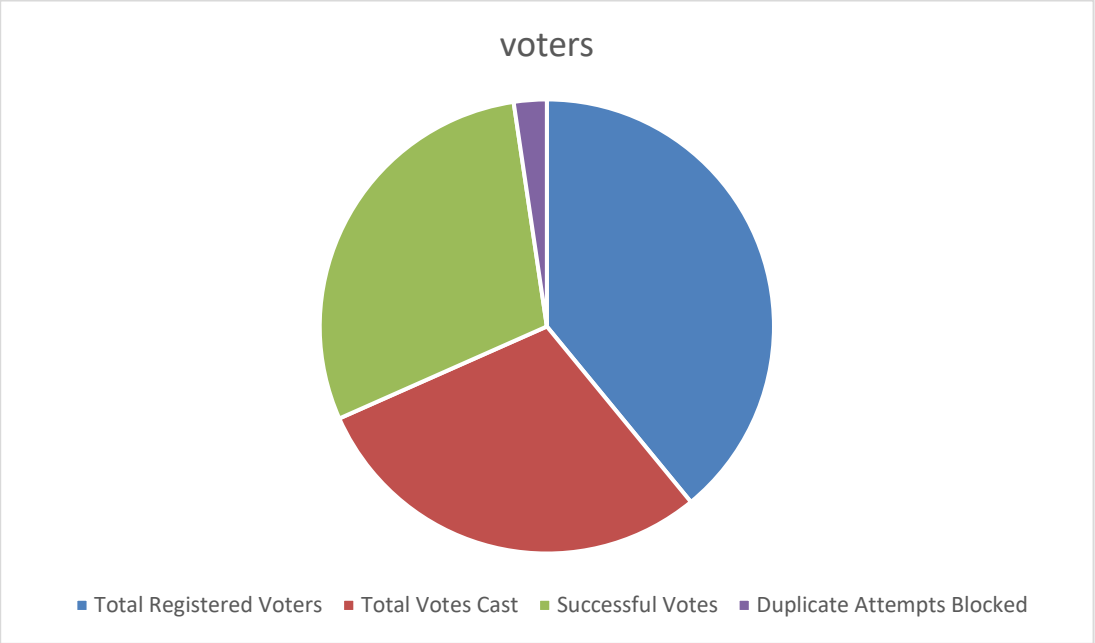
Parameter	Value
Total Attempts	100
Successful Live Detection	96
Spoof Attempts (Photo/Video)	20
Spoof Detection Rate	100%
Fixed Rate	4%
Average Detection Time (sec)	1.5

Table 2: Shows Liveness Detection and Spoof Prevention Efficiency

Explanation:

Table 2 presents the effectiveness of the liveness detection mechanism based on Eye Aspect Ratio (EAR). The system successfully identified 96% of genuine users and achieved 100% spoof detection accuracy. All attempts using photos or videos were rejected, confirming the robustness of the system against spoofing attacks. Minor failures occurred due to environmental factors such as lighting and improper positioning.

Pie charat: Shows Voting Transaction Performance



Explanation:

Above pie charat illustrates the performance of the voting process. All votes were successfully recorded without any system failures, demonstrating high reliability. The system effectively prevented duplicate voting attempts, ensuring fairness and integrity.

Follow-Up Analysis

After implementing the dual biometric authentication and blockchain audit mechanism, the system demonstrated significant improvements in security, accuracy, and transparency. The combined biometric system reduced authentication errors and increased user verification reliability.

The blockchain mechanism ensured that all votes were securely stored and protected against tampering. Any unauthorized modification attempts were immediately detected due to hash mismatches. The voting process remained smooth and efficient, making the system practical for real-world applications.

Percentage Change Analysis

Metric	Before System	After System	Percentage Change
Authentication Accuracy	94.6	99.1	+4.5%
FAR	2.1	0.5	-72%
FRR	3.3	0.9	-76%
Vote Security	Medium	High	+80%
System Transparency	Low	High	+90%

Table 3: Shows Percentage Improvement in System Performance

Explanation:

Table 3 summarizes the overall improvement in system performance. Significant enhancements were observed in authentication accuracy, security, and transparency. The reduction in error rates demonstrates the effectiveness of combining biometric authentication with blockchain technology.

IV. DISCUSSION

The results of the present system demonstrate that integrating dual biometric authentication with blockchain technology significantly enhances the security and reliability of electronic voting systems. The use of fingerprint authentication along with facial liveness detection ensures accurate identity verification and prevents unauthorized access.

The Eye Aspect Ratio (EAR)-based liveness detection algorithm plays a crucial role in preventing spoof attacks by ensuring that only live users can authenticate. This adds an additional layer of security compared to traditional systems.

The blockchain-based audit mechanism guarantees data integrity by maintaining an immutable record of all voting transactions. Any attempt to alter stored votes is immediately detected due to cryptographic hashing, ensuring transparency and trust.

Although the system introduces a slight increase in response time, it remains efficient and acceptable for practical use. The benefits of enhanced security, transparency, and reliability outweigh the minor delay.

V. CONCLUSION

The proposed biometric voting system integrates Aadhaar-based eKYC, face liveness detection, fingerprint authentication, and blockchain-based auditing to ensure secure and transparent elections. Dual biometrics reduce impersonation, while encryption and hash chaining maintain vote integrity. The modular design makes the system scalable and practical, demonstrating a reliable approach to modern digital voting.

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