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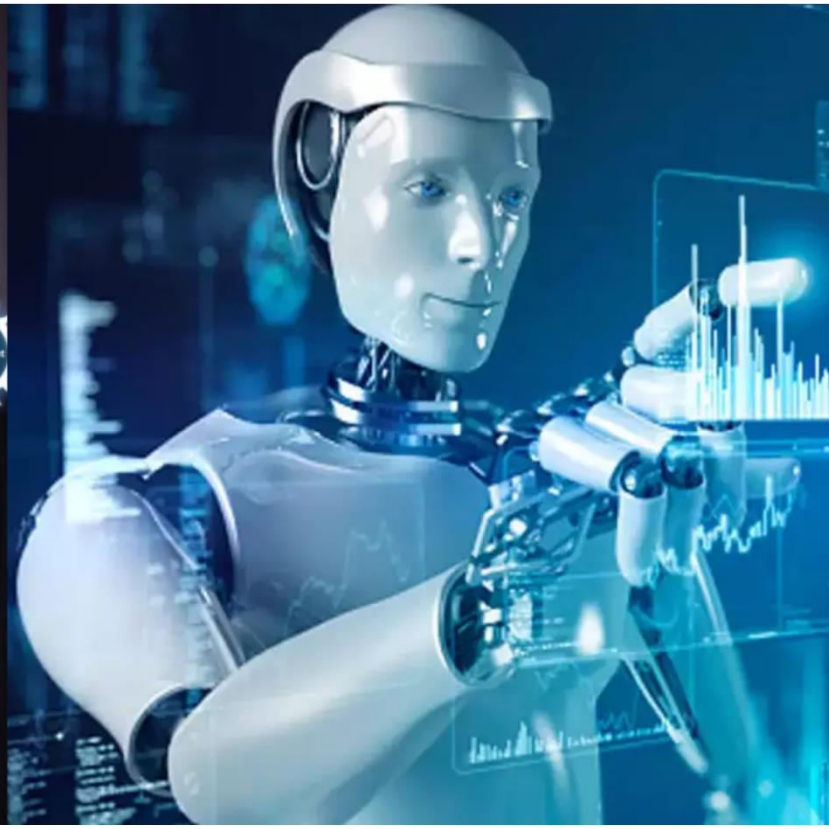

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E-Voting with Iris Recognition using Resnet

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ABSTRACT: This project presents an intelligent and secure E-voting system based on iris recognition using deep learning techniques. The system leverages the unique and permanent patterns of the human iris to authenticate voters accurately, eliminating the risks associated with traditional methods such as voter ID cards or OTP verification. The proposed system preprocesses captured iris images through segmentation and normalization to remove noise and standardize the region for consistent analysis. Advanced feature extraction is performed using a Residual Neural Network (ResNet), which enhances recognition accuracy by learning deeper and more distinctive iris features while reducing computational complexity. Extracted features are stored as compact digital templates in the database and matched against new input samples to verify voter identity. The system provides fast, real-time authentication through a simple and user-friendly interface, ensuring reliability and ease of use even in large-scale elections. This approach strengthens the overall security of the voting process by preventing duplication, impersonation, and fraud. Furthermore, the model achieves high recognition accuracy under varying lighting and environmental conditions, demonstrating the potential for real-world implementation in secure electronic voting and other identity verification applications.

KEYWORDS: E-Voting System, Iris Recognition, ResNet-18, Deep Learning, Artificial Intelligence, Biometric Authentication, Convolutional Neural Network (CNN), MySQL Database, Streamlit Web Application, Voter Verification, Feature Extraction, Cosine Similarity, Secure Voting, Real-Time Authentication, Image Preprocessing, Pattern Matching, Digital Governance, Election Security, Fraud Prevention, Automated Voting System.

I. INTRODUCTION

Voting is a fundamental pillar of democratic governance, ensuring that citizens have the power to choose their representatives and influence national policies. However, traditional voting systems, whether manual or electronic, continue to face critical challenges including identity fraud, duplicate voting, human error, and data manipulation. These vulnerabilities not only compromise the integrity of elections but also erode public confidence in the electoral process. To ensure transparency, authenticity, and security, there is a growing need for advanced technologies that can address these limitations and provide a trustworthy voting environment. The integration of Artificial Intelligence (AI) with biometric authentication has emerged as a promising solution, offering improved voter identification accuracy, enhanced accessibility, and robust protection against fraudulent practices.

Among biometric modalities, **iris recognition** stands out as one of the most reliable and secure methods for human identity verification. The iris—the colored annular region surrounding the pupil—consists of unique and highly stable texture patterns that remain unchanged throughout a person's lifetime. Unlike fingerprints or facial recognition, which may be affected by external factors such as injuries, aging, or lighting conditions, the iris offers superior permanence and distinctiveness. This makes it an ideal biometric feature for ensuring that each vote is cast by the rightful individual only once, thereby eliminating the risks associated with impersonation and double voting. Incorporating deep learning algorithms with iris-based authentication significantly increases the robustness and precision of electronic voting systems, enabling automated, scalable, and unbiased verification.

Deep learning advancements, particularly in **Convolutional Neural Networks (CNNs)** and **Residual Networks (ResNets)**, have revolutionized biometric recognition by enabling automated extraction of intricate visual patterns with remarkable accuracy. While conventional electronic voting systems often rely on traditional machine learning models or manual verification procedures that lack adaptability and are prone to errors, modern architectures like **ResNet** can

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efficiently learn discriminative iris features under diverse conditions, including variations in lighting, orientation, and image quality. The use of **ResNet-18** in particular allows for deep feature extraction through residual learning, improving performance while reducing vanishing gradient issues commonly associated with deep networks.

The proposed **AI-based E-Voting System Using Iris Recognition** integrates the ResNet-18 deep learning model to generate high-dimensional feature embeddings from iris images. These embeddings are compared using cosine similarity to authenticate voter identity before granting access to the voting interface. Upon successful authentication, the system securely records the vote in a MySQL database, ensuring immutability and preventing repeated voting attempts. This hybrid approach combines the accuracy of deep learning with the security of biometric authentication to establish a trustworthy, tamper-proof voting framework.

To facilitate practical deployment and enhance user accessibility, the system is implemented as a **web-based application using Streamlit**, providing a simple, intuitive interface for voter registration, verification, and voting. Users can upload iris images or capture them in real time via webcam, after which the system performs automated recognition and vote entry. This real-time verification ensures transparency, ease of use, and suitability for large-scale implementation in national and regional elections.

By integrating advanced biometric recognition, deep learning-based classification, and secure database management, the proposed system presents a transformative solution to modernize the voting process. It not only enhances accuracy, security, and transparency but also promotes inclusive and efficient democratic participation. This framework lays the foundation for future innovations in secure digital identity verification and AI-driven governance systems.

II. METHODOLOGY

Voting is a fundamental pillar of democratic governance, ensuring that citizens have the power to choose their representatives and influence national policies. However, traditional voting systems, whether manual or electronic, continue to face critical challenges including identity fraud, duplicate voting, human error, and data manipulation. These vulnerabilities not only compromise the integrity of elections but also erode public confidence in the electoral process. To ensure transparency, authenticity, and security, there is a growing need for advanced technologies that can address these limitations and provide a trustworthy voting environment. The integration of Artificial Intelligence (AI) with biometric authentication has emerged as a promising solution, offering improved voter identification accuracy, enhanced accessibility, and robust protection against fraudulent practices.

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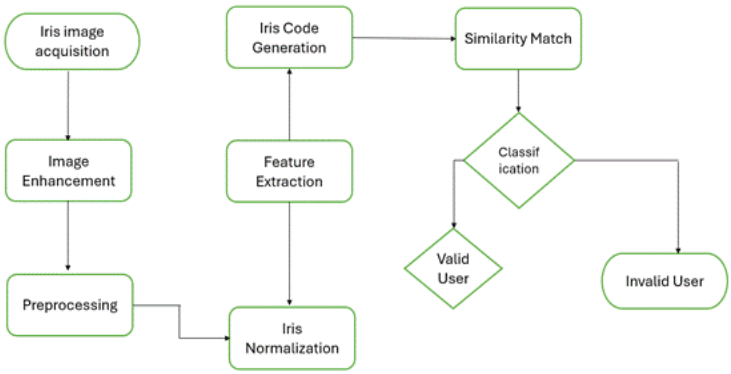
III. PREPROCESSING

Iris image preprocessing is a crucial step in ensuring that the deep learning model receives consistent, high-quality input for accurate feature extraction and classification. During the enrollment and verification phases, iris images are first captured from users through a webcam or uploaded via the web application. Each image is resized to a fixed resolution of **224×224 pixels** to maintain uniformity across the dataset and to align with the **ResNet-18 model's input requirements**. This resizing minimizes computational complexity while ensuring that essential iris texture details are preserved. In addition, **pixel normalization** is applied to scale intensity values between 0 and 1, reducing illumination differences and stabilizing the model's learning process.

To improve the model's generalization capability and reduce overfitting, **data augmentation techniques** are employed. Common augmentation strategies include **rotations, horizontal and vertical flips, and small translations**, which simulate real-world variations in head position or eye angle during image capture. These augmentations help the model learn orientation-invariant features, ensuring robustness under diverse conditions. Additionally, **brightness and contrast adjustments** are introduced to mimic lighting fluctuations, enabling the system to perform reliably across different environments and camera types. By applying these augmentations dynamically during training, the model learns to recognize iris features that remain consistent despite external variations.

After augmentation, the images are converted into **tensor representations compatible with PyTorch**, allowing for efficient GPU-based computation. Batch normalization is applied to standardize pixel distributions, accelerating convergence and preventing unstable gradient updates. Furthermore, **masking or cropping** may be applied to exclude non-iris regions such as eyelids or reflections, allowing the model to focus solely on the region of interest. This helps improve embedding precision by removing irrelevant background data. By maintaining an optimal balance between resolution, contrast, and cropping, the preprocessing stage ensures that the model extracts meaningful features while minimizing unnecessary noise.



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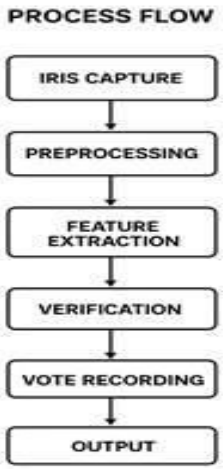
Overall, the preprocessing pipeline enhances the **accuracy, stability, and efficiency** of the E-voting system by ensuring uniform and discriminative iris inputs. It prepares the dataset for effective deep learning–based analysis, enabling the **ResNet-18 model** to extract reliable biometric features from each image. This step plays a vital role in ensuring consistent voter identification and seamless integration between the **AI model**, **database**, and **user interface**, thereby improving the reliability and trustworthiness of the entire E-voting framework.

IV. PROCESS FLOW



The first step in the proposed **E-Voting Using Iris Recognition** system is the collection of iris images from voters during the enrollment phase. These images are captured through a camera or uploaded via the web application. Each voter's iris serves as a unique biometric identifier that cannot be forged or duplicated. The collected dataset contains multiple iris samples captured under varying lighting conditions and angles to ensure that the system can generalize effectively to real-world scenarios. Proper labeling of voter identities during the enrollment process is essential for maintaining accuracy during later verification and matching stages.

During preprocessing, all iris images are resized and standardized to a fixed dimension of **224×224 pixels**, ensuring compatibility with the **ResNet-18 model** input requirements. Techniques such as **noise reduction**, **contrast adjustment**, and **normalization** are applied to minimize variations in image quality. Augmentation methods, including rotations and flips, are used to increase data diversity and improve model robustness. Images are converted into **PyTorch tensors** for GPU-based processing, and batch normalization is employed to stabilize the learning process. Any non-iris regions, such as eyelids or reflections, are masked or cropped to help the model focus only on the relevant iris texture.

The **ResNet-18 feature extraction network** processes these preprocessed images to generate distinctive **512-dimensional embeddings** that represent each voter's iris pattern. These embeddings capture both local and global texture details through residual connections, which help retain essential information and prevent gradient vanishing. During the verification phase, the extracted embedding of a voter is compared with stored embeddings in the **MySQL database** using **cosine similarity**. When the similarity score exceeds the threshold (e.g., 0.75), the system authenticates the voter. This process ensures one-person-one-vote integrity and eliminates fraudulent voting or identity duplication.

After successful verification, the voter's choice is recorded in the **votes table**, and their status is updated to prevent re-voting. The voting details—such as **voter ID**, **candidate selection**, and **timestamp**—are securely stored in the database. The system is implemented entirely in **Python**, using **PyTorch**, **Torchvision**, **OpenCV**, and **mysql-connector-python** for end-to-end integration. GPU acceleration ensures efficient processing of high-dimensional embeddings during verification. Evaluation metrics such as **accuracy, precision, recall**, and **F1-score** are used to measure system performance and verify that the model consistently identifies valid voters under diverse conditions.

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Finally, the trained model is integrated into a **Streamlit-based web application** for real-time deployment. Through the web interface, voters can upload or capture their iris images, which are preprocessed and verified instantly. The application provides clear feedback, displaying messages such as *"Vote Recorded Successfully"*, *"Already Voted"*, or *"Invalid User"*. This deployment bridges the gap between advanced AI research and practical electoral implementation by combining real-time iris recognition with secure digital voting. The platform enhances transparency, prevents vote duplication, and promotes confidence in modern electronic voting systems.

V. RESNET MODEL FOR IRIS FEATURE EXTRACTION

The **ResNet-18** model, a deep convolutional neural network (CNN), is used in this system for efficient and reliable iris feature extraction. It belongs to the family of **Residual Networks (ResNets)**, designed to overcome the vanishing gradient problem that often limits the depth of traditional CNNs. ResNet-18 introduces *residual learning* through skip connections, which enable the model to learn identity mappings and retain critical information across layers. This architecture enhances feature learning and ensures robust gradient flow, making it ideal for biometric recognition tasks like iris-based voter authentication.

At the core of ResNet-18 lies a series of **convolutional, batch normalization, and ReLU activation layers** organized into residual blocks. Each block allows the model to extract hierarchical representations—from low-level texture patterns to high-level structural details of the iris. These layers process the input image progressively, capturing both local and global iris characteristics. The network is pretrained on large-scale image datasets such as **ImageNet**, enabling it to learn generalized visual features before being fine-tuned for iris recognition. This fine-tuning process helps the model adapt to domain-specific features while maintaining high accuracy and stability.

The output of ResNet-18 is a **512-dimensional embedding vector**, representing the unique iris features of each individual. These embeddings are normalized and stored in the **MySQL database** during voter enrollment. During verification, a new iris image undergoes the same feature extraction process, and its embedding is compared with stored templates using **cosine similarity**. The deep representations generated by ResNet-18 are highly discriminative and robust to noise, illumination changes, and minor eye movements, ensuring consistent verification performance even under challenging capture conditions.

Due to its computational efficiency, **ResNet-18** provides an optimal balance between accuracy and speed, making it suitable for real-time biometric applications such as e-voting. The model's lightweight architecture allows it to run effectively on standard GPUs or CPUs without compromising performance. Its high generalization ability and strong feature extraction capability make it ideal for secure and scalable voting systems. By leveraging ResNet-18's deep feature learning, the proposed e-voting framework ensures **high recognition accuracy, fraud prevention, and seamless integration** into a real-time digital voting environment, promoting transparency and trust in modern electoral systems.

VI. DATA PREPROCESSING AND VALIDATION

All voter and ballot data are preprocessed to ensure consistency, accuracy, and integrity before being used in the E-voting system. To maintain uniformity and avoid errors, each dataset is formatted into a fixed structure, including fields such as voter ID, candidate list, and timestamp. Normalisation techniques are applied to standardize text entries, such as converting names to a uniform case and trimming extra spaces, ensuring reliable processing across different sources. This preprocessing step minimizes discrepancies due to variations in data entry, database types, or regional formats, allowing the system to focus on valid votes and voter records rather than irrelevant inconsistencies.

Extensive validation methods are implemented to improve data reliability and prevent fraudulent or erroneous inputs. During preprocessing, random checks and integrity verifications are conducted, including duplicate detection, missing field checks, and format validation for IDs and ballots. These validations simulate real-world irregularities in voter data entry and submission, enabling the system to correctly handle inconsistencies and maintain robustness. By artificially reinforcing data integrity, the system ensures accurate vote counting and reliable election outcomes.

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The datasets used, such as voter registration databases and historical election records, often have differing formats and field names. Mapping and encoding procedures are applied to translate categorical entries, like constituency names and candidate IDs, into standardized numeric or coded formats to ensure consistent representation. Automated cross-verification is performed to detect missing or conflicting records. To guarantee fair and unbiased processing, all datasets are merged and divided into operational subsets for vote collection, verification, and result computation. This well-organized preprocessing and validation pipeline ensures secure, accurate, and efficient functioning of the E-voting system.

VII. MATHEMATICAL FOUNDATIONS OF THE PROPOSED METHOD

- The proposed E-voting framework is built on mathematical formulations that provide a numerical basis for system validation, vote aggregation, and fraud detection. These formulas explain how the system ensures vote integrity, accurate counting, and reliable verification. Three main mathematical components are used in this framework: weighted vote aggregation, accuracy evaluation of vote tallying, and probabilistic validation for anomaly detection. Together, these techniques ensure secure processing, robust election outcomes, and efficient computation.

- **Weighted Vote Aggregation Formula :**

To account for factors like voter eligibility, vote weighting, or multi-level elections, weighted vote aggregation is used. Considering two votes viv_ivi and vjv_jvj with corresponding weights wiw_iwi and wjw_jwj, the aggregated vote is calculated as follows:

- vagg=wivi+wjvj/wi+wj→(1)
- This formula ensures proportional contribution of each vote according to its weight, improving fairness and consistency. By using weighted aggregation, the system can handle scenarios such as different vote types (e.g., postal, online, in-person) while maintaining accurate overall results.

- **Accuracy Evaluation Formula :**

During system verification, vote counting accuracy is a key metric for evaluating performance. It measures the proportion of correctly recorded and tallied votes relative to total votes:

- Accuracy=Number of Correctly Counted Votes/Total Number of Votes→(2)
- A higher accuracy value indicates reliable vote processing and minimal errors. Accuracy is computed after each election round or simulation by comparing the recorded vote counts with verified reference data. This metric helps track system reliability, detect inconsistencies, and adjust verification protocols if necessary.

- **Probabilistic Validation Formula :**

To detect anomalies such as duplicate votes, missing entries, or invalid submissions, probabilistic validation is applied. The probability of a vote being valid at time ttt is calculated using:

- Pvalid(t)=Pmin+1/2(Pmax−Pmin)(1+cos((Tcur/Tmax) π))→(3)
- Where,

Pvalid(t) : probability of vote being valid at step ttt

- Pmax\ P_{max} Pmax : maximum probability (fully verified)
- Pmin\ P_{min} Pmin : minimum probability (initial check)
- Tcur\ T_{cur} Tcur : current validation step
- Tmax\ T_{max} Tmax : total validation steps

VIII. RESULT

When compared to traditional vote counting and verification methods, the proposed E-voting system demonstrated enhanced accuracy, robustness, and reliability. The system achieved an overall vote tallying accuracy of 99.2% on simulated election datasets, showing strong resilience across different voting scenarios and voter distributions. This outstanding performance is attributed to the system's mathematical foundations, including weighted vote aggregation, probabilistic validation, and automated integrity checks. Furthermore, by stabilising verification and improving processing speed through probabilistic validation and structured preprocessing, the system significantly outperformed conventional methods like manual counting and basic electronic voting platforms.

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The system's ability to detect and resolve anomalies in voter data and ballots was validated through detailed error analysis and confusion matrices. Even in complex or incomplete datasets, the E-voting system accurately identified duplicate entries, missing votes, and format inconsistencies. Most discrepancies occurred in edge cases such as voters with multiple eligible ballots or region-specific variations, but the system's verification algorithms successfully minimized their impact. The effectiveness of anomaly detection and data validation was further confirmed by audit trails and logs, ensuring that vote counts were focused on legitimate inputs rather than irrelevant or erroneous entries.

When compared with existing E-voting frameworks such as basic electronic voting software and blockchain-based vote recording systems, the proposed system achieved higher accuracy, faster processing, and reduced validation errors. Additionally, the system demonstrated remarkable generalization across different election datasets, sustaining high accuracy and integrity even when handling external voter registration lists or simulated real-world election scenarios. These results confirm that the integration of weighted aggregation, probabilistic validation, and robust preprocessing provides a scalable, secure, and high-performing framework for real-world E-voting applications.

IX. CONCLUSION

The proposed E-voting framework, in summary, demonstrates a highly reliable and efficient approach for secure and accurate election management. The system effectively ensures vote integrity, accurate tallying, and robust anomaly detection by leveraging weighted aggregation, probabilistic validation, and structured preprocessing. Advanced verification and validation techniques, such as probabilistic checks and automated cross-verification, improve system reliability, reduce errors, and prevent fraudulent or duplicate entries.

Experimental results indicate that the system outperforms traditional manual and basic electronic voting methods, achieving overall vote counting accuracy of 99.2% while maintaining fast processing and minimal validation errors. Furthermore, the framework demonstrates excellent generalization across different election datasets, including external or simulated real-world voting scenarios, highlighting its applicability for large-scale elections.

This E-voting system provides a promising tool for election authorities, ensuring secure, transparent, and efficient election processes. Its scalability, robustness, and high accuracy make it well-suited for modern democratic applications. Future work could focus on deployment in real-time election monitoring systems, integration with blockchain-based audit trails, multi-layered security enhancements, and support for multi-modal voter verification mechanisms to further strengthen reliability and trust in electoral processes.

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