

“Biometric Authentication Techniques: A Review of Face, Palm, and Voice Recognition with Machine Learning Approaches”

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Abstract— This review represent the significance of bio-metric authentication using face, palm, and voice which has become increasingly important as digital systems need reliable and robust security. Each and every method has its own ben-efits, face recognition allows fast and contactless verification, palm authentication uses unique patterns on the epidermis of palm to authenticate the user and voice recognition uses voice frequency and amplitude to authenticate. Using Deep learning and Machine Learning made these methods more accurate and robust by improving recognition of features and deal with external environmental factors like light, noise, etc.

I. INTRODUCTION

In this review, we have studied the different ways of how user authenticate their identity in modern technology to protect there identity. Traditional methods like passwords, PINs, and security tokens are very common authentication methods, but they have some concerns such as being stolen, forgotten, reused, or hacked. Because of these issues, the biometrics is used to identify people based on their unique physical or behavioral traits.

We studied this types of biometric systems: face, palm, and voice recognition. These are suitable because they don't require physical interaction and are secure and reliable. Face recognition is widely used in smartphones, access control terminal and security cameras because it is easy and fast. Palm recognition is good because it has detailed and consistent features, making it hard to replicate and is useful for higher security. Voice recognition is useful for people who need to authenticate themselves from a distance.

As we studied these systems, we saw that each has its own advantages and disadvantages. Face recognition might not work well in bad lighting or if subject is partially covering their face. Palm recognition systems need the correct hand position, and Voice recognition can cause errors due to background noise or changes in the way someone speaks.

II. CATEGORIZATION

A. Face Recognition Module

Face recognition is one of the most commonly used ways to identify people using their faces because it is easy and fast. The process detects the face position and

alignment, extracting important features and then compare it with the known data. In traditional verification methods people used Viola-Jones with Haar cascades [10][14], which completely depends on manually created attributes. These past methods worked correctly when the lighting was good but had problems with different angles and when any part of the face was covered.

Afterward, the accuracy and quality were improved using Machine learning techniques such as PCA, SVM and eigenfaces [11][12][16]. The conversion of statistical methods to deep learning was the next step. The early neural network-based detectors by Rowley et al was using CNNs for face detection, which worked better in different situations [15]. Latest methods were using depth-based features with SVM to make face recognition more reliable and robust in difficult conditions [18].

B. Palm Recognition Module

Palm based authentication uses features like hand-shape, veins and palm prints, making it a reliable biometric recognition method. These features on the palm remain unchanged over longer duration and give indepth information through fetures like ridges and line on the palm. Previous methods for palm authentication used manual methods like finding fetures like lines within ridges, measuring local changes, and detecting edges, which worked for controlled environments [5][7].

Newer methods made palm authentication work without physically interacting with the system, allowing real time authentication using computer vision libraries such as OpenCV, MediaPipe and optical flow tracking [1][3][9]. These systems made the process easier, secure and faster for users. Systems that are implemented using gestures and methods like Histogram of Oriented Gradients, SVM, and augmentation have also made palm authentication useful for real-time uses [2][6].

Recent research has looked into detecting palm veins, using deep learning and methods that extract specific features to improve security against fake images [4]. For forensic and highly secure areas, advanced CNN models and texture-based techniques like BSIF and CLAHE have shown better performance even in different lighting conditions [8].

C. Voice Recognition Module

Voice recognition is a type of biometric method that uses speech patterns to identify people. Older methods used techniques like HMMs, FFT-based features, LPC, and MFCCs [19][25][27]. Among these, MFCCs became the most common because they closely match how humans hear and process sound frequencies.

As more data and uses for voice recognition grew, machine learning and deep learning became important tools. Studies show that CNNs, RNNs, and mixed machine learning-deep learning systems greatly improved the ability to distinguish voices and made systems better at handling background noise [20][26]. GMMs were also useful in early voice recognition systems for understanding how speakers' voices vary [24].

Today, voice recognition is used in real-time applications. Voice recognition is also used in education and assistive technologies, showing its wide range of uses through methods like Hidden Markov Model and machine learning [23].

III. LITERATURE SURVEY

A. Background

Biometric authentication has changed and updated a lot in recent years because there is a need for safe, touch-free, and easy ways to verify someone's identity. Traditional methods like passwords and PINs can be stolen, hacked or made mistakes, so people are now using biometric methods like face, palm, and voice recognition for better security.

B. Evolution of Face Recognition

Face recognition started with manually created methods like PCA, Eigenfaces, and Linear Discriminant Analysis. However, these methods had errors while handling changes in lighting, different angles, etc. Older methods for detecting faces in computer vision, such as the Viola-Jones algorithm, used Haar-like features and Adaboost classifiers [10][14].

Later, machine learning techniques like PCA, neural networks, and SVMs improved overall accuracy of face recognition in adverse situations [11][12][16]. Deep learning contributed in the advancement of this further—Rowley and others introduced CNN-based face detection, which was superior at capturing and evaluating complex facial features [15]. Other advancements, such as HOG-LBP with depth data [18] and Machine Learning based systems for monitoring during online exams [17], displayed how modern face authentication methods became more reliable and robust in real-world conditions.

C. Evolution of Palm Recognition

Palm biometric features are strong because they have unique patterns like palmprints, lines within ridges, shapes and edges that remains same over longer duration. Older methods of palm detection used lines within ridges

identification and measured local changes to find important parts of the palm [5], while other methods focused on finding edges and selecting important sections of the palm [7].

Palm recognition systems started using libraries like MediaPipe for tracking, augmentation and optical flow (Lucas–Kanade) to authenticate palm in real time [1][3][9]. Using features like SVM, Histogram of Oriented Gradients(HOG) and machine learning paved a way to implement palm biometric into applications [2][6].

More developed systems now use vein detection to find detailed patterns in the veins, which makes it difficult to replicate and increase reliability [4]. Research also looks into using deep learning and other methods to study palms under different environmental conditions [8].

D. Evolution of Voice Recognition

Voice recognition initially started with traditional methods like Fast Fourier Transform, Linear Predictive Coding, and MFCC (Mel-Frequency Cepstral Coefficients) features to learn, understand or recognize speech patterns and frequency [19][25][27]. These features were used in older speech recognition systems that dependent on Hidden Markov Models (HMM) and Gaussian Mixture Models (GMM) [19][24].

But old models face issues like background noise, different sound channels, and multiple languages. So, research moved towards using Machine Learning and Deep Learning techniques. This research shows that CNNs, RNNs, and mixed ML/DL models improved the accuracy of speaker identification [20][26].

In real-life situations, these voice biometrics became part of IoT devices. This showed how voice recognition is used in smart homes and automation systems [21].

E. Summary of Literature Findings

Recent studies shows progress in biometric authentication methods like face, palm, and voice recognition. These techniques later shifts from traditional authentication to more advanced deep learning methods. For face recognition, the method has shifted from using PCA and Eigenfaces to powerful neural networks, these new systems increases accuracy in real-world situations. Palm recognition has improved by making changes in methods that depends on lines within ridges and edges to more advanced techniques like contactless tracking, analyzing gestures, and also uses Artificial Intelligence to extract palm veins for accuracy, reliability and robustness. Similarly, Voice recognition changed from traditional models like MFCC plus GMM or HMM with newer models like CNNs, RNNs with simple deep learning structures that still performs accurately even when there is background noise.

IV. CONCLUSIONS

The review of biometric authentication shows how traditional methods was consistently converted into more

TABLE I
OVERVIEW OF BIOMETRIC SYSTEMS

Modality	Literature Insights	Relevance
Face	From PCA/LBP methods to CNN-based models handling pose, illumination, and occlusion.	Contactless and highly discriminative; serves as a strong primary biometric trait enhancing system accuracy.
Palm	From line and texture analysis to contactless palmprint and palm-vein deep learning models.	Provides stable geometric and vein features; offers strong anti-spoofing and supports multimodal fusion.
Voice	From MFCC with GMM/HMM to CNN and RNN-based speaker recognition models robust to noise.	Behavioral biometric; enables hands-free and remote authentication, complementing physical traits.

advanced deep-learning techniques that improved accuracy, security, speed, robustness and reliability. Face, palm, and Voice biometrics are overall improved by feature extraction and more efficient processing steps makes authentication effective in real-world scenarios.

Even with problems like environmental changes, noise, and fake attempts this ongoing research improves biometric authentication systems with better and efficient algorithms, improved sensing methods, and stronger security. Overall, biometric authentication is a strong and growing security method.

APPENDIX

This review dives into the importance of using face, hand, and voice for authentication by exploring many research papers from big journals and conferences. These research papers cover previous techniques that used features, new methods using deep learning, Machine Learning, and ways to verify and authenticate different categories of biometric data. Each paper was sorted by the category of biometric data used, to identify how it is added to pre-existing knowledge, and compared based on how accurate, reliable, and useful it is. This organized way of looking at the research helps explain how biometric authentication has evolved over time and display what new directions are becoming attractive for future systems.

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