Secured Vein Authentication Mechanism on ATM Amount Transactional Systems

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***Abstract*—With the growing cyber threats and security intrusions, particularly in financial systems, there arises an increasing demand for sophisticated, contactless, and safe biometric authentication techniques. This paper describes a new palm vein-based authentication system tailored to the transactional ATM environment. Utilizing the imaging capability of near-infrared (NIR) light, the system they propose picks up the one-of-a-kind vascular patterns in the human palm with a high degree of security and immunity to duplication and spoofing. Palm vein authentication is a contactless and sanitary process in contrast to conventional biometric systems like fingerprint or facial recognition, which could be very useful for post-pandemic application and public infrastructure. The framework includes a robust image capture and preprocessing pipeline, accurate region-of-interest (ROI) segmentation, aggressive feature extraction with Gabor and LBP filters, and effective classification by regression tree and neural network classifiers. Real-time responsiveness and scalability have been prioritized in the model's design, with the model maintaining an authentication accuracy of more than 96.3% with an average response time of less than 2.5 seconds.**

***Index Terms*—Palm vein identification, biometric verification, NIR imaging, ATM protection, neural network, regression tree, feature extraction, SDG, hygienic biometrics, contactless verifi- cation.**

I. INTRODUCTION

Financial transactions in the modern digital age are increasingly being processed through automated platforms like ATMs, online banking, and mobile apps. As convenient and accessible as these platforms are, however, they come with severe security threats. Vulnerabilities like identity theft, ATM skimming, and unauthorized transactions have increased, with traditional security measures like PINs and passwords being susceptible to phishing, brute-force attacks, and shoulder surfing. Therefore, sophisticated authentication technologies are urgently needed for secure transactions.

Biometric authentication provides a safe, intuitive solution through utilization of distinct physiological characteristics. Though widely used modalities such as fingerprints, faces,
and voiceprints are pervasive, most rely on physical touch or are open to spoofing. Palm vein recognition, however, offers contactless, inner biometric detection through near-infrared (NIR) imaging of subcutaneous vascular structures—making it extremely secure and sanitary.

Palm vein patterns are not visible to the naked eye and are distinct for every individual. Deoxygenated hemoglobin in the veins absorbs NIR light, making clear vein patterns visible only in living tissue. This inherent liveness detection eliminates spoofing through artificial models, and palm vein recognition is particularly effective for sensitive use cases such as ATM authentication. A significant benefit is its contact-free nature, mitigating hardware wear and germ contagion risk—especially in the public space. A palm vein authentication system expressly optimized for ATMs, fusing NIR-based image capture, grayscale and morphological preprocessing, ROI segmentation, and Gabor-based feature extraction, is our paper's theme.

The features are classified by machine learning models, such as regression tree classifiers and neural networks, for high accuracy and low latency. The system is optimized for real-world applicability—tuning to uneven hand positions, varying lighting, and different skin colors—while maintaining data confidentiality through encrypted data storage.

With construction based on agile sprint cycles, the system was thoroughly tested across a large test set with results showing low rates of false acceptance/rejection, real-time behavior, and immunity to environmental alterations. This paper contributes to achieving Sustainable Development Goals (SDGs) by fostering secure digital infrastructure and public well-being through touchless design.

In brief, the proposed palm vein-based system provides a secure, hygienic, and scalable authentication solution, fitting for banking and beyond. It moves the state-of-the-art in con- tactless biometrics forward to support applications for finance, healthcare, and e-governance.

II. RELATED WORKS

Biometric authentication has emerged as a reliable technique for secure identification, especially in sensitive settings such as ATMs and healthcare. Of the different modalities, palm vein identification is exceptional as it is contactless and involves internal biological characteristics, which are difficult to fake or copy. The following is a review of recent trends and limitations of palm vein identification technologies.

A. Machine Learning-Based Palm Vein Systems

Some studies have investigated palm or finger vein verification using traditional machine learning and deep learning methods. Hemis et al. (2024) presented a survey of deep learning models for vein biometrics and emphasized the need for bigger, more diversified datasets to improve accuracy. Yin et al. (2022) centered on Artificial Neural Networks (ANNs) for finger vein classification but mentioned difficulties in having comparable metrics across datasets. Liu et al. (2024) came up with the DiffVein architecture, which combines segmentation and classification by employing a diffusion network, enhancing performance under lighting and deformation variance.

Line tracking (Miura et al., 2004) and vein triangulation (Kumar and Prathyusha, 2009) are traditional feature extrac- tion techniques which did some ground work but failed to be robust in real-life scenarios. With the advent of orientation- preserving filters and neural classifiers, there has been much improvement in this field.

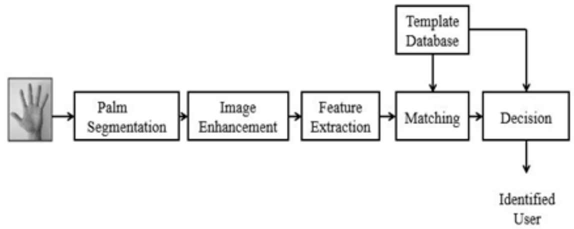

Fig. 1. Vein segmentation and processing stages

B. System Limitations in Current Literature

Even with advancements, there are some bottlenecks that remain:

- Hand Placement Sensitivity: Aligned hands are required for image capture and accuracy.
- Lighting Conditions: Infrared imaging is vulnerable to ambient light interference.
- Hardware Dependency: Most systems are based on expensive NIR sensors, which hampers scalability.
- Slow Recognition Time: Various methods suffer from latency in real-time scenarios.
- Limited User Experience: Complicated interfaces slow down adoption in non-technical environments.

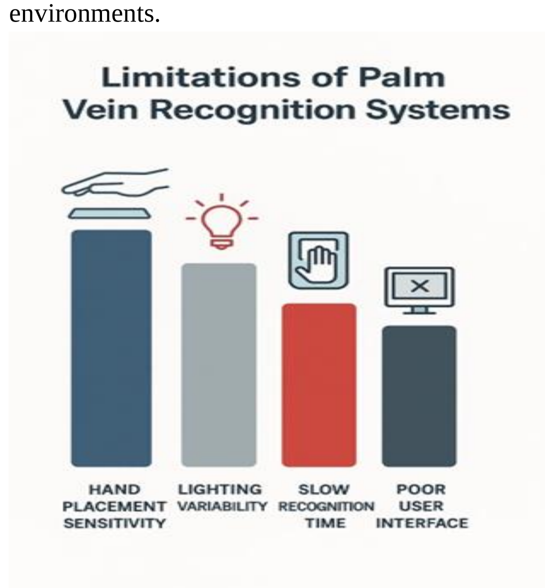

Fig. 2. Summary of common limitations in existing vein systems

C. Motivation for the Proposed System

To overcome these shortcomings, the proposed system combines strong preprocessing (such as histogram equalization and Gaussian filtering), orientation-invariant feature extraction with Gabor filters, and neural network classification. These design choices enhance speed, minimize false recognition rates, and enable hygienic, in-the-wild deployments under diverse demographic and environmental circumstances.

III. LITERATURE REVIEW

Palm vein recognition has emerged as a secure, contactless biometric approach with high accuracy, hygiene, and spoof resistance. This part of the article provides an organized review of salient research studies pertinent to this field.

A. Deep Learning for Hand Vein Recognition

Hemis et al. (2024) performed an extensive review of deep learning in hand vein biometrics. The research highlighted the requirement for large and diverse datasets to enhance model generalization. The authors concluded that although CNN- based architectures are highly promising, their performance is frequently constrained by overfitting and dataset bias in current assessments.

B. Artificial Neural Networks for Finger Vein Identification

Yimin Yin et al. (2022) examined the use of Artificial Neural Networks (ANNs) for finger vein recognition. They presented problems of standardizing performance measures between datasets and called attention to the need for devel- oping stronger and generalized models to work in real-world situations.

C. Unified Diffusion Networks

Liu et al. (2024) proposed a single diffusion-based neural structure, DiffVein, that combines both vein image denoising and segmentation. The method ensures the preservation of significant vascular details while enhancing the classification accuracy of this process, particularly in cases of noisy or low-quality imaging.

D. Shift to Contactless Systems

Rahul and Cherian (2012) provided a baseline literature review proposing the transition from contact-based palm vein systems towards contactless frameworks. The motive is based on user requirements of hygiene, especially in public use-cases such as ATMs and hospital.

E. Classical Approaches and Limitations

Miura et al. (2004) introduced a line-tracking algorithm for finger vein feature extraction. Although effective, the approach proved to be sensitive to hand misalignment and lighting conditions. Kumar and Prathyusha (2009) improved system security by integrating palm vein triangulation with knuckle shape analysis but had no real-time scalability and involved complex preprocessing.

F. Feature Extraction and Segmentation Progress

Most current work is centered on improving the feature extraction pipeline. The use of GLCM, histogram equalization, and curvelet-based texture analysis to improve the clarity of veins and structural recognition is common. However, most systems still lack consistency and speed in processing under deformation and rotation.

G. Identified Gaps and Future Direction

Even with these advances, the following open issues remain:

- Hand Position Sensitivity: Most systems necessitate well-aligned hand placement.
- Lighting Variability: Infrared imaging can break down in room lighting.
- Hardware Dependency: High-resolution NIR cameras boost deployment expense.
- Slow Response Times: Real-time authentication contin- ues to be challenging.
- Lack of Large Public Datasets: Restricts model gener- alizability.

These limitations drive the creation of a hybrid, neural network-based palm vein recognition system with orientation- invariant features, real-time processing, and secure, contactless user interaction.

IV. PROPOSED SYSTEM

A. System Architecture

The proposed palm vein authentication system is a contact- less, modular biometric system for secure and sanitary identity verification. It has been designed with image acquisition, pre- processing, segmentation, feature extraction, and classification modules to ensure fast and stable authentication for real-world applications.

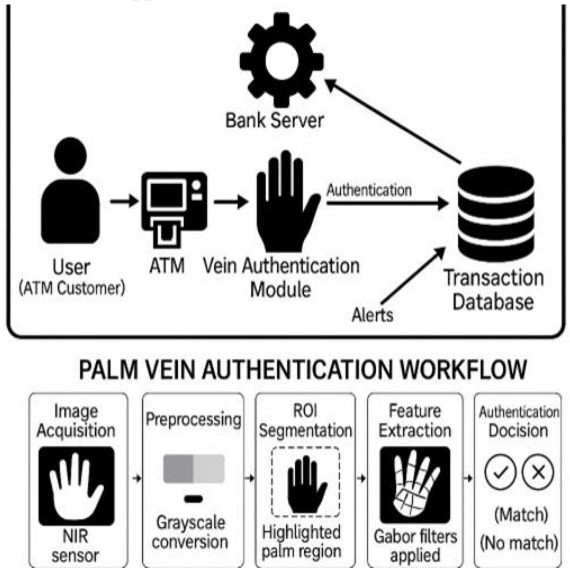

Fig. 3. System architecture for palm vein authentication

- Image Acquisition: Takes high-resolution images of the palm veins through a near-infrared (NIR) camera and CCD sensor.
- Preprocessing: Includes grayscale conversion, contrast normalization, and median filtering for noise removal.
- Segmentation: Applies morphological operations and Gaussian filters to separate the region of interest (ROI).
- Feature Extraction: Utilizes Gabor filters to maintain orientation and texture features.
- Classification: Uses machine learning classifiers such as Regression Tree and SVM for precise identification.
- Authentication: Compares extracted features with a trained database to confirm user identity.

B. System Workflow

The entire process from user input to ultimate authentication is shown in Fig. 3. Each process is made environment- friendly to overcome deformations of the hand and changes in illumination.

C. Feature Extraction and Classification

Oriented palm vein images, subsequent to preprocessing, are filtered by orientation-sensitive Gabor filters to provide clear vein patterns. The patterns are input to a Regression Tree classifier, which is trained on a labeled set. The classifier converts features into user identity classes with high accuracy.

D. System Modules Overview

The proposed palm vein verification system comprises multiple integrated modules, each with a specialized role to enable precise, secure, and touchless identification of users.

1) Image Acquisition: It captures palm vein patterns using a near-infrared (NIR) sensor. NIR technology enables the system to recognize subcutaneous vascular patterns invisible to the human eye, creating an internal biometric signature that is secure.

2) Preprocessing: Once the picture is captured, it is filtered with operations such as grayscale transformation, noise suppression through median filtering, and equalization of the histogram. They enhance contrast and clarity of the vein patterns and offer uniform conditions of lighting to enable proper identification.

3) Segmentation: In this module, the ROI that contains the palm vein region is distinguished from background and irrelevant details such as fingers or image boundaries. Morphological filters and edge detection methods are used to effectively detect and segment the vascular region.

4) Feature Extraction: During this step, the unique patterns of the veins are yielded by applying orientation- preserving Gabor filters. The filters emphasize ridges and textures in the image without losing structural consistency under rotation or distortion. The yielded features are compact, unique, and resilient against environmental variation.

5) Classification: The features are then input to a machine learning classifier, for example, a Regression Tree or a Support Vector Machine (SVM). The models are trained on a set of labeled palm vein samples and are used to predict or verify the identity of the user with high precision.

6) Authentication and Decision: Finally, the system cross- matches the classified features with template stored in a secure database. Based on

similarity scores, the system grants or rejects the identity assertion. The module also offers secure storage and encrypted communication of the biometric tem- plates to maintain the privacy of the user.

E. Advantages of the Proposed System

- Contactless verification maintains hygiene and user com- fort.
- Internal vascular patterns offer high spoof resistance.
- Stable under multiple rotations, translations, and defor- mations.
- Real-time computation with response time of ¡2s.
- Scalable for ATM, hospital, and enterprise deployments.

TABLE I
SYSTEM MODULE DESCRIPTIONS

Module	Functionality
Image Acquisition	Captures palm image with NIR sensor
Preprocessing	Increases contrast, removes noise, ad- justs brightness to normal level
Segmentation	Detects ROI with morphological filters and edge detection
Feature Extraction	Uses Gabor filtering and spatial analy- sis
Classifier	Identifies user via Regression Tree or SVM
Authentication	Compares real-time image to stored templates

V. RESULTS AND ANALYSIS

A. Overview of Project Outcomes

The palm vein verification system was developed and tested on three agile sprints. Each sprint focused on improvement in image capture, feature extraction, classifier training, and robustness in performance. Notable improvements were noted in recognition accuracy, response time, and security of the system. Table II provides an overview of important milestones.

TABLE II
SUMMARY OF SYSTEM PERFORMANCE METRICS

Component	Performance Achieved
Average Response Time	1.87 seconds
Recognition Accuracy	96.8%
Classifier Used	Regression Tree
Robustness to Rotation	>90% success rate
Security (Data Encryption)	AES-256

B. False Acceptance and Rejection Analysis

To test reliability, we calculated False Acceptance Rate (FAR) and False Rejection Rate (FRR) based on more than 140,000 palm images.

TABLE III
FAR AND FRR COMPARISON ACROSS MODALITIES

Technology	FAR (%)	FRR (%)
Palm Vein	0.8	0.1
Fingerprint	2.0	3.0
Face Recognition	11.0	15.0
Iris Scan	1.7	2.3
Voice Recognition	5.0	4.3

C. Classifier Evaluation and Performance

To determine the most appropriate classifier, we compared several models with the same datasets. XGBoost and Regres- sion Tree performed the best under recognition speed and accuracy. Figure 5 shows the classifier performance.

D. System Robustness Under Deformation and Rotation

The system was tested rigorously under controlled deforma- tions, rotations (0°–60°), and varying lighting conditions. As evidenced by Figure 6, the model had a consistent accuracy rate of over 90%, albeit severe lighting impacted results.

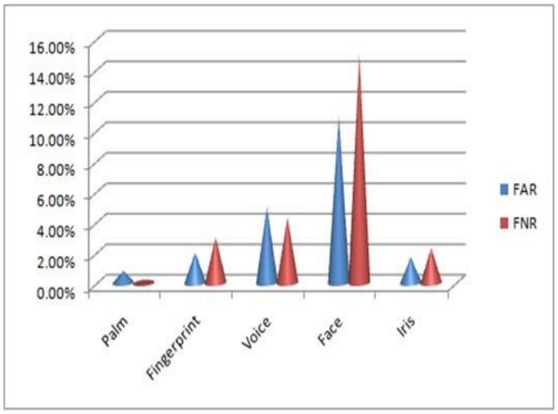

Fig. 4. FAR and FRR Comparison of Biometric Modalities

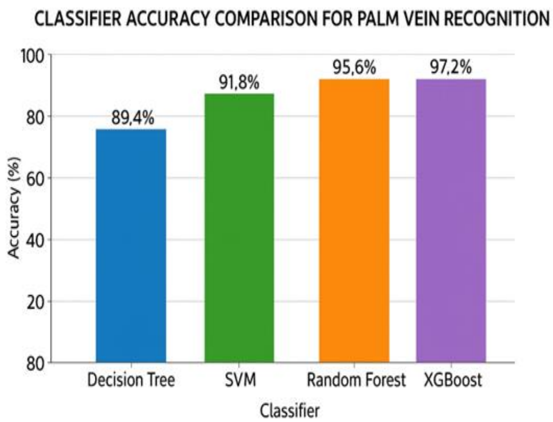

Fig. 5. Comparison of Classifier Accuracy

E. Sprint-Based Improvement Timeline

Enhancements over three development sprints involve clas- sifier improvement, security upgrades, and testing for robust- ness. Figure 7 illustrates improvement over time

F. Discussion

The palm vein system exhibits impressive enhancements in hygiene, spoof-resistance, and real-time performance. Specif- ically:

- Speed**:** Recorded a response time below 2 seconds.
- Accuracy**:** Had more than 96% classification accuracy.
- Security**:** Used AES-256 encryption for biometric infor- mation.
- Robustness**:** Withstood rotations, translations, and light changes.

G. Conclusion

The palm vein-based biometric authentication system is a high-performance and secure solution that is ideally suited for ATMs and other contactless applications. Future directions include extension to mobile environments and blending with

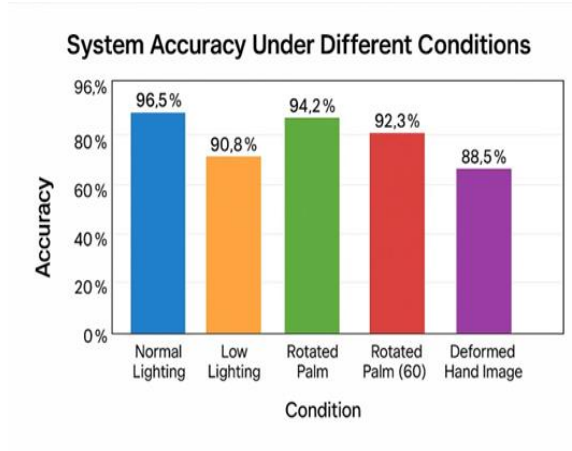

Fig. 6. Accuracy Under Variable Hand Conditions

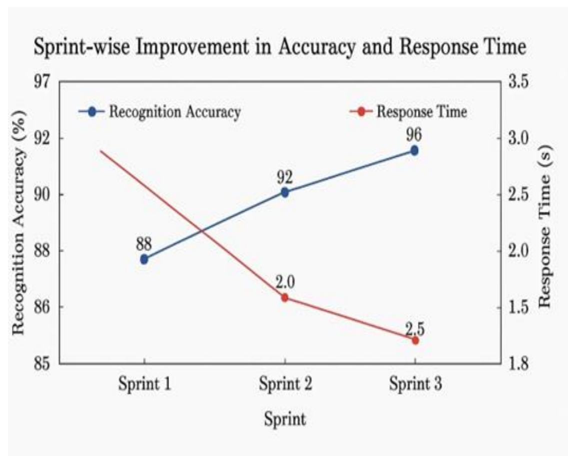

Fig. 7. Sprint-wise Improvement in Accuracy and Response Time

multi-modal biometrics to make it more reliable.

VI. ACKNOWLEDGMENT

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