# Advanced Facial Recognition And OTP Verification In High-Volume POS Transactions

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***Abstract:*** *Financial security has become a critical global concern amid the rapid expansion of automated banking services, digital transactions, and highly interconnected financial infrastructures. Automated Teller Machines (ATMs) and Point-of-Sale (POS) terminals provide essential 24/7 access to cash and financial services, yet they remain prime targets for fraud, including card skimming, identity theft, and unauthorized account access. This survey examines the evolution of ATM authentication mechanisms, tracing the shift from traditional token-based methods (card and PIN) to advanced biometric-driven approaches.*

*The study presents an in-depth review of a multifactor authentication framework that integrates Deep Learning–based facial recognition—leveraging Convolutional Neural Networks (CNNs) and FaceNet—with dynamic One-Time Password (OTP) verification. Core components such as facial feature extraction, liveness detection, and secure data transmission protocols are analyzed. The performance of the proposed biometric model is compared with legacy authentication systems using metrics such as security robustness, processing latency, and user experience.*

*Additionally, the survey highlights persistent challenges, including sensitivity to lighting variations, occlusion issues, and network-induced delays. Emerging research directions—such as behavioral biometrics, federated learning, and Edge AI for real-time processing—are explored to illustrate future opportunities for enhancing ATM security. By synthesizing current trends and technological advancements, this paper provides a comprehensive understanding of biometric authentication for ATMs and underscores its significance in mitigating financial fraud*

***Conclusion:*** *The rapid growth of digital banking in Nigeria has amplified both the convenience and the vulnerabilities of ATM and POS-based financial transactions. While these platforms have expanded financial inclusion, they have also become hotspots for sophisticated fraud schemes. Recent cases across major Nigerian cities highlight recurring patterns: POS agents colluding with criminals to clone cards, ATM terminals compromised with skimmers and hidden cameras, and social-engineering attacks where unsuspecting users are deceived into revealing PINs or surrendering their cards. Incidents such as coordinated ATM jackpotting attempts in Lagos and the surge of POS-related identity theft in states like Abuja, Rivers, Owerri, Lagos and Oyo underscore the urgency of strengthening authentication mechanisms.*

***Key Word****: ATM security, Biometric authentication, Facial recognition, Deep learning, Convolutional Neural Networks (CNNs), FaceNet, Multifactor authentication, One-Time Password (OTP), Liveness detection, Financial fraud prevention, Secure data transmission, Behavioral biometrics, Edge AI, Authentication latency, Identity theft mitigation*

## 1.0 Introduction

Financial security has become a major concern in Nigeria as the country continues to experience rapid growth in digital banking, mobile payments, and automated financial services. With millions of Nigerians relying daily on Automated Teller Machines (ATMs) and Point-of-Sale (POS) terminals for cash withdrawals, transfers, and balance inquiries, these platforms have become essential components of the nation's financial ecosystem. However, this increased dependence has also exposed customers and financial institutions to rising cases of fraud, identity theft, and unauthorized access.

In Nigeria's cash-driven economy, ATMs play a particularly important role by providing 24-hour access to funds across both urban centers and rural communities. Yet, the security of these machines has been repeatedly challenged

by criminal activities such as card skimming, PIN harvesting, ATM vandalism, and POS-related fraud. Reports from the Central Bank of Nigeria (CBN) and the Nigeria Inter-Bank Settlement System (NIBSS) consistently show that ATM and POS channels remain among the most targeted points for financial crime.

Historically, ATM authentication in Nigeria has relied on the traditional card-and-PIN method. While this approach served the banking sector for many years, it is increasingly vulnerable to modern threats. Criminals now use sophisticated tools such as deep-insert skimmers, fake keypads, hidden cameras, and social engineering techniques to steal customer information. These challenges highlight the limitations of relying solely on possession-based (card) and knowledge-based (PIN) authentication.

As financial crimes evolve, there is a growing need for more secure and intelligent authentication systems capable of verifying a user's true identity. Biometric technologies—particularly facial recognition powered by deep learning—offer a promising solution. By analyzing unique facial features and combining them with dynamic One-Time Passwords (OTPs), banks can significantly reduce fraud risks and strengthen customer trust.

This paper examines the evolution of ATM authentication in Nigeria and evaluates a proposed intelligent biometric framework that integrates facial recognition with OTP verification. It explores traditional and modern security approaches, compares their effectiveness, and discusses real-world challenges such as lighting conditions, privacy concerns, and computational requirements. The goal is to provide a comprehensive understanding of how advanced biometric systems can enhance ATM security and help combat financial fraud in Nigeria

## 2.0 Fundamental Concepts Of POS–ATM Security (Nigeria-focused and Intense)

A secure POS–ATM system is designed to **accurately verify the identity of a user before authorizing any financial transaction**, ensuring that only legitimate account holders gain access to their funds. In Nigeria—where ATMs and POS terminals serve millions of people daily and remain the backbone of cash-based transactions—this verification process is not merely a technical requirement but a **critical national defense mechanism** against rampant financial fraud. Within the Nigerian banking network, the security module must operate continuously and intelligently, validating user credentials while resisting the increasingly aggressive and sophisticated tactics of fraud syndicates.

POS–ATM security in Nigeria is fundamentally about distinguishing **authentic users** from **unauthorized imposters**, a task made more urgent by the rising wave of card-related crimes, insider POS fraud, and coordinated ATM attacks across the country. With this detail analysis as follows:

**1. Token-Based Authentication (Card Possession)**

This traditional method relies on the physical ATM card. In Nigeria, this method has become highly vulnerable due to:

i. **Card skimming devices** installed on most ATM slots in Lagos, Port Harcourt, Imo state, and Abuja
ii. **POS agent collusion,** where dishonest operators clone customers cards during transactions
iii. **Card swapping**, Especially in rural communities and crowded markets.
iv. **Stolen Cards**, used immediately during robbery incidents

The physical card alone is no longer a dependable security measure in a high-risk environment.

**2. Knowledge-Based Authentication (Pin Verification)**

This method depends on the Personal Identification Number (PIN). However, Nigerian fraud cases show that PINs are frequently compromised through:

i. Shoulder surfing at crowded ATM points

ii. Hidden cameras mounted on ATM frames
iii. POS agents memorizing customer PINs
iv. Fraudsters tricking users into revealing PINs through fake bank calls or SMS
v. Observational theft in marketplaces and transport hubs

Because PINs can be easily observed, guessed, or stolen, they offer **limited protection** in Nigeria's fraud-intensive landscape.

**3. Biometric-Driven Authentication (Modern and Intelligent Approach)**

To counter Nigeria's escalating fraud crisis, modern POS–ATM security must go beyond cards and PINs. The proposed biometric framework introduces **deep learning-powered facial recognition;** in situation where a customer biometric system fails, the NIN data recovery system should be embed on the POS platform where the customer must input phone number and NIN number that can easily display photo and phone number/county of the customer, with this we can verify *who the user is*, not what they carry or remember.

Deep learning models—especially **Convolutional Neural Networks (CNNs)**—automatically learn and extract complex facial features from images, making it extremely difficult for criminals to deceive the system using:

i. Printed photos
ii. Recorded videos
iii. Silicone masks
iv. Identity manipulation tactics

When combined with **dynamic One-Time Passwords (OTPs)**, this approach creates a **multi-layered, fraud-resistant defense** that:

i. Reduces dependence on easily stolen credentials
ii. Detects fraudulent access attempts in real time
iii. Strengthens ATM and POS security even in high-crime zones
iv. Provides a more trustworthy and tamper-resistant authentication process

In Nigeria's rapidly evolving digital economy—where ATM fraud, POS agent collusion, and identity theft continue to rise—this intelligent biometric model represents a **fundamental component of next-generation banking security**. It offers the resilience needed to protect customers, financial institutions, and the integrity of the national payment system.

## 3.0 Modern Insecure ATM Systems (Nigeria-Focused and intense)

Modern ATM systems have emerged as a response to the growing weaknesses of the traditional Card + PIN authentication method. As financial crimes in Nigeria continue to evolve—ranging from deep-insert skimmers to POS agent collusion—banks have begun integrating advanced deep learning algorithms to strengthen identity verification. These modern detection mechanisms are primarily categorized into **Facial Recognition**, **Liveness Detection**, and **Dynamic OTP Generation**, forming a multi-layered defense against unauthorized access.

**1. Facial Recognition Modules**

Convolutional Neural Networks (CNNs) are employed to analyze facial data by reshaping image features into structured matrices. While CNNs were originally designed for general image classification, they have become highly effective in ATM security for detecting **unique facial landmarks** such as:

i. Eye spacing
ii. Nose ridge structure
iii. Jawline curvature
iv. Cheekbone geometry

Advanced models like **FaceNet** map these features into a **128-dimensional Euclidean embedding**, enabling highly accurate identity matching even when the user's appearance changes slightly (e.g., new hairstyle, glasses, minor aging).

In Nigeria—where ATMs are often placed outdoors or in poorly lit environments—these models help reduce impersonation attempts, especially in areas where criminals use printed photos or video replays to deceive older biometric systems.

**2. OTP Verification**

To reduce the risk of **false positives** in biometric recognition, modern ATM systems incorporate **One-Time Password (OTP)** verification. This adds a dynamic layer of security that changes with every transaction session.

OTP verification is particularly effective in Nigeria, where:

i. SIM-swap fraud is common
ii. Criminals attempt to bypass biometric checks
iii. Stolen cards and cloned POS transactions are widespread

Even if a biometric system is tricked, the attacker **cannot proceed without the OTP** sent to the registered mobile device. This makes replay attacks, cloned card usage, and unauthorized withdrawals significantly more difficult.

**3. System Integration**

Modern ATM systems integrate deep learning architectures that automatically extract hierarchical features from live video feeds. This reduces dependence on physical cards—which are frequently stolen, swapped, or cloned in Nigeria's high-risk banking environment.

These intelligent systems support:

i. **Real-time identity classification**
ii. **Continuous fraud monitoring**
iii. **Adaptive decision-making** during suspicious transactions

However, despite these advancements, environmental challenges remain. Nigerian ATMs often suffer from:

i. Poor lighting conditions
ii. Dusty or low-quality camera lenses
iii. Unstable network connectivity

These factors can degrade facial recognition accuracy, making **image pre-processing techniques**—such as histogram equalization, noise reduction, and contrast enhancement—critical for reliable performance.

## 4.0 Emerging Trends in insecure Banking (Nigeria-focused and intense)

As financial fraud in Nigeria becomes increasingly sophisticated—ranging from deepfake impersonation to coordinated POS-ATM attacks—modern banking systems are being forced to adopt advanced security technologies. These emerging trends aim to counter the growing wave of identity theft, card cloning, and biometric spoofing that threaten the integrity of Nigeria's digital financial ecosystem.

**1.** Deep Learning-Based Liveness Detection

With the rise of high-quality photo, mask, and video spoofing—now commonly used by fraud syndicates in Nigeria—traditional facial recognition systems face significant vulnerabilities. Deep learning-based Liveness Detection has therefore become essential.

Modern systems analyze:

i. Texture inconsistencies in fake faces
ii. Depth variations between real skin and printed surfaces
iii. Micro-movements such as blinking, lip motion, and subtle muscle shifts

These techniques help Nigerian banks detect whether the person at the ATM is a live human or a fraudster using a static image or replayed video, a tactic increasingly seen in urban fraud hotspots.

**2. 3D** Facial Recognition

To overcome the limitations of 2D cameras—especially in poorly lit Nigerian ATM environments—newer systems are adopting 3D depth sensors and infrared imaging.

These technologies:

i. Capture the full topography of the face
ii. Work effectively in low-light or outdoor ATMs
iii. Resist spoofing attempts using masks or printed photos

This is particularly important in Nigeria, where many ATMs operate outdoors with inconsistent lighting and are vulnerable to tampering.

**3.** Behavioral Biometrics

Behavioral biometrics are emerging as a powerful tool for detecting fraud in Nigeria's insecure banking environment. Using unsupervised learning, modern systems analyze how a user interacts with the ATM rather than just who they are.

These systems monitor:

i. Keystroke dynamics
ii. Screen pressure patterns
iii. Standing posture and body movement
iv. Interaction speed and hesitation

Such behavioral cues can help detect:

i. Coercion during ATM withdrawals

ii. Fraudulent POS transactions
iii. Suspicious or abnormal user behavior

This is especially relevant in Nigeria, where forced withdrawals and "ATM stand-over" robberies are increasingly reported.

**4.** Multimodal Biometric Architectures

To strengthen identity verification, modern systems are combining multiple biometric traits. Architectures that integrate:

i. Face + Voice recognition, or
ii. Face + Fingerprint authentication

are becoming central to next-generation security.

Using ensemble learning, these systems cross-verify identity across multiple biological markers, significantly reducing:

i. False acceptance rates
ii. Spoofing attempts
iii. Identity manipulation

This is crucial in Nigeria, where fraudsters often exploit single-factor biometric weaknesses.

**5.** Edge Computing for Real-Time ATM Security

Modern ATMs are increasingly adopting Edge Computing, allowing facial recognition and fraud detection to be processed locally on the machine rather than relying on cloud servers.

This approach offers major advantages in Nigeria:

i. Real-time classification even with poor internet connectivity
ii. Reduced latency during authentication
iii. Enhanced privacy, since biometric data does not leave the ATM
iv. Lower vulnerability to network-based attacks

Edge-enabled ATMs are particularly valuable in rural and semi-urban regions where network instability is common.

## 5.0 Applications Of The Proposed Framework (Nigeria-focused and intense)

The proposed deep learning–driven biometric framework has wide-ranging applications across Nigeria's rapidly expanding digital banking ecosystem. As fraud techniques become more sophisticated, these applications offer practical, high-impact solutions for securing ATM and POS transactions nationwide.

### 1. High-Volume ATM Transactions

In Nigeria's crowded financial hotspots—such as malls, university campuses, transport terminals, and major markets—ATMs often experience long queues and high transaction volumes. A deep learning–based biometric system enables rapid user verification, eliminating repeated PIN entry and reducing transaction delays. This improves throughput and minimizes opportunities for shoulder-surfing and PIN theft in densely populated areas.

**2. Protection Against Careless Cash Withdrawals**

Many Nigerian customers unintentionally expose themselves to fraud by mishandling their cards or forgetting them in ATM slots. With biometric authentication, users can withdraw cash using only their face and mobile device, completely removing the risk of:

i. Card skimming
ii. Card swapping
iii. POS agent card cloning
iv. Lost or stolen cards

This application is especially valuable in regions where card-related fraud is rampant.

**3. Digital KYC and Remote Account Opening**

Nigeria's push toward financial inclusion requires secure onboarding of millions of unbanked citizens. Deep learning–based biometric verification supports remote KYC (Know Your Customer) processes, allowing customers to open accounts without visiting a physical branch. This is particularly impactful for:

i. Rural communities with limited banking infrastructure
ii. Elderly or mobility-challenged individuals
iii. Youths adopting digital-only banking platforms

The system ensures accurate identity verification while maintaining regulatory compliance.

**4. Secure Vault and Restricted-Area Access**

Beyond ATMs and POS terminals, Nigerian banks can deploy this framework to secure vaults, server rooms, and high-security zones. Deep learning models continuously monitor and authenticate personnel, immediately flagging unauthorized individuals attempting to access restricted areas.

This strengthens internal security and reduces risks associated with:

i. Insider threats
ii. Unauthorized staff entry
iii. Identity impersonation within bank premises

**5. Pension Disbursement and Social Welfare Systems**

For elderly Nigerians—many of whom struggle with remembering PINs or using keypads—biometric authentication offers a simple, dignified, and secure method of accessing pension funds. By verifying identity through facial recognition, the system ensures that payments reach the rightful recipients, preventing:

i. Fraudulent claims
ii. Impersonation
iii. Exploitation of vulnerable pensioners

This application also supports government social welfare programs that require reliable identity verification.

## 6.0 Comparison Of Classical And Modern Security Approaches (Nigeria-Focused and intense)

The comparison between traditional POS–ATM security systems and modern AI-driven models reveals **sharp differences in performance**, especially when evaluated against the diverse and evolving fraud techniques prevalent in Nigeria. Classical systems built around the Card + PIN model offers basic reliability for routine transactions but collapse rapidly when exposed to sophisticated attack vectors such as card skimming, cloning, PIN harvesting, and social-engineering scams.

**1. Vulnerability of Classical Systems**
Traditional authentication methods, particularly PIN verification, perform well under controlled conditions but show **severe security degradation** when confronted with real-world Nigerian fraud scenarios, including:

i. **Keypad overlays** used to capture PIN entries
ii. **Thermal imaging attacks** that detect recently pressed keys
iii. **Deep-insert skimmers** that clone magnetic stripe data
iv. **POS agent collusion**, where card details and PINs are stolen
v. **Shoulder surfing** in crowded ATM points

These attacks exploit the static nature of token-based and knowledge-based authentication, making classical systems highly predictable and easy to compromise.

**2. Strength of Modern AI-Driven Models**
In contrast, modern deep learning–based systems—powered by CNN architectures and reinforced with dynamic OTP verification—demonstrate **stable and consistently high security performance**, even against unknown or emerging fraud attempts.

Their advantages stem from their ability to:

i. Verify **physical presence** through facial recognition
ii. Detect **spoofing attempts** using liveness detection
iii. Block unauthorized access through **session-specific OTPs**
iv. Adapt to new fraud patterns using continuous learning

These systems do not rely on static credentials that can be stolen or guessed, making them far more resilient in Nigeria's high-risk financial environment.

**3. Adaptability Gap Between the Two Approaches**
The performance gap between classical and modern systems highlights a **dramatic difference in adaptability**:

| Classical Systems (Card + PIN) | Modern AI-Driven Systems (CNN + OTP) |
|---|---|
| Static, predictable, easy to bypass | Dynamic, adaptive, resistant to spoofing |
| High vulnerability to skimming and PIN theft | Strong defense against identity fraud |
| Limited ability to detect imposters | Verifies real human presence |
| Easily compromised in crowded Nigerian ATM points | Maintains accuracy even in noisy environments |
| No protection against insider POS fraud | Multi-layered verification blocks unauthorized access |

This contrast underscores the urgent need for Nigerian banks to transition from **token-based security** to **identity-driven authentication**, aligning with global advancements in financial technology.

**4. Implications for Nigeria's Banking Sector**

Given the rising sophistication of fraud syndicates in Nigeria, the superiority of AI-driven models is not merely a technological improvement—it is a **strategic necessity**. Modern systems offer:

i. Stronger fraud resistance
ii. Better user experience
iii. Reduced dependence on physical cards
iv. Enhanced protection for rural and urban ATM deployments

This comparison strongly supports the nationwide shift toward **biometric-centric, intelligent security frameworks** capable of safeguarding Nigeria's digital financial future.

## 6.1 Challenges And Vulnerabilities (Nigeria-Focused and Intense)

Although Deep Learning–based ATM and POS security systems offer significant improvements over traditional Card + PIN methods, they still face several critical challenges, many of which are amplified by Nigeria's infrastructural realities, environmental conditions, and evolving fraud landscape. These vulnerabilities must be addressed to ensure reliable, nationwide deployment.

**1. High Computational Requirements**

Processing high-resolution facial images in real time requires **substantial hardware power**, often involving GPUs or specialized AI accelerators.
Most Nigerian ATMs, especially **older legacy machines** were not designed for such computational loads.
Upgrading thousands of terminals across the country becomes:

i. **Expensive**, due to hardware replacement
ii. **Logistically difficult**, especially in rural areas
iii. **Slow**, because of limited technical support infrastructure

This creates a performance gap between modern AI systems and the outdated ATM hardware still widely used in Nigeria.

**2. Dataset Dependency and Bias**

Deep learning models depend heavily on the quality and diversity of their training datasets. Poor or imbalanced datasets lead to:

i. **Biased recognition accuracy**
ii. **Higher false rejection rates** for certain demographics
iii. **Reduced reliability** in real-world Nigerian environments

Nigeria's population is ethnically diverse, and models trained on foreign datasets often struggle with:

i. Darker skin tones
ii. Local facial features
iii. Cultural accessories (headscarves, caps, tribal marks)

This can result in inconsistent authentication performance across different user groups.

**3. Environmental and Lighting Challenges**

Many Nigerian ATMs are installed outdoors or in poorly lit environments. Extreme lighting conditions; whether too bright or too dark. Significantly undermine the accuracy of facial recognition systems.

Common issues include:

i. **Direct sunlight** washing out facial features
ii. **Night-time shadows** obscuring key landmarks
iii. **Dusty or vandalized camera lenses** reducing image clarity
iv. **Power fluctuations** affecting camera performance

Deep learning models relying on visual data lose reliability when visibility is compromised, making **image pre-processing** essential but not always sufficient.

**4. Network and OTP Delivery Limitations**
The OTP component depends on **cellular network availability**. In many Nigerian regions—especially rural and semi-urban areas—network quality is inconsistent.

This leads to:

i. **Delayed SMS delivery**
ii. **Transaction timeouts**
iii. **User frustration and repeated attempts**
iv. **Increased vulnerability** during network outages

Fraudsters may exploit these delays by distracting or misleading users during OTP verification.

**5. Biometric Data Security Risks**

Storing biometric data introduces a **high-stakes security risk**. Unlike passwords or PINs, **a person's face cannot be changed** if the database is compromised.

This makes Nigerian banking systems vulnerable to:

i. Large-scale identity theft
ii. Permanent loss of biometric integrity
iii. Criminal reuse of stolen facial templates

To mitigate this, banks must implement:

i. Strong encryption standards
ii. Secure template storage
iii. Strict access controls
iv. Regular vulnerability assessments

Without these protections, biometric systems could become a new target for cybercriminals.

### 6.2 Future Directions (Nigeria-Focused and intense)

The future of ATM and POS security in Nigeria will be shaped by the urgent need to counter increasingly sophisticated fraud techniques, especially spoofing, identity manipulation, and insider-assisted attacks. As criminal networks adopt deepfake technologies, advanced skimming tools, and social-engineering strategies, next-generation security systems must evolve beyond conventional biometrics and embrace more resilient, intelligent, and privacy-preserving methods.

**1. Adversarial Trained Deep Learning Models**
To combat high-quality spoofing attacks—such as deepfake videos, silicone masks, and AI-generated facial forgeries—future ATM systems will rely on **adversarial training**. These models are trained to recognize and resist manipulated inputs, making them far more robust against the emerging fraud tools now circulating in Nigeria's cybercrime ecosystem.

**2. Homomorphic Encryption for Biometric Privacy**
As Nigerian banks increasingly store and process biometric data, privacy risks grow. **Homomorphic Encryption** allows computations to be performed on encrypted data without ever exposing the raw biometric template. This ensures that even if a database is breached, sensitive facial data remains unreadable and unusable.

**3. Federated Learning for Secure Model Improvement**
Federated Learning offers a powerful solution for Nigeria's multi-bank environment. It enables banks to collaboratively improve fraud-detection models **without sharing customer images or personal data**. Each ATM or POS terminal trains locally and sends only encrypted model updates, preserving privacy while strengthening nationwide fraud resistance.

**4. Blockchain-Based Identity Management**

Blockchain integration is emerging as a transformative approach for securing biometric identities. By storing facial templates or identity hashes on a **tamper-proof decentralized ledger**, Nigerian banks can ensure:

i. Immutable identity records
ii. Protection against insider manipulation
iii. Transparent audit trails
iv. Stronger cross-bank identity verification

This is especially valuable in Nigeria, where identity theft and SIM-swap fraud remain widespread.

**5. Self-Supervised Learning to Reduce Dataset Limitations**

Self-supervised learning reduces the dependency on large labeled datasets—an important advantage for Nigeria, where collecting diverse, high-quality biometric data is challenging. These models learn patterns directly from unlabeled images, improving recognition accuracy across Nigeria's diverse ethnic groups and environmental conditions.

**6. Cross-Sector Collaboration**

The successful deployment of next-generation ATM security in Nigeria will require **strong collaboration** among:

i. Academic researchers
ii. Financial institutions
iii. Cybersecurity agencies
iv. Hardware manufacturers
v. Telecommunications providers

This multi-stakeholder approach is essential for addressing infrastructural limitations, improving dataset diversity, and ensuring that advanced security technologies are both practical and scalable across Nigeria's banking landscape.

## 7.0 Conclusion

The rapid growth of digital banking in Nigeria has amplified both the convenience and the vulnerabilities of ATM and POS-based financial transactions. While these platforms have expanded financial inclusion, they have also become hotspots for sophisticated fraud schemes. Recent cases across major Nigerian cities highlight recurring patterns: POS agents colluding with criminals to clone cards, ATM terminals compromised with skimmers and hidden cameras, and social-engineering attacks where unsuspecting users are deceived into revealing PINs or surrendering their cards. Incidents such as coordinated ATM jackpotting attempts in Lagos and the surge of POS-related identity theft in states like Abuja, Rivers, and Oyo underscore the urgency of strengthening authentication mechanisms.

This study demonstrates that traditional card-and-PIN systems are no longer sufficient to counter these evolving threats. The proposed multifactor biometric framework—integrating deep learning–based facial recognition with dynamic OTP verification—offers a more resilient alternative. By enhancing liveness detection, improving feature extraction accuracy, and securing data transmission channels, biometric authentication significantly reduces the likelihood of unauthorized access, even in environments with high fraud prevalence.

However, challenges remain. Environmental lighting inconsistencies common in outdoor Nigerian ATMs, network latency in rural areas, and the adaptability of fraudsters continue to pose risks. Addressing these issues requires a combination of technological innovation, regulatory enforcement, and user education. Emerging solutions such as behavioral biometrics, federated learning, and Edge AI present promising pathways for real-time, fraud-resistant authentication.

Ultimately, strengthening ATM and POS security in Nigeria demands a holistic approach. By adopting advanced biometric systems and aligning them with local infrastructural realities, financial institutions can better safeguard users, reduce fraud losses, and reinforce public trust in automated banking services.

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