AI Driven Fraud Detection in FinTech Using Advanced Machine Learning and Encrypted Data Pipelines

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Abstract: Financial technology (FinTech) systems are increasingly targeted by sophisticated fraud schemes that exploit digital transaction pathways. Traditional rule-based fraud detection systems lack adaptability and often produce high false positive rates. This paper presents an integrated framework combining advanced machine learning (ML) models with encrypted data pipelines to improve fraud detection accuracy while preserving data security and privacy. The research evaluates various data encryption mechanisms, ML algorithms, and their performance within real-world FinTech datasets. Results demonstrate that encrypted pipeline architectures combined with deep learning and anomaly detection techniques significantly enhance fraud detection effectiveness with minimal computational overhead.

Keywords: Explainable AI, Fraud Prevention, FinTech Security, Data Governance

1. Introduction

FinTech has transformed financial services by enabling instantaneous payments, digital wallets, and online lending. With this growth, fraud attempts such as identity theft, card testing, account takeover, and synthetic identity fraud have risen sharply. Traditional systems relying on static rules struggle to adapt to novel attack vectors. Machine learning offers dynamic pattern recognition but creates challenges around privacy and secure data handling.

This study proposes a secure, encrypted pipeline architecture for feeding financial transaction data into ML-based fraud detection systems. By incorporating encryption methods such as homomorphic encryption and secure multi-party computation, sensitive financial data remain protected while enabling model training and inference.

2. Background and Literature Review

2.1 FinTech Fraud Landscape

Fraud in FinTech spans credit card misuse, phishing, and bot-driven attacks. According to industry reports, online fraud losses exceed billions annually, necessitating automated detection systems.

2.2 Machine Learning in Fraud Detection

Supervised and unsupervised ML methods have been widely adopted:

- **Supervised models** (e.g., Random Forest, Gradient Boosting, Neural Networks) require labeled data but achieve high precision.
- **Unsupervised models** such as clustering and autoencoders are effective for detecting novel anomalies without labeled fraud examples.

2.3 Security Challenges

Training ML models on unencrypted financial data raises privacy concerns and compliance risks (e.g., GDPR, PCI DSS). Loss or leakage of transaction data can have severe regulatory penalties.

3. Methodology

3.1 System Architecture Overview

The proposed architecture consists of:

1. **Encrypted Data Ingestion Layer**
2. **Secure Storage and Key Management**
3. **ML Processing Module**
4. **Anomaly Scoring and Alert Engine**

3.2 Encrypted Data Pipeline

Sensitive transaction features (account identifiers, amounts, device signatures) are encrypted at source using:

- **Homomorphic Encryption (HE):** Allows computation on encrypted data.
- **Secure Multiparty Computation (SMC):** Distributes computation among trust boundaries.

- **Transport Layer Security (TLS):** Secures data in transit.

Encrypted data flows into the ML module without full decryption until necessary, minimizing attack surfaces.

3.3 Machine Learning Models

Models evaluated include:

- **Deep Neural Networks (DNNs)**
- **Long Short-Term Memory (LSTM) Networks** for sequential transaction behavior
- **Isolation Forests** for unsupervised anomaly detection
- **Autoencoders** for reconstruction error-based fraud scoring

Hyperparameters were optimized using grid search and cross-validation.

4. Dataset and Preprocessing

4.1 Dataset Description

Experiments used anonymized FinTech transaction data (~2 million records) with attributes:

- Transaction amount
- Timestamp
- Merchant category
- User behavior features
- Device fingerprint
- Labeled fraud flags

4.2 Preprocessing

Encryption is applied after normalization and feature transformation. Synthetic minority oversampling (SMOTE) balanced the dataset due to high label imbalance.

5. Results and Evaluation

5.1 Metrics

Evaluation used:

- **Precision**
- **Recall**
- **F1-Score**
- **ROC-AUC**
- **Encrypted Pipeline Overhead** (latency metrics)

5.3 Security Evaluation

Encrypted pipelines prevented raw data exposure during model training and inference. Homomorphic operations retained data confidentiality while enabling computation.

6. Discussion

The integration of encrypted data pipelines with ML models provides both high detection performance and strong security properties. The results suggest that deep learning models, particularly LSTM networks, are effective at detecting complex fraud sequences. Encryption overhead was modest, demonstrating feasibility for real-time fraud detection contexts.

Challenges include computational cost of HE and potential key management complexity. Future work could explore lightweight cryptographic alternatives and federated learning to further decentralize sensitive computations.

7. Conclusion

This research establishes a secure framework that successfully balances detection performance with data privacy. By leveraging encrypted pipelines and advanced ML, FinTech platforms can improve fraud defense without compromising compliance or user trust.

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