LandTitleX Neural Ledger: Distributed Proof-of-Ownership Continuum with Embedded Cognitive Fraud Differentiation

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ABSTRACT

The rapid advancement of blockchain networks and digital transaction platforms has increased the demand for intelligent and reliable fraud detection mechanisms, particularly in decentralized environments such as Ethereum. Traditional verification approaches, which rely on manual inspection and rule-based systems, are inadequate for processing large-scale and complex transactional data, leading to inefficiencies, low accuracy, and poor adaptability to evolving fraud patterns. To overcome these challenges, this research proposes a hybrid fraud detection framework that integrates multiple Machine Learning (ML) techniques, including Logistic Regression (LR), Support Vector Machine (SVM), Random Forest (RF), Extreme Gradient Boosting (XGBoost), and Light Gradient Boosting Model (LGBM), along with a Deep Learning (DL)-based Convolutional Neural Network (CNN2D). Feature selection is performed using Analysis of Variance (ANOVA), and normalization techniques are applied to enhance model performance and stability. All models are developed and evaluated in a Jupyter environment, where CNN2D demonstrates superior performance and is selected for deployment. The system is implemented using the Django framework, providing role-based access where buyers can register, authenticate, and upload land transaction data, while sellers can review and approve or reject requests based on Artificial Intelligence (AI)-driven fraud predictions. The deployed CNN2D model enables real-time prediction of fraudulent activities. Furthermore, transaction data is stored in the InterPlanetary File System (IPFS), generating unique hash values, while transaction records and prediction outcomes are securely recorded on the Ethereum blockchain using Smart Contracts (SC), ensuring immutability, transparency, and traceability. The proposed framework enhances fraud detection accuracy, ensures secure data storage, and provides a scalable and trustworthy solution for digital land transaction systems.

Keywords: Blockchain, Convolution Neural Networks, ANOVA, Deep Learning, Digital Land Transactions, Fraud detection

1.INTRODUCTION

Blockchain is a distributed digital ledger technology that facilitates secure data storage, validation, and verification without the involvement of a centralized intermediary, enabling trustless interactions among participants. In this architecture, data is replicated across multiple nodes, ensuring that all stakeholders have synchronized access to the same information, thereby enhancing transparency and accountability. Once recorded, the data becomes immutable due to cryptographic linking of blocks, making it resistant to unauthorized modification or deletion. The system operates based on core principles such as governance, accountability, transparency, flexibility, availability, usability, manageability, and sustainability, which collectively strengthen data integrity and operational reliability. However, advancing agriculture is inherently complex and cannot be addressed through a single technological intervention, as it involves diverse processes, stakeholders, and environmental dependencies. Previous studies emphasize this multidimensional nature; for example, research analyzing young Irish farmers highlights the socio-economic and technological factors influencing the adoption of cloud computing for smart farming applications [1], while another study explores the role of machine learning and big data analytics in improving agricultural decision-making and productivity [2]. The integration of Information and Communication Technology (ICT) within agriculture requires continuous coordination among heterogeneous technologies, leading to iterative, cyclic, and multi-parameter improvements that make the domain highly research-intensive. In recent years, blockchain has emerged as a promising innovation with practical feasibility, motivating researchers to explore its applications across various agricultural verticals such as supply chain traceability, land registration, crop monitoring, and financial transactions. Agriculture itself is a broad domain encompassing several branches including horticulture, agronomy, soil science, crop production, animal husbandry, and livestock management, each contributing uniquely to food production systems, as categorized in existing literature [3].

The referenced figure illustrates a secure land registration framework that integrates blockchain with artificial intelligence to ensure data authenticity, prevent fraudulent ownership claims, and provide tamper-proof record management. Horticulture, regarded as both an art and a science, follows a systematic workflow beginning with the selection of suitable crops or plants based on climatic and soil conditions, followed by soil preparation through plowing, nutrient enrichment, irrigation setup, and fertilization. Subsequently, seeds or seedlings are sown, monitored during growth stages, and finally harvested at maturity, as outlined in prior studies [4]. Agronomy, on the other hand, focuses more on scientific soil and crop management practices, starting with soil testing to evaluate nutrient composition and pH levels, which guides the selection of appropriate fertilizers and soil amendments. This is followed by land preparation, aeration, sowing of crops, irrigation management, and ultimately harvesting once optimal growth is achieved [5]. These structured and sequential agricultural processes demonstrate the increasing reliance on technological interventions and data-driven methodologies, reinforcing the need for integrating advanced technologies such as blockchain and artificial intelligence to enhance efficiency, transparency, and sustainability in modern agricultural systems.

2.LITERATURE SURVEY

Mengesha, et al. [6] conducted an in-depth study on the contribution of land registration and certification programs toward achieving the United Nations Sustainable Development Goals (SDGs), particularly in the context of the Amhara region of Ethiopia. Their research employed a mixed-method approach, including interviews, focus group discussions, and document analysis, to evaluate the socio-economic impact of secure land tenure. The findings revealed that formal land registration significantly enhances tenure security, which in turn encourages long-term agricultural investment, improves land management practices, and reduces land-related conflicts. The study further demonstrated that secure land rights positively influence poverty reduction, food security, gender equality, and sustainable land use. By strengthening ownership confidence, these programs also promote inclusive development and environmental sustainability, making them a critical component of national development strategies. Biraro, et al. [7] analyzed land information system updating practices across multiple countries that adopted unconventional approaches in systematic land registration. Their study identified several critical success factors that contribute to efficient and reliable land administration systems. These include decentralized service delivery models that bring services closer to users, user-friendly and accessible digital databases, affordable registration costs, availability of trained personnel, and strong institutional coordination. The authors emphasized that regular updating of land records is essential to maintain data accuracy and system relevance. Their findings suggest that integrating technological solutions with institutional reforms can significantly improve transparency, reduce administrative delays, and enhance public trust in land management systems. Cienciała, et al. [8] focused on improving land consolidation and management processes through the use of modern measurement technologies, particularly Unmanned Aerial Vehicle (UAV)-based data acquisition. Their research compared traditional surveying methods with advanced drone-based imaging systems to evaluate differences in accuracy and efficiency. The results indicated that UAV technology provides higher-resolution data with lower error margins, enabling more precise mapping and better decision-making in land consolidation projects. The study also highlighted that reliance on outdated cartographic data can lead to inconsistencies and inefficiencies, whereas modern geospatial technologies significantly enhance data reliability. This work demonstrates the importance of integrating innovative technological tools into land management practices to achieve higher levels of precision and operational efficiency.

Singirankabo, et al. [9] critically examined the widely accepted assumption that land registration directly leads to increased agricultural productivity and investment. Their study identified several limitations in this relationship, including weak empirical evidence in certain contexts, potential risks to informal land tenure systems, and unequal gender impacts that may disadvantage vulnerable groups. The authors argued that land registration alone is not sufficient to guarantee improved productivity unless it is supported by complementary factors such as access to credit, agricultural inputs, and institutional support. They also emphasized the importance of maintaining updated and accurate land information systems, as outdated records can undermine the effectiveness of registration programs. The study concludes by advocating for more context-specific and localized research to better understand the complex dynamics between land tenure security and agricultural development. Gedefaw, et al. [10] investigated the impact of land certification on rural farming households, particularly focusing on its role in improving agricultural practices and reducing land disputes. Their empirical analysis showed that land certification leads to a significant decline in conflicts related to land ownership and boundaries, thereby creating a more stable environment for agricultural activities. The study also found that certified landholders are more likely to adopt improved land management practices, such as soil conservation and sustainable farming techniques. Several influencing factors were identified, including farm size, distance from residence, perception of land degradation, access to financial resources, training in land management, and livestock ownership. Overall, the findings indicate that land certification contributes positively to both productivity and sustainable resource utilization. Abab, et al. [11] evaluated the operational success of the National Rural Land Administration Information System (NRLAIS) using a structured analytical framework based on survey data, interviews, and literature review. Their study applied structural equation modeling to examine the relationships between various system attributes and user acceptance. The results showed that system quality, information quality, service quality, and perceived usefulness significantly influence user satisfaction and adoption levels. Interestingly, perceived ease of use was found to have a relatively low impact, suggesting that users prioritize functionality and reliability over simplicity. The study concluded that effective implementation of land information systems can enhance service delivery, improve data integration, and support evidence-based decision-making in land administration. It also highlighted the need for continuous system improvements and stakeholder engagement to ensure long-term success.

Panwar, et al. [12] presented a comprehensive study on the application of blockchain technology in the agricultural sector to address critical challenges such as lack of transparency, inefficiencies in supply chains, and issues related to product authenticity. Their work analyzed how traditional agricultural systems suffer from fragmented data management and limited traceability, leading to trust deficits among stakeholders. By introducing blockchain-based solutions, the authors demonstrated how decentralized ledgers can securely record every stage of the agricultural supply chain, from production to distribution. The integration of smart contracts enables automated transaction validation, reducing human intervention and minimizing errors. Additionally, the study highlighted the role of blockchain in facilitating secure digital payments and ensuring product traceability, which ultimately improves operational efficiency and consumer trust. The findings suggest that blockchain has significant potential to modernize agricultural ecosystems by enhancing reliability, accountability, and data security. Byamugisha, et al. [13] explored large-scale land registration initiatives in developing countries, focusing on strategies to efficiently secure land rights across diverse populations. Their study examined case examples from regions such as Asia and Africa, where a substantial portion of land remains unregistered, limiting economic growth and access to financial services. The authors emphasized that insecure land tenure discourages investment and restricts the ability of individuals to use land as collateral for credit. To address these challenges, the study proposed scalable and cost-effective land registration approaches that leverage simplified procedures and technological support. Their findings indicate that rapid and systematic land registration programs can significantly improve tenure security, promote inclusive economic development, and strengthen governance frameworks. The work underscores the importance of policy support and institutional capacity in successfully implementing such large-scale initiatives. Panday, et al. [14] evaluated the effectiveness of the fit-for-purpose land administration (FFPLA) approach through pilot implementations conducted in Nepal across both urban and rural regions. Their research demonstrated that FFPLA, which emphasizes flexibility, inclusivity, and cost-efficiency, is particularly suitable for developing countries with limited resources. The study highlighted the use of participatory mapping techniques combined with modern technologies such as satellite imagery and smartphone-based data collection to accelerate the land registration process. The results showed that large-scale mapping and registration could be completed within short timeframes at a significantly reduced cost per parcel compared to conventional methods. Furthermore, the approach encourages community involvement, which improves data accuracy and acceptance among local populations. The authors concluded that FFPLA provides a practical and scalable solution for achieving comprehensive land administration coverage while ensuring affordability and efficiency.

3. PROPOSED SYSTEM

The proposed system architecture as illustrated in Fig. 2 integrates ML models, DL techniques, and decentralized technologies to establish a secure, transparent, and intelligent land transaction management framework. It begins with a Django-based web application that provides a user-friendly interface with role-based access control for buyers and sellers, enabling functionalities such as registration, secure authentication, structured data upload in CSV format, and real-time transaction monitoring. Once the data is uploaded, it undergoes a comprehensive preprocessing pipeline that includes data cleaning, handling missing values through appropriate imputation techniques, elimination of redundant or irrelevant attributes, and normalization using standard scaling to maintain uniform feature distribution.

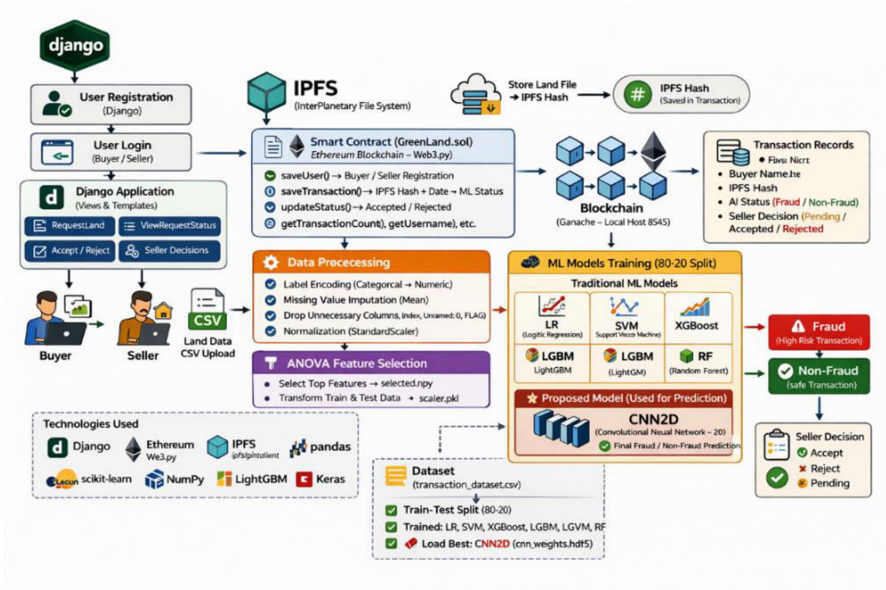

Fig. 2: Proposed system architecture.

To further enhance efficiency, ANOVA-based feature selection is applied to identify the most influential attributes, thereby reducing dimensionality, minimizing noise, and improving model performance. The refined dataset is then utilized to train multiple supervised learning models, including LR, SVM, RF, XGBoost, and LGBM, along with a DL-based CNN2D model using an 80:20 train-test split to ensure proper generalization. Each model is rigorously evaluated using standard performance metrics such as accuracy, precision, recall, and F1-score, and based on comparative analysis, CNN2D is selected as the optimal model due to its superior predictive capability and effectiveness in capturing complex data patterns. This trained CNN2D model is seamlessly integrated into the Django application to enable real-time fraud detection, where incoming transactions are classified as fraudulent or legitimate, providing actionable decision support to sellers who can choose to accept, reject, or hold transactions accordingly. In parallel, all uploaded land-related documents are securely stored in IPFS, which generates unique cryptographic hash values acting as immutable identifiers to ensure data integrity and prevent tampering. These hash values, along with transaction metadata and prediction results, are subsequently recorded on the Ethereum blockchain through smart contracts, which automate validation processes and enforce immutability, transparency, and traceability of records. This end-to-end integrated architecture effectively combines intelligent analytics with decentralized storage and blockchain mechanisms, resulting in a robust, tamper-proof, and trustworthy digital land transaction system that significantly reduces fraud risks while enhancing security, accountability, and operational efficiency.

3.1 CNN2D MODEL

The CNN2D model is a deep learning architecture as shown in Fig. 2 designed to analyze communication data by transforming it into 2D feature maps and extracting spatial patterns through convolutional operations. Unlike traditional machine learning models that rely only on statistical relationships, the CNN2D captures localized interactions, hierarchical structures, and subtle variations present in the communication signals. This makes it highly suitable for anomaly detection, where complex patterns and non-linear behaviors must be identified accurately. In secure communication analysis, the model effectively learns both low-level and high-level features, allowing it to differentiate normal transmissions from suspicious or malicious ones with improved reliability.

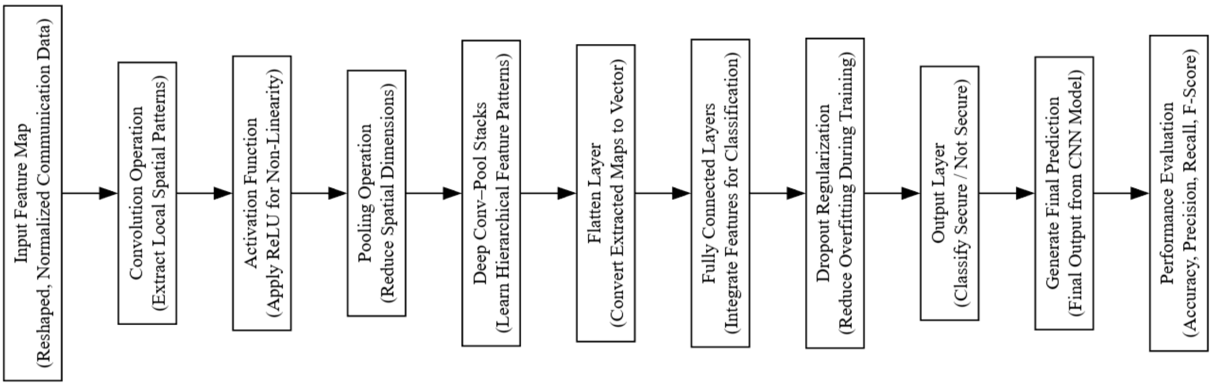

Fig. 4.9: CNN 2D Model Internal Workflow

Input Feature Map Construction: The communication dataset is reshaped, normalized, and converted into 2D feature grids to preserve spatial dependencies among parameters. This transformation enables the CNN to perform convolution operations effectively on structured representations.

Convolution Operation: The first convolution layer applies a set of learnable filters to identify localized spatial patterns. These filters capture edges, gradients, and essential communication characteristics that help the model detect early-stage anomalies.

Activation Function: A non-linear activation such as ReLU is applied to enhance the model's learning capacity. This step introduces non-linearity into the network, enabling it to detect complex patterns that cannot be captured by linear models.

Pooling Operation: Pooling reduces the spatial dimensions of the feature maps while retaining the most important information. This step helps decrease computational cost and increases the model's robustness against noise and irrelevant variations.

Deep Conv–Pool Stacks: Multiple layers of convolution and pooling are applied to learn deeper and more abstract communication patterns. These layered structures enable the model to understand hierarchical properties, making it effective in distinguishing secure and non-secure signals.

Flatten Layer: The multi-dimensional feature maps generated by the convolutional stack are flattened into a single vector. This prepares the extracted features for dense layer processing.

Fully Connected Layers: Dense layers integrate the learned features and refine the decision boundaries needed for accurate classification. These layers help the network synthesize information extracted from all convolution stages.

Dropout Regularization: Dropout is applied to prevent overfitting by randomly deactivating neurons during training. This boosts generalization capability and ensures stable performance when evaluated on unseen communication data.

Output Layer: The final dense layer generates the classification result, predicting whether each communication instance is *Secure* or *Not Secure*. This output forms the basis for blockchain logging and anomaly monitoring.

Generate Final Prediction: The model combines all learned representations to produce the final classification decision. This prediction represents the aggregated understanding of all convolutional and fully connected layers.

Performance Evaluation: The trained model is assessed through metrics such as accuracy, precision, recall, F-score, and ROC-AUC. These metrics validate the model's capability to correctly identify anomalies and ensure reliable communication security.

4. RESULTS DESCRIPTION

The results demonstrate the effectiveness of the proposed hybrid fraud detection framework in accurately identifying fraudulent land transactions. Multiple machine learning models, including LR, SVM, RF, XGBoost, and LGBM, were evaluated and compared with the CNN2D model. Among all models, it achieved superior performance by effectively capturing complex and non-linear patterns in transaction data. The evaluation metrics indicate improved accuracy, precision, and recall, highlighting the robustness of the deep learning approach. Additionally, the integration of blockchain and IPFS ensured secure, transparent, and tamper-proof storage of transaction records. The system provides a reliable, scalable, and intelligent solution for real-world fraud detection and land record management.

Fig. 3 depicts the confusion matrix and ROC-AUC curve for the proposed LandGuardNet model, showcasing its performance in comparison with other models. The confusion matrix reveals that 14 "Allow" instances and 2284 "Deny" instances are correctly classified, while 655 "Allow" cases are misclassified as "Deny" and 0 "Deny" cases are incorrectly classified as "Allow." This indicates that the model achieves perfect classification for the "Deny" class with no false positives, demonstrating strong reliability in detecting fraudulent cases. The ROC-AUC curve is positioned very close to the ideal region, reflecting excellent classification capability. Although the model still shows limitations in identifying "Allow" instances, it significantly reduces critical misclassification errors.

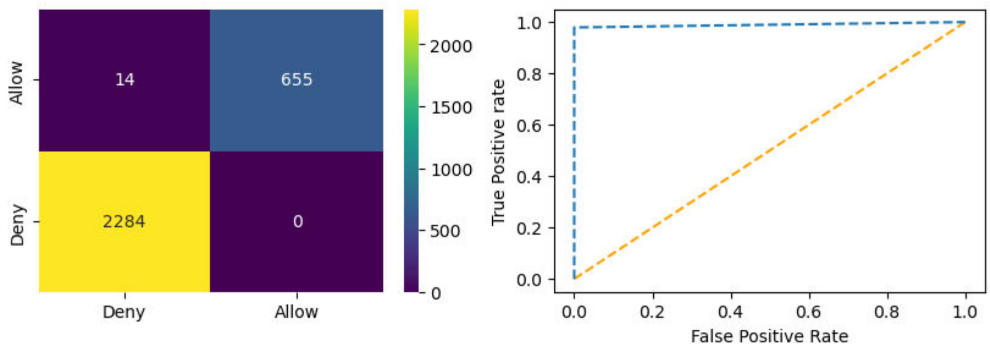

Fig. 3: Confusion matrix and ROC-AUC Curve obtained for CNN2D model

The table 1 presents a comparative performance analysis of various machine learning and deep learning models used for land transaction fraud detection. Traditional models such as Logistic Regression and SVM show moderate accuracy and recall, indicating limitations in capturing complex transaction patterns. Ensemble-based models, including Random Forest, XGBoost, and LightGBM, demonstrate significantly higher performance due to their ability to model non-linear feature interactions. Among all approaches, the CNN2D model achieves the highest accuracy, precision, recall, and F-score, indicating superior classification capability. The improved performance of the CNN2D model highlights its effectiveness in learning deeper feature representations from transaction data. These results suggest that advanced deep learning architectures can further enhance fraud detection accuracy when compared to conventional machine learning techniques.

Table 1: Comparative Analysis of Models Used

Algorithm Name	**Accuracy (%)**	**Precision (%)**	**Recall (%)**	**F-Score (%)**
Logistic Regression	86.15	84.96	72.87	76.47
SVM	89.10	86.46	80.95	83.22
Random Forest	98.34	98.89	96.39	97.57
XGBoost	99.32	99.35	98.72	99.03
LightGBM	99.36	99.42	98.74	99.08
CNN2D	99.53	99.70	98.95	99.32

5. CONCLUSION

The developed system presents an advanced and reliable framework for managing land transactions by combining decentralized technologies with intelligent analytics, aligning with the concepts of Industry 5.0. The use of blockchain ensures that all transaction records remain immutable, verifiable, and transparent, thereby addressing major issues such as unauthorized modifications, fraud, and ownership disputes commonly found in conventional systems. The integration of AI-driven fraud detection, particularly through the CNN2D model, enhances the system’s capability to identify potentially fraudulent activities at an early stage, enabling better decision-making for stakeholders. In addition, the adoption of IPFS enables secure and distributed storage of transaction documents, where each file is linked through a unique hash, ensuring both integrity and easy accessibility. The system also achieves improved performance through effective data preprocessing techniques, including feature selection and normalization, which contribute to higher prediction accuracy and efficiency. Furthermore, the overall design follows a modular and scalable architecture, supported by blockchain integration, allowing the platform to efficiently manage increasing transaction volumes while maintaining low processing delays and high reliability.

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