Synthetic Generation and Augmentation of Rice Disease Images Using Conditional GANs

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Abstract: Rice disease identification suffers from limited labeled datasets, class imbalance, and poor field generalization. This paper proposes a conditional, GAN (cGAN)-driven synthetic image generation and augmentation framework for rice leaf disease diagnosis. The methodology integrates dataset preprocessing, class-conditioned image synthesis, hybrid augmentation, and a CTLCN-based classifier, followed by expert system deployment for decision support. Experimental design targets improved diversity, reduced overfitting, and robust recognition of blast, bacterial blight, brown spot, and sheath blight. Expected findings include improved classification accuracy, F1-score, and robustness over non-augmented baselines. The framework applies to scalable smart agriculture, mobile advisory systems, and precision crop disease surveillance.

Keywords: Rice disease; Conditional GAN; Image augmentation; CTLCN; Expert system

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Introduction

Rice (Oryza sativa) is a major staple crop and a cornerstone of food security across Asia and Africa. Its productivity is frequently threatened by leaf diseases such as blast, bacterial blight, brown spot, and sheath blight, leading to serious yield and quality losses. Hence, timely and accurate disease detection is vital for precision agriculture and sustainable crop protection. Recent deep learning-based approaches have shown strong potential for automated rice disease recognition from leaf images [1].

However, real-world deployment remains challenging due to limited labeled samples, class imbalance, and weak field-level generalization, often resulting in overfitting and poor minority-class detection. Recent SCI studies suggest that GAN-based augmentation and hybrid transformer models can effectively improve dataset balance and model robustness [2], [3].

To overcome these limitations, this work introduces a conditional GAN (cGAN)-based synthetic image generation and augmentation framework for rice disease diagnosis. The proposed pipeline integrates preprocessing, class-wise image synthesis, hybrid augmentation, CTLCN-based classification, and expert system deployment. By enriching data diversity, the framework is expected to reduce overfitting and improve performance metrics such as accuracy and F1-score compared with non-augmented baselines [4].

The framework is well suited for smart agriculture, mobile crop advisory, and precision disease surveillance systems, supporting scalable real-time diagnosis for farmers and agricultural experts.

Related Work

Related work

Recent advances in rice leaf disease detection have increasingly focused on deep learning, GAN-based augmentation, hybrid CNN-transformer models, and explainable AI frameworks. A recent systematic review highlighted that dataset scarcity and field-level variability remain the key bottlenecks in robust rice disease recognition systems [1].

Several recent studies have improved performance through GAN-assisted data balancing, in which synthetic disease images were generated to enhance minority-class learning [2], [4] - [6]. Meanwhile, advanced classification systems using DenseNet, graph attention networks, and handcrafted multi-level features have further improved disease discrimination capability [7] - [12].

The proposed work extends these contributions by integrating conditional GAN-driven class-wise synthesis, hybrid augmentation, CTLCN-based optimization, and expert system deployment, an approach that is still rarely explored in the current literature.

Table 1. Comparison of recent related works with the proposed framework

Reference	Synthetic Augmentation	Hybrid Deep Model	Rice-specific Dataset	Expert System	Explainability	Real-time Deployment
[1]	No	Yes	Yes	No	No	No
[2]	Yes	Yes	No	No	Yes	No
[4]	Yes	Yes	Yes	No	No	No
[5]	No	Yes	Yes	No	No	Yes
[6]	Yes	No	Yes	No	No	No
[7]	No	Yes	Yes	No	No	Yes
[8]	No	Yes	Yes	No	No	No
[9]	No	Yes	Yes	No	No	Yes
[10]	Yes	Yes	Yes	No	No	No
[11]	No	Yes	Yes	No	No	No
[12]	No	Yes	Yes	No	No	No
This Work	**Yes**	**Yes (CTLCN)**	**Yes**	**Yes**	**Possible**	**Yes**

Key Contribution

The paper contributes: (i) a class-conditioned rice disease image generation pipeline, (ii) hybrid real-synthetic augmentation, (iii) CTLCN-based optimized disease classification, and (iv) expert system integration for practical decision support.

Method, Experiments and Results

The proposed four-stage workflow begins with Kaggle-based dataset collection and preprocessing. A cGAN is then trained to generate class-specific disease samples. The methodology is depicted in Figure 1. Real and synthetic images are fused for augmentation and passed to the CTLCN architecture for feature extraction, optimization, and classification. Evaluation metrics include accuracy, precision, recall, F1-score, and confusion matrix analysis.

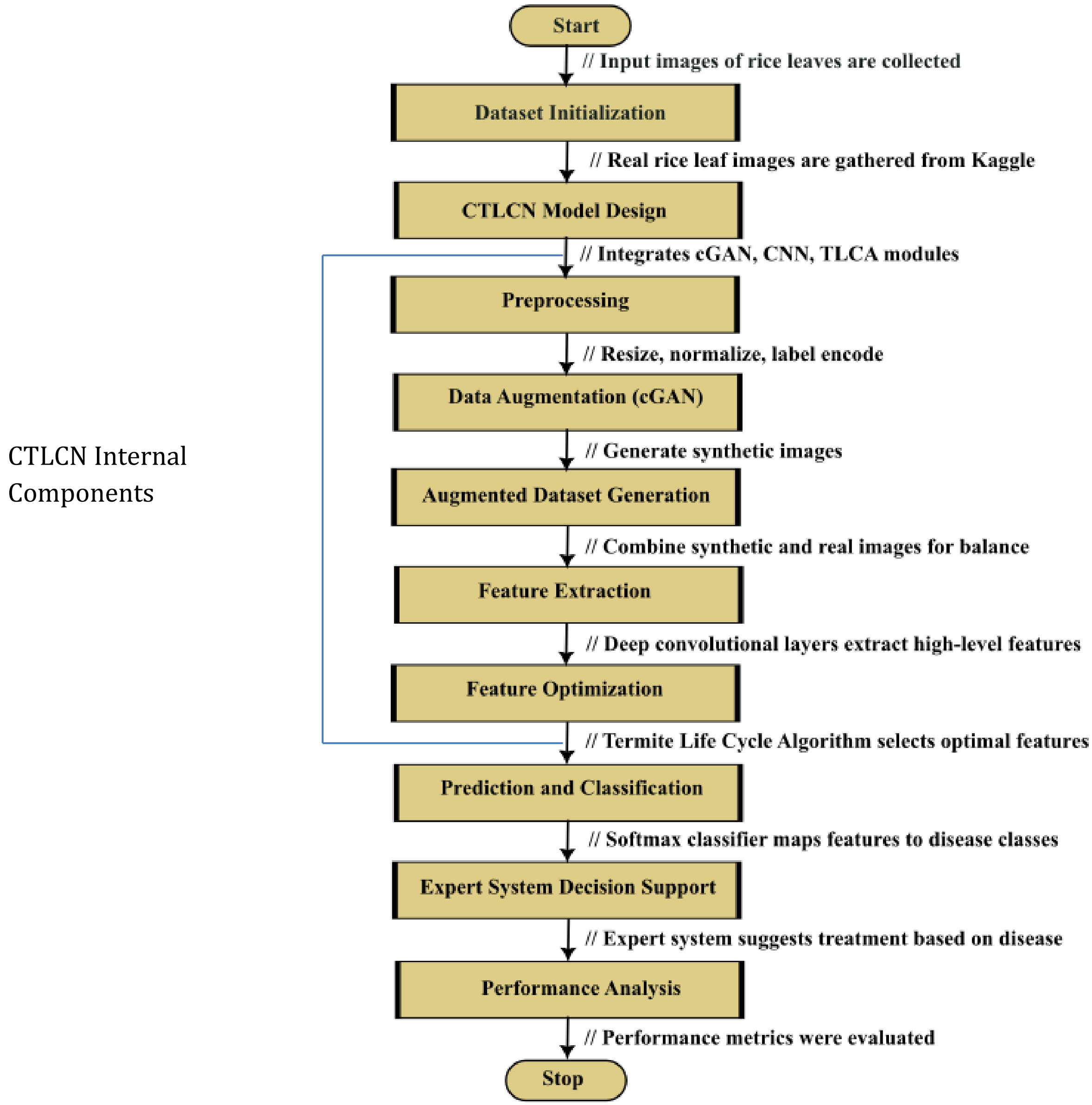

Figure 1. Proposed cGAN-based rice disease generation, augmentation, classification, and expert system pipeline.

Discussions

The use of cGAN-generated data is expected to mitigate imbalance and improve minority disease recognition. Integration with the termite life-cycle optimization concept further enhances discriminative feature learning. The expert system layer enables practical deployment in advisory platforms.

Conclusions

This study addresses rice disease data scarcity using cGAN-based synthetic generation and augmentation. The CTLCN classifier and expert integration provide a scalable architecture for real-time diagnosis. Future work may include multispectral imagery, federated deployment, and field-level validation.

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