2nd INTERNATIONAL CONFERENCE ON
Artificial Intelligence
31 May - 1 June 2026

IICAI
Second International Interdisciplinary Conference on Artificial Intelligence

Intelligent Leaf Disease Diagnosis Using EfficientNetB0 Combined with CBAM in a Multi-Task Framework

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Abstract

This study presents a lightweight multi-task deep learning model for intelligent diagnosis of plant leaf diseases. The framework is built on EfficientNetB0 combined with the Convolutional Block Attention Module (CBAM) to simultaneously predict leaf health status, plant species, and disease type. A Gated Disease Heads design and consistency supervision mechanism are implemented to improve reliability among outputs. Using a dataset of about 4,000 leaf images of barley, jujube, and pomegranate, the model achieves 97% accuracy in health classification and 93% accuracy in both species and disease identification. The results demonstrate an efficient and reliable solution for real-world applications in smart agriculture.

Research method

The proposed framework utilizes an end-to-end architecture designed for accurate plant disease diagnosis. As depicted in **Fig. 1**, the input leaf images are processed through an **EfficientNet-B0** backbone integrated with a **CBAM** module to extract and refine high-level features. These features are subsequently passed to the multi-task head structure shown in **Fig. 2**, which includes three specialized heads: **Health**, **Plant Species**, and a **Gated Disease Head**. To ensure diagnostic reliability, a **Consistency Layer** is integrated into the training process, imposing logical constraints between the predicted health status and disease classes to prevent contradictory outputs. This multi-task approach allows for robust, species-aware diagnosis while maintaining high computational efficiency.

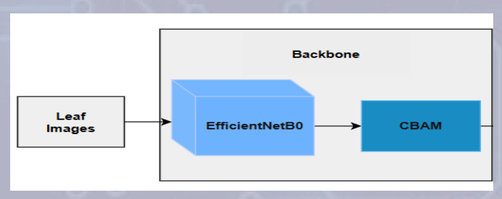

Fig. 1. Feature extraction

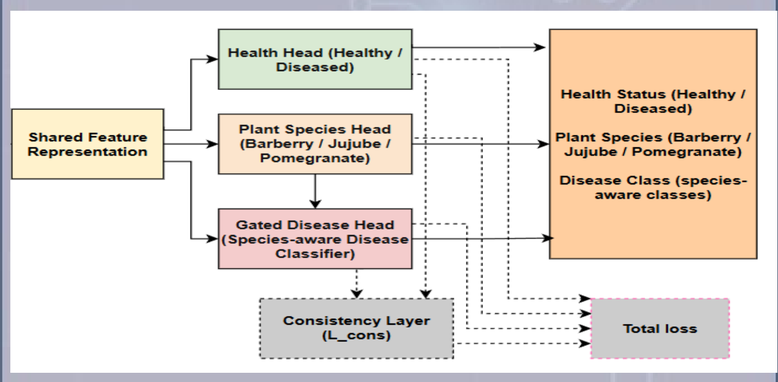

Fig. 2. Multi-task classification and consistency layer

conclusion

- **Unified Intelligence:** We proposed a lightweight multi-task framework that simultaneously performs leaf health classification, plant species identification, and disease recognition, outperforming conventional single-task models.
- **Efficiency & Scalability:** By achieving high-accuracy results with only ~5.3M parameters, our model offers a practical, low-cost solution for real-field deployment, overcoming the heavy computational burden of traditional segmentation-based methods.
- **Reduced Annotation Cost:** The transition from pixel-level mask annotations to image-level supervision significantly reduces data preparation overhead while maintaining robust performance.
- **Future Outlook:** Future efforts will focus on enhancing model interpretability, broadening dataset diversity to include complex disease patterns, and exploring multi-label disease scenarios.

The purpose of the research

The primary objective of this research is to develop an efficient, multi-task framework for simultaneous leaf-health, species, and disease classification. By integrating an **EfficientNetB0** backbone with a **CBAM** module and a novel **Consistency Layer**, we provide a unified model that optimizes performance for agricultural diagnostics. To ensure real-world effectiveness, we utilize the **BNPL dataset** (featured in **Fig. 4**), which contains **4,293 images across 9 classes** (e.g., Barberry, Jujube, Pomegranate). This dataset captures the complexities of natural field conditions, such as background noise and variable lighting. Our approach bridges the gap between high-precision requirements and edge-device constraints by:

Enhancing Accuracy: Using CBAM to focus on discriminative features despite inter-class similarities.

Optimizing Efficiency: Achieving high-performance results with a significantly reduced parameter count.

This robust architecture ensures reliable, real-time diagnostic capabilities for modern agriculture.

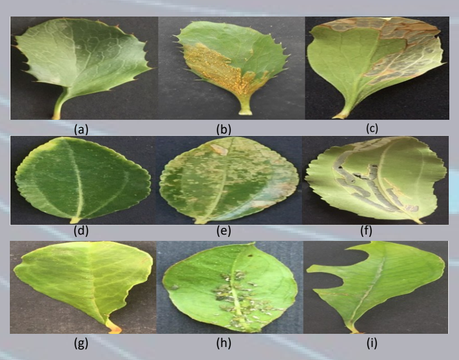

Fig. 3. Sample images of the dataset: (a) Barberry–Healthy, (b) Barberry–Rust, (c) Barberry–Pandemis, (d) Jujube–Healthy, (e) Jujube–Tingid, (f) Jujube–Caterpillar, (g) Pomegranate–Healthy, (h) Pomegranate–Aphid, and (i) Pomegranate–LeafCuttingBee.

Practical or simulation results

Training Performance

Optimization Strategy: A two-stage process (warm-up followed by fine-tuning) ensured stable convergence and effective feature extraction.

Loss & Accuracy: Validation loss declined significantly (from ~2.35 to 0.46), with validation accuracies reaching ~0.98, ~0.94, and ~0.93 for leaf-health, species, and disease classification, respectively.

Robustness: The model demonstrates stable and reliable performance during training and validation..

Confusion Matrix Analysis

Multi-task Effectiveness: As illustrated in the figure below, the model demonstrates high classification performance across all three tasks.

Error Analysis: Misclassifications are minimal and primarily confined to samples with high inter-class visual similarity (e.g., specific plant species or related disease symptoms).

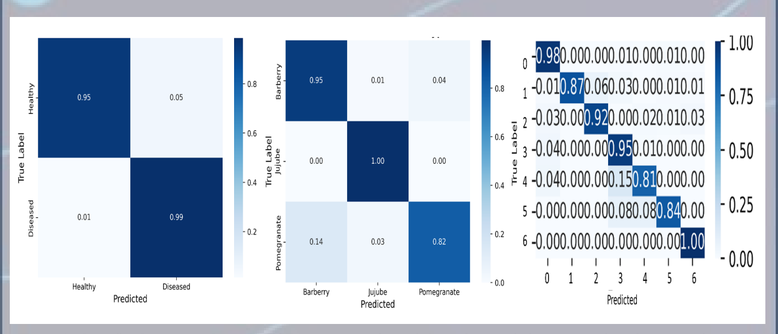

Fig. 4. Confusion matrices of the proposed multi-task model across the three tasks, showing high classification accuracy and limited confusion mainly among visually similar classes.

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