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NOVEL APPROACH FOR EFFECTIVE PLANT PEST MONITORING USING KNOWLEDGE DISTILLATION

The increasing demand for sustainable agriculture necessitates efficient and automated plant health monitoring systems. Deep learning models have shown promising results in plant disease and pest detection, but their computational complexity often limits deployment on resource-constrained edge devices like Raspberry Pi, crucial for real-time monitoring in greenhouses. Knowledge distillation offers a solution by transferring knowledge from a large, accurate teacher model to a smaller, more efficient student model.

Traditional KD relies on matching the teacher's output logits or intermediate feature representations. A key component is the feature mapping layer that transforms teacher features into a space compatible with the student. However, this layer can quickly become parameter-heavy, especially when dealing with high-dimensional feature maps. This large number of parameters can lead to overfitting and hinder the distillation process.

This work (Khabarlak, 2022; Khabarlak et al., 2024) addresses this challenge by proposing a novel feature mapping layer based on group convolutions. Group convolutions decompose a standard convolution into multiple smaller convolutions operating on different input channels, drastically reducing the number of parameters. We hypothesize that this reduction in parameters will not only improve computational efficiency but also enhance the distillation process by preventing overfitting and enabling better generalization.

Our approach utilizes a teacher-student framework for knowledge distillation. The teacher model is a pre-trained convolutional neural network with high accuracy on the IP.102 plant pest dataset. The student model is a lightweight MobileNetV.3 architecture, chosen for its efficiency and suitability for edge deployment.

The core innovation lies in the design of the feature mapping layer. Instead of a standard convolution, we employ a group convolution with a configurable number of groups. The number of groups determines the degree of parameter reduction. A standard convolution can be considered a group convolution with one group. The feature mapping layer transforms the

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teacher's intermediate feature maps into a space compatible with the student's architecture.

We evaluated our approach on the IP.102 dataset, a challenging benchmark for plant pest classification containing 102 different pest species. We conducted extensive hyperparameter tuning to optimize the number of groups in the feature mapping layer, the number of inner channels, kernel sizes, loss weights, and distillation temperature.

The group convolution-based mapping layer significantly reduced the number of parameters compared to a standard convolutional mapping layer. Configurations with 64 inner channels and both group convolutions achieved a 21.8x reduction in parameters compared to configurations using standard convolutions. Combining the group convolution mapping layer with soft targets distillation improved the student network's accuracy from 72.14% to 74.83% on the test set.

Our results demonstrate that feature mapping layer design is crucial for effective knowledge distillation. The group convolution approach successfully reduces the number of parameters while improving accuracy. This is likely due to the regularization effect of the reduced parameter count, which prevents overfitting and promotes better generalization.

Conclusions. This paper presents a novel approach to knowledge distillation using a group-convolution-based feature mapping layer. Our results demonstrate that this approach can significantly reduce the number of parameters while improving student network accuracy on a challenging plant pest classification task. This makes it a promising solution for deploying deep learning models on resource-constrained edge devices for real-time plant health monitoring.

Future work will focus on more advanced distillation approaches and evaluating the performance of our approach on other plant disease and pest datasets. We aim to deploy our optimized model on a Raspberry Pi platform and evaluate its performance in a real-world greenhouse environment.

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