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Research Paper

AERIAL IMAGE SEMANTIC SEGMENTATION USING U-NET AND EFFICIENT-NET

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ABSTRACT— To address the challenges of few-shot aerial image semantic segmentation, where unseen-category objects in query aerial images need to be parsed with only a few annotated support images, we propose a novel approach by integrating a U-Net architecture with Efficient Net. The rotation sensitivity of aerial images causes substantial feature distortions, leading to low confidence scores and misclassification of same-category objects with different orientations.

To overcome these limitations, we propose an enhanced solution by combining U-Net for robust semantic segmentation with Efficient Net for efficient feature extraction and scale adaptability. This architecture, which we refer to as Efficient U-Net, introduces rotation-invariant feature extraction to handle the varying orientations of aerial objects. By leveraging Efficient Net's scalable Convolutional layers for feature extraction, we ensure that the network can capture orientation-varying yet category-consistent information from support images. This approach enhances the segmentation accuracy by aligning same-category objects, irrespective of their orientation, thereby minimizing the oscillation of confidence scores and improving the detection of rotated semantic objects. This Efficient U-Net model provides a scalable, rotation-invariant solution to the few-shot segmentation of aerial images.

I. INTRODUCTION

Few-shot semantic segmentation of aerial images is a challenging task, particularly when attempting to segment objects of unseen categories with only a few annotated examples. The irregular orientations, varying scales, and diverse distributions of objects in aerial imagery make traditional segmentation techniques less effective due to their sensitivity to feature variations. In conventional few-shot segmentation, category prototypes are extracted from limited support samples and matched pixel-wise with query images to generate segmentation masks. However, the arbitrary rotation of objects in aerial views can lead to significant feature distortions, resulting in low confidence scores and misclassifications, especially when objects of the same category appear in different orientations. To address these challenges, we propose an enhanced approach by integrating a U-Net architecture with Efficient Net, termed as Efficient U-Net, which is designed for robust and rotation-invariant feature extraction. By leveraging Efficient Net's scalable convolutional layers, our model can adapt to different scales and orientations, ensuring consistent feature alignment for improved segmentation accuracy. This approach significantly mitigates the impact of rotation-induced feature variations, enhancing the detection and segmentation of aerial objects, even with limited annotated data, thereby offering a scalable solution for few-shot semantic segmentation in aerial imagery.

II. RELATED WORK

A. Shape based deep estimation of future plant images

This paper introduces an innovative approach for estimating future plant images by leveraging shape-based features through deep learning techniques. The proposed method focuses on analyzing the morphological features of plants to predict their future states. By employing a deep learning framework that captures shape-based characteristics, the study addresses the challenge of forecasting plant growth and development. The authors present a detailed methodology for generating accurate predictions of plant images over time, which is crucial for optimizing agricultural practices and managing plant health. The effectiveness of the approach is demonstrated through comprehensive experiments and comparisons with existing methods, highlighting its potential in advancing precision agriculture.

B. A novel shape based plant growth prediction algorithm using deep learning and spatial transformation

This paper proposes a novel algorithm that combines deep learning with spatial transformation techniques to predict plant growth. The algorithm utilizes shape-based features to enhance the accuracy of growth predictions, addressing common challenges in plant growth forecasting. The study introduces a spatial transformation component that adjusts the model's predictions based on the spatial relationships within the plant images. This approach improves the model's ability to adapt to different growth patterns and environmental conditions. The authors validate their method through extensive experiments, demonstrating its effectiveness in generating precise growth predictions and its applicability in various agricultural scenarios.

C. Plant leaf segmentation using knowledge distillation

This paper explores the application of knowledge distillation to plant leaf segmentation tasks. Knowledge distillation is used to transfer knowledge from a large, complex model to a smaller, more efficient model, enhancing the segmentation of plant leaves in images. The authors detail their approach to leveraging distillation techniques to improve the performance of the segmentation model while maintaining computational efficiency. The paper highlights the benefits of this method in terms of accuracy and speed, making it suitable for environments with limited resources. The study includes a thorough evaluation of the proposed method, showcasing its effectiveness in achieving high-quality leaf segmentation and its potential for practical agricultural applications.

D. Deep clustering based plant disease segmentation network

Malaria is a The paper presents a deep-clustering based network designed to enhance plant disease segmentation. The proposed network integrates deep learning with clustering techniques to accurately identify and segment diseased regions in plant images. The authors introduce a novel approach that combines clustering algorithms with deep learning models to refine the segmentation process. This method addresses the challenge of distinguishing disease patterns amidst varying plant textures and backgrounds. The study includes extensive experiments to validate the network's performance, demonstrating its capability to

improve disease detection accuracy and its practical relevance in plant disease management.

III. PROPOSED METHODOLOGY

The Efficient U-Net model is well-suited for a range of real-world applications involving aerial imagery. In urban planning, it can help accurately segment and map buildings, roads, and other infrastructure, even when objects are captured from different angles. In disaster response, Efficient U-Net can be used to detect and assess damage to buildings or infrastructure after natural disasters like earthquakes or floods, where objects may appear at various orientations. In environmental monitoring, the model's ability to handle different scales and rotations is particularly useful for tracking changes in land cover, forests, or water bodies over time. Additionally, in aerial surveillance, Efficient U-Net can help identify and track vehicles, aircraft, or other moving objects across different angles and scales, making it a powerful tool for security and defense applications.

To address the challenges of few-shot aerial image semantic segmentation, we propose a novel Efficient U-Net approach, integrating U-Net's robust segmentation capabilities with EfficientNet's scalable feature extraction. This model enhances traditional few-shot segmentation by introducing rotation-invariant feature extraction, a critical improvement for aerial images where objects like buildings and roads often appear in arbitrary orientations, leading to significant feature variations. The combination of U-Net and EfficientNet ensures that the network captures orientation-varying yet category-consistent features, aligning same-category objects regardless of their rotation. EfficientNet's multi scale adaptability allows the model to effectively handle aerial objects of varying sizes, enhancing accuracy across different scales.

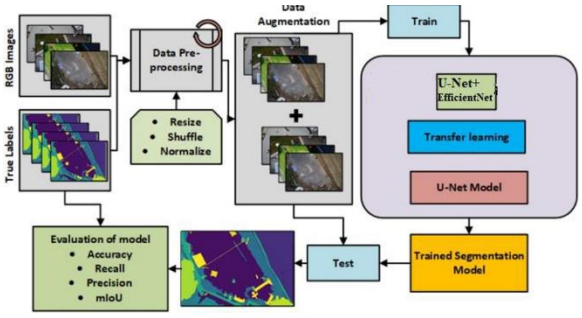


Fig. 1: System Overview

3.1 Data Collection and Preparation

- **Image Acquisition:** Gather a comprehensive set of crop images from varied field conditions, including different disease types and stages. This will provide a robust dataset for training and evaluation.
- **Annotation:** Manually annotate

images to identify and label Regions of Interest (RoI) affected by diseases. This step is crucial for creating a high-quality ground truth dataset.

- **Data Augmentation:** Enhance dataset variability through augmentation techniques like rotation, scaling, flipping, and color adjustments to improve model robustness and performance.

3.2 Model Design and Development

- **U-Net Implementation:** Develop the U-Net model with its encoder-decoder structure and skip connections. U-Net's design facilitates the integration of both high-level and detailed features, essential for precise segmentation.
- **EfficientNet Implementation :** EfficientNet is a family of deep convolutional neural network architectures designed to optimize both accuracy and computational efficiency. It was introduced by Google Research in 2019 and is known for its ability to scale effectively while maintaining a relatively small computational footprint compared to other deep learning models of similar performance. The key innovation behind EfficientNet is the introduction of a compound scaling method, which uniformly scales the network's width, depth, and resolution.
- **Architectural Adjustments:** Experiment with variations of U-Net, including modifications to the number of layers, filter sizes, and the incorporation of attention mechanisms, to optimize performance for detecting small disease regions.

3.3 Training and Optimization

- **Loss Function Selection:** Utilize specialized loss functions such as Dice coefficient or IoU (Intersection over Union) to effectively handle class imbalance and improve segmentation accuracy.
- **Optimization Techniques:** Apply algorithms like Adam or RMSprop for training the model, adjusting learning rates and other parameters to enhance convergence and learning efficiency.
- **Hyperparameter Tuning:** Conduct systematic experiments to fine-tune hyperparameters, including batch size, learning rate, and number of epochs, to achieve optimal model

performance.

3.4 Evaluation and Validation

- **Performance Metrics:** Assess model performance using metrics such as precision, recall, F1-score, and pixel accuracy to gauge segmentation effectiveness.
- **Model Comparison:** Compare the U-Net model's performance against previous models, like the RoI-Attention Network (RA-Net), to evaluate improvements in detecting small disease regions.

3.5 Integration and Deployment

- **System Integration:** Incorporate the trained U-Net model into an automated agricultural management system, enabling real-time disease detection and monitoring.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

The experimental results show that the Using UNet with an EfficientNet encoder pr ovides a powerful approach for high-resolution aerial image segmentation. This c ombination leverages EfficientNet's efficient and deep feature extraction and UNet's prec ise segmentation capabilities, making it ideal for detecting fine-grained features like roads, buildings, and ve getation in aerial imagery datasets.

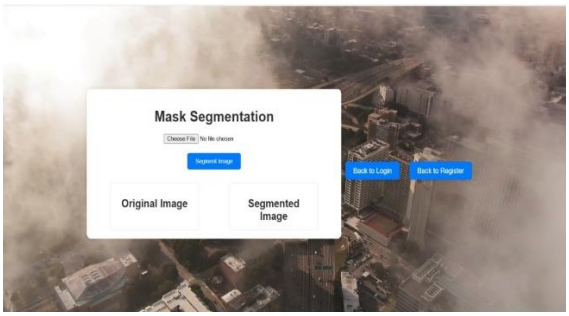


Fig. 2: Prediction

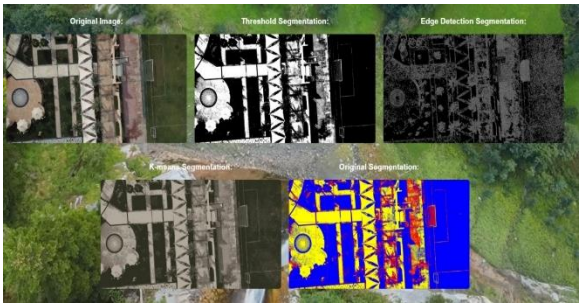


Fig. 3: Prediction done

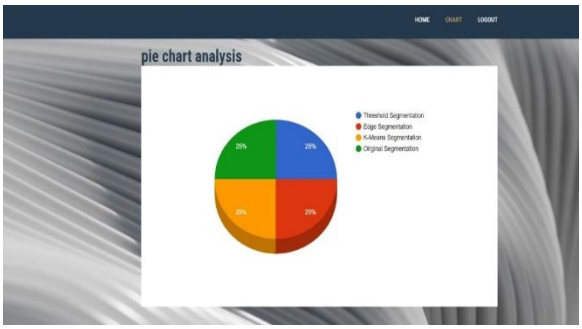


Fig. 4: Chart analysis

V. CONCLUSION

This study demonstrates the Efficient U-Net model presents a novel and effective solution for few-shot semantic segmentation of aerial images, addressing the significant challenges posed by rotation sensitivity, varying scales,

and object distributions. By combining the powerful feature extraction capabilities of Efficient Net with the robust segmentation framework of U-Net, the model provides a scalable, rotation-invariant approach capable of segmenting objects in aerial imagery with minimal annotated data. This enhanced model not only improves segmentation accuracy but also mitigates the misclassification issues caused by varying object orientations. The proposed approach holds strong potential for practical applications in areas such as environmental monitoring, urban planning, and disaster response, where reliable and efficient segmentation is crucial. As the model evolves with further enhancements and optimizations, it promises to offer even more advanced solutions for real-world aerial image analysis tasks.

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