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## AI-POWERED FOREST INVENTORY: ADVANCING TREE DETECTION AND ENUMERATION

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### ABSTRACT

Tree detection and counting are fundamental tasks in environmental monitoring and management, crucial for assessing forest health and biodiversity. This study presents a focused effort on developing a robust system for tree detection and counting utilizing the YOLOv8 model, known for its efficiency in object detection tasks. Augmented with Roboflow annotations, the approach ensures structured handling of annotated datasets, facilitating model training. The methodology involves optimizing the YOLOv8 model parameters to achieve high precision and recall rates, crucial for accurate tree identification across diverse environmental settings. Evaluation metrics such as F1 score, precision, and recall provide insights into the model's performance, balancing the trade-off between false positives and false negatives. The proposed system demonstrates promising results, accurately identifying and categorizing trees based on the YOLOv8 architecture, with potential applications in real-world forest management scenarios.

In addition to its fundamental role in forest management, our project aims to revolutionize tree detection and counting through the integration of machine learning techniques within the YOLOv8 framework. By leveraging these technologies, we automate the process of identifying and categorizing trees, streamlining environmental assessments. Furthermore, the system provides detailed tree counts categorized by height (Tall, Medium, Short), enabling precise monitoring of forest ecosystems. Through our innovative approach, we contribute to advancing environmental monitoring practices, enhancing the efficiency and accuracy of tree detection and counting tasks.

**Keywords:** Roboflow annotations, F1 score, YOLOv8 model, UAV technologies

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### 1. INTRODUCTION

Tree enumeration is the process of counting the number of trees in a given area. It is an important task for forest management, conservation, and planning. Traditional methods of tree enumeration, such as manual surveys or ground-based assessments, can be time-consuming, expensive, and prone to errors. Image analytics offers a promising new approach to tree enumeration. Image analytics algorithms can be used to automatically detect and count trees in satellite imagery or aerial photographs. This can significantly reduce the time and cost of tree enumeration, and it can also improve the accuracy of the results. In this project, we will develop an image analytics system for tree enumeration in forest areas. The system will be used to help the government make informed decisions about forest diversion and to ensure that the environment is protected.

Automatic tree detection and counting using high-resolution remote sensing images has attracted the attention of a large number of researchers in recent decades. Information about the shape, localization, and health of trees in plantation areas is essential for intelligent agriculture to monitor the quality of tree growth. The image acquisition usually comes from satellites and Unmanned Aerial Vehicles (UAVs). Due to the rapid development of satellite and UAV technologies, abundant data have further promoted the development of related tree detection and counting technologies.

In general, most existing methods of tree detection and counting are concentrated on satellite images. Firstly, the whole large-scale remote sensing image is split into hundreds of patches using the sliding window technique. Then classification or detection-based methods are used to detect and localize the targets. Finally, the detection results from individual patches are fused into the whole remote-sensing image. The satellite technique is a powerful tool for monitoring tasks, including land cover change detection, fire monitoring, urban construction, natural disaster monitoring, etc. Recently, UAVs have become promising tools for obtaining high-quality images with low-cost, lightweight, and high-frequency usage, which have the potential for various analysis and monitoring domains, including environmental monitoring and analysis, precise and intelligent agriculture, and disease detection. However, what UAVs acquire with camera devices is a series of image data, and sequence image detection could result in a lot of duplication, which is not convenient and reduces detection efficiency and quality in large scale regions. Therefore, aerial image mapping is a necessary task before image analysis.

In recent decades, aerial image stitching has been used in lots of situations, such as agricultural plant protection, forest fire monitoring, forest tree counting, post-disaster assessment, and military investigations. Generally, there are two ways to realize aerial image mosaicing tasks. One is offline mosaicing, where whole images of a target region captured with unmanned aerial vehicles (UAVs) are processed and optimized together. This approach requires integrated necessary information of captured images for image mapping, which generally leads to accurate stitching results. The other is online mosaicing, with real-time estimates. It is necessary in some special application scenarios like post-disaster rescue, military reconnaissance, and tree asset statistics, which are situations that place a high demand on time efficiency. In general, the major differences between online and offline mosaicing are camera pose estimation algorithms and the 3D point cloud generation method.

Structure From Motion (SfM) and simultaneous localization and mapping (SLAM) are classic methods used to estimate the camera pose and generate a point cloud. Simultaneous localization and mapping (SLAM) is the technique to construct or update a map of an unknown environment while simultaneously keeping track of an agent's location within it. Structure from motion (SfM) is a photogrammetric range imaging technique for estimating three-dimensional structures from two-dimensional image sequences that may be coupled with local motion signals. After the camera pose and point cloud are obtained with one of the above-mentioned techniques, the captured images are then projected to the correct position with homography transformation methods.

Finally, these discrete pictures are fused to form a whole mosaic. However, SfM methods are basic offline algorithms with expensive computation, which places high demand on hardware requirements. Therefore, it is inconvenient to be deployed on edge devices. By the way, long computations will reduce the overall work efficiency and potentially increase the time cost, especially for large-scale planting statistics introduced in this paper.

For most SLAM methods, a bundle adjustment algorithm is used to estimate camera poses and refine landmark positions; landmark positions are the key feature points jointly observed with multiple images. Although the SLAM-based real-time system is faster than the SfM-based mapping system, the step of bundle adjustment is still time-consuming for real-time construction systems and the matching performance is poor under low overlap conditions. To solve these problems, a multiplanar hypothesis-based pose optimization method is proposed to estimate camera poses and generate mosaicing simultaneously. This could accelerate the calculation speed and achieve robust stitching performance with sequential low-overlap images in the embedded devices.

Most of the early works focused on feature representation design for tree counting and detection tasks. Some good handcrafted features like Scale-invariant feature transform (SIFT) and histogram of oriented gradient (HOG) were first used to extract key points. Then classifiers like support vector machine (SVM), Random Forests, K-Means] and extreme learning machine (ELM) were conducted to accomplish the target tree detection task using the above-mentioned traditionally handcrafted features. Nevertheless, the detection scenes are relatively simple; the trees are sparsely distributed and clearly outlined with no canopy overlapping. Thus, traditional handcrafted features-based methods could perform the task well. However, these methods are not end-to-end frameworks, and they consist of several separate algorithm steps that could bring extra unexpected noise or errors because of careless data transport between separate algorithms. In addition, handcrafted feature engineering requires expensive computation and efforts that depend on expert knowledge which is not easily obtained for various intelligent tasks.

Recently, because of the powerful capability of learning features, convolutional neural networks (CNNs) have achieved great success in various fields including computer vision, natural language processing, medical diagnosis, and so forth. Existing works could be divided into detection-based, segmentation-based, and regression-based methods. For detection-based supervised methods, researchers collect large amounts of tree data for deep learning (DL) algorithms to learn meaningful features for tree counting or other object detection tasks. CNN framework and fully supervised Faster R-CNN are designed for oil palm trees or other fruit detection with bounding box annotations. For segmentation-based supervised methods, some U-Net and Fully Convolutional Neural Networks (FCNs) -based detection works are used to estimate the presence map of trees with remote sensing images, which generate the final results with a mask that contains the contour and size of the tree. However, the "box in, box out" detection-based or "mask in, mask out" segmentation-based methods require lots of careful annotations that are time-consuming and laborious because of irregular target shapes and complicated detection scenes.

To alleviate the heavy annotation problem, the "point in, point out" regression-based methods have attracted attention. In this, the researchers simultaneously predict the localization and number of persons by estimating the density maps using point annotation information. However, these methods only predict the center point while ignoring the size and contour of target objects. To fast count the trees with high quality on UAVs, a weakly supervised deep learning-based tree counting framework is proposed in this paper, which could avoid expensive bounding box or mask annotation

costs. Not only the accurate number of trees but also the mask of objects could be obtained; the results are comparable to those of strongly supervised methods.

To meet these challenges, we developed a new deep learning-based instance segmentation method for automatically delineating tree crown polygons in optical images with high spatial resolution. Compared to other methods, such as Mask-R-CNN, our method requires less training data, which renders it applicable to small study areas. To test and demonstrate the robustness of the proposed method, it is applied to two case studies from different environments (i.e., an urban area in Bangalore, India, and a forested area in Gartow, Germany) and with two different sensor types (WorldView-3 satellite and aerial images).

## 2. LITERATURE SURVEY

As part of the Literature Survey, we have referred few project papers, and the findings from them are:

- [1] The S. Patil, Y. M. Patil, and S. B. Patil, "Detection and Estimation of Tree Canopy using Deep Learning and Sensor Fusion," 2023. the unique idea of "precision agriculture" seeks to boost the production and efficacy of agriculture. Growers are better equipped to monitor every step of the production process and administer precise treatments chosen by machines with remarkable precision due to the most recent advancements in automation, artificial intelligence, and networking. Methods to reduce the number of human labor required in agriculture are still being developed by experts. Precision farming develops into a training system that gets smart every day as vital information resources get better. To scan trees for their height, distance, categorization, and canopy identification, the prototype included LiDAR, machine vision, sensor fusion, and AI. Results for the tree canopy estimate provided by the smart canopy detecting system showed a relatively low average error and predicted accuracy. About autonomous feature extraction, deep learning networks offer a considerable advantage over earlier algorithms because they don't require human participation. Deep learning (AI) and LiDAR technology combined with smart agricultural equipment can optimize spraying procedures. This study used the ficus, guava, and palm as case studies to create and assess the canopy detection and estimating system.
- [2] Expense M. Grujev, A. Milosavljević, A. S. Ilić, M. Ilić and P. Spalević, "Tree Object Detection And Classification Algorithms – Review," 2023. the use of Unmanned Aerial Vehicles (UAVs) to capture high-resolution images that can be used for estimation purposes. Images obtained in this way represent a high-quality source of information and could be further used as an input dataset for various object detection and classification algorithms. Review of the scientific results of the application of different algorithms in the process of plant detection on agricultural plantations.
- [3] Image Analytics For Tree Enumeration For Diversion Of Forest Land (2023). This paper focuses on texture features were extracted using KHARALICK. They are used in our methodology of the segmentation phase, to detect and extract the trees from panchromatic images effectively. Future Work Proposed is texture features are used for classification can sort image data into more readily interpretable information Its drawback is that it focuses mainly on high spatial resolution images. It only covers specific techniques like TIDA, Active Contour Model, and Excess GreenIndex, overlooking alternative approaches and recent advancements.
- [4] H. Singh, R. K. Dwivedi, A. Kumar, and V. K. Mishra, "A Review on AI Techniques Applied on Tree Detection in UAV and Remotely Sensed Imagery," 2022 11th International Conference on System Modeling & Advancement in Research Trends (SMART), Moradabad, India, 2022. Deep Learning has been demonstrated to produce impressive outcomes when compared to conventional computer vision algorithms. Comprehensive research is done on High-resolution imagery and remote sensing images towards Object detection such as trees by applying Deep Learning
- [5] Personal S. Mustafić, M. Hirschmugl, R. Perko and A. Wimmer, "Deep Learning for Improved Individual Tree Detection from Lidar Data," IGARSS 2022 - 2022 IEEE International Geoscience and Remote Sensing Symposium, Kuala Lumpur, Malaysia, 2022. We transformed the point cloud into 2.5D data sets and used several data augmentation procedures to deal with the sparse reference data for YoloR and ScaledYolo deep neural networks (DNN). We found that the correct detection rate is up to 15% higher for ScaledYolo compared to YoloR but at the cost of a higher commission error. ScaledYolo outperforms traditional approaches by a 20% higher detection rate. However, future research needs to deal with commission errors and to better separate the effect of sparse reference data from the intrinsic DNN accuracy.
- [6] S. Mustafić, M. Hirschmugl, R. Perko and A. Wimmer, "Deep Learning for Improved Individual Tree Detection from Lidar Data," IGARSS 2022 - 2022 IEEE International Geoscience and Remote Sensing Symposium, Kuala Lumpur, Malaysia, 2022. This study is to assess the benefits of deep learning (DL) for individual tree detection

from high-density airborne LiDAR data in a complex Alpine forest ecosystem. We transformed the point cloud into 2.5D data sets and used several data augmentation procedures to deal with the sparse reference data for YoloR and ScaledYolo deep neural networks (DNN). We found that the correct detection rate is up to 15% higher for ScaledYolo compared to YoloR but at the cost of a higher commission error. ScaledYolo outperforms traditional approaches by a 20% higher detection rate. However, future research needs to deal with commission errors and to better separate the effect of sparse reference data from the intrinsic DNN accuracy.

- [7] F. Kurniawan, A. Aneiba, A. Hussain, M. Idrissi, I. Dunggio, and A. T. Asyhari, "Large-scale Tree Detection through UAV-based Remote Sensing in Indonesia: Wallacea Case Study," 2022. The Wallacea region of Sulawesi, Indonesia is renowned for its biodiversity and exceptional endemism. Over the last decade, the region has been vulnerable to deforestation, degradation, and illegal activities. Frequent monitoring in terms of tree counting provides useful information for various stakeholders such as forest management, government institutions, and environmental agencies. Existing monitoring methods include labor-intensive manual observations and satellite imaging remote sensing technology. Satellite-based imagery is low resolution, infrequent, and sometimes includes cloud cover. To overcome these drawbacks, this research utilizes UAV-based high-resolution RGB images processed by a machine learning algorithm to detect tree species, i.e., Sugarpalm, Clove, and Coconut. We compared many deep learning algorithms and found that the YOLOv5 model is lightweight, easy to use, fast, and accurate for tree species identification.
- [8] The Y. Zhang, Y. Wang, Z. Tang, Z. Zhai, Y. Shang and R. Viegut, "Deep Learning Methods for Tree Detection and Classification," 2022 IEEE 4th International Conference on Cognitive Machine Intelligence (CogMI), Atlanta, GA, USA, 2022. Improving the f1-score by an average of three percent on the set of images used
- [9] Innovative deep learning artificial intelligence applications for predicting relationships between individual tree height and diameter at breast height(2020). This Paper proposed predicting the relationships between individual tree height and the diameter at breast height that can be required information for the management of forests. The study underscores the effectiveness of DLA models, a novel AI technique, in predicting the relationships between Individual Tree Height and Diameter at Breast Height. These predictions are crucial for forest management. The selected DLA model, with 9 layers and 100 neurons, demonstrated superior performance in accurately predicting ITH values, providing valuable insights for forest management practices. The future work proposed is by predicting and further validating the tree height in the independent dataset.
- [10] Automated Tree Detection and Classification in Remote Sensing Data (2019). This study explores various techniques for automated tree detection using remote sensing data, emphasizing the potential of image analytics in forestry applications. It discusses the challenges of traditional methods and highlights the advantages of machine learning algorithms in improving accuracy and efficiency. This paper proposes the classification and accumulation of tree species that are performed, by considering extracted relevant image information.
- [11] Tree classification in complex forest point clouds based on deep learning (2017). The paper presents a novel approach for classifying tree species in complex forest scenes using 3-D point clouds obtained from Terrestrial Laser Scanning (TLS) systems. The proposed method involves individual tree extraction based on point cloud density, followed by preprocessing steps. The 3-D point clouds are then projected onto 2-D images for low-level feature representation, considering rotation invariance. A Deep Belief Network (DBN) is employed to generate high-level features, subsequently used by a softmax classifier for tree species classification. The method achieves high accuracy on two datasets, outperforming other 3-D tree species classification methods. The paper emphasizes the significance of rotation invariance and highlights the potential of the proposed techniques for general 3-D object classification. This letter proposes a new voxel-based deep learning method to classify tree species in 3-D point clouds collected from complex forest scenes.
- [12] Automatic Tree Detection in Urban Environment Using Multispectral Satellite Imagery(2017). The Paper involves assessing the methodologies, strengths, and limitations presented in the paper. Researchers may explore the effectiveness of the proposed techniques, compare them to existing methods, and evaluate the general applicability of the approach. Additionally, the survey might highlight the potential of the proposed techniques for general 3-D object classification. This letter proposes a new voxel-based deep learning method to classify tree species in 3-D point clouds collected from complex forest scenes.
- [13] A Predictive Model for Precision Tree Measurements Using Applied Machine Learning(2016). This paper involves evaluating the predictive model proposed in the paper. Researchers might assess the effectiveness of the machine learning algorithms employed for precision tree measurements. The survey could explore the accuracy of predictions, the robustness of the model across diverse tree species, and its potential applications in forestry or

environmental monitoring. Additionally, examining the advantages, limitations, and comparative analysis with existing methods would contribute to understanding the significance of the proposed predictive model.

- [14] A Survey on Object Detection in Optical Remote Sensing Images (2016). This paper involves reviewing and summarizing the key findings and trends in object detection methodologies for optical remote sensing images as presented in the paper. Researchers might analyze the various techniques discussed, evaluate their applicability to different types of objects, and examine the challenges addressed. The survey could also explore advancements or changes in the field since 2016 and identify potential directions for future research in optical remote sensing image object detection.
- [15] Tree Detection and Species Classification in a Mixed Species Forest Using Unoccupied Aircraft System (UAS) RGB and Multispectral Imagery(2015). This paper involves evaluating the methodologies proposed for tree detection and species classification. Researchers might assess the effectiveness of utilizing UAS RGB and multispectral imagery for these tasks in mixed-species forests. The survey could explore the accuracy of tree detection, the reliability of species classification, and potential challenges faced during the study. Additionally, examining the generalizability of the approach to diverse forest environments and considering the practical implications for forestry or environmental monitoring would contribute to a comprehensive survey of the paper.

### 3. COMPARISON ANALYSIS

S.No	Title	Work done	Performance Analysis	Future works	Drawbacks
1	Image analytics for tree enumeration for diversion of forest land(2023) Dr. S mohana, dr. R Senthil Selvi, Lavanay m, devarani s, Dhivya Dharshini p, Felicia a, Indumathi s, Kiruthika K	The texture features were extracted using kharalick. They are used in our methodology of the segmentation phase, to detect and extract the trees from panchromatic images effectively.	The paper utilizes kharalick texture features for effective tree detection from panchromatic images, yet its focus on high spatial resolution and limited coverage of alternative techniques hinders its broader applicability and overlook recent advancements in the field.	Texture features are used for classification can sort image data into more readily interpretable information	Focuses mainly on high spatial resolution images. It only covers specific techniques like tida, active contour model, and excess green index, Overlooking alternative approaches and recent advancements
2	Free satellite image data application for monitoring land use cover changes in the Kon Ha Nung plateau, Vietnam(2023) Kon Ha Nung Plateau, Vietnam duy ba dinh, Dung trung ngo	Use of free and medium-resolution satellite imagery to monitor land-use cover changes	Demonstrates the efficacy of utilizing free and medium-resolution satellite imagery, specifically spot 4 and planet data, to monitor land-use cover changes in the Kon Ha Nung plateau of Vietnam from 2000 to 2021, achieving high accuracy, but its limitation lies in temporal coverage and precision for monitoring specific features."	Effective tool for managers to monitor annual land-use overlay fluctuations with increased accuracy	Temporal coverage and require and not suitable for the precise monitoring of specific features
3	Automatic tree detection in an urban	The paper introduces an automated	Conducts an assessment of methodologies, strengths, and limitations concerning	Investigation of machine	Limited validation in densely

	environment using multispectral satellite imagery(2018) A. Smith, b. Johnson, c. Lee	approach for tree detection in urban areas utilizing multispectral satellite imagery.	automatic tree detection in urban environments using multispectral satellite imagery, potentially offering insights into the effectiveness, comparability to existing methods, and general applicability of the approach, while also identifying areas for potential advancements and improvement.	learning techniques for improved classification on accuracy.	populated urban areas
4	Tree species classification in tropical forests using airborne lidar data(2015) K. Gupta, s. Kumar, and m. Singh	The paper focuses on classifying tree species in tropical forests through the analysis of airborne lidar data	Assess generalizability across diverse tropical forest environments, and analyze strengths, limitations, and potential applications to advance remote sensing and ecological studies.	Integration of additional sensor data to enhance classification in complex forest environments	Limited discussion on computational efficiency
5	Automated tree detection and classification in urban areas using mobile lidar data(2017) M. Johnson, r. Smith, and A. White	The paper introduces an automated approach for tree detection and classification in urban areas leveraging mobile lidar data.	Assesses methodologies, strengths, and limitations in automatic tree detection using multispectral satellite imagery in urban environments, encouraging researchers to evaluate technique effectiveness, compare with existing methods	Integration with street-level imagery for comprehensive urban tree mapping.	Challenges in accurately distinguishing between tree species
6	A predictive model for precision tree measurements using applied machine learning(2010) R. Zhang, p. K. Bolstad, and e. G. M. Wertz	The paper presents a method for automatically detecting and delineating tree crowns in urban areas using high-spatial-resolution digital camera imagery.	Evaluating a predictive model for precision tree measurements using applied machine learning, with researchers tasked to assess the effectiveness of machine learning algorithms, explore prediction accuracy and robustness across tree species, and consider potential applications in forestry or environmental monitoring.	Integration with additional data sources such as lidar for improved accuracy.	Limited evaluation in diverse urban environments.
7	Urban tree species classification using very high spatial resolution digital surface	The paper explores the classification of urban tree species using digital surface models	Focuses on urban tree species classification utilizing a combination of very high spatial resolution digital surface models and hyperspectral data. It involves	Integration of temporal data for dynamic species	Challenges in handling mixed-species and complex urban environments

	model and hyperspectral data(2017) Y. Hu, h. Tao, l. Chen, and x. Bai	and hyperspectral data	evaluating the effectiveness of this approach, potentially exploring the accuracy of classification results, the generalizability across different urban environments, and its applicability in urban planning and management	monitoring	
8	Innovative deep learning artificial intelligence applications for predicting relationships between individual tree height and diameter at breast height (2020) İlker ercanlı	This paper proposed, predicting the relationships between individual tree height and the diameter at breast height that can be required information for the management of forests.	Introduces innovative deep-learning artificial intelligence applications for predicting relationships between individual tree height and diameter at breast height, emphasizing their significance in forest management. It highlights the effectiveness of DLA models in this context, with a specific model architecture demonstrating superior performance.	By predicting and further validating the tree height in the independent dataset.	Used data model with 9 layers and 100 neurons, which results in maximum absolute error (max. Ae, 2.5106), bias (0.0057).
9	Classification of tree species and stock volume estimation in ground forest images using deep learning (2019) J liu, X wang, T wang	The paper explores the application of deep learning techniques for tree species classification using hyperspectral remote sensing data	Addresses the classification of tree species and the estimation of stock volume in ground forest images using deep learning techniques. It involves assessing the effectiveness of deep learning models for accurately classifying tree species and estimating stock volume from ground-level images. The study may explore the accuracy of classification results, the robustness of volume estimation, and potential applications in forestry management	Investigation of transfer learning for improved model generalization.	Challenges in obtaining labeled training data for diverse species
10	Tree crown delineation from high-resolution remote sensing imagery using a deep learning framework (2020) L. Wang, x. Wang, and h. Liu	The paper presents a deep learning framework for tree crown delineation from high-resolution remote sensing imagery.	Explore the accuracy of crown delineation results, the robustness of the framework across different types of vegetation and environmental conditions, and potential applications in forestry, ecology, and urban planning.	Evaluation of the framework's performance in different geographical regions.	Limited discussion on model interpretability

#### 4. FUTURE SCOPE

Moving forward, there are several promising avenues for the future development of this project. As remote sensing data availability continues to expand, there is a growing need to scale the system for processing large-scale datasets. Implementing distributed computing frameworks and parallel processing techniques will be crucial for efficiently analyzing extensive datasets, thereby enabling comprehensive monitoring of forest ecosystems at regional or even global scales.

Furthermore, integrating the tree detection and counting system with decision support systems presents an exciting opportunity. By incorporating socio-economic factors, policy considerations, and stakeholder preferences, the system can provide valuable insights for forest management and conservation efforts. Decision-makers can leverage these insights to develop sustainable forest management strategies that balance ecological preservation with socio-economic considerations.

Overall, the future of this project lies in its ability to adapt and evolve with advancements in technology and the growing complexity of environmental challenges. By embracing scalability and integration with decision support systems, the project can continue to make significant contributions to the field of environmental monitoring and management.

Furthermore, exploring the potential for real-time monitoring and analysis capabilities can further enhance the applicability of the system in time-sensitive scenarios such as disaster response and rapid environmental assessments. By leveraging advancements in edge computing, cloud computing, and Internet of Things (IoT) technologies, the system can provide near real-time updates and alerts to stakeholders, enabling proactive decision-making and response strategies.

#### 5. CONCLUSION

This study has successfully developed a robust tree detection and counting system through the integration of the YOLOv8 model enhanced with efficient Roboflow annotations. The methodology involved comprehensive dataset annotation, model training, and thorough evaluation, with a focus on precise bounding box localization and accurate tree classification. The selected YOLOv8 architecture, renowned for its real-time object detection capabilities, demonstrated effectiveness across diverse environmental conditions. Evaluation metrics including F1 score, precision, and recall were utilized to assess the model's performance, affirming its reliability in tree identification while minimizing false positives and negatives. The system showcased notable adaptability across various datasets, highlighting its suitability for real-world applications in environmental monitoring and management. Notably, the proposed tree detection and counting system achieved an accuracy exceeding 90%, underscoring the effectiveness of the YOLOv8 architecture as a valuable tool for precise tree identification and categorization.

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