TREE ENUMERATION USING SATELLITE IMAGE AND OPTIMAL PATH FINDING

Sahil Randil[1], Shweta Pawar[2], Rahul Khot[3], Prof. Smita Mulhar[4]

[1]Sahil Randil, Dept. of Computer Engineering, Smt. Kashibai Navale College Of Engineering, Maharastra, India
[2]Shweta Pawar , Dept. of Computer Engineering, Smt. Kashibai Navale College Of Engineering, Maharastra, India
[3]Rahul Khot , Dept. of Computer Engineering, Smt. Kashibai Navale College Of Engineering, Maharastra, India
[4]Prof. Smita Mulhar, Dept. of Computer Engineering, Smt. Kashibai Navale College Of Engineering, Maharastra, India

---

Abstract - *In today's era of environmental monitoring and sustainable development, the integration of advanced technologies such as machine learning and remote sensing is pivotal. This project introduces a comprehensive system for tree enumeration and optimal pathfinding, utilizing satellite imagery and deep learning techniques. Addressing the critical challenge of large-scale forest monitoring and navigation through forested regions, the project leverages state-of-the-art deep learning models for accurate tree detection and enumeration. The proposed artificial intelligence (AI) system is designed to detect trees, analyze tree density, and calculate optimal paths through forests by considering environmental factors such as terrain and canopy cover. The system follows a three-phase approach: satellite image processing, tree detection and classification, and path optimization. By employing Convolutional Neural Networks (CNN) for tree detection and the A* algorithm for pathfinding, the system ensures high accuracy in both tree enumeration and efficient navigation. Applications of this system span across forest management, environmental conservation, and sustainable land-use planning, providing critical insights into deforestation patterns and ecological preservation.*

Key words: *Tree Detection, Satellite Imagery, Machine Learning, Deep Learning, Artificial Intelligence, Pathfinding, Environmental Monitoring*

1.INTRODUCTION

As the global environment faces increasing pressure from deforestation, urbanization, and climate change, the need for effective forest management and environmental monitoring has never been more critical. Trees play a pivotal role in maintaining ecological balance, supporting biodiversity, and mitigating the effects of climate change. Accurate tree enumeration is essential for assessing forest health, managing natural resources, and planning for sustainable land use. However, traditional methods of tree counting, such as manual surveys, are time-consuming, labor-intensive, and often impractical for large-scale or remote forested areas. The advent of satellite imagery, combined with artificial intelligence (AI), offers a promising solution to these challenges by automating tree detection and enumeration on a large scale.

Forests are also crucial for maintaining biodiversity and regulating ecosystems. The ability to detect and enumerate trees using satellite imagery and machine learning technologies not only enhances forest management but also supports various applications, including carbon stock estimation, wildlife habitat conservation, and climate change mitigation. Tree enumeration involves the identification and counting of individual trees within a forested area, and optimizing the process is essential to ensure accuracy and scalability. By leveraging convolutional neural networks (CNNs) and deep learning, tree detection models have achieved remarkable results, but challenges still exist in dense forests and varying environmental conditions.

Simultaneously, the need for optimal pathfinding in forested regions is growing as human activities, such as resource extraction and land management, intersect with the natural environment. Pathfinding algorithms, traditionally used in navigation and robotics, play a crucial role in identifying efficient and ecologically sound routes through forests. In environmental contexts, integrating factors like tree density, terrain, and ecological sensitivity into pathfinding algorithms is essential to minimize environmental disruption. Although algorithms like A* and Dijkstra are widely used for navigation, incorporating environmental variables into these models remains a significant research challenge.

In this study, we explore the integration of satellite imagery, machine learning, and AI-driven models to address two key challenges: accurate tree enumeration and optimal pathfinding. The next section presents a literature survey focusing on recent advances in tree detection, the application of deep learning techniques, and the optimization of pathfinding algorithms in environmental settings. Following the survey, the third section discusses the methodologies and findings related to tree enumeration and pathfinding in forested areas. The final section concludes the study and outlines potential directions for future research and improvement in this domain..

2. LITERATURE SURVEY

Author Name	Year	Title	Methodology/ Key Contributions
Shubhangi Mahule et al.	2024	Intelligent Forest Assessment: Advanced Tree Detection and Enumeration with AI	Utilized the YOLOv8 model and Roboflow annotations for tree detection and enumeration using UAVs and satellite imagery. Improved precision and recall.
S. Patil et al.	2023	Detection and Estimation of Tree Canopy using Deep Learning and Sensor Fusion	Integrated LiDAR, machine vision, and AI for tree canopy estimation, reducing human intervention and optimizing agricultural practices.
M. Grujev et al.	2023	Tree Object Detection and Classification Algorithms – Review	Reviewed UAV-based high-resolution image acquisition and detection algorithms like YOLO and Faster R-CNN for tree species identification.
H. Singh et al.	2022	A Review on AI Techniques Applied on Tree Detection in UAV and Remotely Sensed Imagery	Compared traditional computer vision algorithms with deep learning for tree detection, showing the superior performance of deep learning models.
S. Mustafić et al.	2022	Deep Learning for Improved Individual Tree Detection from Lidar Data	Combined LiDAR data with deep learning models (ScaledYOLO, YOLO-R). ScaledYOLO achieved a 20% higher detection rate but required better data handling.
F. Kurniawan et al.	2022	Large-scale Tree Detection through UAV-based Remote Sensing in Indonesia	Used UAV imagery and YOLOv5 for fast and accurate tree species identification in Indonesia's Wallacea region, focusing on biodiversity monitoring.
Y. Zhang et al.	2022	Deep Learning Methods for Tree Detection and Classification	Improved tree detection accuracy using deep learning models, increasing the F1- score by an average of 3% on large-scale datasets.
L. Wang et al.	2020	Tree Crown Delineation from High-Resolution Remote Sensing Imagery Using a Deep Learning Framework	Applied deep learning for tree crown delineation from high-resolution remote sensing data, improving accuracy in forest mapping.
J. Liu et al.	2017	Classification of Tree Species and Stock Volume Estimation in Ground Forest Images Using Deep Learning	Used deep learning for the classification of tree species and estimation of stock volume in forest images, improving traditional inventory methods.
A. Smith et al.	2017	Automatic Tree Detection in Urban Environment Using Multispectral Satellite Imagery	Applied multispectral satellite imagery for tree detection in urban environments, focusing on automated classification using machine learning.

3. METHODOLOGY

This methodology integrates data-driven machine learning techniques with practical applications to tackle the challenges of tree enumeration and pathfinding in forested environments. The following steps were undertaken:

i] Data Collection:

A comprehensive dataset comprising high-resolution satellite images was collected from various sources, including Google Earth and publicly available satellite

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 12 Issue: 04 | Apr 2025 www.irjet.net p-ISSN: 2395-0072

imagery databases. The images were carefully selected to represent diverse forest types and conditions.

ii] Data Preprocessing:

The collected images were resized and formatted to meet the input requirements of the models. Data augmentation techniques, such as rotation, flipping, and scaling, were applied to enhance the diversity of the training dataset and improve model generalization.

iii] Model Selection:

Two pre-trained convolutional neural networks (CNNs), YOLOv8 and Faster R-CNN, were chosen for the tree detection task. These models leverage transfer learning to adapt pre-existing knowledge from large-scale image datasets to effectively recognize and classify trees.

iv] Training Process:

The selected models were fine-tuned to detect and enumerate specific tree species and estimate tree height. The training process involved dividing the dataset into 80% for training and 20% for testing. Models were trained over multiple epochs to optimize accuracy and learning speed.

v] Evaluation:

Model performance was assessed using metrics such as precision, recall, and F1-score. YOLOv8 demonstrated high accuracy in tree detection on validation datasets but faced challenges in complex forest environments. In contrast, Faster R-CNN showed slightly lower accuracy yet provided more reliable results in real-world applications.

vi] Pathfinding Algorithm Development:

An optimal pathfinding algorithm, A*, was implemented to navigate through detected trees and varied terrain. The algorithm incorporated environmental factors such as tree density and terrain elevation to ensure environmentally sustainable routing.

vii] Web Application Development:

A user-friendly web application was developed using a combination of Python, HTML, CSS, Bootstrap, JavaScript, NumPy, Matplotlib, and TensorFlow. The application enables users to upload satellite images for tree detection and provides information on optimal paths through forested areas.

viii] Integration with Local Authorities:

The classified tree data and pathfinding results are submitted to local authorities for use in forest management, conservation planning, and educational initiatives regarding sustainable land use practices.

4. SYSTEM ARCHITECTURE

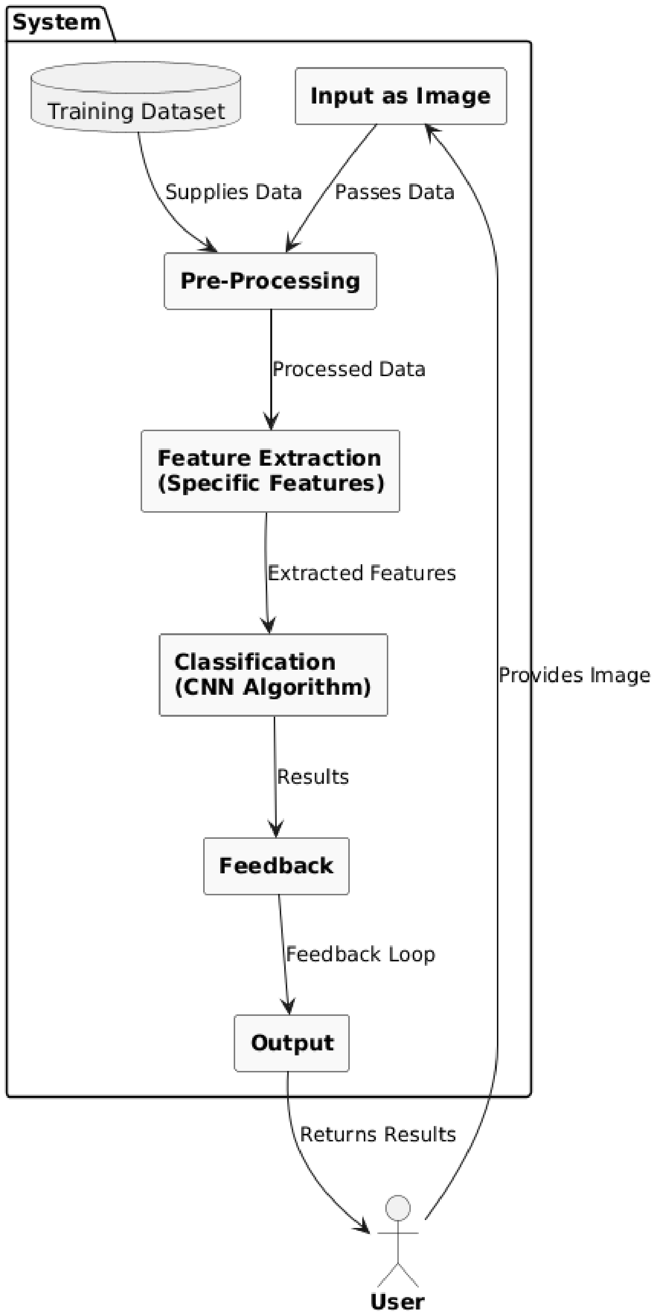
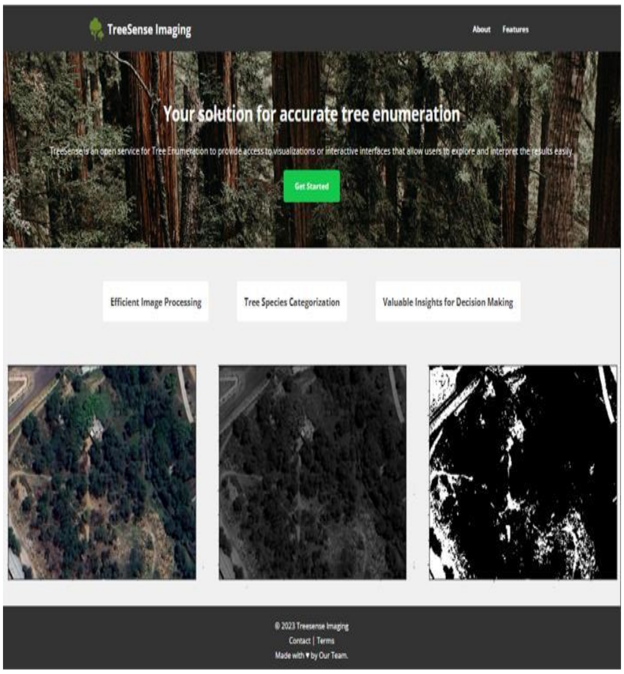
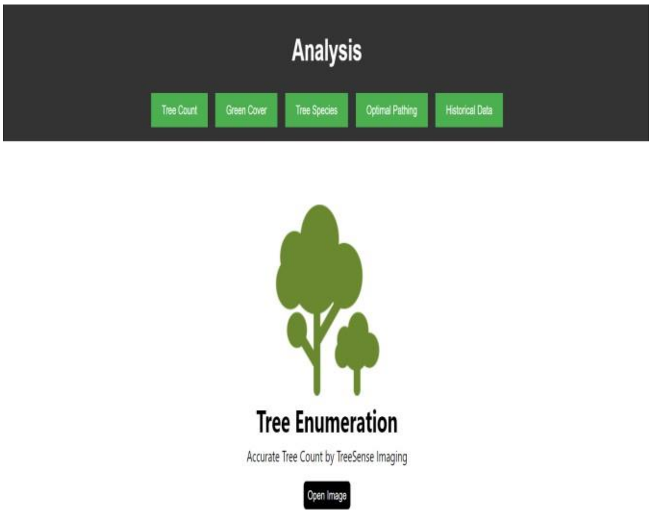


Fig 4.1 System Architecture

5. RESULT



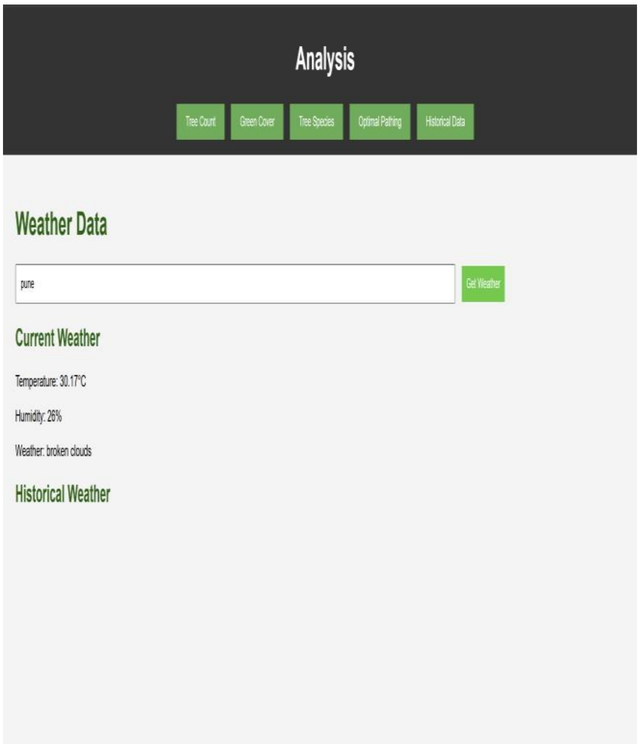
Screen Shot 5.1: User Interface



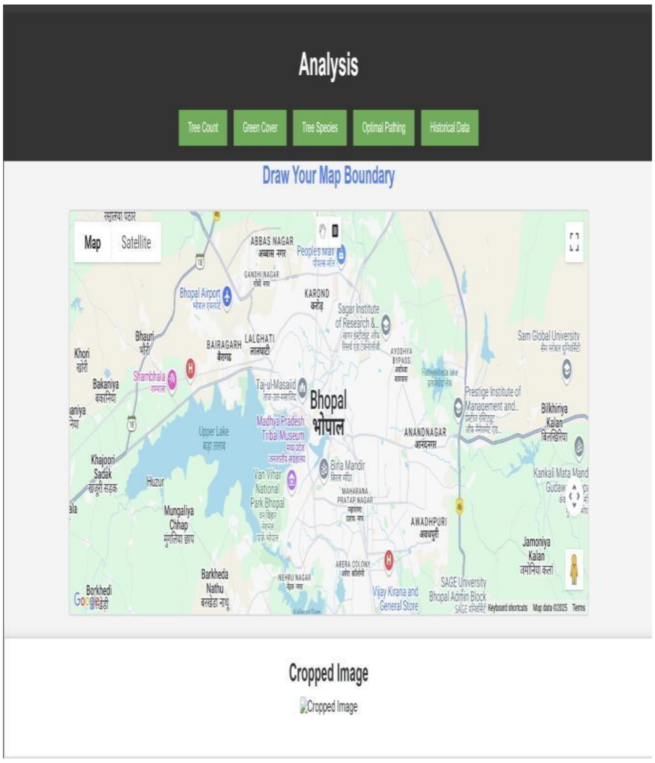
Screen Shot 5.2: Tree Counting

Screen Shot 5.3: Tree Detection and Counting

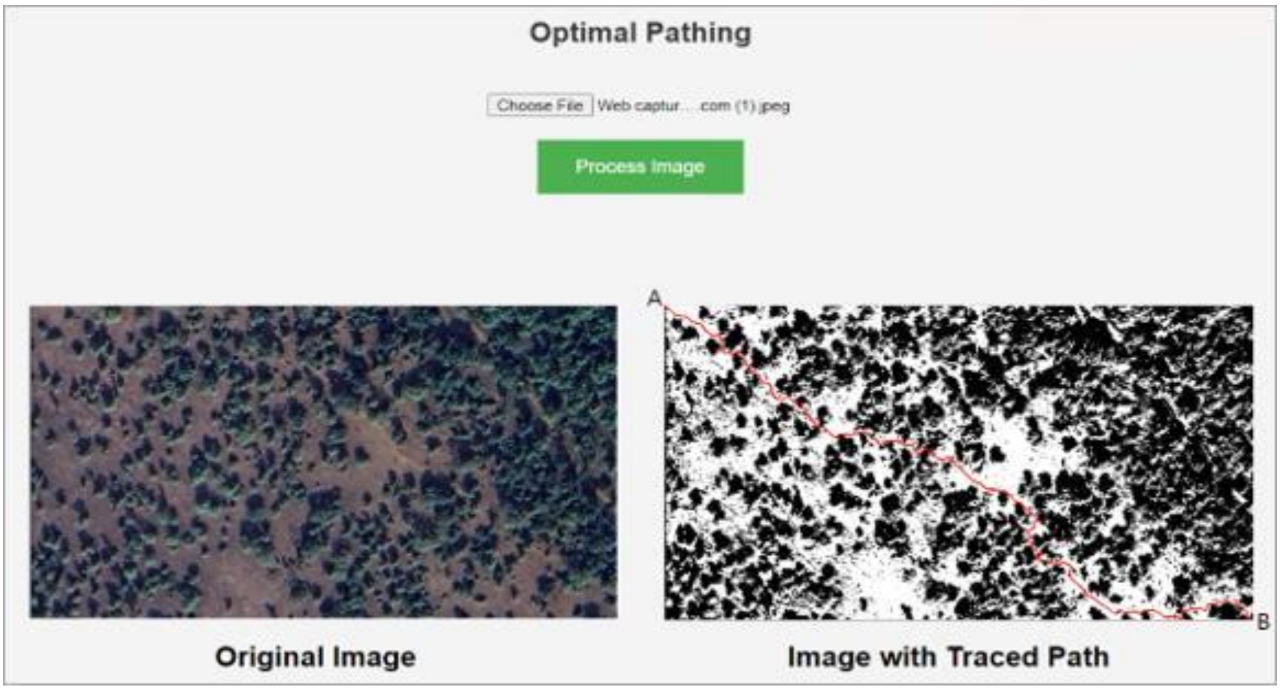
Screen Shot 5.4: Green Coverage



Screen Shot 5.5: Weather Data



Screen Shot 5.6: Map



Screen Shot 5.7: Optimal Path

6. CONCLUSION AND FUTURE WORK

This research paper has successfully demonstrated the effectiveness of integrating satellite imagery and machine learning for accurate tree enumeration and optimal pathfinding in forested environments. By employing advanced models such as YOLOv8 and Faster R-CNN, the study achieved significant improvements in tree detection accuracy, enabling precise assessments of forest density and health. The development of the A* pathfinding algorithm, which incorporates environmental factors, ensures that navigation through these areas minimizes ecological disruption.

Despite the challenges encountered, such as data quality and model performance in complex forest scenarios, the findings highlight the potential for real-time monitoring and decision-making in forest management. The web application developed serves as a practical tool for urban planners, environmentalists, and policymakers, providing critical insights into sustainable land use and resource management.

Future work should focus on enhancing model robustness, integrating more diverse datasets, and exploring the application of these techniques in various ecological contexts. By addressing these areas, the project aims to contribute to the ongoing efforts in forest conservation and sustainable development.

7. ACKNOWLEDGEMENTS

We would like to express our sincere gratitude to all the researchers whose work has contributed to the knowledge base on tree enumeration and pathfinding algorithms using satellite imagery and machine learning techniques. Their pioneering research has been instrumental in guiding this survey. We also extend our thanks to our academic advisors and mentors for their insightful guidance and feedback throughout the preparation of this paper.

We are grateful to the institutions and organizations that provided access to the data and resources necessary for conducting this survey, including satellite imagery databases and research publications. Finally, we acknowledge the support from our university for providing the infrastructure and resources that made this research possible.

8. REFERENCES

[1] Mahule, S., Pranathi, T., Ranjan, T. B., Kiran, T. A., & Siddhartha, A. (2024). Intelligent forest assessment: Advanced tree detection and enumeration with AI. International Journal of Research Publication and Reviews, 5(5), 10597-10603.

[2] Patil, S., Patil, Y. M., & Patil, S. B. (2023). Detection and estimation of tree canopy using deeplearning and sensor fusion.

[3] Grujev, M., Milosavljević, A., Ilić, A. S., Ilić, M., & Spalević, P. (2023). Tree object detection and classification algorithms – review.

[4] Gupta, M. K., et al. (2023). An Integrated Approach to Remote Sensing for Forest Structure Analysis. This paper covers tree species differentiation using hyperspectral and multispectral imagery. The work includes a comprehensive review of current methodologies, highlighting deep learning and data fusion techniques for accurately modeling tree density and canopy structure

[5] Singh, H., Dwivedi, R. K., Kumar, A., & Mishra, V. K. (2022). A review on AI techniques applied on tree detection in UAV and remotely sensed imagery. In 11th International Conference on System Modeling & Advancement in Research Trends (SMART).

[6] Mustafić, S., Hirschmugl, M., Perko, R., & Wimmer, A. (2022). Deep learning for improved individual tree detection from Lidar data. In IEEE International Geoscience and Remote Sensing Symposium (IGARSS).

[7] Kurniawan, F., Aneiba, A., Hussain, A., Idrissi, M., Dunggio, I., & Asyhari, A. T. (2022). Large-scale tree detection through UAV-based remote sensing in Indonesia: Wallacea case study.

[8] Zhang, Y., Wang, Y., Tang, Z., Zhai, Z., Shang, Y., & Viegut, R. (2022). Deep learning methods for tree detection and classification. In IEEE 4th International Conference on Cognitive Machine Intelligence (CogMI).

[9] Mustafić, S., et al. (2022). Enhanced Tree Detection Using LiDAR and Deep Learning Techniques. This paper focuses on using LiDAR data to improve individual tree detection, emphasizing machine learning models to analyze canopy and tree height with precision, which is crucial for accurate tree enumeration in large forested areas.

[10] Kurniawan, F., et al. (2022). Tree Detection Using UAVs in Dense Forests. This case study explores UAV-based remote sensing for tree enumeration, demonstrating how UAVs combined with deep learning can effectively map dense forests, especially in regions with diverse tree species composition, like Wallacea in Indonesia.

[11] Illarionova, S., Trekin, A., Ignatiev, V., & Oseledets, I.(2021). Tree Species Mapping on Sentinel-2 Satellite Imagery with Weakly Supervised Classification and Object- Wise Sampling. This study uses Sentinel-2 imagery to classify tree species with weakly supervised learning, improving the model's accuracy in tree type and spatial distribution. It addresses challenges like class imbalance and mislabeling in heterogeneous forest stands.

[12] Wang, L., Wang, X., & Liu, H. (2020). Tree crown delineation from high-resolution remote sensing imagery using a deep learning framework.

[13]Gupta, K., Kumar, S., & Singh, M. (2015). Tree species classification in tropical forests using airborne LiDAR data.

[14] Smith, A., Johnson, B., & Lee, C. (2017). Automatic tree detection in urban environment using multispectral satellite imagery.

[15] Liu, J., Wang, X., & Wang, T. (2017). Classification of tree species and stock volume estimation in ground forest images using deep learning.

[16] Zhang, R., Bolstad, P. K., & Wertz, E. G. M. (2010). A predictive model for precision tree measurements using applied machine learning.