"Design and Implementation of AyurLeafNet: A Deep Learning Framework for Automated Ayurvedic Leaf Recognition"

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ABSTRACT-*Ayurvedic medicine, one of the oldest holistic healing systems, extensively depends on plant-based treatments where leaves hold significant therapeutic value. Precise identification of medicinal leaves is crucial for ensuring the authenticity and effectiveness of formulations, yet manual recognition is time-consuming and error-prone. This study introduces AyurLeafNet, a deep learning-based framework that employs convolutional neural networks integrated with preprocessing, segmentation, and feature extraction techniques including grayscale conversion, edge detection, and Histogram of Oriented Gradients. Deployed through a Flask web application, the system allows users to upload leaf images, obtain classifications, and access medicinal properties. Experimental evaluation on a curated dataset demonstrates high accuracy, while the integrated dashboard supports analysis, usage tracking, and broader applications in healthcare, education, and research.*

Keywords: Ayurvedic medicine, leaf recognition, convolutional neural networks, HOG features, image classification, Flask web app, traditional medicine modernization.

1. INTRODUCTION

Ayurveda, one of the world's most ancient systems of medicine, has thrived for centuries and continues to play an important role in modern healthcare. Leaves, among the most widely available natural resources, are particularly valued for their medicinal properties [1]. Traditionally, Ayurvedic practitioners identify plants based on morphological traits such as texture, color, and overall appearance. However, manual identification is not only labor-intensive but also prone to misclassification, especially when different species exhibit similar features [2]. This challenge highlights the need for automated approaches that ensure precise and reliable classification of Ayurvedic leaves, both for research purposes and practical healthcare applications. Recent progress in computer vision and deep learning has revolutionized image recognition, enabling machines to achieve remarkable accuracy in classification tasks [3]. Convolutional Neural Networks (CNNs) have demonstrated strong performance by automatically learning hierarchical feature representations from raw input images [4]. Unlike hand-crafted feature engineering, CNNs generalize effectively across domains such as medical imaging, agriculture, and biometrics [5]. Leveraging these advancements, this study introduces AyurLeafNet, an intelligent deep learning framework for Ayurvedic leaf recognition. The system integrates preprocessing, segmentation, and feature extraction with CNN-based classification to enhance robustness. Preprocessing steps such as grayscale conversion and noise reduction improve image quality [6], while segmentation methods isolate leaf regions using contour and edge detection. Histogram of Oriented Gradients (HOG) features further complement CNN learning by capturing textural and structural cues [7]. The framework is deployed as a Flask-based web application, incorporating a MySQL database for storing predictions and an analytics dashboard for monitoring accuracy, trends, and user interactions [8][9]. By combining computational intelligence with traditional knowledge, AyurLeafNet demonstrates the potential of hybrid deep learning solutions in preserving Ayurvedic practices, reducing misclassification, and improving accessibility for education, research, and healthcare applications [10].

2. PROBLEM STATEMENT

Accurate identification of Ayurvedic medicinal leaves remains a critical challenge due to heavy reliance on expert knowledge and manual examination of morphological traits such as shape, color, and vein patterns. Many species exhibit similar visual characteristics, which increases the likelihood of misclassification. The problem is exacerbated by limited access to trained practitioners, variability in results across individuals, and the labor-intensive nature of traditional identification methods. The lack of an efficient, automated, and reliable system for recognizing Ayurvedic leaves hampers large-scale adoption, restricts research progress, and limits the consistent sharing of plant-based medicinal knowledge.

3. OBJECTIVES

The primary objective of this study is to develop AyurLeafNet, an intelligent deep learning framework for the accurate classification of Ayurvedic leaves. The system leverages a CNN model trained on a curated dataset of diverse medicinal leaf images to ensure robust recognition. To improve feature representation, the framework integrates additional techniques such as Histogram of Oriented Gradients (HOG) for texture analysis and edge detection for precise segmentation. Another objective is to provide an intuitive, web-based interface via a Flask application, allowing users to upload leaf images for real-time classification. Additionally, the framework aims to store predictions in a structured database and offer statistical insights through an interactive analytics dashboard.

4. METHODOLOGY USED

1) Data Collection: The dataset for this study is sourced from Kaggle, which provides a curated collection of leaf images from numerous plant species, including those relevant to Ayurvedic medicine. The dataset is organized into labeled classes to support supervised learning, ensuring diversity in leaf size, color, and orientation. Additional classes such as 'Non-Ayurvedic leaf' and 'Not a leaf' are included to enhance robustness and handle real-world variations. This setup ensures the system can handle scenarios where input images may not belong to known medicinal categories.

2) Data Pre-processing: Pre-processing is performed to improve image quality and prepare data for feature extraction and training. Images are resized to uniform dimensions for consistent model input. Noise reduction techniques, including Gaussian blurring, are applied to minimize distortions. Colour normalization and background removal are also employed to ensure the model focuses on leaf-specific features rather than irrelevant environmental details.

3) Feature Extraction: Feature extraction combines traditional and deep learning approaches. Histogram of Oriented Gradients (HOG) captures shape and texture descriptors critical for distinguishing visually similar species. Edge detection and contour-based methods highlight structural details such as vein patterns and leaf margins. These features complement the CNN's automatic feature learning, improving the framework's accuracy and reliability.

4) Model Selection: Convolutional Neural Networks (CNNs) are chosen as the core classification algorithm due to their ability to learn hierarchical spatial features automatically. CNNs reduce reliance on manual feature engineering and have demonstrated success in plant recognition and medical imaging. The architecture is optimized through experimentation with different layers, configurations, and hyper parameters.

5) Model Training: The CNN is trained on the curated dataset, augmented with techniques such as rotation, flipping, and zooming to increase diversity and mitigate over fitting. Supervised learning minimizes categorical cross-entropy loss, using optimizers like Adam or SGD. Validation ensures the model generalizes well to unseen data.

6) Model Evaluation: Performance is assessed using precision, recall, accuracy, and F1-score. A confusion matrix analyses misclassifications across Ayurvedic, Non-Ayurvedic, and Non-leaf classes. Cross-validation is performed to verify robustness, highlighting improvements from the hybrid CNN and feature extraction approach.

7) Integration with Flask: To make the system user-accessible, the model is deployed in a Flask-based web application. Users can upload leaf images for real-time predictions. A MySQL database stores inputs, predictions, and statistics. An analytics dashboard visualizes classification trends and performance metrics, enhancing usability and practical application.

5. LITERATURE SURVEY

Article[1]'A CNN-based image detector for plant leaf diseases with reduced computational burden for edge computing applications' by L. Falaschetti, C. Tassini, L. Cappelletti, L. Giraldi, and C. Burattini in 2022: This IEEE-based research proposes an image detector embedding a resource-constrained convolutional neural network implemented in low-cost, low-power edge computing platforms. The work focuses on developing efficient CNN architectures that can perform real-time plant leaf disease detection while maintaining high accuracy with minimal computational overhead. The study demonstrates the feasibility of deploying deep learning models on resource-limited devices for agricultural applications, achieving significant reduction in processing time while preserving classification performance. The framework integrates optimized CNN architectures with edge computing capabilities, making it suitable for field deployment in agricultural settings

Article[2]'Classification of Plant Leaves Using New Compact Convolutional Neural Network Models' by S.A. Wagle, H. Harikrishnan, S.N. Ali, and S. Gupta in 2021: This research presents computationally compact CNN models specifically designed for plant leaf classification tasks. The study develops three different CNN architectures (N1, N2, N3) with varying filter sizes and configurations to optimize both accuracy and computational efficiency. The proposed models consist of three convolutional layers followed by batch normalization and ReLU activation, with strategic placement of max-pooling layers and fully connected layers. The work achieves high classification accuracy while maintaining low computational complexity, making it suitable for real-time applications.

Article[3]'Classification of Various Plant Leaf Disease Using CNN with Transfer Learning Approach' by G.S. Hukkeri, M.V. Hatti, and R.M. Banakar in 2024: This paper introduces a comprehensive model designed to classify leaf diseases effectively using the publicly available PlantVillage dataset. The research utilizes transfer learning approaches with pre-trained CNN models to improve classification accuracy while reducing training time and computational requirements. The study focuses on implementing various data augmentation techniques to enhance dataset diversity and improve model generalization capabilities. The framework demonstrates superior performance in identifying multiple plant diseases across different species, with particular emphasis on practical deployment scenarios.

Article[4]'DeepLeaf: Automated Leaf Classification Using Convolutional Neural Networks' by N. Althuniyan, A.R. Al-Shamasneh, A. Bawazir, Z. Mohiuddin, and S. Bawazir in 2024: This European Scientific Journal publication presents a methodology for automated classification of leaves using sophisticated CNN architectures. The framework consists of several key stages including preprocessing, data augmentation, model architecture design, training, and evaluation procedures. The research leverages transfer learning techniques to utilize pre-trained models for optimizing training efficiency while maintaining high classification accuracy. The study demonstrates the effectiveness of deep learning approaches in accurately classifying various leaf types across different plant species.

Article[5]'Identification of medicinal plant using hybrid transfer learning technique' by authors from Indonesian Journal of Electrical Engineering and Computer Science in 2023: This research emphasizes the identification and classification of medicinal plants using advanced deep learning approaches, specifically focusing on Ayurvedic applications. The study addresses the challenge of look-alike features and availability issues of medicinal plants by implementing hybrid transfer learning techniques on a dataset comprising 30 different medicinal plant species from Mendeley Data. The research achieves a test accuracy of 95.25%, outperforming other popular transfer learning techniques.

Article[6] 'Identification of Ayurvedic Medicinal Plant Using Deep Learning' by researchers in International Journal of Intelligent Systems and Applications in Engineering in 2024: This demonstration presents a novel technique utilizing convolutional neural networks and leaf images for identifying Ayurvedic medicinal plants. The research addresses the challenge of identifying locally available herbal remedies without requiring extensive botanical knowledge. The system implements comprehensive image preprocessing, rectified linear units activation, and deep CNN architectures for robust feature extraction and classification. The framework enables easier feature extraction from leaf images without requiring extensive preprocessing, allowing raw photo data to be directly fed into deep convolutional neural networks.

Article[7]'Ayur-PlantNet: An unbiased light weight deep convolutional neural network for classification of ayurvedic medicinal plants' by B.R. Pushpa and colleagues in 2023: This research proposes an unbiased lightweight deep convolutional neural network specifically designed to classify forty Ayurvedic plant species with high accuracy and computational efficiency. The study addresses the computational limitations of existing deep learning models while maintaining classification performance suitable for practical applications. The Ayur-PlantNet architecture incorporates optimized convolutional layers, efficient pooling strategies, and regularization techniques to prevent overfitting.

6. SYSTEM DESIGN

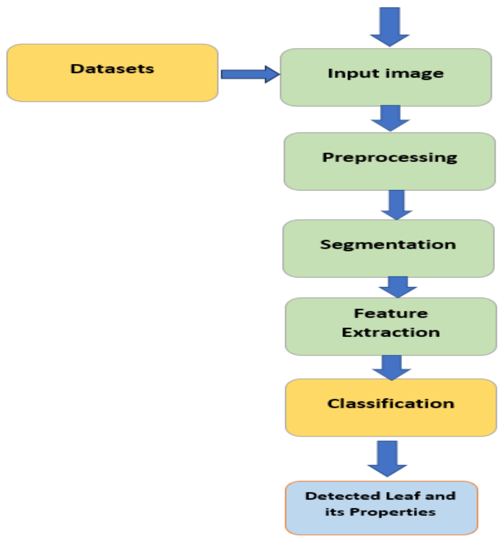

Figure1: System Architecture of Ayurvedic leaf detection

The system architecture for Ayurvedic leaf recognition is composed of several essential stages designed to ensure precise identification and classification. The workflow begins with the dataset, which supplies images of various leaf samples. These images undergo preprocessing to enhance quality, remove noise, and standardize dimensions, preparing them for effective analysis. In the segmentation phase, the leaf is separated from the background, allowing the model to focus solely on relevant regions. Feature extraction follows, capturing critical attributes such as shape, texture, and color, which are vital for distinguishing between species. These extracted features are then processed by a deep learning-based classification module, which accurately categorizes the leaf into its respective class. Finally, the system presents the recognized leaf along with its medicinal or botanical properties, providing actionable insights for research, healthcare, and educational purposes.

7. SCREENSHOTS

Figure 6: Home page

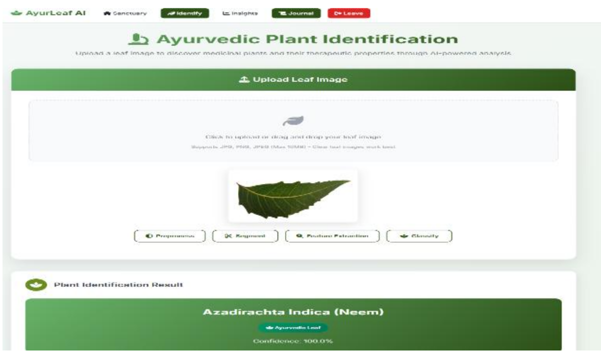

Figure 7: Predicated Result

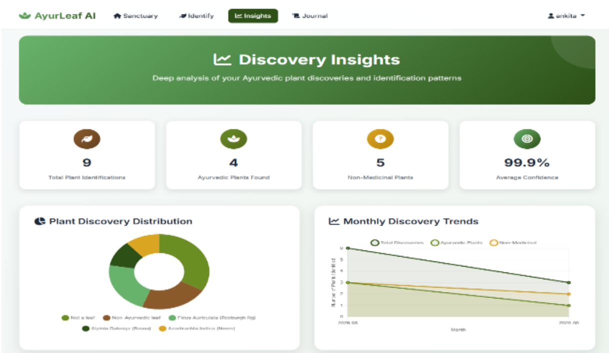

Figure 8: Dashboard

8. CONCLUSION

In this research, an automated system for Ayurvedic leaf identification was successfully developed using deep learning techniques, primarily leveraging a fine-tuned VGG19 convolutional neural network. The methodology included dataset collection from a curated Kaggle Ayurvedic leaf dataset, comprehensive preprocessing, data augmentation, feature extraction, model training, and evaluation using categorical cross-entropy loss and accuracy metrics. The trained model achieved high accuracy on the test set, demonstrating reliable classification across multiple leaf species, with performance visualized through detailed graphs. Integration with a Flask-based web application enabled real-time leaf image predictions, storing results in a MySQL database, and providing detailed information for each identified leaf, including medicinal properties and recommended usage. The system streamlines traditional manual or SVM-based identification methods, reducing errors while offering a scalable, user-friendly interface that supports practitioners, researchers, and herbalists in accurate plant recognition.Future enhancements could focus on expanding dataset diversity to include more species, variations in lighting, seasonal changes, and additional plant parts like stems and bark. Incorporating advanced data augmentation, synthetic image generation, ensemble models, attention mechanisms, or lightweight architectures such as MobileNet could improve accuracy and efficiency. Extending functionalities through mobile applications, cloud APIs, IoT-enabled scanners, multilingual support, explainable AI, and herbal recommendation systems would increase usability, trust, and field applicability. These improvements would broaden adoption in healthcare, research, and education, making AyurLeafNet a robust and versatile tool for medicinal plant classification.

9. REFERENCES

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