A Comprehensive Review of Plant Recognition Approaches: Techniques, Challenges, and Future Direction

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***Abstract*—Ayurveda, the ancient Indian system of medicine, relies heavily on the use of medicinal plants, which not only serve as the foundation of this holistic practice, but also provide a lucrative source of income. India is renowned for providing an ideal habitat for a diverse array of medicinal plants, with different parts of these plants being used as key components in the production of natural remedies. Interestingly, many of these medicinal plants can be found growing in our very own backyards or along the sidewalks. It is next to impossible for untrained person to identify and distinguish between various medicinal plants. Identifying plant species through manual processes is a challenging and time-consuming task, often made more difficult by a lack of expertise in the field. This is particularly true when it comes to correctly identifying and classifying medicinal plants, which can be a complex and confusing process. To address these challenges, this study seeks to leverage the power of machine learning to automatically detect medicinal plants, streamlining the identification process and reducing the need for manual labor. By automating this critical task, the study aims to improve efficiency and accuracy, while also making it more accessible to individuals with varying levels of expertise. This comparative study will also explore the accuracy of single attribute plant identification systems and examine the potential for incorporating multiple attributes in future systems to enhance their overall effectiveness.**

Keywords*— Machine learning, Convolutional neural Network, plant recognition, feature extraction, Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs)

I. Introduction

Plant identification systems play a crucial role in the field of botany and horticulture, allowing experts and hobbyists alike to identify and categorize different species of plants based on their unique characteristics. One commonly used method of plant identification is based on the comparison of a single attribute, such as leaf, flower, seed, fruit and trunk. This approach to plant identification has its advantages, as it can make the identification process quicker and simpler. However, relying solely on a single attribute can also lead to errors and misidentifications, especially when dealing with closely related species that may have similar characteristics. This manual process is often dependent on the availability of experienced botanists and taxonomists, who may not be readily accessible in remote areas. Additionally, the manual process is subject to human error, and it can be challenging to differentiate between similar-looking species based on a limited set of characteristics. Furthermore, manual identification methods often require the collection and preservation of plant specimens, which can be difficult, especially for rare or endangered species. The use of machine learning and computer vision in plant identification offers a potential solution to these challenges. These technologies can automate the identification process and reduce the dependence on expert knowledge, making it easier and more accessible to identify plant species. Additionally, machine learning algorithms can be trained on large datasets of plant images and other relevant data, allowing for the rapid and accurate identification of species, even in remote areas. In the field of medicinal plants, the use of machine learning and computer vision can aid in the discovery of new medicinal compounds and help to conserve and sustainably manage these resources. By streamlining the identification process, these technologies can support the development of more effective treatments and promote the sustainable use of medicinal plants. The manual process of plant species identification has its limitations, and the use of machine learning and computer vision holds great potential to improve the accuracy and efficiency of plant identification and support the conservation and sustainable use of medicinal plants. This paper will compare various single attribute plant identification systems currently in use, evaluating their strengths and weaknesses and discussing the challenges and limitations associated with this approach to plant identification. Ultimately, this comparison will provide valuable insight into the most effective methods for single attribute plant identification, helping to inform future development in this field.

II. Related Studies and Findings

The study involved comparing research articles that focused on plant identification, with several studies being conducted on this topic. Table I outlines the models, features, dataset used, dataset division strategy, and performance metrics utilized in the comparison. The study involved comparing research articles that focused on plant identification, with several studies being conducted on this topic.[1] The paper delivers a valuable impact for recognizing a medicinal plant by demonstrating the feasibility and usefulness of deep learning techniques for this task. In their work, the authors delve into the intricacies of developing and deploying a deep learning-based system for the purpose of recognizing various plant species. Through their experimentation and analysis, the authors demonstrate that their deep learning model is superior in performance compared to traditional machine learning algorithms. By leveraging the advanced techniques and capabilities of deep learning, the authors were able to accurately identify and classify various plant species based on their unique characteristics and attributes, thereby contributing to the field of plant recognition and classification. The outcomes of the research have important implications for the development of automated systems for the identification and classification of medicinal plants. This paper focus on deep learning methodology for identifying a medicinal plants and their usage in daily life. Author proposed a model to focus on medicinal plant detection based on their medical attributes. Author trained their own MNN (Medicinal Neural Network) model from scratch to avoid a misclassification on dataset which was collected manually and contains around 8000 images belongs to four different classes. MNN model use the Dropout concept to avoid the over fitting problem. Along with that author also use Augmentation to make the image according to fixed size. SoftMax function is also used in last layer for splitting the input. MNN model works efficiently on medicinal image classification and show 85.15% of accuracy percentage.

TABLE I. COMPARISON OF MODELS, FEATURES, DATASET USED, DATASET DIVISION STRATEGY, AND PERFORMANCE METRICS

Paper Title	Model Used	Features	Dataset Used	Dataset division	Performance Metrics
[1]	MNN	Leaf	Private Dataset (8259 images)	60% Training 40% Testing	85.15%
[2]	RF MLP, Naïve bayes, J48	Scale, Texture of leaves	Multi-feature Dataset	60% Training 40% Testing	RF – 81.75% MLP - 98.14% Naive bayes- 75.7% J48 – 80.34%
[3]	VGG16	Leaf	Middle European Woody (MEW), UCI Folio Leaf data set	60% Training 40% Testing	Middle European Woody (MEW) - 93.4%, UCI Folio Leaf data set - 97.9%
[4]	CNN, GG16, MobileNet, Xception, InceptionResNetV2	Leaf	(Kaggle Segmented medicinal leaf images) (32312 images)	60% Training 40% Testing	CNN - 92.01% GG16 - 96.30% MobileNet - 98% Xception - 93.25% InceptionResNetV2 - 98%
[5]	AyurLeaf CNN	Leaf	AyurLeaf Dataset (2400 images)	80% Training 20% Testing	96.76%
[6]	CNN	Leaf	Private Dataset	60% Training 40% Testing	95%
[7]	InceptionResNetV2 ResNet50, Xception, InceptionV3, MobileNetV2	Leaf Texture, Leaf color	UBD_45, VP_200	80% Training 10% Testing 10% Validation	InceptionResNetV2 - 91% ResNet50 - 88.68% Xception - 91.80% InceptionV3 - 88.65% MobileNetV2 - 85.58%
[8]	PNN	Leaf	Private Dataset (1800 images)	60% Training 10% Validation 30% Testing	90%
[9]	CNN	Leaf	SPMontany (7000 images)	80% Training 20%à Testing	99%
[10]	VGG16, MobileNet, Xception	Leaf	ImageNet Dataset (700 images)	50% Training 10% Validation 40 Testing	VGG16 - 76% MobileNet - 87.92% Xception - 88.26

[2] The authors aim to summarize the current state of the art in this area and provide a glimpse of the challenges and prospects associated with the use of deep learning for plant recognition. The authors begin by providing an overview of the importance of plant recognition in the context of traditional medicine, and discuss the challenges associated with manual methods for plant identification. They then introduce the concept of deep learning and explain how it can be used to automate the plant recognition process. The authors then examine the various deep learning techniques which have been applied to the issue of plant recognition, including RF, MLP, Naïve Bayes and J48. All models work on multi feature dataset, among them, 60% of data is used for training purposed and 40% of data is used for Testing. All models work on medicinal image classification and show following accuracy on each model i.e. RF – 81.75%, MLP - 98.14%, Naive Bayes- 75.7%, J48 – 80.34%. They also describe the architecture and training of each of these models, and provide examples of their application in plant recognition. The authors conclude by summarizing the strengths and weaknesses of the various deep learning techniques for plant recognition, and highlight some of the key challenges and opportunities in this field. They also provide recommendations for prospect study in this region, including the need for larger and more diverse datasets, the development of more robust and scalable models, and the exploration of other applications of deep learning in the field of plant recognition. [3] The author presents a method for identifying plant using the images of their leaves. The authors use the VGG16 deep learning network and transfer learning to achieve high accuracy in leaf species recognition. The VGG16 network was previously trained on the IMiddle European Woody (MEW), UCI Folio Leaf data set and then refined on a foliar data set from six different species. The results showed that the VGG16 network with transfer learning having different accuracy on different dataset i.e. Middle European Woody (MEW) → 93.4%, UCI Folio Leaf data set →97.9% in recognizing the six species of plants. The authors conclude that their method is a promising solution for plant species recognition and can be applied to other tasks in the field of plant biology. [4] The present study introduces the latest Deep Learning techniques for accurately identifying medicinal leaves. To accomplish this task, the authors utilized a dataset from Kaggle, consisting of segmented medicinal

leaf images representing 30 different types of medicinal plants, with a total size of 32,312 images. By using this comprehensive dataset and state-of-the-art Deep Learning techniques, the authors aim to provide a more accurate and efficient means of identifying medicinal leaves, ultimately improving the ability of researchers and practitioners to develop effective natural remedies and medicines. The prediction model is build using Convolutional neural network, data augmentation along with transfer learning concepts. To improve the robustness of the model and mitigate the risk of overfitting, the authors implemented a data augmentation technique. This method involved generating new training data by applying various transformations and modifications to the existing images, such as rotation, scaling, and cropping. By doing so, the authors were able to increase the size of the training dataset and introduce greater diversity and variability in the images, ultimately improving the performance and accuracy of the model. Author adopted four transfer learning models such as MobileNet, VGG16, Xception and InceptionRosNetV2 to enhance the processing time and accuracy of proposed model and compare the results with simple CNN model. Model worked on reshaped color images to produce the output. [5] The authors aim to develop an automated system that can accurately identify and classify different medicinal plants using images of the plants. The methodology proposed by the author involves a number of key stages, including image preprocessing, feature extraction and classification. The image pre-processing stage transforms the image to 227*227*3 for further analysis. The feature extraction stage involves using convolutional neural networks (CNNs) to extract relevant features from the images, such as color and texture information. During the classification stage, the features that were extracted earlier are utilized to train a deep learning model, such as a Convolutional Neural Network (CNN), which can then classify the medicinal plant images into different species based on the identified features. This stage is critical in achieving accurate and reliable results in the identification of medicinal plants, and is an important step in the overall process of utilizing machine learning for plant recognition. Author proposed AyurLeaf model based on CNN approach for medicinal plants classification which was inspired from Alexnet. Unlike a traditional approach which was use shape, texture and color based features for classification here author performed same with the help of Softmax and SVM classifier. Author trained the model on 80% of images and test it on 20% images. The authors evaluate the results of the proposed methodology on a dataset of medicinal plant images and compare it with Support Vector Machines (SVMs) and K-Nearest Neighbors (KNNs). Accuracy of the model is about 96.76%. [6] The paper is based on efficient and reliable Machine learning algorithm along with image processing for plant catalogues using leaves images. Study is performed on Leaf with plain background with the help of solidsheet algorithm and CNN based model for identification purpose. Function-oriented container method is used to separate the leaves segments. System works on five Work is divided into the 5 modules. In first module, they acquire the Herb images. The study involves a multi-stage approach to image analysis. In the second module, RGB images are converted to grayscale and filtered to enhance image composition. In the third module, the image is segmented using an active contour system with default definitions. The model also uses a polygon model and resulting polygon as a condition prior to calling the active server. The fourth module is focused on classification, utilizing a Convolutional Neural Network (CNN) algorithm to rank potential solutions. Finally, a fifth module provides usage details for users to better understand the functioning and performance of the overall system. By using this multi-stage approach, the model is better equipped to accurately and efficiently analyze input images. Model works on private dataset which get divides into two parts 60% data is used for training and 40% is for testing. Model also provides the important insights and usage details for users by giving 95% accuracy. [7] The study introduces a new model for fine-grained plant species identification, leveraging the power of ensemble Deep Learning. This approach involves combining multiple individual models, each with its own unique strengths and features, to create a more robust and accurate system. By using this ensemble approach, the authors aim to improve the ability of researchers and practitioners to accurately identify and classify plant species, particularly in cases where the differences between species are subtle and difficult to discern. This method represents a significant advancement in the field of plant identification and offers the potential for improved natural resource management, conservation, and biodiversity research. Author trained six deep learning models on two Datasets. i.e. USB_45 and VP_200. Dataset USB_45 is collected using DSLR which contains 1232 images of 45 medicinal species. From this dataset, 80% of the data was used for training, while 20% was reserved for validation (10%) and testing (10%) purposes. In addition, the authors also employed a separate dataset, VP_200, containing images of different species, with 100 images of each species. For this dataset, 60% of the data was used for training, with the remaining 40% reserved for validation (20%) and testing (20%) purposes. In this study, the authors trained six Deep Learning models using four different ensemble techniques: Mean, Weighted Mean, Voting, and Stacked Generalization. To improve the accuracy and efficiency of the models, the authors initialized each model with pre-trained ImageNet weights and fine-tuned them to the specific dataset. By using this approach, the models were able to leverage the rich and diverse features learned from the massive ImageNet dataset and apply them to the task of fine-grained plant species identification. Author used Bayesian optimization technique for finding optimized value of each model with objective function of Gaussian process model. Here they used heterogeneous assembling by combining six models and each model's result was evaluated with the help of evaluation matrix. [8] The author has proposed a new approach to foliar image using plant classification, which consists of three main steps: image preprocessing, feature extraction, and classification. In the pre-processing step, the authors apply morphological operations for noise removal from the input images and improve the edges. In the feature extraction step, the authors extract color and shape features from the processed images. Finally, in the classification step, the authors use a PNN to classify the plants based on the extracted features. The authors evaluate the proposed algorithm on a dataset of leaf images, among them 80% from the available data is used for training purpose, 10% is used for testing and 10% is for validation purpose. Paper also produce the comparison of the results of Support Vector Machines (SVMs) and Neural Networks (NNs). The results show that the PNN-based algorithm outperforms other algorithms in terms of accuracy and robustness. The accuracy of the PNN- Based algorithm is 90%. [9] This paper focuses on the development of a digital system that utilizes neural networks to identify plant species based on a single leaf image. For that, the author proposed the approach which make a use of Keras, Tensorflow and Convolutional neural network. The model was trained using a dataset of 7,000 images, with 1,000 images representing each of the 7 different plant species included in the study. This comprehensive dataset provides a robust foundation for training the model, allowing it to accurately distinguish between different plant species based on key features and characteristics. By leveraging this extensive dataset, the model is better equipped to handle real-world scenarios and variations, improving its overall performance and effectiveness. 80% from the available data is used for training purpose and 20% is for testing purpose. In this paper they first perform the data preprocessing which includes resizing the image data 180*180 pixels. Using Numpy all images are converted into an array for data standardization purpose. The study employed a Sequential Convolutional Neural Network (CNN) architecture, with each layer consisting of four components: Conv2D, MaxPooling2D, Flatten, and Dense with a softmax activation function. Feature extraction is performed on image. Information of picture with various procedures/bits are use in convolutional layer. Each channel has a specific work. After every convolutional layer Max pooling is performed. To get more accuracy training is performed using sequential CNN using 20 epochs for a 60batch size. As an epoch's increases accuracy is also increases and loss get decreases. Overall model gives 99% accuracy for pre-stored images. [10] The paper delivers a valuable involvement to the field of medicinal plant recognition by demonstrating the feasibility and usefulness of CNNs for this task. The authors provide insights into the strategy and application of a CNN system for plant recognition, and show that it can outperform traditional machine learning algorithms. The outcomes of this research have important implications for the development of automated systems for the recognition and grouping of medicinal plants in the wild. This paper proposed a model which is combination of CNN, Advance computer vision solution and Transfer learning for medicinal plant identification. Author experiments on various available datasets such as Swedish leaves dataset, Flavia dataset, BJFU100 dataset. Data is split in 50% for training, 10% for validation and 40% for testing. They use 3 algorithms KNN, SVM, PatternNet network for classification. CNN is performed with the help of 6 different models like VGG16, Inception model, Resnet, DenseNet, Xception and MobileNet. Handcrafted algorithms like SURF and SIFT descriptor shows poor results on VNPlant-200 dataset but GIST and PCA combined shows good result i.e. 98.7% accuracy on Flavia Dataset.

In conclusion, a thorough analysis of the identification and classification of therapeutic plants has been conducted. The majority of methods are primarily concerned with the categorization task. When compared to the other models, CNN appears to be the model that performs best. This is because while other deep learning models, such as ANN, have millions of neurons, extracting functionality is not one of their capabilities. However, CNN uses a convolution layer and pooling layer combination to enable feature extraction. The input is calculated using the point multiplied by the filter parameters as a sliding window moves through the picture in the convolution layer. CNN is able to extract the most essential features because to this. In contrast to the other machine learning models, CNN's convolutional layer automatically extracts features, whereas the other models require manual feature extraction. The accuracy appeared to be 98% when parameters like leaf texture, veins were included. The precision of the model appeared to drop by 3–5% when only one feature, such as leaf form, texture, or color, was used. The research appears to act upon on average, with a precision rate of 71%, when more than three features, such as leaf texture, color, and shape, are employed. This occurs because as the number of features rises, there is a belief that the model should perform more accurately. However, selecting the proper features is more crucial than selecting more features, which is why this occurs. Therefore, it appears that the accuracy rate changes as the number of characteristics does. Other models, such as SVM, AutoML, and MLP, have accuracy levels above 70% aside from the CNN model. In summary, feature extraction is essential for controlling the model's performance. A good dataset and a valid set of features can enable neural networks to perform better than expected.
Research Gaps:

III. Gaps Observed

1. Many AI-based systems are designed by the researchers to categorize a plants are based on a single feature of the plant i.e. leaves and these systems do not consider other features viz. stem, root, flowers, petals and seeds of a plant for their identification and medicinal usage.
2. The accuracy of such AI-based system is very high when plant identification is done on a single feature such as leaves (90%) but it is difficult to achieve a similar accuracy for multi attributes.

There is no significant research work found for AI-based systems on identifying plants using multi-attribute.

IV. Proposed Methodology

Here is a proposed methodology for AI-based systems on identifying plants using multi-attributes of a tree:

- **Data collection:** Collect data on the plants that need to be identified. This can include images of the plants, as well as other relevant data such as their scientific name, location, and growing conditions.
- **Pre-processing:** The data collected needs to be pre-processed to remove any noise or errors. For image data, this may involve resizing, cropping, or normalizing the images.
- **Feature extraction:** Extract the relevant features from the pre-processed data. For image data, this can include extracting color, texture, and shape features from the

images.

- **Model training:** Train a machine learning model on the extracted features to classify the plants. There are various algorithms and architectures that can be used for this, such as convolutional neural networks (CNNs), decision trees, or support vector machines (SVMs).
- **Testing and validation:** Test the trained model on a separate set of data to validate its performance and accuracy. This can involve using techniques such as cross-validation or hold-out validation.
- **Integration and deployment**: Once the model has been tested and validated, it can be integrated into a larger system or deployed as a standalone application. This may involve creating a user interface for inputting plant data and displaying the results of the classification.
- **Continuous improvement:** As more data becomes available or new plant species are discovered, the model can be retrained and updated to improve its accuracy and performance.

This requires continuous data collection, pre-processing, and model training. It's important to note that the accuracy of the AI-based system will depend on the quality and diversity of the training data. Therefore, it's essential to collect a large and diverse dataset of images to ensure the system's accuracy.

V. CONCLUSION

Multi-attribute species identification systems have proven to be effective tools for species recognition and have the potential to overcome some of the limitations of traditional methods. Such systems allow for the integration of multiple attributes can improve the accuracy of species identification. Additionally, multi-attribute systems can leverage the strengths of different attributes and provide results that are robust to variability and variability across species. However, the effectiveness of a multi-attribute species identification system depends on the quality of the attributes used and the ability to accurately identify and extract relevant information from the data. As with any species recognition system, multi-attribute systems also face challenges such as the need for large and representative annotated datasets, and the difficulty of dealing with inter- and intra-specific variability. Multi-attribute species identification systems have the potential to provide more robust and accurate results compared to traditional methods, and have a wide range of applications in biology, ecology, and conservation. Further deep research is needed to address the challenges of multi-attribute systems and to develop methods for the effective integration of multiple attributes for species recognition.

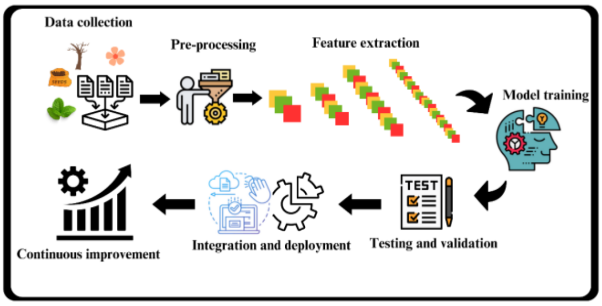

Fig. 1. Proposed methodology for AI-based systems on identifying plants using multi-attributes of a tree

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