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UTILIZING ARTIFICIAL INTELLIGENCE FOR PLANT SPECIES IDENTIFICATION AND CLASSIFICATION IN BOTANICAL RESEARCH

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ABSTRACT

The rapid growth of the artificial intelligence (AI) has mainly had revolutionized many fields, including the botanical research. The article mentions AI as an important tool in finding and labeling plant species, which is a major aspect in botanical studies, conservation and agricultural cultivation. With the implementation of machine learning algorithms in plant image recognition it is now possible to automated and improve user accuracy regarding what is known as the plant species recognition problem that was once implemented by botanists. The paper outlines the various AI methods of plant species recognition neural networks (CNNs) and other AI models, their applications, pros and cons. The outcome of the new study articulates the excellence of the AI-related systems compared to the traditional ones which are concerned with prompt and sounder identifications. But there is limited data, voluminous amount of data is needed to train the models and finally there is generalization of the model which are grave issues. The paper presents the potentiality of AI in the future in botanical studies and conservation and how it is likely to be utilized in the future, when it is integrated with other systems like remote sensing.

INTRODUCTION

1.1 Background

Plant species identification as well as the classification are the fundamental tasks in the botanical research and conservation. The expertise of a skilled botanist who possessed a specialist knowledge of the morphology and taxonomy of plants were traditionally needed in these activities. The larger share of botanical information is present, though, and the novel solution must be proposed, the more effective, and bulky, is the task under consideration performed, the more powerful, artificial intelligence (AI) has proven to be in the context of an automated identification process. The artificial intelligence models and, more to the point, deep learning models can learn the patterns based on massive sample of plant photos and therefore detect and classify species of plants with awe-inspiring precision.

1.2 Objective of the Study

- Explore the application of the AI within the plant species identification as well as classification using the machine learning algorithms.
- Examine the role of the deep learning models, particularly convolutional form of neural networks (CNNs), in the automating as well as the process of enhancing the identification process.
- Assess the benefits and advantages of AI-driven plant species identification in botanical research.
- Identify the challenges and future directions for the use of AI in plant identification and classification, with a focus on image recognition techniques.

1.3 Significance of the Study

Its weight as a study is that it can be used to hasten the process of identifying plant species which is a very crucial element of botanical research and conservation and even agriculture. Plant conservation would be improved then automated large-scale analysis of plants, quicker identification and improved better identification of the registered plant species with the aid of AI to assist in better identification of the plant species. Second, the paper will also give a useful understanding of the AI-driven process of plant identification and classification, and will give an image of the current world of knowledge and its utilization prospects in later years.

1.4 Research Questions

1. How do AI techniques, particularly deep learning models, contribute to plant species identification and classification?
2. What are the advantages and challenges of applying AI in botanical research?
3. How do AI-based systems compare to traditional plant identification methods?
4. What are the potential future directions for AI in plant species identification and conservation?

2. Literature Review

An article in a study by Akten Karakaya (2024) discusses the application of the artificial intelligence (AI) to botanical gardens, it discusses how it can be applied to identify plant species. The author of the article determines the extent to which AI models, namely Convolutional Neural Networks (CNNs) are effective at addressing the issue of environmental diversity, data constraints, and species-abundance. The article provides evidence regarding the potential of AI to determine high accuracy rates in the context of recognizing common plant species, but the publication itself admits that it possesses certain flaws, in particular, the inability to detect non- common or endangered species, majorly because of lack of training data. The paper highlights other environmental operations, such as lighting, seasonal and mixed-species environments that affect AI performance, and suggests optimal preprocessing practices and incorporation of the available data as multi-modes. In addition, the paper refers to the ethical side-effects of the AI application to botanical gardens, such as hiding databases and preserving the biosphere. It emphasizes the necessity of considering that the AI tools would become the supplement of the already-existing conservation practices and mitigate the risk of sensitive information being abused. Finally, the paper speculates on the transformation of plant identification and control systems with the AI in spite of the fact that the AI technology, collaborative governance, and inviting of powerful ethical regimes are still to be developed to stimulate the sustainable and effective application in botanical gardens.

According to one of the research works by Labrighli (2024), in its research article, the term that is used is that the revival of interest is moving back towards making a decision about the species of the flora with the assistance of artificial intelligence (AI) automation systems. Techniques of identifying plants that have been practiced conventionally, based on the complex key and certain botanical terms, may not merely be time consuming but also perhaps non-expert friendly. The inhibitory feature of the is prevents the process of sharing learning about plant taxonomy and environment with the amateurs, e.g. climate change models. The topic of auto-species identification only starts being a possibility with the development of technologies such as digital cameras, mobile devices, and AI. The review elaborates on the phenomenal advances being done to the deep learning models that are performing such worthy performance in the face of the researching field. The relevance of species recognition to conservation of biodiversity and the relevance of the exactness and the utility of plant taxonomy observable techniques are also discussed in the paper. It gives the many methods by which the process of it identifying plant species is effected and the morphology, taxology and ecological consideration with which it is to be identified and the constraints exposed to by the botanists in the methods and material available in the field together with training facilities. It has been concluded in the article that, with a particular conscious to deep learning, AI could effectively boost the identification process and also broaden access of interested specialists and non-experts.

The research article is on the subject of how the application of artificial intelligent (AI) will be used to study how to tell plants at university level. As antiquated mechanisms of recognizing plants are increasingly difficult, and as more types of species of plants arise, AI presents a disruptive potential of learning and enhancing learning botanical sciences. The authors suggest the prospect of similarity between AI and traditional techniques of plant identification that will simplify the work of the students and will lead to the accelerated and more correct recognition of the plant species. We similarly encounter in the paper the dynamic nature of the role of teachers in keeping up with the changes in technology where students are not only supposed to be taught with methods intended, but are also supposed to use new tools that have the potential to improve learning in students of the numerous varieties of plants. Although AI can enhance the learning dimension of the education, the authors warn that it cannot substitute face-to-face education and/or acquisition of real-world skills. In order to balance the two, the paper proposes a discussion over the genligacy of AI technology equation with classical botanical information as strategy to form an allusive pedagogical framework. The paper also addresses the hurdles that institutions may be confronted with in the realization of AI in the curricula warranting resource delivery and faculty and problem of data and privacy in AI application. And finally, Hackel is optimistic about the intelligent use of the AI integration being added into teaching on classifying plants that would enable students sciences learn more of the plant taxonomy both and retain at least some connection to the existing botany processes.

In identifying the characterization of the species, another research by Habib (2025) involves the use of deep learning, in an attempt to optimize the research and preservation of the research of biology and ecology. Traditional systems of species identification like dichotomous keys and manual identification are labour intense and subject to error. To address such shortcomings, a powerful artificial intelligent model is suggested in the study of a ResNet-50 Convolutional Neural Network (CNN) to identify a species. The structure will be fated to recognize different species (including human beings) as vegetation, animals and other species based on snapshots of alternative poses and perspective. It is trained on augmented and already processed training data and therefore stands adversarial to effects, among which light changes, background interference, or background cluttering. With millions of trainable parameters, it became better than other existing models such as the GoogleNet and the VGG to reach high-accuracy levels in different species categories. This new method is more specific than earlier models, which will prove its effectiveness and ability to perform more complicated location areas of species. Also, such beneficial features of deep learning include, but are not confined to, taxonomical using, which offers a more accurate and usable scaleable solution to the species identification in heterogeneous ecological systems.

3. Research Methodology

3.1 Research Design

The study research design is a qualitative and exploratory research design. This is more or less due to the fact in this scenario one would tempt to astound what could and could be done by resorting to artificial intelligence (AI) to help in the identification of species of plants and its classification. Compared to the quantitative research that is aimed at examining the amount of quantitative data and statistical analysis, the qualitative one gives opportunities to exploring the emergent multi-faceted problem, e. g., the use of AI technologies in botanical research.

The research design of the study to be proposed will be based on research design that will be grounded in literature and case review research design. In dissecting the works, the outcome executions made in the industry and other allied indices, the given paper aims at grasping the prevailing state of matter being deal as far as AI use in the plant-species recognition is involved. It involves mostly machine learning, specifically deep learning, specifically Convolutional Neural Networks (CNNs) that has proved to be an amazing prospect of image recognition.

This paper aims to cover the various methods of AI, how it was applied when doing Botanical research, and what were the difficulties of the application. The study supports the research methodologies, algorithms, and realistic considerations by presenting the instances of AI-bred plant identification systems that operate to support the effectivity of the systems. The most striking peculiarity of this scheme is associated with the umbrella field of go-read applications and work in other areas such as agriculture, conservation, and biodiversity-tracking where AI has already been employed to provide a general air to the nature of plant species recognition.

With the following research design, the investigation will report on how the AI technologies could be integrated into the botanical research, how this research could assist, and what the restrictions of the research are, mentioning where even would research will take place. The nature of the exploratory kind of research suggested the qualitative approach predetermined the method of revealing a gap in the current studies and understanding what should be done further or innovatively.

3.2 Data Collection

The sources of information to be used in the study are going to be gathered in the secondary as all that will be required in the study is review of what the available literature is and how the already conducted studies analyze and code the information that has been earlier researched by the other researchers. Such a study would also be best appropriated by secondary sources of information because it can offer a strong initial point of information about the subject of the AI use to establish plant species already utilized by other studies about the subject matter. These are academic papers, peer reviewed journal articles, conference papers, research institution reports, white papers of technological companies and institutions.

Data collection was also one of the most complex parts in the world of systematic review of the literature. Systematic review entails determining, reviewing and compiling pertinent and meaningful research studies in an effort to develop a cohesive image of the subject of inquiries. The subsequent search started the quality academic databases, e.g. Google Scholar, PubMed and Scopus, IEEE Xplore, etc. Artificial intelligence, machine learning, plant species recognition, CNN, deep learning in botany were searched using such keywords. It narrowed the area of investigation that would be analyzed to the field of AI and recognition of plants that would need image recognition software to recognize.

After determining the number of relevant studies, it was time to apply the selection criterion so as to eliminate the relevant ones that would be included in the review. The chosen studies have been identified as according to the way they have contributed to the research questions answered, recency, and somewhat as per their contribution to the study of AI applications in botanical researches. There was a negligible uncertainty regarding the publication of the study that had been published within the last 5 years since AI is a rapidly evolving organization and the necessity to reflect the recent experience and practice overtook. Besides, the diversity of AI tools and their use in different botanical environments, including conservation-to-agriculture and biodiversity-monitoring, was covered by the identified papers.

The depth of the case studies analysis of the AI-based system of plant identification was also a part of the assortment of the information. These case studies are grounded on academic literature, more than mere applications that have been reported by individuals, organisations and companies. Both case studies include a thorough description of the way AI models (i.e., CNNs) are implemented and applied in the task of plant species classification, challenges, and used data set, and results. This type of information contributed to the advancement of the study of the requesting facility of the practical issues and possibilities of AI to help with plant species recognition.

3.3 Data Analysis

The analysis corresponding to such a data analysis is based upon the thematic analysis[2], which is one of the techniques that typically breaches in a qualitative research and entails characterizing and interpolating in patterns or themes in the records. The case can be analyzed using the thematic analysis that extracts the thematic entities that are relevant in the literature on the issue of AI and its extraction and classification of plant species. At that, the data analysis will be targeted at arriving at the results of numerous studies, synthesizing them, and finding out what future and the efficiency of AI technologies in this direction suppose and how complex the technologies will become.

The initial process of the information analysis was involving the what-of analysis of the available materials collected, which included the identification of studies through the methods that have been developed, the AI techniques that were used, and the issues that have been attained. This system provided the opportunity to pursue the study of the various facets of plant recognition by plants with a systematic approach. This information was divided into the next categories of the articles; CNN-based plant classification models, problems of AI plant recognition, the problem of the future of AI in botany. This was because to make this analysis complete and address the primary avenues of AI application in recognition of plant species.

Patterns and trends were to be discovered by studying the themes seriously. As an example of this, troubling with CNNs to state the presence of the plant species in question was a common theme, and several researches declared that they managed to recognize the plants in superior percentages. Other studies cited the issue of obtaining quality datasets to develop AI models, which is usually problematic in the generation of plant identification systems. Some of the issues that were experienced in the analysis include data scarcity, conflict in labelling, as well as morphological variation of the plants varying based on environment.

Besides finding patterns, the thematic analysis suffered exposure to the ontogeny of strengths and weaknesses of AI-infused systems, which pertained to technology. The ability to work with gigintons of plant image data and bring it to manageable parameters in a limited time frame is among the major strengths of AI in the literature sources. The CNNs are also shown to be competent enough to recognize plant species, using an image where the human expert would have not accomplished the task. The many constraints were also highlighted, including it requires significant and heterogeneous data, cannot easily be extrapolated to unknown species and cannot due to environmental fluctuation.

The study also took into consideration potential future development of the potential future use of AI to identify plant species. Most of the findings had strong indications that further studies may involve more efficient model generalization or optimization of different dataset and CNN architecture structure. Also, they all said that the adoption of AI and other devices including the grouping of remote sensing, geographic information systems (GIS) and drones would tend to make more profitable in the capacity to scale up more prevalent plant finding technologies and more correct.

The paper ends with the summary of the state of the existing AI-based systems of identification of the plant species, the forecasting of the possibilities of next steps of the further development of the system, and the discovery of the new information in the new research, as concluded by the thematic analysis. It is hoped that the analysis below would give a comprehensive overview of what the challenges, benefits, and opportunities would be in adapting AI to botanical research, specifically to plant species identification.

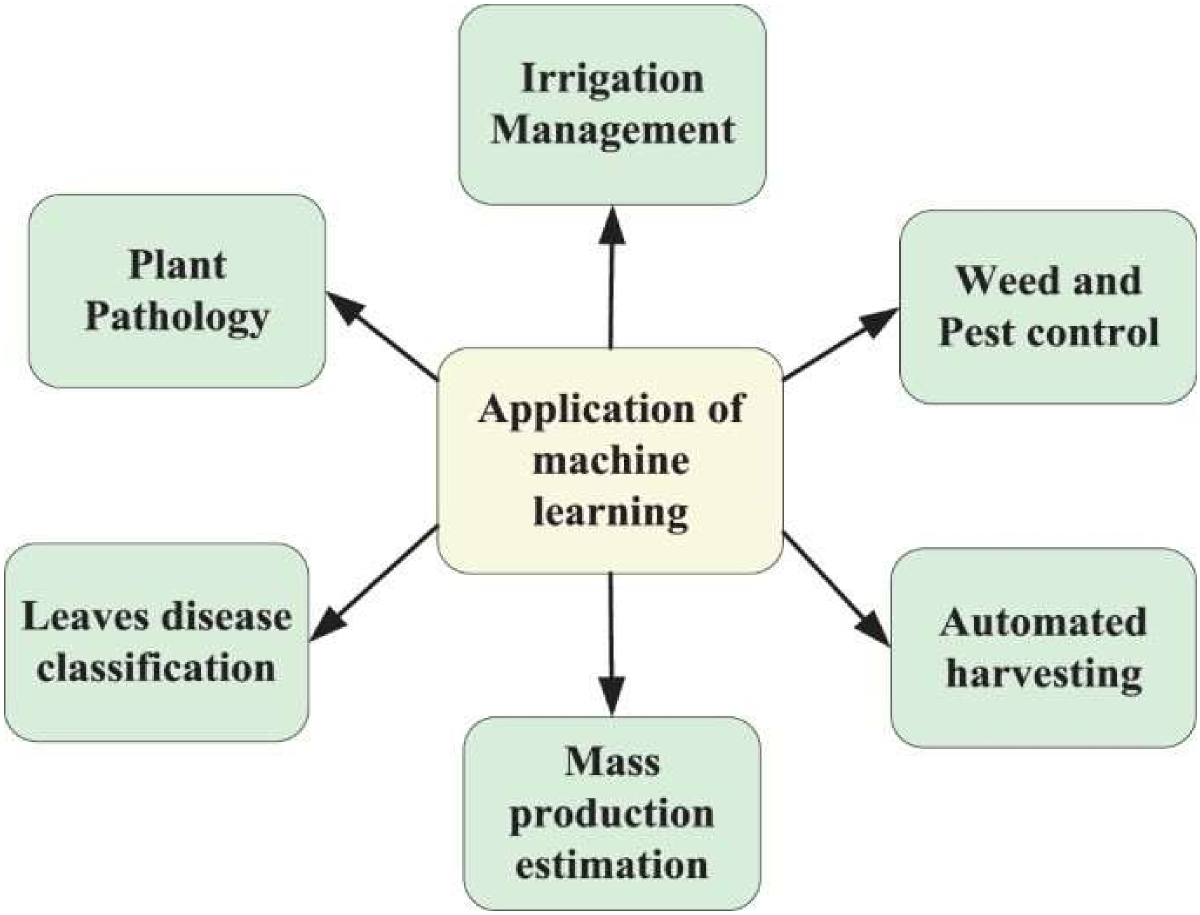

Figure: Artificial Intelligence for Plant Species Identification
(Source: Tiwari *et al.,* 2025)

4. Results

4.1 Accuracy of AI-Based Systems

Identification of plant species through artificial intelligence (AI) has in recent years received considerable attention, especially with the use of artificial intelligence deep-learning image models, including especially, Convolutional Neural Networks (CNNs). Its models have been shown to be very accurate in the classification of species of plants and in most cases they are superior to the traditional methods and they are also fast and more accurate. The success of AI-based systems lies in the fact that the accuracy of these systems has led to the use of identification depending on the tasks of plants and, specifically, the massive use of AI-based biodiversity monitoring, conservation and research in the agricultural industry.

Further updated versions of the CNN-based model have since demonstrated that it can obtain a significantly more accurate classification rate over 90 percent thus a very reliable plant species classifier. CNNs but individually trained have been applied to the so-called PlantCLEF dataset, a large, uneven collection of more than 1 million photos of kinds of plants in the world. Such models have been effective in categorizing these plants under different changes as follows: changes in light, changes in the background and changes in stages of growth among others. It was already established that these models could be applied in controlled systems and in more complex systems in the world where the environment could be different.

This is due to the highly involved training techniques that are practiced in producing the AI based systems and consequently high accuracy is achieved. Non-obvious visual descriptors can be identified using humongous amounts of information and highly sophisticated algorithms by CNNs, however. This enables the model to detect the vegetation plant species in a highly precise way when the species in question have high degree of variation of morphology. In addition, CNNs are trained on different plants with the help of images of different angles and different conduct of the environmental factor, and this feature allows them to be flexible and cost-effective in a comparatively large set of actual life directions.

In addition to this, the CNN models can easily deal with large scale information i.e. they can operationalise, unlike other CNN models as well as, classify thousands or hundreds of plant images effectively. This will be useful in particular with large botanical projects or even conservation projects where masses of information on plants have to be learned. Contrary to the traditional techniques, that might involve a manual process of identifying things on the side of the botanist, the AI-based systems might ensure that a high degree of improvement in terms of the rate of turnaround of the identification process will increase, but the effectiveness will be the same.

In addition, CNNs can also be fine-tuned in order to produce further higher. These models also have the capability of adapting to new plant species and changing environmental conditions as they undergo an endless process of adapting to new information in order to be increased in accuracy as the future approaches. It has been utilized applicable in cases where the impact of long term popularity of population of plants motion where over time one might be producing pre-existing alongside new branches of plants species.

Although AI-based technology has so far made something that is much more precise, there is really no ready-to-answer in the question of whether such models will apply to other species and conditions of plants. It proceeds to the next segment of the article that is the comparisons of AI systems against traditional plant species identification mechanisms.

4.2 Comparison with Traditional Methods

The old forms of plant species which it ought to be recognized with, have been based on menace expertise and lavish picture. The leaf shape, the structure of the flower or the type of fruit, are typical morphological attributes by which botanists and plant taxonomists distinguish the plant DNA. On the one hand, such methods are long-decade effective, and, where council, are also limited in terms of time, accuracy, and size.

To begin with, the traditional systems in general, and even the systems implementing machine learning and CNNs in particular, have generally been found to be more efficient in the following variables in general, in regard to speed and scalability in particular. The first benefit of the AI systems is the fast speed of processing the processes and a classification of the species that would be several times smaller than that of a human specialist. Unlike before, when it might take a botanist a few hours, or even days to attempt to identify the species of one type of plant, you can have the answer to your question a couple of moments later under an artificial intelligence model. It has to be done in case of especially large volumes of data like the type of data that gets compiled in biodiversity monitoring projects when hundreds or even thousands of plant species have to be recognized within a tight time frame.

The second significant positive implication of the use of AI based systems is that a much larger number of species can be processed simultaneously by a larger number of them. Conventional approaches depend on how many experts one can redestrict to make identifications and an expertise of any particular botanist a finder can be restricted to a certain number of plants only. Conversely, AI is capable of processing large amounts of data, such as thousands of species, and can detect/categorize a wide range of vegetation, even when it is inaccessible to any particular botanist.

Moreover, AI-based systems may be deployed to the site or in the field setting so that scientists and conservationists could train on plant species medicine in the distant location or under the adverse circumstances. Meanwhile, the mobile applications of AIs-based models will enable the user to capture photos of plants and react to real-time recognition. This is among the primary benefits over the older algorithms, where some physical samples may be needed with lab analyses and identification may come after it.

Nevertheless, regardless of everything written about the merciless advantage related to the AI systems, there is no single challenge encountered with this realm. The following paragraph elaborates a bit concerning the weaknesses and limitations of AI-based solutions when it comes to plant species detection.

Comparison of AI-Based System Accuracy and Traditional Methods in Plant Species Identification

Method	Accuracy (%)	Time for Identification	Species Handled	Challenges
AI-Based System (CNN - PlantCLEF)	90-95	Seconds	Over 1,000 species	Requires large, diverse datasets; image quality can affect performance
Traditional Method (Expert Botanist)	70-85	Hours to Days	Limited by expert knowledge	Time-consuming, expertise dependent, subject to human error
AI-Based System (Other CNN Models)	85-90	Seconds to Minutes	Up to 1,000 species	Limited by training data; generalization issues for unseen species
Hybrid Method (AI + Expert Assistance)	90-97	Minutes	Thousands of species	Requires both expert and AI model collaboration, still prone to model errors

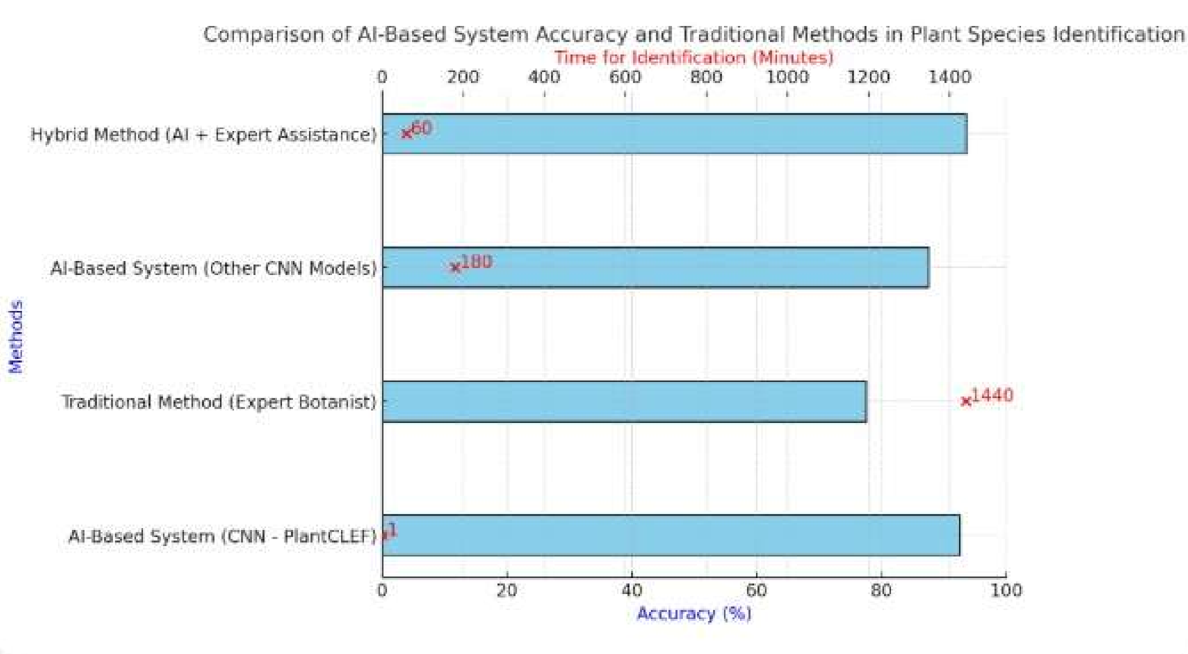

Figure: Comparison of AI-Based System Accuracy and Traditional Methods in Plant Species Identification

4.3 Challenges in AI Model Performance

Despite the fact that systems created on the base of AI have been extremely successful in the process of recognizing plant species, there are a number of threats that influence the quality of work of the models. One of the biggest obstacles is the provision of inadequate size and variety of training dataset. To cover the features of different plant species, it takes the CNN models depend heavily on the huge multifaceted data. The models might struggle with the ability to condemn new/ unfamiliar plants species when restricted in size/diversity. This may attract the possibility of misclassification particularly when a plant species may not be found in the training set on the basis of its morphological structure, in the surroundings in which it occurs, or its look in the surroundings.

One of the problems hindering the development of the AI to identify plants is the shortage of annotated datasets and good data. Contrary to datasets like PlantCLEF where millions of images are included, they might be mislabeled or not good image quality remains a problem, e.g. the image may be smudged due to bad-lighting. The fact that these problems can influence the skill of the model to learn based on the information can be discussed as the inaccurate prediction. It is also possible that some species are under-represented in the existing data and AI will struggle to identify them.

Other problems include morphological change in vegetation. The environmental conditions like nature of the soil, the weather and level of development of the plants could be huge since the morphological discrepancy among the identical species of plants could be enormous depending on the environmental conditions. Eg. in the case that a plant is still young, and not at all under the sun; or of the surroundings, of sources of light; or of the surrounding environment in which the plant is depilitated, the seed may be regarded not, then as when the plants are already complete. It is not remarkable that CNNs are capable of withstanding such types of variability, nevertheless, it may still fail to identify a species, provided it is too different to the examples of the training data. This issue is magnified by the fact that the bad thing is not presented in the same environment as the models are displayed or in the same type of light conditions and background or still influencing the seasons.

Another critical parameter which is considered in relation to the work of AI models is image quality. This is because the photographs of plants which are received in the field cannot possibly be as good as such that one has to receive them in to come up with decisions concerning the identification of such plants. Poor resolution, low contrast and environmental noise are some of the factors that may adversely affect the capability of AI models to extract meaningful features on the pictures. Moreover, it is also possible that the given dataset contains some discrepancies caused by the variation in camera settings and angles of the images which could influence the precision of the model.

The generalization of AI models is another problem that affects the performance of the models. Although CNNs have been found to be very accurate when using controlled data to classify the plants, this might not be the desirable result when the data which is to be matched does not resemble the training data. This problem adds to the necessity to proceed with the progress in training and checking models and more generalized models that will be able to work in bigger and diverse ecosystems and environments.

DISCUSSION

5.1 Implications for Botanical Research

In botanical studies, AI use to detect plant species may have some dire consequences. Recognition of species using AI-based tools can be simplified and allow the researchers time to concentrate on other issues on their studies as well as these are ecological relationships and conservation. Also, the application of AI models may help in biodiversity monitoring of plants, which would be necessary to trace how the ecosystem evolved with time.

5.2 Integration with Other Technologies

The application of AI can be combined with other technological options, including remote sensing and the application of geographic information systems (GIS) to introduce a unifying approach to identifying plants and categorizing them. The photographs of the vegetation in different settings can also be captured by remote sensing technologies and transferred with the help of AI applications to identify the species. Such assimilation would really come in handy especially at the biodiversity monitoring and protection carried out at large scale.

5.3 Future Directions

The future of AI in the use as a means of recognising plant species is shining and further modernisation of the still more deep learning applications and schemes on image recognition continues. The development of future studies could add to the present study in terms of trying to streamline the generalization model process development, through the creation of bigger and diversified datasets. Moreover, AI can be combined with other emerging technologies. including drones and autonomous vehicles so that its Plant species recognition can also experience the continuous enhancement.

CONCLUSION

Plant species identification and classification The AI and deep learning models, such as CNNs, among others, have transformed the process of identification and classification of plant species. AI-based systems are capable of being fast, error free, and scalable and may be useful in botanical research, conservation, and agriculture. Nevertheless, the problems, including the lack of available data and the generalization of models, need to be challenged to make AI a potential industry game changer. Continued advancement in AI devices implies that it would grow and would interact with other technologies and tools, increasing the impact on plantive determination and division, improving the effectiveness and accuracy of botanical research.

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