PlantGuard: Intelligent Plant Disease Detection

by

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A project submitted to the Department of Computer Science and Engineering
in partial fulfillment of the requirements for the degree of
Master of Engineering in Computer Science and Engineering

Department of Computer Science and Engineering
Brac University
May 2024

Declaration

It is hereby declared that

1. The project submitted is my own original work while completing my degree at Brac University.
2. The project does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The project does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I have acknowledged all main sources of help.

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Approval

The project titled "PlantGuard" , submitted by Nazifa Khanom (24173004) of Spring, 2024 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Engineering in Computer Science and Engineering on May 15 , 2024.

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Abstract

Every year, there is significant crop loss in developing countries due to delays in identifying plant diseases. Prompt and accurate identification of these diseases, with less reliance on field experts, could greatly mitigate this issue. Recognizing plant diseases correctly, particularly when they present similar leaf textures, poses a significant challenge. It's crucial to consider factors such as leaf color and various texture features to accurately predict plant defects. The objective of this project is to employ Deep Learning methodologies for the detection of plant diseases based on leaf images. Deep learning, specifically Convolutional Neural Networks, is chosen due to its effectiveness in extracting features from plant leaves, making it well-suited for image data analysis in this context.

Keywords: Crop loss; Developing countries; Plant diseases; Prompt and accurate identification; Delays; Field experts; Leaf textures; Leaf color; Texture features; Deep Learning,; Convolutional Neural Networks;Image data analysis

Acknowledgement

I extend my heartfelt gratitude to Muhammad Iqbal Hossain, my mentor, for granting me the invaluable opportunity to undertake the project "PlantGuard." His guidance and encouragement have been instrumental in navigating through extensive research, enriching my understanding, and unveiling myriad new insights in this field.

Furthermore, I am deeply indebted to my parents and friends whose unwavering support and assistance have been pivotal in ensuring the timely completion of this project within the constraints of our schedule.

Lastly, I wish to express my profound appreciation to Md Sadek Ferdous, the project head, whose dedicated efforts in mentoring me have played a crucial role in attaining our objectives. I am also grateful for the invaluable guidance provided by our other supervisors and panel members, whose constructive feedback during the project presentation has significantly enhanced my documentation skills.

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Chapter 1

Introduction

1.1 The idea behind the project "PlantGuard"

Detecting plant diseases swiftly and accurately is crucial for preventing significant losses in agriculture, particularly in impoverished regions. However, the task becomes daunting for experts, especially in remote areas. These systems leverage sophisticated technologies like Deep Learning, which excel at analyzing leaf images to identify signs of illness.

Through Convolutional Neural Networks (CNNs), even subtle indications of disease can be detected with precision. The primary aim of this research is to harness the power of Deep Learning to develop a robust and user-friendly method for early detection of plant diseases. Furthermore, this system will go beyond identification; it will provide detailed descriptions of diseases, along with preventive measures. Additionally, it will offer recommendations on supplements and fertilizers to be used.

By empowering farmers with such comprehensive information, they can better safeguard their crops, ensuring an ample food supply, especially in challenging agricultural environments. This initiative aims to bridge the gap between technological advancements and agricultural practices, ultimately fostering food security and sustainable farming practices worldwide.

1.2 Objective

The aim of this project is to create and execute a novel intelligent system for identifying and averting diseases that affect plant leaves. Utilizing advanced Deep Learning techniques, particularly Convolutional Neural Networks (CNNs), the project aims to develop a reliable framework capable of accurately identifying various plant diseases based on leaf images. The focus will be on creating a user-friendly interface that enables farmers and agricultural stakeholders to easily capture and analyze leaf images using smartphones or similar devices. By providing timely and accurate disease diagnosis, the project seeks to empower farmers to take proactive measures to mitigate the spread of diseases, thereby improving crop yield and contributing to food security. Additionally, the project will explore the integration of preventive measures and recommendations into the system to assist farmers in implementing

effective disease management strategies. Through collaborative efforts with agricultural communities, the project endeavors to develop a practical and impactful solution that addresses the pressing challenge of plant disease management in agricultural settings.

1.3 Web Application

In the PlantGuard project, the web application serves as the central hub for managing and accessing information related to plant diseases. Unlike traditional software installed on individual devices, the application runs on a web server, making it accessible through any web browser with an internet connection.

The web application acts as the administrator of the entire system, providing a user-friendly interface for users to interact with the various components of the project. It serves as the super administrator, granting privileged access to manage information across all components.

Through the web application, users can upload leaf images for disease detection, view diagnostic results, access detailed descriptions of identified diseases, and receive recommendations for prevention and treatment. Additionally, the application facilitates communication between different components of the project, ensuring seamless integration and efficient workflow. For example, if a picture of a leaf is uploaded, the app sends it to be checked for diseases, then brought back to show the results.

Overall, the web application plays a pivotal role in the leaf disease detection project, providing users with a powerful tool for managing plant health and combating diseases effectively.

Chapter 2

Literature Review

2.1 Mobile Application for Plant Leaf Disease Detection

In Bangladesh, plant leaf disease detection is critical for maintaining agricultural productivity and food security. Traditional methods are often impractical, especially in remote areas. Modern technologies like image processing and machine learning offer promising solutions by enabling accurate and efficient disease detection from leaf images. Implementing these technologies can revolutionize agriculture in Bangladesh, empowering farmers to protect their crops effectively and ensure food security for the population.

Nowadays, smartphones are cheaper in countries offered by different companies and there is a very competitive internet connectivity market offered by ISPs, different mobile companies, etc. Consequently, people of all levels across the country are using the internet to get connected with SNS, to take advantage of network-based services, etc., including mobile applications for detecting plant diseases. Many applications are already in the market. Such as:

- Agrio
- Plantix
- Leaf Doctor etc.

My project on plant leaf disease detection can empower farmers in Bangladesh or other countries by helping them quickly identify and manage diseases affecting their crops. This will minimize crop losses, promote sustainable farming practices, and enhance food security in the country.

2.2 Existing App Review from App Store

2.2.1 Plantix [1]:

- Rating: 4.6 stars
- Description: Plantix has received 87.6K reviews on Google Play. Users appreciate its accuracy in detecting pests and diseases on crops. The app covers 30 major crops and detects over 400 plant damages just by analyzing a photo of a sick crop. It also offers disease alerts, cultivation tips, agri-weather forecasts, and a fertilizer calculator.

2.2.2 Agrio [2]:

- Rating: 4.5 stars
- Description: Agrio is a precision plant protection solution that helps growers and crop advisors remotely monitor, identify, and treat plant diseases and pests. It offers features like integrated pest management protocols, effortless monitoring of large fields, leaf chlorophyll content monitoring, hourly hyperlocal weather data, and warning notifications.
- User Testimonial: "Agrio was rated 4.67 out of 5 based on 7 reviews from actual users.
- User Testimonial: "As an agronomist, I highly recommend this app. It's been effective in identifying and providing solutions to combat plant diseases." - Alejandro Escarra, Agronomist (Spain).

2.2.3 Leaf Doctor [3] :

- Rating: 1.9 stars
- Description: Leaf Doctor performs quantitative assessments for plant diseases on organs like leaves. Users can submit photos of diseased plant organs, and the app calculates the percentage of diseased tissue. It's a useful tool for assessing plant health.
- User Testimonial: There is something wrong with my Aloe and I figured that this app could tell me what was wrong with it and how to fix it. Instead, it told me that my plant was healthy when it obviously is not.

2.3 Background

Detecting plant diseases accurately and swiftly is essential for ensuring food security and preventing significant agricultural losses. Traditionally, experts rely on manual inspection of plants to identify diseases, which can be time-consuming and impractical, especially in remote areas. With the advent of intelligent systems powered by technologies like Deep Learning, the task of disease detection has become more efficient and effective. In this project, Convolutional Neural Networks (CNNs) are utilized for plant disease detection from leaf images. CNNs have shown superior performance compared to other Deep Learning Models like ResNet-50 and AlexNet in this context. While ResNet-50 and AlexNet models may struggle to capture intricate patterns and features in leaf images, CNNs excel at extracting relevant information, making them better suited for this task.

2.3.1 Why CNN is better?

CNNs outperform other models in plant disease detection due to several key advantages: Firstly, CNNs are adept at capturing spatial hierarchies within images. By utilizing multiple convolutional layers, CNNs can extract low-level features like edges and textures, which are then combined to form higher-level features. This hierarchical feature extraction enables CNNs to identify complex patterns associated with different diseases in plant leaves. Secondly, CNNs leverage parameter sharing, reducing the number of parameters to be learned compared to fully connected networks. This makes CNNs more efficient and less prone to overfitting, particularly in scenarios with limited training data. Additionally, CNNs exhibit translation invariance, meaning they can recognize patterns irrespective of their position in the image. This property is crucial for disease detection in plant leaves, where the location of symptoms may vary across instances of the same disease. Furthermore, CNNs benefit from data augmentation techniques such as image flipping, rotation, and scaling. These techniques enhance the diversity of the training dataset without requiring additional labeled samples, thereby improving the generalization ability of the model and reducing the risk of overfitting. Lastly, CNNs have demonstrated state-of-the-art performance in various image recognition tasks, including plant disease detection. Their ability to learn intricate patterns and features from large datasets makes them highly effective in accurately distinguishing between healthy and diseased plants.

The CNN model in this project achieves an impressive 95% accuracy, outperforming ResNet-50 (27%) and AlexNet (24%) models. This high accuracy is attributed to the use of a diverse and augmented dataset consisting of 38 classes of plant leaf and background images sourced from the Plant Village Dataset. The dataset, comprising 61,486 images, undergoes various augmentation techniques such as image flipping, gamma correction, noise injection, PCA color augmentation, rotation, and scaling to enhance its size and diversity.

After splitting the dataset into train, test, and validation sets, the training process involves leveraging the augmented data to train the CNN model. With 36,584 images

in the training set, 15,679 images in the validation set, and the remaining images reserved for testing, the model learns to accurately classify plant diseases based on leaf images. By integrating CNN-based disease detection systems into agricultural practices, farmers can receive timely and accurate insights into their crop health. This empowers them to take proactive measures to prevent disease outbreaks and optimize the use of supplements and fertilizers, ultimately contributing to improved crop yields and sustainable farming practices.

2.4 Improvements in PlantGuard

PlantGuard may face limitations such as the need for internet access, which can be a barrier in remote areas, and challenges in accurately diagnosing less common diseases due to limited training data. To enhance the project, a feature providing seasonal disease alerts could be added. Utilizing historical data and predictive modeling, this feature would notify farmers about potential diseases based on seasonal patterns, weather conditions, and crop cycles. Additionally, incorporating the Bangla language for Bangladeshi farmers would improve accessibility and understanding, ensuring that more farmers can benefit from PlantGuard's capabilities.

Chapter 3

PlantGuard what it is?

3.1 Project summary

PlantGuard is a user-friendly website designed to aid farmers, agricultural stakeholders, and anyone interested in detecting plant diseases. The website features an AI Engine, which highlights the significance of plant disease detection and allows users to upload images of plants for analysis. Upon uploading an image, the AI Engine swiftly identifies whether the plant is infected or healthy, displaying the results along with an accuracy score. Furthermore, users receive detailed descriptions of detected diseases and recommendations for supplements or fertilizers to prevent and manage them effectively. With its intuitive interface and comprehensive features, PlantGuard aims to empower users to safeguard their crops and promote agricultural health and productivity.

The process includes:

- Image Upload: Users can navigate to the AI Engine page and upload images of plants they suspect may be infected with diseases.
- Disease Detection: The AI Engine analyzes the uploaded images using advanced algorithms to detect any signs of disease.
- Result Display: After analysis, the AI Engine displays the results, indicating whether the plant is infected or healthy. It also provides an accuracy score for detection.
- Disease Description: Users receive detailed descriptions of any detected diseases, including information about symptoms, causes, and potential impact on plant health.
- Prevention Recommendations: PlantGuard offers recommendations for preventive measures and management strategies to mitigate the spread of diseases. This may include suggestions for supplements or fertilizers.

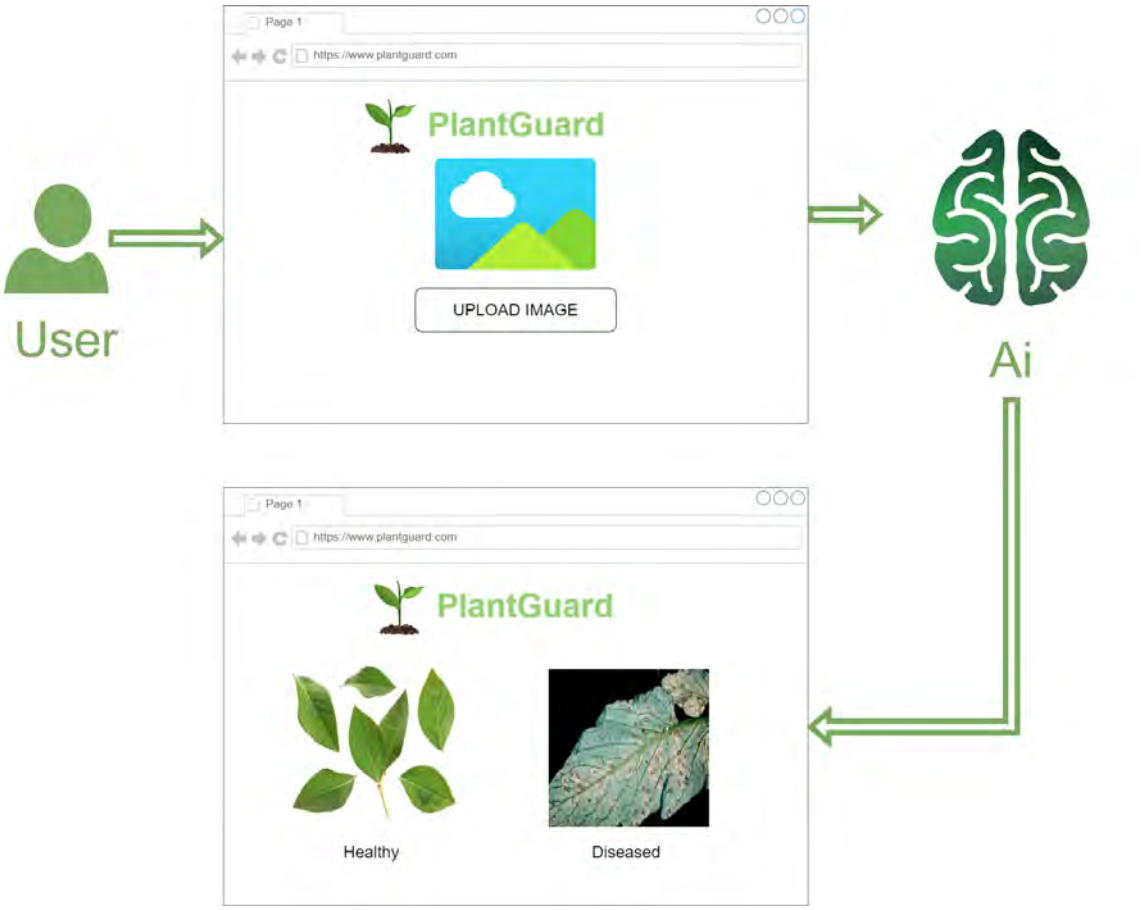

Figure 3.1: PlantGuard Process Summary

3.2 Problem Identification

In many agricultural communities, farmers face significant challenges in identifying and managing plant diseases effectively. Limited access to expert advice and diagnostic services hampers their ability to detect diseases accurately and in a timely manner. Traditional methods of disease detection, often reliant on visual inspection by experts, are labor-intensive, subjective, and prone to human error. As a result, diseases may go undetected or be misdiagnosed, leading to widespread crop damage and economic losses.

Furthermore, the delay in disease management exacerbates the problem, allowing infections to spread rapidly and compromise the health of entire crops. Farmers may also struggle to implement preventive measures due to a lack of awareness about disease symptoms, causes, and appropriate management strategies. This gap in knowledge and resources underscores the need for scalable solutions that can provide accessible and accurate assistance to farmers.

Innovative technologies that might expedite the process of disease identification and prevention in agriculture are desperately needed to meet these difficulties. By leveraging the power of artificial intelligence and image recognition, PlantGuard seeks to revolutionize the way farmers identify and manage plant diseases. By providing a user-friendly platform for uploading plant images, analyzing disease symptoms, and receiving tailored recommendations for disease management, PlantGuard aims to empower farmers with the tools and knowledge they need to protect their crops and livelihoods effectively.

3.3 Importance of the Project

The PlantGuard project holds significant importance in the realm of agriculture and plant health for several reasons:

- Enhancing Crop Protection: Plant diseases pose a serious threat to crop productivity and food security worldwide. By providing farmers with a reliable tool for early disease detection and prevention, PlantGuard helps safeguard crops against potential threats, thereby reducing the risk of yield losses and ensuring a more stable food supply.

- Timely Intervention: One of the critical aspects of disease management is early intervention. PlantGuard's AI-powered detection system enables farmers to identify diseases promptly, allowing them to take timely action to mitigate the spread of infections and minimize crop damage. This proactive approach can significantly enhance agricultural resilience and mitigate economic losses.

- Accessible Expertise: In many agricultural communities, access to expert advice and diagnostic services is limited. PlantGuard bridges this gap by offering

a user-friendly platform where farmers can receive accurate disease diagnoses and recommendations without the need for specialized knowledge or expertise. This democratization of information empowers farmers of all skill levels to make informed decisions about disease management.

- Sustainable Agriculture: Effective disease management is essential for promoting sustainable agricultural practices. By helping farmers implement preventive measures and optimize resource use, PlantGuard contributes to the sustainability of farming operations, reducing the reliance on chemical inputs and minimizing environmental impact.

- Economic Benefits: Crop losses due to plant diseases can have significant economic implications for farmers and agricultural economies. By preventing disease outbreaks and optimizing crop health, PlantGuard helps farmers protect their livelihoods and improve their economic resilience. Additionally, by increasing crop yields and quality, the project can contribute to higher farm incomes and overall economic growth.

In conclusion, the PlantGuard initiative is essential to the advancement of food security, agricultural sustainability, and economic prosperity because it gives farmers the skills and information they need to prevent plant diseases and safeguard their harvests.

3.4 Development Models

3.4.1 Dataset Acquisition and Preprocessing

The project begins by acquiring the "Plant Village Dataset," consisting of 61,486 images representing 38 different classes of plant diseases and healthy conditions. Preprocessing techniques, such as image resizing, cropping, and normalization, are applied to standardize the dataset and enhance its quality.

3.4.2 Model Selection and Architecture Design

The convolutional neural network (CNN) architecture presented here is tailored for image classification tasks. Commencing with an input layer designed to accommodate images sized 256x256 pixels with three color channels (RGB), the model systematically integrates convolutional layers interleaved with max-pooling layers. These convolutional layers employ 3x3 filters, with the initial layer featuring 32 filters, each followed by Rectified Linear Unit (ReLU) activation to introduce nonlinearity. Successive convolutional layers adhere to this pattern, progressively increasing to 64 filters. After each convolutional layer, a max-pooling layer with a 2x2 pixel pool size is applied, facilitating dimensionality reduction in the feature maps and computational efficiency.

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 254, 254, 32)      896

 max_pooling2d (MaxPooling2  (None, 127, 127, 32)      0
 D)

 conv2d_1 (Conv2D)           (None, 125, 125, 64)      18496

 max_pooling2d_1 (MaxPoolin  (None, 62, 62, 64)        0
 g2D)

 conv2d_2 (Conv2D)           (None, 60, 60, 64)        36928

 max_pooling2d_2 (MaxPoolin  (None, 30, 30, 64)        0
 g2D)

 conv2d_3 (Conv2D)           (None, 28, 28, 64)        36928

 max_pooling2d_3 (MaxPoolin  (None, 14, 14, 64)        0
 g2D)

 flatten (Flatten)           (None, 12544)             0
...
Total params: 6586854 (25.13 MB)
Trainable params: 6586854 (25.13 MB)
Non-trainable params: 0 (0.00 Byte)
```

Figure 3.2: Model Summary of CNN

Following the convolutional layers, the model incorporates a flattening operation, transforming the output from the final convolutional layer into a one-dimensional array. Subsequently, two dense (fully connected) layers are appended. The first dense layer encompasses 512 units and is coupled with a ReLU activation function, followed by a dropout layer with a dropout rate of 0.2, strategically placed to mitigate overfitting. This is succeeded by a second dense layer comprising 128 units, also employing ReLU activation.

For the final classification, a dense output layer is integrated, outfitted with 38 units and a softmax activation function, tailored for multi-class classification tasks. Upon compilation, the model is configured with the Adam optimizer, categorical cross-entropy loss function, and accuracy as the primary evaluation metric. Furthermore, to safeguard against overfitting and ensure optimal model preservation, a model checkpointing mechanism is established. This callback monitors validation accuracy during training and selectively saves model weights whenever there's an enhancement in validation accuracy, guaranteeing retention of the best-performing model iteration. This comprehensive architecture, when trained on pertinent image data, stands poised to effectively classify images across the designated categories.

3.4.3 Training and Validation

The training process begins by determining how many steps, or batches of data, will be processed in each epoch. This is calculated by dividing the total number of training and validation samples by the batch size. With this information, the model is then trained over 20 epochs, where it learns from the training data and adjusts its parameters to minimize the loss function. This training is facilitated using the 'fit' method, which takes in data generators providing batches of training and validation data. Alongside this, a 'ModelCheckpoint' callback is employed, which continuously monitors the model's performance on the validation data. This callback ensures that the weights of the model yielding the best accuracy on the validation set are saved. Following training, the epoch with the highest validation accuracy is identified from the training history. This epoch represents the point at which the model demonstrated the most optimal performance on unseen validation data. After completion, it is noted that the model achieved an impressive accuracy of 95%, indicating its capability to effectively classify data into different classes. By employing these techniques, the training process aims to iteratively enhance the model's ability to generalize well to new, unseen data, thus enhancing its overall effectiveness and reliability in real-world applications.

3.4.4 Accuracy and Loss

Moreover, in the following figure, the left subplot displays the training and validation loss over epochs, and the right subplot displays the training and validation accuracy over epochs. It is seen that the two plots don't have much difference.

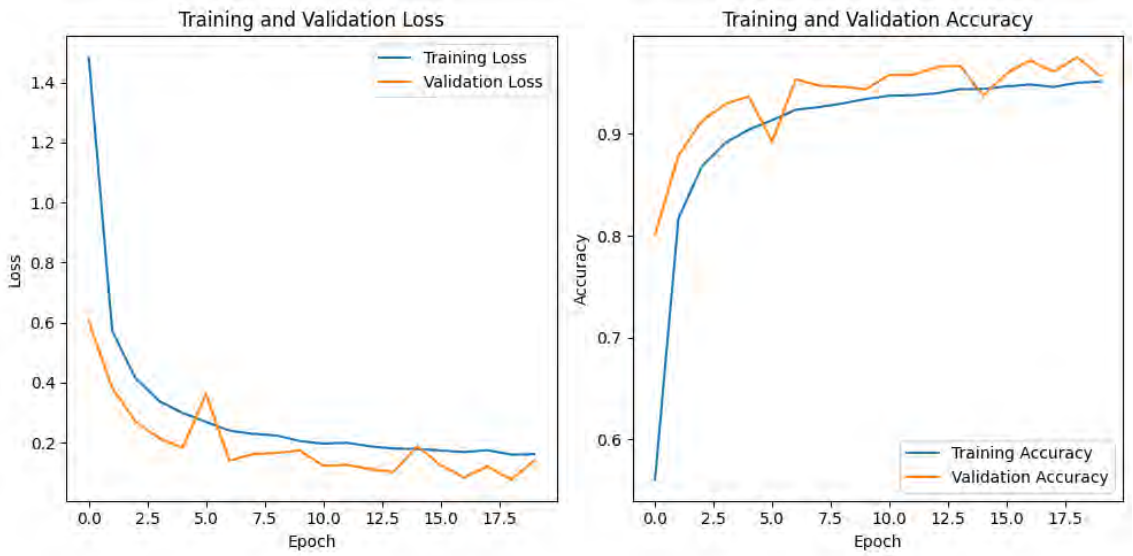

Figure 3.3: Accuracy and Loss

3.4.5 Confusion Matrix

The confusion matrix plot provides a comprehensive view of the model's performance across different classes, helping to identify misclassified classes and guide targeted improvements. The confusion matrix, computed using 'confusion_matrix(true_classes, predicted_classes)', displays the number of correct and incorrect predictions for each class, highlighting areas of correct classification and misclassification.

In the following picture, it is seen that the Predicted Label and True Label matched in most cases.

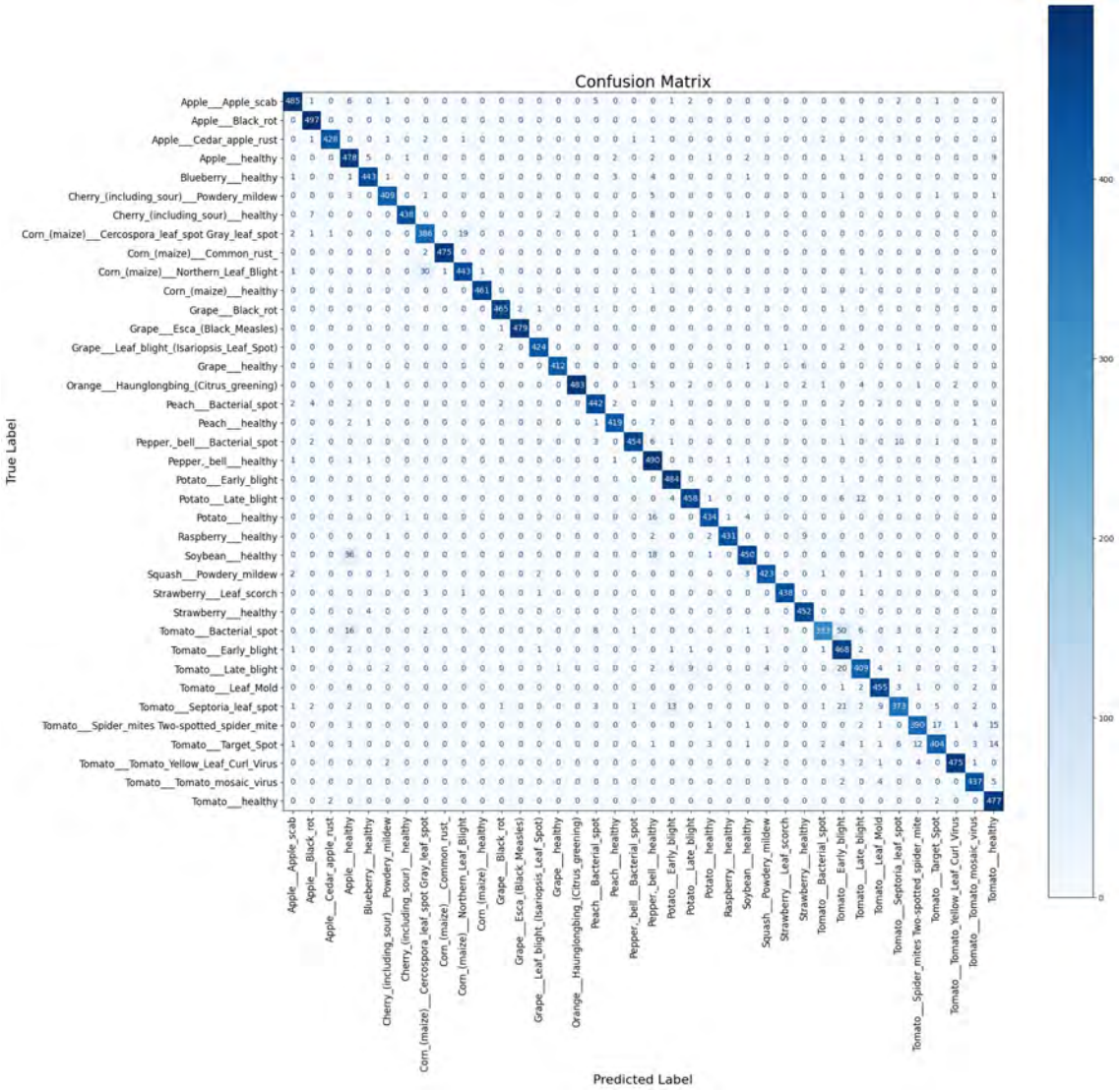

Figure 3.4: Confusion Matrix

3.4.6 Testing and Evaluation

The overall weighted F1 score, recall, and precision using f1_score, recall_score, and precision_score with the average='weighted' parameter. This parameter ensures that the scores are averaged across all classes, taking into account the class distribution. These metrics are crucial for understanding the model's overall performance:

- F1 Score: The harmonic mean of precision and recall, providing a balance between the two.
- Recall: The ability of the model to correctly identify all relevant instances.
- Precision: The accuracy of the model in predicting relevant instances.

The following image shows the values of the F1 score, recall, and precision.

Classification Report:

	precision	recall	f1-score	support
Apple___Apple_scab	0.98	0.96	0.97	504
Apple___Black_rot	0.97	1.00	0.98	497
Apple___Cedar_apple_rust	0.99	0.97	0.98	440
Apple___healthy	0.84	0.95	0.89	502
Blueberry___healthy	0.98	0.98	0.98	454
Cherry_(including_sour)___Powdery_mildew	0.98	0.97	0.97	421
Cherry_(including_sour)___healthy	1.00	0.96	0.98	456
Corn_(maize)___Cercospora_leaf_spot Gray_leaf_spot	0.91	0.94	0.92	410
Corn_(maize)___Common_rust_	1.00	1.00	1.00	477
Corn_(maize)___Northern_Leaf_Blight	0.95	0.93	0.94	477
Corn_(maize)___healthy	1.00	0.99	0.99	465
Grape___Black_rot	0.99	0.99	0.99	470
Grape___Esca_(Black_Measles)	1.00	1.00	1.00	480
Grape___Leaf_blight_(Isariopsis_Leaf_Spot)	0.99	0.99	0.99	430
Grape___healthy	0.99	0.98	0.98	422
Orange___Haunglongbing_(Citrus_greening)	1.00	0.96	0.98	503
Peach___Bacterial_spot	0.95	0.96	0.96	459
Peach___healthy	0.98	0.97	0.98	432
Pepper,_bell___Bacterial_spot	0.99	0.95	0.97	478
Pepper,_bell___healthy	0.86	0.99	0.92	497

...

Weighted F1 Score: 0.96
Weighted Recall: 0.96
Weighted Precision: 0.96

Figure 3.5: F1 score, recall and precision

3.4.7 Integration into PlantGuard Platform

Once validated, the trained CNN model is integrated into the PlantGuard platform. This involves developing the necessary infrastructure to support real-time disease detection and user interaction.

Chapter 4

Product Description

PlantGuard's web application provides a seamless platform for swift detection and prevention of plant diseases. Through the AI Engine page, users can effortlessly upload images of plant leaves, initiating a sophisticated analysis by cutting-edge algorithms to identify signs of disease. Upon analysis completion, the results are promptly showcased, indicating whether the plant is healthy or afflicted, accompanied by an accuracy score.

What sets PlantGuard apart is its user-friendly approach; the website requires no registration, allowing anyone to access its features hassle-free. This inclusive design ensures that farmers and enthusiasts alike can benefit from its capabilities without any barriers.

4.1 Home Page

The homepage of PlantGuard greets users with a visually engaging display of 14 types of fruits and vegetables, including familiar favorites like apple, blueberry, and corn. These images serve as options, inviting users to explore the detection capabilities tailored to each specific crop. At the top of the page proudly sits the website's name, PlantGuard, signifying its mission to safeguard agricultural produce.

Directly accessible from the homepage is the AI Engine page, where users can initiate the powerful analysis process with just a click. This seamless navigation ensures that users can swiftly transition from browsing to utilizing the advanced features of PlantGuard's detection system.

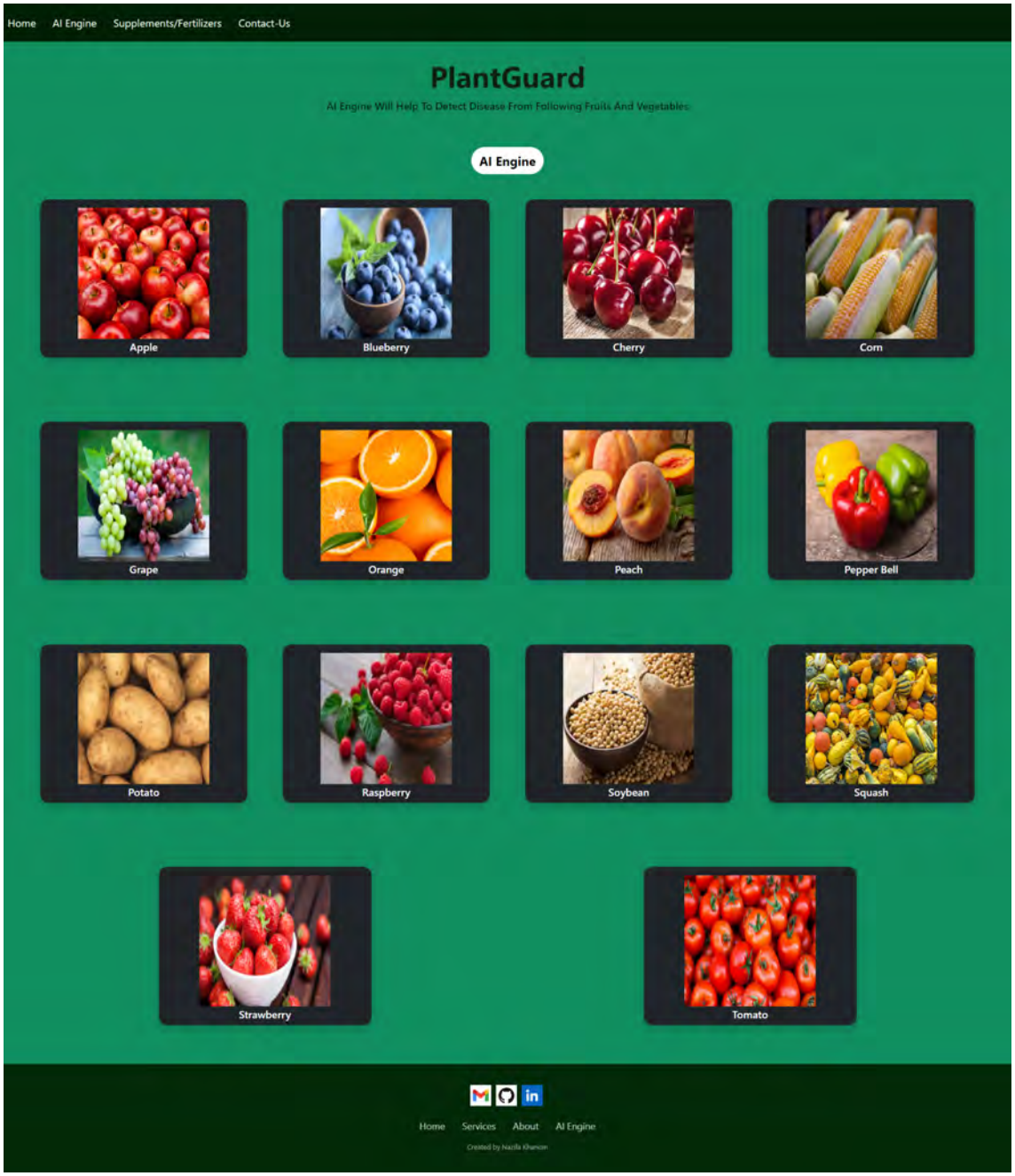

Figure 4.1: Home Page

4.2 Navigation Bar Menu

The navigation menu of the PlantGuard website offers a user-friendly experience with easy access to key sections:

- Home: This section serves as the welcome gateway to the website, providing an overview of PlantGuard's offerings and features.
- AI Engine: Users can navigate to the AI Engine page to leverage cutting-edge technology for plant disease detection. Here, they can upload images of plant leaves and receive instant analysis results.
- Supplements: This section provides valuable information on recommended supplements and fertilizers to prevent and manage plant diseases effectively. Users can access expert guidance on maintaining crop health.
- Contact Us: For any inquiries, feedback, or support needs, users can easily reach out through the Contact Us page. This section ensures open communication and assistance for users seeking additional assistance or information.

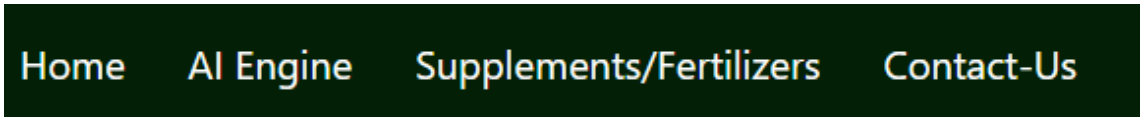

Figure 4.2: Navigation Bar

4.3 Admin Login Page

This page will be accessible only to admins, such as doctors or experts in plant leaf diseases, who can recommend appropriate treatments, and they will also be given permission to make changes with the recommendations. For now, the password credential is "password" and the admin can log in with this credential.

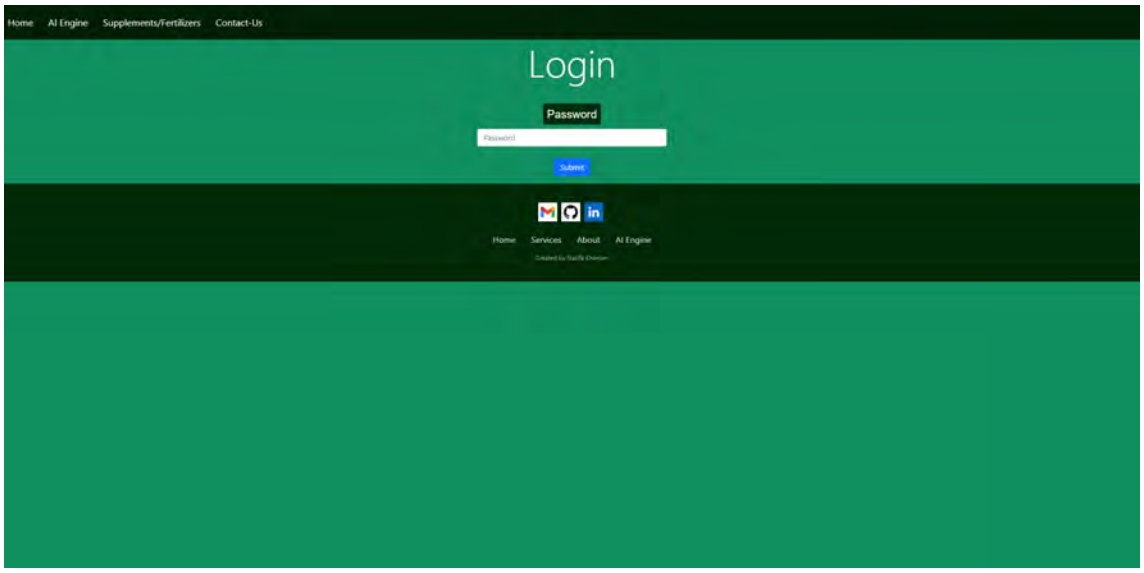

Figure 4.3: Admin Login Page

4.4 AI Engine

The AI Engine underscores the critical importance of detecting diseases in plants. Plant diseases not only impede growth but also pose significant challenges to agricultural productivity. Recognizing this, the AI Engine fills vital research gaps, aiming for early disease detection even before symptoms become apparent. This proactive approach is pivotal, as it prevents potential losses and optimizes disease control efforts.

The platform empowers users to take action by allowing them to upload files directly from their devices. With just a few clicks, users can submit their images for analysis, facilitating swift disease detection.

Moreover, PlantGuard offers practical steps to prevent plant diseases, ensuring comprehensive plant care. Users are encouraged to follow good sanitation practices, maintain soil health through fertilization, and inspect plants before acquisition. Additional measures such as crop rotation and adequate air circulation, further enhance plant resilience.

For users seeking detailed information, the "More Info" button provides access to comprehensive resources and insights, enabling them to deepen their understanding of plant disease prevention and management.

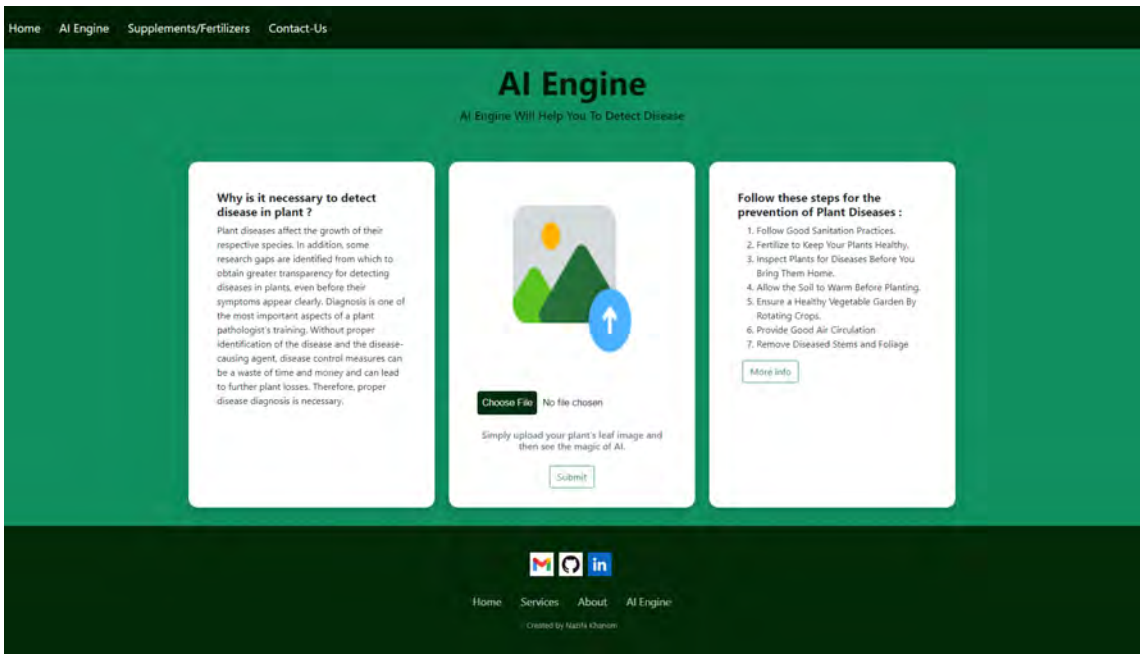

Figure 4.4: AI Engine

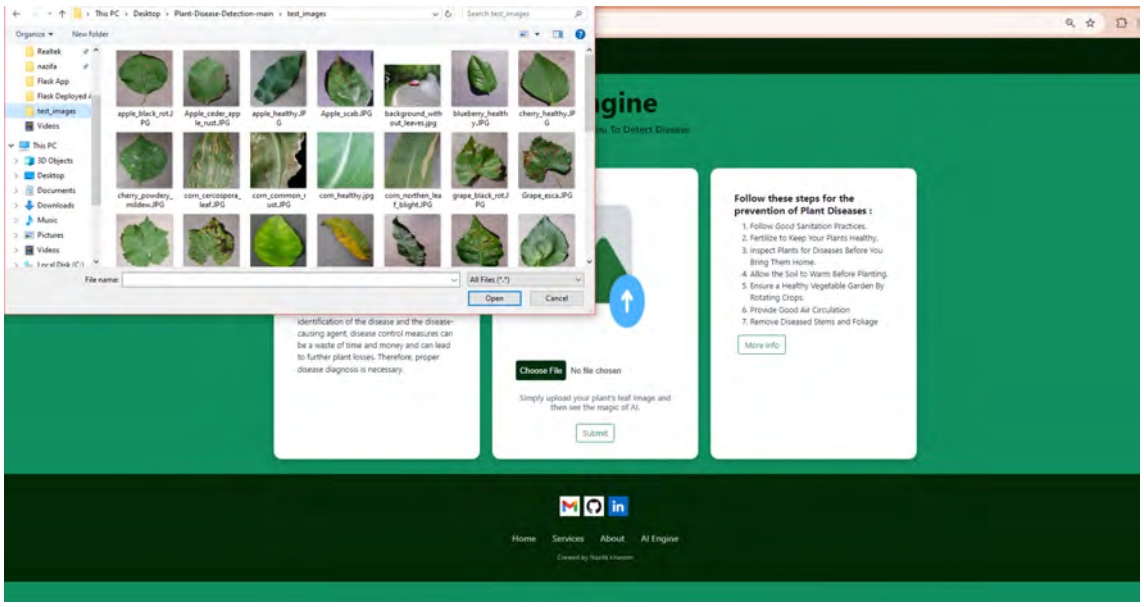

Figure 4.5: File Upload

4.4.1 Detection of Diseased Plant

Upon clicking the submit button, users are directed to a dynamic page tailored to their plant disease detection needs. Here, they encounter a wealth of information essential for effective disease management:

- Disease Identification: The page prominently displays the name of the detected disease, providing users with immediate clarity on the plant's health status.
- Visual Confirmation: An image of the infected leaf accompanies the disease name, offering users a visual reference for easy recognition and confirmation.
- Prediction Accuracy Display: Users are provided with the prediction accuracy, indicating the percentage of damage to the leaf, enabling informed decision-making regarding disease management.
- Disease Description: A concise yet comprehensive description of the disease appears, outlining its symptoms, causes, and potential impact on plant health. This empowers users with valuable insights into the nature of the disease.
- Prevention Strategies: Practical prevention measures are outlined, equipping users with actionable steps to mitigate the spread and impact of the disease. From sanitation practices to cultural management techniques, users gain essential knowledge to safeguard their plants effectively.
- Supplement Recommendations: To bolster disease management efforts, specific supplements tailored to combating the detected disease are recommended. Each supplement is accompanied by an image for easy identification.
- Purchase Options: For convenient access to recommended supplements, a "Buy Product" button is provided. Clicking this button redirects users to a dedicated page where they can seamlessly purchase the recommended products, ensuring swift and hassle-free procurement.

This comprehensive approach ensures that users not only identify plant diseases promptly but also receive actionable guidance and access to essential resources for effective disease prevention and management.

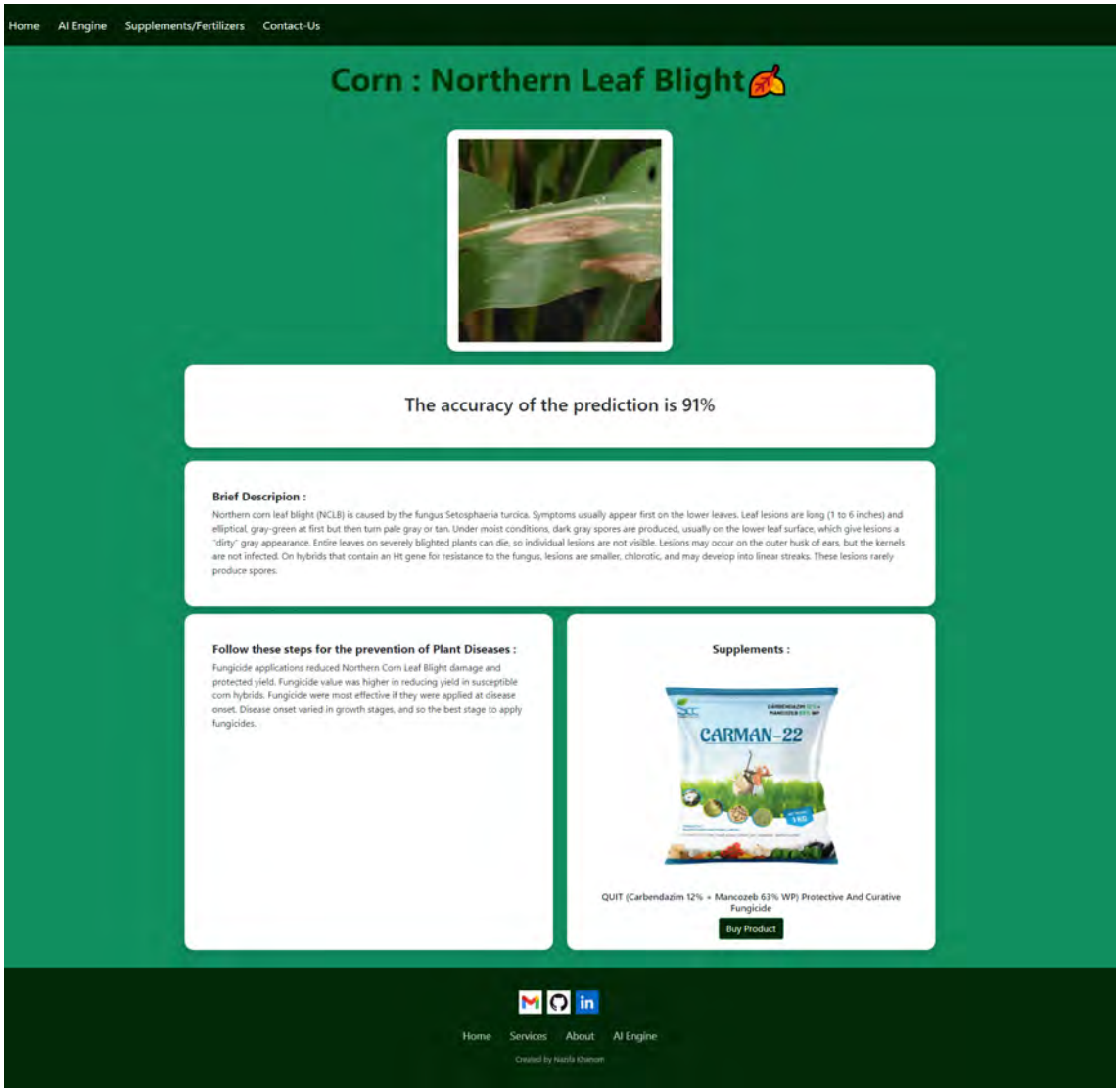

Figure 4.6: Detection of Diseased Plant

4.4.2 Detection of Healthy Plant

Upon clicking the submit button, users are directed to a dedicated page on PlantGuard where they can explore valuable insights and resources to nurture healthy plants:

- Plant Identification: The page displays the name and an image of the identified healthy plant, providing users with instant recognition and validation of their plant's health status.
- Prediction Accuracy Display:Users are provided with the prediction accuracy, indicating the percentage of healthiness of the leaf, enabling informed decision-making regarding plant care.
- Expert Growing Tips: Users are presented with a brief yet informative description outlining essential tips and best practices for cultivating healthy plants. From optimal watering schedules to sunlight requirements, users receive expert guidance to maximize plant growth and vitality.
- Benefits of the Plant: PlantGuard highlights the unique benefits and advantages of the identified healthy plant, showcasing its diverse features, such as air purification properties, aesthetic appeal, or edible produce.
- Tailored Fertilizer Recommendations: Alongside the plant details, users are introduced to recommended fertilizers tailored to the plant's specific needs. Each fertilizer is accompanied by an image and a description, allowing users to explore and select the most suitable option for their gardening needs.
- Seamless Product Purchase: To streamline the purchasing process, a prominent "Buy Product" button is provided, enabling users to conveniently purchase the recommended fertilizer with a single click. Upon clicking the button, users are redirected to a secure page where they can complete their purchase transaction.

By leveraging the information and resources provided on this page, users can effectively enhance the health and well-being of their plants, fostering a thriving and vibrant garden environment. Whether seasoned gardeners or novice plant enthusiasts, PlantGuard empowers users to cultivate healthy, beautiful plants with confidence and ease.

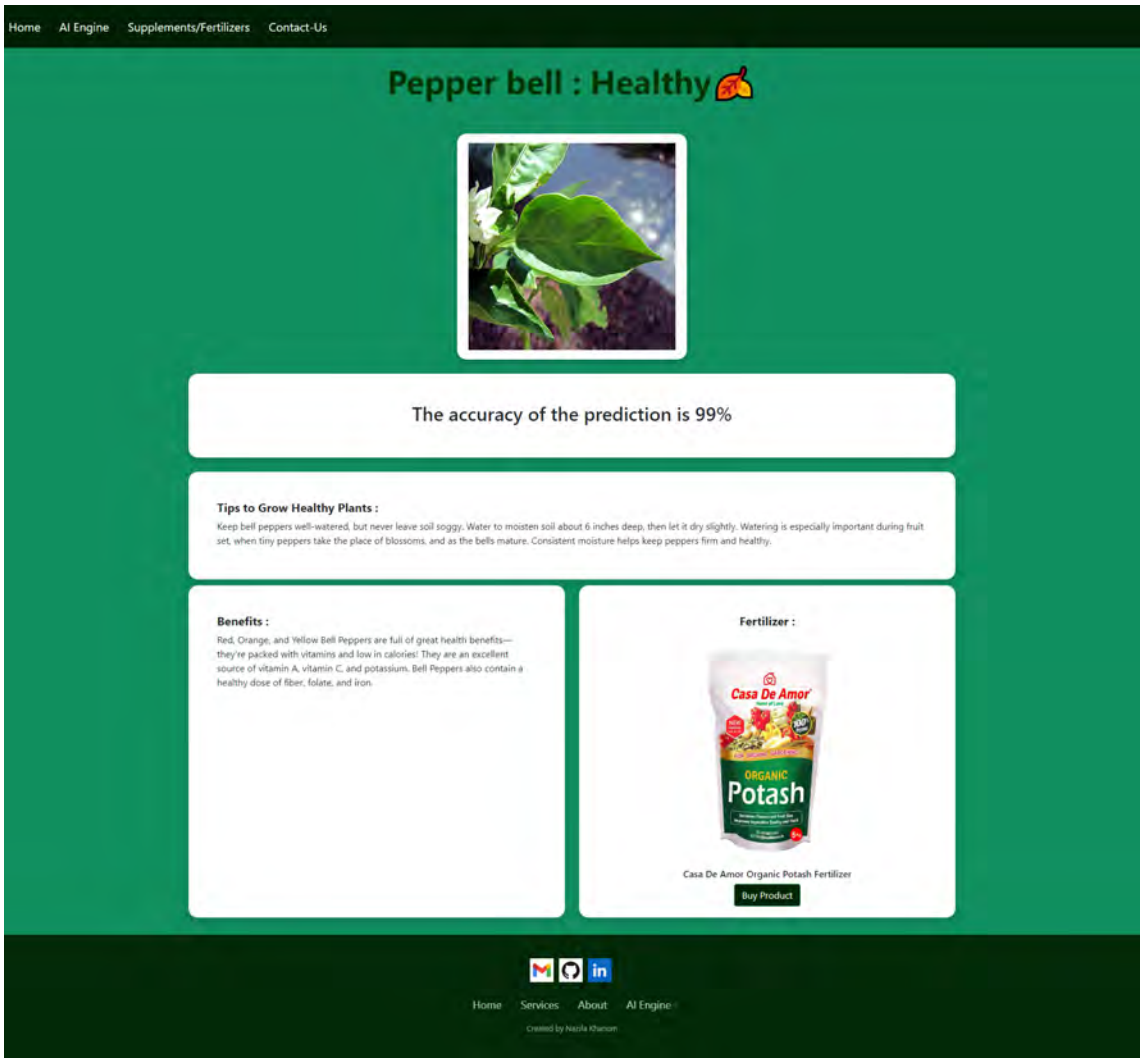

Figure 4.7: Detection of Healthy Plant

4.5 Detection of Unknown Image

When an unknown image is submitted then it will show that it is not available in the database for now.

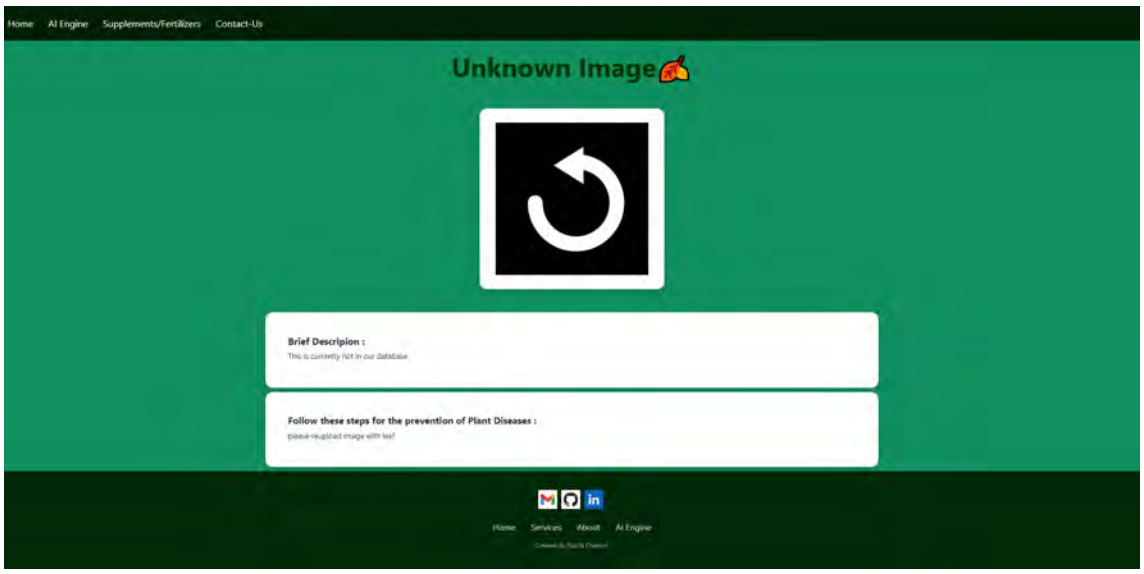

Figure 4.8: Unknown Image

4.6 Treatment Options Management

The admin page allows doctors or experts to update the supplement name, image, and purchase link and to make changes to the recommended medicines, ensuring the appropriate fertilizers and supplements are suggested for curing specific plant leaf diseases. After clicking the submit button, changes are applied. Admins can select and modify any fruit or vegetable name, image, and purchase link from the database.

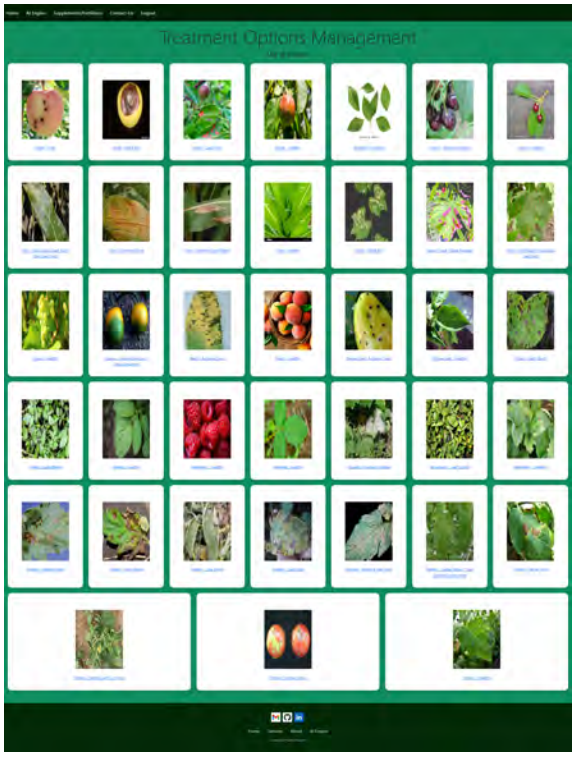

Figure 4.9: List of Treatment Options Management

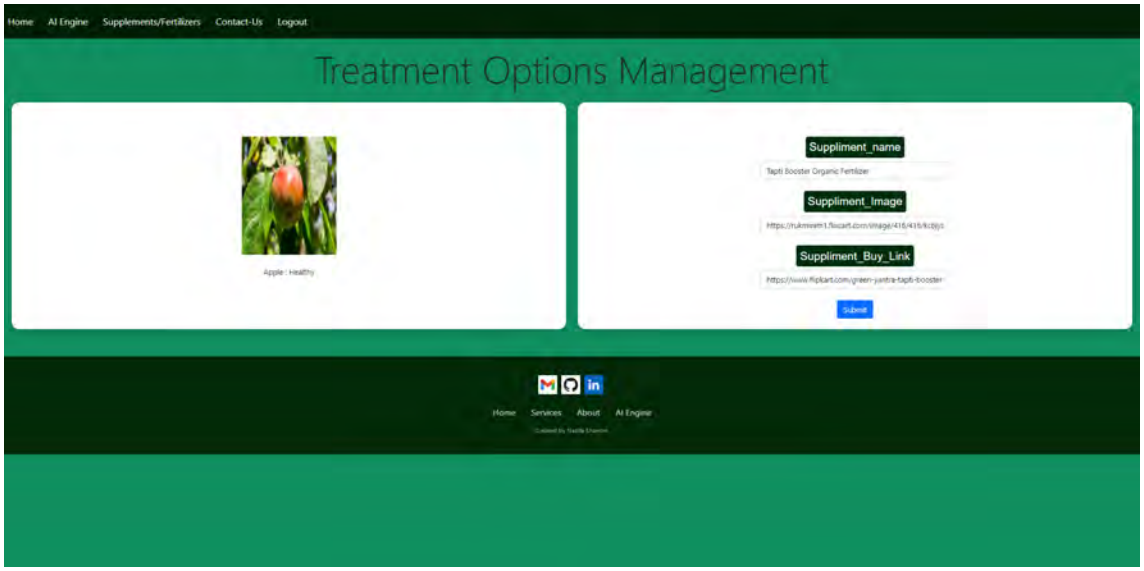

Figure 4.10: Treatment Options Management

4.7 Supplements/Fertilizers

On the supplements/fertilizer page of PlantGuard, users are presented with a comprehensive list of supplements and fertilizers tailored to meet the specific needs of their plants. Each supplement is accompanied by a visually appealing image and a clear, descriptive name, allowing users to easily identify and explore the available options. Whether users are seeking organic fertilizers, nutrient-rich supplements, or specialized plant treatments, PlantGuard provides a diverse selection to cater to various gardening preferences and requirements.

With the convenience of online shopping integrated into the platform, users can seamlessly purchase their desired products with a simple click of a button. The prominent "Buy Product" button associated with each supplement offers users a direct pathway to acquire the chosen item, streamlining the purchasing process and enhancing user convenience. Upon clicking the button, users are swiftly redirected to a secure checkout page where they can finalize their transaction and complete the purchase of the selected supplement or fertilizer.

By offering a user-friendly interface, visually appealing product displays, and hassle-free purchasing options, PlantGuard ensures that users can access high-quality supplements and fertilizers with ease. Whether users are seasoned gardeners or beginners embarking on their gardening journey, PlantGuard provides a convenient and reliable platform for obtaining essential products to nurture healthy and thriving plants.

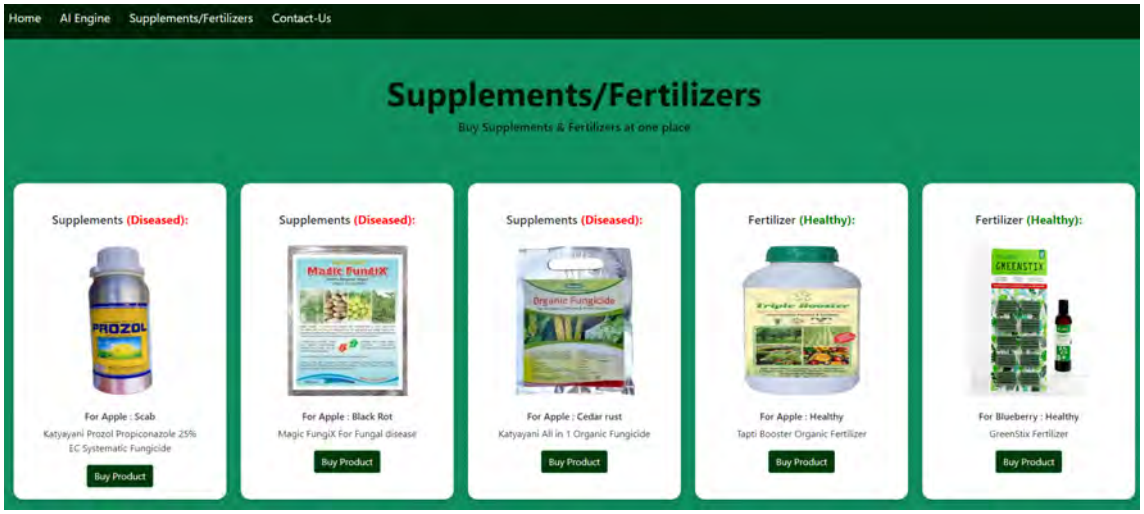

Figure 4.11: Supplements/Fertilizers

4.8 Contact Us

The Contact Us page of PlantGuard serves as a valuable resource for users seeking assistance, guidance, or wishing to provide feedback. Users are encouraged to reach out with their queries, suggestions, or concerns through various communica-

tion channels, including Gmail, LinkedIn, and GitHub.

For users preferring email correspondence, PlantGuard provides a direct avenue to submit queries and suggestions via Gmail. By leveraging the provided email address, users can conveniently communicate their inquiries or share their thoughts with the PlantGuard team, ensuring prompt and personalized responses to their messages.

Additionally, users can connect with PlantGuard through professional networking platforms such as LinkedIn. By accessing the LinkedIn profile associated with PlantGuard, users can engage with the team, network with industry professionals, and explore opportunities for collaboration or partnership.

Moreover, users have the option to utilize GitHub, a popular platform for collaborative software development, to communicate with PlantGuard. GitHub provides a centralized hub for users to submit bug reports, contribute to ongoing projects, or suggest enhancements or features for the platform.

By offering multiple channels of communication, including Gmail, LinkedIn, and GitHub, PlantGuard ensures accessibility and responsiveness, enabling users to seek assistance, provide feedback, or engage in dialogue with the platform's team effectively. Whether users prefer email communication, professional networking, or collaborative development platforms, PlantGuard accommodates diverse communication preferences to foster meaningful interactions and support user needs.

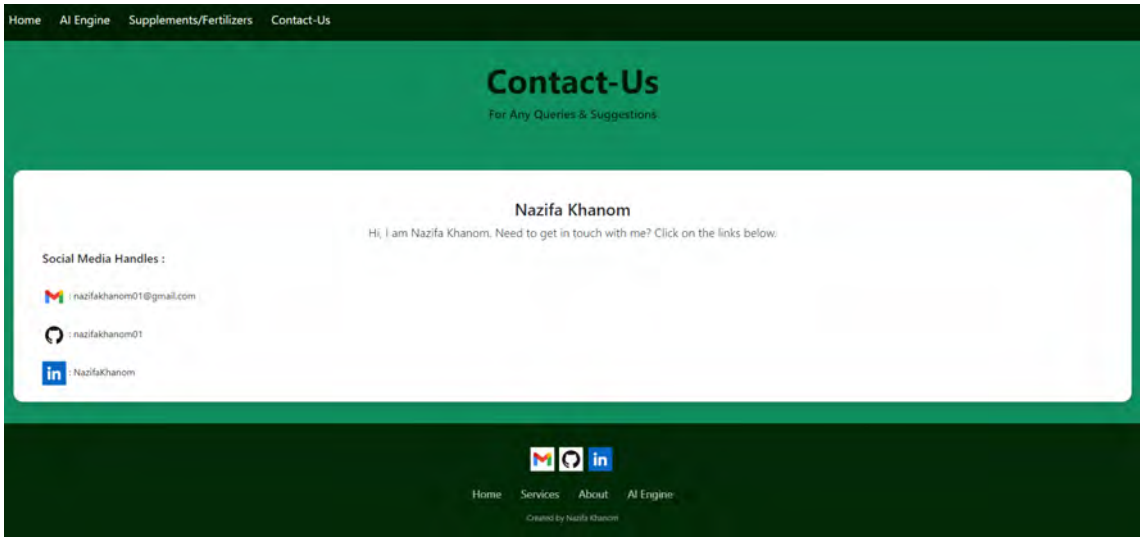

Figure 4.12: Contact Us

4.9 Convenient Platform

Agri Begri is a convenient platform linked to the website for buying supplements and fertilizers.Agri Begri is known for supplying Seeds, Fertilizers, Pesticides, Plant Growth Regulators, Irrigation and Farming Tools, and Equipment that are required

Figure 4.13: Convenient Platform

in agriculture. It also provides guaranteed market's best price and customer support with Free Home Delivery throughout India.

Chapter 5

Flow Diagram

5.1 Use Case Diagram

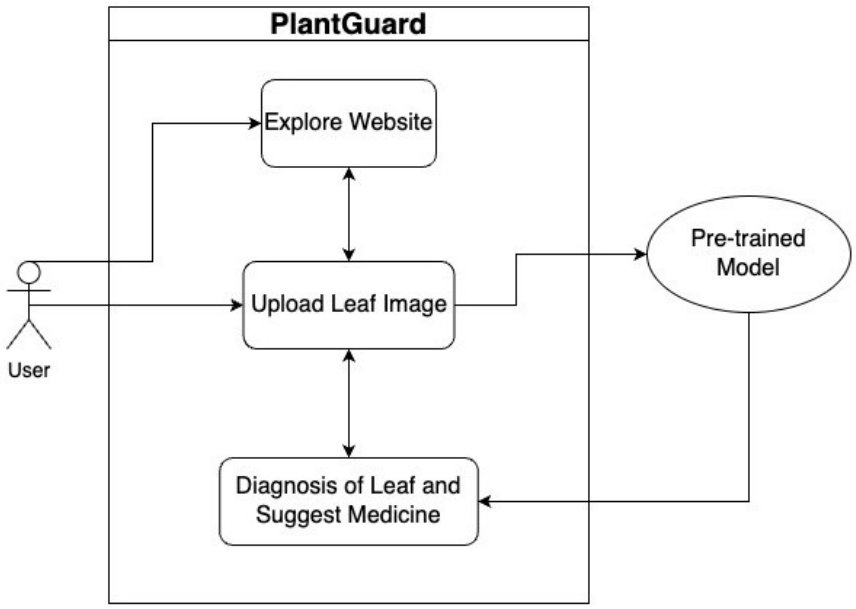

Figure 5.1: Use Case Diagram

The PlantGuard web application allow users to interact with various features aimed at plant health management. The user can explore the website and then upload an image of a leaf for diagnosis. This diagnosis is done by a pre-trained model and after the diagnosis, supplements or fertilizers are suggested according to the disease detection or health of the plant accordingly.

5.2 Sequence Diagram

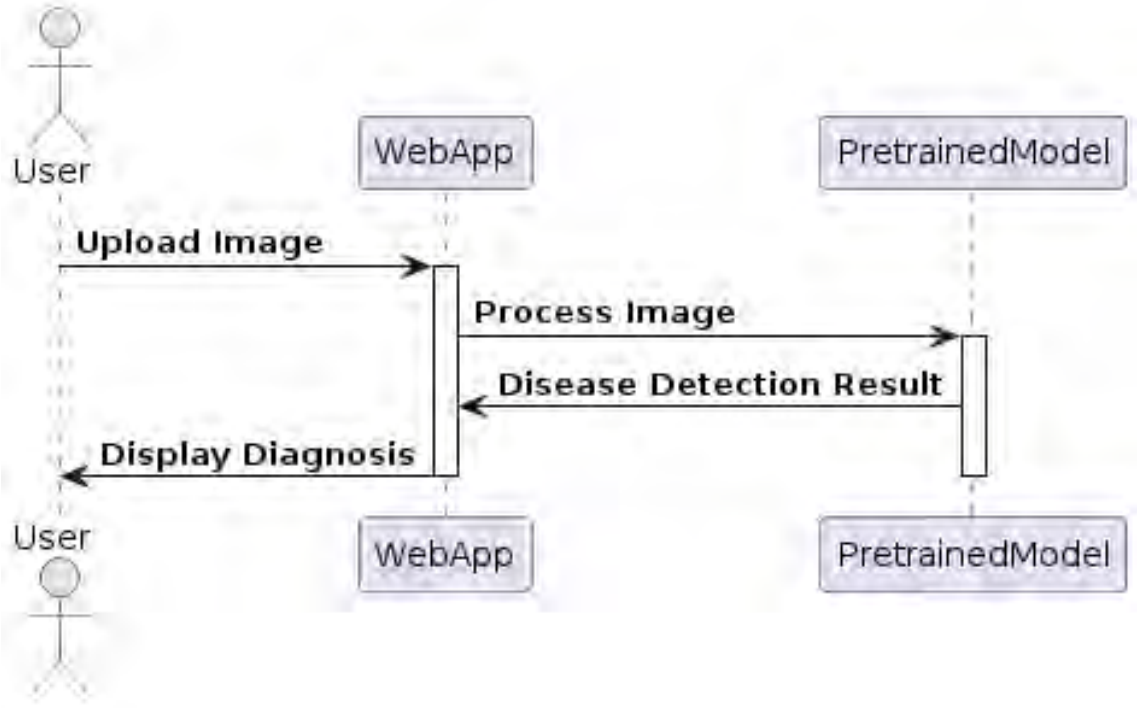

Figure 5.2: Sequence Diagram

The sequence diagram showcases the steps involved in the PlantGuard web application's disease detection process.

- User Uploads Image: The user uploads an image of a plant leaf through the "Upload Image" function in the"AI Engine" section.
- Pre-Trained Model Processing: The uploaded image is processed by a pre-trained model within the"Pre-Trained Model" component.
- Disease Detection Result: The pre-trained model analyzes the image to detect any signs of disease, producing a diagnosis based on the detected patterns.
- Display Diagnosis to User: The diagnosis, including the identified disease and relevant information, is displayed to the user, providing insights into the plant's health status.

This seamless flow allows users to swiftly diagnose plant diseases and take the necessary actions for plant care and management.

5.3 Result and Analysis

PlantGuard's advanced disease detection system ensures precise identification of plant diseases, empowering users with effective prevention strategies. With its user-friendly interface and impactful contributions to agriculture, PlantGuard revolutionizes plant health management, driving positive outcomes for farmers worldwide.

5.3.1 Lighthouse tool for testing PlantGuard

Lighthouse, developed by Google, is a comprehensive tool for assessing and enhancing website quality. It evaluates performance, accessibility, best practices, and SEO.

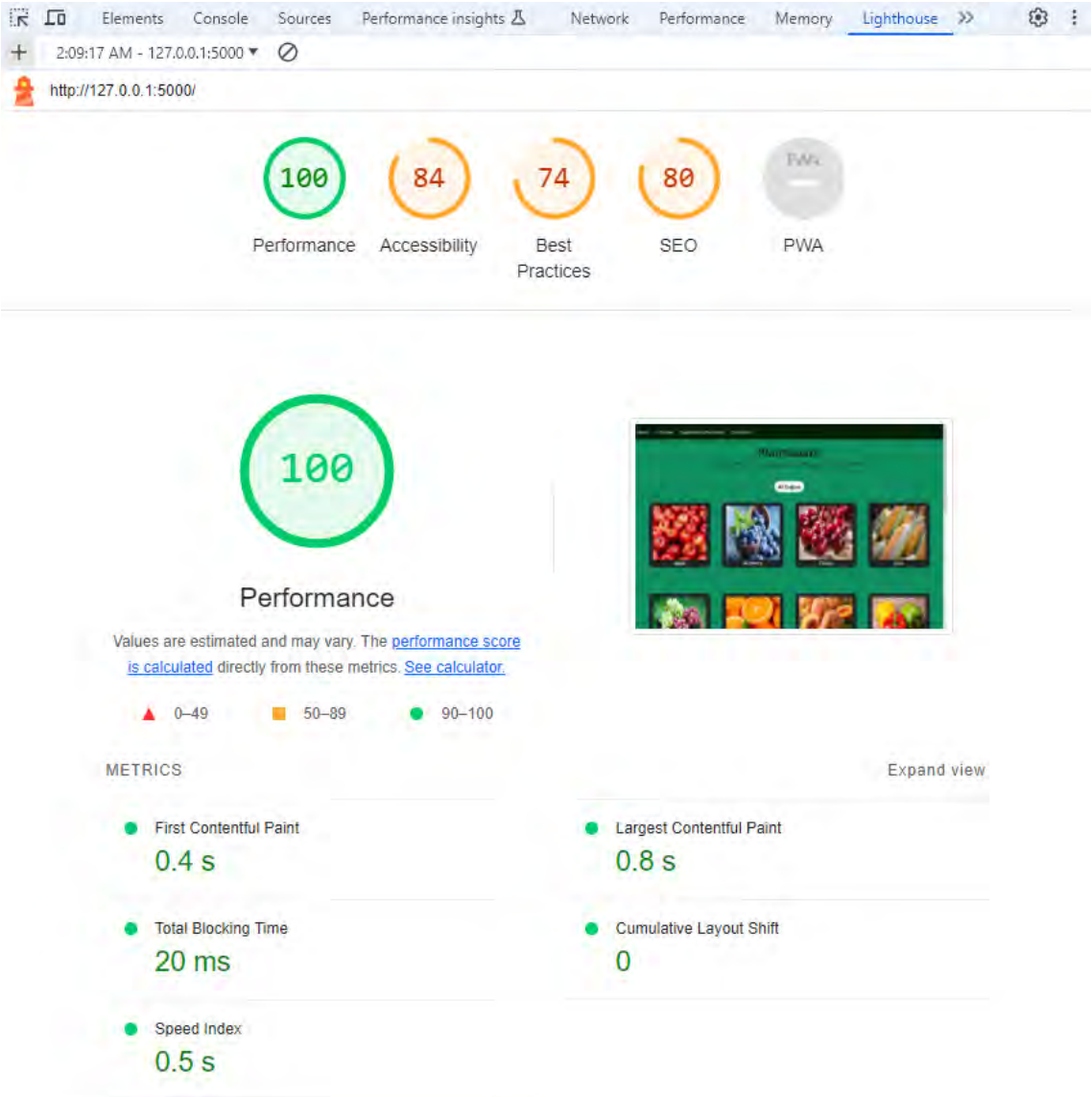

Figure 5.3: Lighthouse tool

The website's Lighthouse report shows:

- Performance: A perfect score of 100 indicates fast loading and responsiveness.
- Accessibility: Scored 84, suggesting good but improvable accessibility for users with disabilities.
- Best Practices: Scored 74, indicating areas for adherence to development standards and practices.
- SEO: Scored 80, implying decent optimization for search engine visibility.

Addressing Lighthouse recommendations can improve overall website quality, user experience, and effectiveness.

5.4 Benefits

- Early Disease Detection: One of the primary advantages of PlantGuard is its capability to detect plant diseases at an early stage, often before visible symptoms manifest. By identifying diseases in their incipient stages, farmers can swiftly implement targeted interventions, minimizing the spread of infections and reducing crop losses.
- Enhanced Crop Health: Through accurate disease diagnosis and timely recommendations, PlantGuard contributes to the overall health and vitality of crops. By addressing diseases promptly and effectively, the platform helps maintain optimal plant growth conditions, resulting in healthier and more robust crops.
- Cost Savings: Efficient disease management facilitated by PlantGuard translates into significant cost savings for farmers. By preventing unnecessary expenditures on ineffective treatments or lost yields due to undetected diseases, farmers can optimize their resource allocation and improve the profitability of their operations.
- Increased Yield: By minimizing the impact of diseases on crop health, PlantGuard ultimately leads to higher agricultural productivity and increased yield. Healthy plants are more resilient to environmental stressors and have greater potential for achieving their full growth and yield potential.
- User Accessibility: PlantGuard prioritizes user accessibility and ease of use, ensuring that farmers and agricultural stakeholders of all backgrounds can benefit from its capabilities. The user-friendly interface and intuitive design make it accessible to users with varying levels of technological proficiency, fostering widespread adoption and utilization.
- Knowledge Enhancement: Beyond disease detection and prevention, PlantGuard serves as a valuable educational tool, offering insights into various aspects of plant pathology and agricultural management. By providing detailed information about diseases, their causes, and preventive measures, the platform promotes continuous learning and skill development among users.

- Sustainable Agriculture: PlantGuard supports sustainable farming practices by advocating for environmentally friendly disease management strategies. By reducing reliance on chemical pesticides and promoting integrated pest management approaches, the platform contributes to the long-term sustainability of agricultural ecosystems and the preservation of natural resources.

Overall, PlantGuard represents a transformative solution for modern agriculture, empowering farmers with the tools and knowledge needed to safeguard their crops, maximize productivity, and ensure food security for future generations.

Chapter 6

Conclusion

6.1 Future Prospect

In the near future, PlantGuard envisions a transformative role in both rural and urban areas, not only in Bangladesh but also in countries around the world. In rural areas, where agriculture forms the backbone of livelihoods, PlantGuard holds the potential to revolutionize farming practices. By providing easy access to cutting-edge technology for disease detection and prevention, PlantGuard empowers farmers to safeguard their crops more effectively, leading to increased yields and improved food security. In urban areas, where there is a growing interest in sustainable agriculture and home gardening, PlantGuard serves as a valuable tool for urban farmers and gardening enthusiasts. With its user-friendly interface and comprehensive disease detection capabilities, PlantGuard facilitates healthy plant growth and promotes environmental sustainability in urban settings.

In Bangladesh, a country with a significant agricultural sector and diverse agroecological regions, PlantGuard's impact is poised to be particularly significant. By leveraging digital technologies and machine learning algorithms, PlantGuard addresses the unique challenges faced by Bangladeshi farmers, including the prevalence of crop diseases and limited access to agricultural extension services. Through partnerships with local agricultural organizations and government agencies, PlantGuard aims to reach farmers in remote rural areas and provide them with the tools and knowledge needed to protect their crops and optimize agricultural productivity.

Beyond Bangladesh, PlantGuard's future prospects extend to other countries grappling with similar agricultural challenges. By adapting its technology to local contexts and collaborating with agricultural stakeholders, PlantGuard can make a meaningful difference in countries across Asia, Africa, Latin America, and beyond. Whether it's helping smallholder farmers in sub-Saharan Africa combat plant diseases or supporting urban agriculture initiatives in Latin American cities, PlantGuard has the potential to transform agriculture and improve livelihoods on a global scale.

6.2 Government's Initiatives

Government initiatives aimed at enhancing agricultural practices should encompass a multifaceted approach. Firstly, allocating substantial funding towards research and development in disease detection technologies is paramount. This investment would facilitate the advancement of innovative tools like PlantGuard, which enable farmers to swiftly identify and address plant diseases, thereby minimizing crop losses.

Secondly, the government should prioritize providing comprehensive training and extension services to farmers. Equipping farmers with the necessary knowledge and skills to effectively utilize these technologies is essential for their widespread adoption and impact. Training programs can include workshops, seminars, and hands-on demonstrations, ensuring that farmers are proficient in leveraging digital solutions for disease management and crop protection.

Furthermore, policymakers should focus on implementing supportive policies that incentivize sustainable agricultural practices. These policies may include subsidies for adopting environmentally friendly farming methods, tax incentives for investing in disease prevention technologies, and regulations promoting responsible pesticide use. By creating a conducive regulatory environment, governments can encourage farmers to embrace practices that prioritize long-term environmental health and agricultural resilience.

Lastly, fostering public-private partnerships is instrumental in accelerating the adoption and scale-up of innovative agricultural solutions. Collaborations between government agencies, research institutions, private companies, and non-profit organizations can leverage diverse expertise, resources, and networks to drive meaningful change in the agricultural sector. By working together, stakeholders can co-create solutions that address the unique challenges faced by farmers while advancing the broader goals of food security and sustainable development.

In summary, government initiatives in agriculture should encompass funding research, providing training and extension services, implementing supportive policies, and fostering partnerships. By taking a holistic approach and leveraging the collective efforts of various stakeholders, governments can effectively promote agricultural innovation, resilience, and sustainability.

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