Machine Vision Based Fertilizer Recommendation System

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Declaration

We declare that the work contained in this thesis is our own, except where explicitly stated otherwise. In addition this work has not been submitted to obtain another degree or professional qualification.

Signed:
Date:

Acknowledgments

First of all, we wish to thank the Almighty Allah for giving us strength in fulfilling this work. It gives us great pleasure to express our deep sense of gratitude and respect to our supervisor, Sir Samyan Qayyum Wahla , for infusing confidence and a sense of excitement and inspiring us in our work, through his encouragement and guidance. Our sincere and heartful thanks to him for his valuable suggestions and guide. It is with great pride and pleasure that we submit this dissertation work as his students. Last but not least we would like to thank our parents for their unconditional love, affection, kind cooperation and encouragement.

To our parents and respected members

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Abstract

In this work, a leaf image based automatic system is proposed to identify a plant, diagnose plant health and recommend suitable treatment including fertilizers to alleviate the effects of a diagnosed disease. The purpose of this automation is to reduce agricultural loss by replacing the traditional and manual methods used in the agricultural sector. Also, the work done on such systems needs considerable attention in Pakistan as there is not even a dataset available having the leaf images of local plants which is necessary for the development of such systems. The dataset collected during this work includes around 1100 images targeting 14 species of local plants of Pakistan. It is made publicly available to promote research and development in this field. The proposed system is developed using this dataset along with the use of machine learning and computer vision techniques for automating the process of plant identification, disease identification and fertilizer recommendation based on the input image of the leaf. These modules are successfully implemented in the proposed system. Which is evaluated using various methods including confusion matrix, accuracy, precision, etc.

Chapter 1

Introduction

1.1 Overview of Project

Agricultural land is one of the most crucial factors for the development of human life and the economy of the country. Plants diseases result in reduced quantity and quality of agricultural products and may cause a periodic outbreak of the diseases that lead to famine and deaths at large scale. Therefore, at the earliest detection of disease(s) in plants and its elimination has tremendous importance. Keeping that in view, to automatically detect and alleviate the diseases of targeted crops, a Machine Vision based Fertilizer Recommendation System is established using image processing techniques. The proposed system diagnose plant health and detects the targeted disease(s) based on the symptoms extracted from the input image of the leaves of the targeted plants. Based on the diagnosed disease(s) it recommends remedies like fertilizers to alleviate the effects of a disease.

1.2 Agricultural Background

The most generally adopted method for detection of diseases in plants, especially in Pakistan, is simply naked eye observations by the experts. This approach requires a large team of experts as well as continuous monitoring of plant that proves to be costly. It is also time-consuming for the farms spread at large scale. At the same time, in some countries, many farmers do not have access to expert advice from a rural extension that makes their crops vulnerable to the yield losses and further problems due to plant diseases. Therefore Identification of plant diseases by visual assessment is more laborious, time-consuming, less accurate and can be considered only for limited areas. Whereas the use of automatic detection methods significantly reduces the time, cost, efforts, and gives more accurate results i.e. more accurate disease detection and proper treatment recommendation. Although advancements have been made to introduce such automatic systems still most methods have low accuracy rates and are not robust enough to deal with a wide variety of plants diseases. In Pakistan, the work done to develop such automatic systems is very rare and needs considerable attention and efforts. Proposed Project is the part of this chain of efforts to improve the productivity of Pak Agricultural Land.

1.3 Motivation

In today's world Agricultural Land is considered more than just being a feeding source. Agricultural Loss can have very drastic effects on living beings as well as the environment. Some major aspects that motivate us to opt this project are:

- In Pakistan usually, the **community of farmers** is also not well trained and don't have enough knowledge to identify and control the plant diseases timely due to which they have to approach experts. For this, they have to travel long distances and pay high amounts to the experts that only a few farmers can afford.
- Pakistan is ranked at 106 out of 119 countries on the Global Hunger Index, 2018 having a score of 32.6 which is the **second highest hunger score** in whole Asia. It was reported that about one-fifth of Pakistan's total population is suffering from undernourishment whereas the child mortality rate under the age of five remained 8.1 percent due to malnutrition[1].Unfortunately, there is no improvement and the condition for year 2018 is almost same as that of 2017 .[2]
- In Pakistan, Tharparkar District is witnessing the ongoing drought since 2013, this drought took the lives of 190 children and sent 22,000 to the hospitals in 2016 due to waterborne and viral diseases resulted by the **food insecurity** in the region [4].
- Agriculture is the **Backbone for Economic Development** in most countries, as in Pakistan, it contributes about 24 percent of Gross Domestic Product[3].
- In Pakistan, agriculture **accounts for half of employed labour force** and is the largest **Source of Foreign Exchange Earnings**[3].
- **Provision of industrial raw material** for various major industries like medical, sports, clothes, leather etc is majorly dependant on agricultural yields.

1.4 Objectives of the project

1.4.1 Industry Objectives

Automation in agriculture industry plays a vital role today. As by it, detection of diseases is fast and accurate as compared to the naked eye observation. So, our main aim is to develop an automatic system which would lead to progress and advancements in industry.
Few of the industrial objectives are as follows:

- System must reduce loss percentage of industry and will lead to progress in industry by its advancements through technology.
- It must minimize consultancy costs of experts as by help of system, experts will be able to work on plant diseases in an easy, fast and accurate way.
- It must make advancements in industry from old to new methods of detection and classification of plant diseases through research work and practical work of desired system's fields.
- Developers of system should focus on local crops of Pakistan as this type of system is rarely build and used for local crops of Pakistan.
- System must fulfill all requirements for crop diseases detection as well as recommendation of preventive measures like fertilizers to reduce the loss of major crops yield.
- Main aim of project work is to develop a new system which must be better in performance than the previous ones and will eventually lead to progress in industrial field.

- On basis of survey of diseases in leaves, various precautionary methods must be applied, so that plant leaves can be saved before the initial stage of disease.

1.4.2 Research Objectives

Research objective of system is to go through all the recent research work done in the system's development fields and then on its basis, developing a system which must be able to detect and classify plant diseases speedily as well as accurately and should be better than the previous systems. Few of the research objectives are as follows:

- Project's research is related to precise recognition and classification of particular diseases. So, initial project work is concerned with the search on the symptoms of plant leaf diseases.
- The high level research part in this field is the research of detection and classification techniques of plant leaf diseases through image processing techniques.
- Developers of system should develop local database of plant leaves. And that database should be available online, so that students as well as other researchers can use it and will ultimately provide benefits to agricultural field of Pakistan.
- Research should be that much deep that developers must be able to discover new techniques, which should be better in accuracy and speed than the previous ones.
- Techniques which are not yet researched and commonly used in projects should be preferred, so that by researching on them, their benefits should be utilized for the system and in this way system becomes better in performance than the previous systems.

1.4.3 Academic Objectives

Academic objective of this project work is to gain skills in the project's development fields, as these fields are of such high market value and it will have a big impact on developers' careers.
Few of the academic objectives are as follows:

- The main academic objective of the developers of this project is to learn major computer fields which are involved in this project i.e. machine learning and computer vision.
- On basis of computer fields used in project, developers must be able to work on real world problems which can be solved by computer science technology e.g. plant leaf diseases detection and classification, which is the ultimate task of this project.
- Developer must complete all work before the respective deadlines. So, in this way, by working in a professional way, their project will be at its best.
- Developers must take the project as professional responsibility. So that their working on project must take them to upstaging in professional life.
- Practical performance should be made better and better by continuously working on projects, as practical work has a big impact on career.
- Developers must be able to do risk and change management in their projects, as while doing projects, developers have to face different kinds of situations and their decision making plays an important role in leading them to the road of success.

- Developers must strive hard to build systems, which should be better in speed as well as accuracy than the previous build systems. Because, only then, they can prove the worth of their work in respective field.

1.5 Problem Statement

Fast, efficient, accurate and automatic system is needed to reduce agricultural loss. Therefore an ,image based system is proposed to detect plant disease and recommend the preventive measures to alleviate effects of disease.

1.6 Scope of the project

The proposed system will identify and diagnose the plants based on visual symptoms that appear on a plant leaf and will recommend the remedies respectively. Dataset for training the system will comprise almost 14 species of local plants of Pakistan and will target at most 2 diseases common in these species.

1.7 Challenges

1. **Local Dataset Collection:** The collection of local datasets of the images and the diseases of targeted crops to train the system is a major challenge.
2. **Viewpoint Variation** If the leaf image has different viewpoints then the shape change drastically and due to this the features of the leaf image may also change. Since the system is trained to specific viewpoints then system may not predict or identify correctly.
3. **Camera Resolution Difference** Different cameras have different resolution hence the quality of image is changed and values of features is also changed. When system receive the input image then image is converted to some specific resolution so that all the images became on same resolution.
4. **Scale Difference** If user take image from different height then the leaf size change and the values of features may also change and system may not predict correct. Image scaling is performed to deal with this challenge. When user take the leaf image then the leaf is cropped and only leaf part is extracted from image. Then all the leaves image become same scale.
5. **Poor Quality Image:** It is a challenging task to extract the required portion of a leaf from an image which may be of poor quality, low contrast, noise or blur etc.

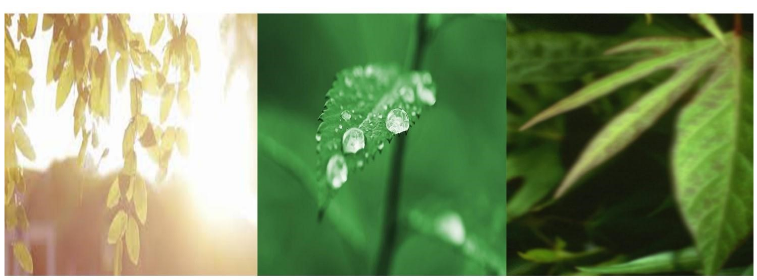


Figure 1.1: Leaf with contrast, noise and blur images respectively

6. **Complex Backgrounds:** Input images with complex background or having low quality can be a hindrance as well. It is challenging task to extract plant leaf from picture there may be something leaf like in the background.

Figure 1.2: Input image with complex background

7. **Image Deformation** For better prediction and identification leaf image must be complete and in proper shape. If the image has deformation then the system cannot calculate features properly due to which the system cannot predict correct.
8. **Work on limited Plants and Diseases** The proposed system will work on the plants and diseases for which it will be trained more data and training of the system is required to cover more plants.
9. **Illumination:** For better prediction leaf image must be in proper light neither too light or nor too dark as it create shadow. If the image has shadow then system may consider it as a disease area on the leaf and features may not calculate properly.
10. **Occlusion:** In a leaf image some part of leaf can be hidden behind background or behind one another, as a result, the features that can be extracted and calculated from image are not strong enough to predict or identify properly.
11. **With-in Class Variation:** It is a challenging task to detect the plant through leaf as in one plant a leaf has variation w.r.t shapes, colors and sizes during its development cycle to do this more samples and training is required.

Figure 1.3: Same plant leaf with different shapes, sizes and colors respectively

12. **Improper Position of Leaf:** For accurate detection and classification, leaf should be in proper position otherwise system will not give the proper and accurate results.

Figure 1.4: Leaf images with fold position and in correct position respectively

1.8 Assumptions and Constraints

System is dependent upon the dataset for which system is trained and the leaf image which user upload or capture from mobile camera. Assumptions for the accurate working of the system are:

- Image must be of leaf only
- There will be single leaf in the image(No multiple leaves)
- Leaf image must be with White background
- In image, leaf must be in proper position without folds or damage

1.9 Possible Applications of Work

- **Fertilizers Advertisement**
  The proposed system will cover the diseases of plants, and recommend fertilizers. So, it is helpful for fertilizer companies to advertise their products by suggesting their products for the diseased plants.

- **Gardening at Home**
  The persons in cities have trees in their home and they do not have knowledge about the diseases of plants. By using the proposed system, they can identify the plant diseases, make their plants healthy and more productive.

- **Increase in Economy**
  According to the economic survey, the Pakistani share in GDP is about 24 percent. The climate of Pakistan is conductive for the growth of insects, pests, diseases and weeds [8]. If the formers will use the propose system then the fields of Pakistan will become healthy and it can reduce the agricultural loss of Pakistan. This can increase the economy of Pakistan.

- **Wild plants and Weed Detection by Survival Experts**
  If the proposed system is trained for wild plants and herbs then it will be helpful for the Survival Experts who like to go in forests and must have knowledge about the plants that sustaining of life over a period of time.

- **Disease Detection in Farms**
  Farmers may have to go long distances to contact experts in some developing countries, this makes consulting experts time consuming and expensive. The proposed system will automatically detect the symptoms of diseases as soon as they appear on plant leaves and prove beneficial in monitoring large fields of crops.

- **Research in Botany**
  A botanist, plant scientist is a scientist who specializes in the science of plant life. The study of Botany highly depends upon plants, to search native plants and its diseases is not easy task. Botanist may use the proposed system to identify plants and their diseases for study purposes.

- **Crop Consulting Companies**
  The main purpose of Crop Consulting companies is to maximize the profitability by giving unbiased recommendations to the farmers. The proposed system can help the Crop Consulting companies to identify diseases in plants, its treatment in order to increase productivity.

- **Automatic Monitoring**
  If the proposed system is connected with a Drone then it can automate the crop monitoring and landowners can monitor their lands while sitting away from their lands. To increase the agricultural productivity and to promote agriculture, it is important to monitor crop growth, field environment, and farming operations. Although, it is hard to realize these monitoring operations automatically in the agricultural field as it requires the deployment of specialized equipment and the improvement of facilities that require considerable cost, effort and space.

Figure 1.5: Applications of Proposed System

1.10 Beneficiaries of the Project

1. **Farmers**
   The aim of the proposed system is to equip the farmer with affordable and adequate information and control technology. In Pakistan farmers are not well trained and only have knowledge of native diseases which occur mostly in their areas. By using the proposed system to identify plants diseases through leaf image, they will be able to diagnose the problems related to fields and get the suitable recommendations of remedies and fertilizers etc. They will get access to expert level knowledge at a very low cost. It will also bring ease in their lives as there will be no need to go outside to detect the disease.

2. **Botanist**
   A botanist is a scientist who specializes in the science of plant life. The study of Botany requires identification and information related to plants and it is a difficult task to collect data about native plants. So, Botanist can use the proposed system for research and study purposes and collect the knowledge about plants.

3. **General Public**
   The amateur gardeners or the persons who like gardening can use this system to get the knowledge about plants and their diseases. Every person who is at home or outside can use the proposed system to identify the plant through leaf and get the knowledge about plant diseases and its suitable treatments without efforts.

4. **Crop Consultants**
   The main purpose of Crop Consulting companies is to maximize the grower portability by giving unbiased recommendations to the farmers. The proposed system can help for the Crop Consulting companies to identify diseases in plants and its treatment to increase productivity.

5. **Land Owners**
   To increase the agricultural productivity and to promote agriculture, it is important to monitor crop growth, field environment, and farming operations. Although, it is hard to realize these monitoring operations automatically in the agricultural field as it requires the deployment of specialized equipment and the improvement of facilities that require considerable effort, space, and cost. If the proposed system is connected with a Drone then it can automate the crop monitoring and landowners can monitor lands while sitting away from their lands.

6. **Survival Experts**
   If the proposed system is trained for wild plants and herbs then it will be helpful for the Survival Experts who like to go in forests and must have knowledge about the plants that are sustaining life over a period of time. They can detect the plants which are harmful for the humans.

1.11 Thesis Organization

Thesis is organized in such a way that at start complete introduction of project is in Chapter 1. And then in Chapter 2, there is complete details regarding research, which we did for our project understanding and development including all relevant projects. And then in Chapter 3, there is complete detail about the online available datasets and also the dataset collection of our own local dataset and all the details regarding leaf species as well as leaf diseases on which we worked on. Afterwards, in Chapter 4, we cover our complete research regarding disease treatment and it involves fertilizers, sprays, precautionary measures, treatment process related to diseases covered by the project. Chapter 5 related to development phase of project. It covers all the details regarding all development phases and technologies used in it.After that, there is a chapter regarding results obtained from the project. And then a chapter on conclusions and future work of project.

Chapter 2

Literature Review

2.1 Literature Review

Jayamala K. Patil, Raj Kumar delivers a survey established on several image processing techniques used to classify leaf diseases. According to them the subsequent approaches are used by many scholars for plant disease detection & analysis: (1) Image Processing with PNN and PCA (2) Image analysis incorporated with Central Lab. of Agricultural Expert System (CLASE) diagnostic model, (3) Image snipping, cleaning & threshoulding, (4) Otsu segmentation, K-means clustering (5) Wavelet based image processing technique and neural network etc. Speed and accuracy are two main features of automatic plant disease detection system. So there is opportunity to develop an effective, innovative and speedy algorithms or hybrid algorithms which will aid plant researcher in discovering disease. [8]

Arya M S, Anjali K and Mrs.Divya Unni also offers the survey based on plant diseases classification methods and they also developed an algorithm for plant leaf diseases. We can identify plant diseases at start by using this system. For better accuracy rate Fuzzy Logic, Bayes classifier, ANN and Hybrid Algorithm can be used.[9]

Flower and fruit appear in a limited life that's why these are not a good choice for automatic plant identification. Leaves are present almost throughout the year and numerous in quantity that is why these are suitable for computerised classification of plants. Different statistical features of plants are used for survey. Some features like aspect ratio and rectangularity based upon length and width which require a human operator to mark extreme points on leaf image. Neto et al in 2006 use Elliptic Fourier Technique and shape of leaf to identify plant. Collect leaves of different fruits at different areas and collect from different parts, size and heights. Leaves should be green and not ruptured. Place the leaves on white sheet and captured the image using DSLR camera and all images in RGB. The three stages of method include image pre-processing, feature extraction and then classification of plants. When some other features shape defining features are combined the accuracy is 95.5%. [10]

The general method of moments is used in all those cases in which we require automatic identification of different measurements of an image. Using dedicated digital processors all work can be done in real time. Coherent optical processor used in high speed film scanner that uses moments to identify biological patterns. By using a number of image moments, we can recapture the information of image if moments up to second order are consider then image will equal to an ellipse with definite size, orientation, eccentricity and image centroid. We can reconstruct the image by two methods: (1) Using higher order moments (2) Using orthogonal moments based on Legendre Polynomial. In an image maximum distance of any point from the center of image plane is less than one because we only consider image places of finite extent. When we solve linear coupled set of equation, one shows a continuous function that gives moments which matches a finite set of previous moments. As increasing more moments matched then method recreates the original function. To get the Legendre moments solve any coupled algebraic equations and calculate them using known coeffects of Legendre polynomial. [11]

Commonly proposed methods of Plants identification didn't consider color feature including an efficient classification algorithm (90.3% accuracy) for plant classification which included features like aspect ratio, the ratio of leaf parameter to its diameter and veins. In this research shape, color and textures features were considered along with PNN as a classifier. The classification technique used showed up to 93.75% of accurate results. [12]

Spots on leaves can be symptomatic of crop diseases, where leaf spots are usually observed and exposed to expert opinion. By using image preprocessing method spot features are extracted from image. The proposed system consists of four steps; (1)enhancement using HIS transformation, histogram analysis, and intensity adjustment (2) segmentation, which includes adaptation of fuzzy c-means algorithm (3)Feature extraction (4)Classification, which is based on back propagation based neural networks. [13]

Timely information on disease detection and crop's health can expedite the diseases control. For it, techniques are: K-means clustering, SVM, SGDM and BPNN. It's challenges viz. specific leaf disease optimization, background data in the output image and automated system running in real world scenario. [14]

A system is proposed which automatically detects and classify plant leaf diseases. Four main steps of the proposed system, first of all, a color conversion (transformation) for the RGB input image is done, second threshold value is used to mask the green pixels and then these pixels are removed, third is the process of segmentation in which the statistics of texture of useful segments are calculated, fourth all extracted features are tested using SVM classifier. The proposed system's algorithm showed an accuracy of 94%. [15]

The main phases of the system include: image Pre-processing and image segmentation using kmeans clustering performed. Green pixels are masked and removed the cells and GLCM is generated to pixel map for images of H & S. After that Texture analysis (features computation) and Neural network-based classification is done. After analyzing feature sets, decision can be made by comparing properties of healthy leaf with that of infected leaf whether it is healthy or infected. In order to get target output, the network is trained using training feature sets. It is experimentally found that using HS color feature (M4) we can get highest classification accuracy of 94-96% compared to other models. Grading can be assigned based on affected pixel area to measure the severity of disease. Some challenges in such techniques are effect of removal of background noise in the acquired image, optimization of the technique for a specific plant. [16]

In this paper [17]mainly they have discussed the detection and classification of plant diseases using image processing. We can check their performance using two factors: speed and accuracy. So image processing work consist of four phases. In 1st phase we work on color transformation for our input image, then image is segmented using the K-means clustering. In the second phase, unnecessary part (green area which is disease free) within leaf area is removed based on threshold value set.

Then image is converted to HSI color format from RGB. In phase 3, statistical analysis work on modified infected cluster obtained in previous phase is carried out and it's also on basis of feature extraction of specified cluster. In phase 4, neural network based classification is to be carried out so that on its basis inputs could be tested by comparing them with the database and its accuracy can be checked on basis of error or percentage accuracy. Feed-forward Back propagation neural network has the best performance being a function of Mean Square Error (MSE). The network is trained based on training feature sets in order to get target output then it is tested for various types of diseases & accuracy is computed.

The authors of this paper claim that the disease spots on leaves have different colors but same intensity, with respect to plant leaf color. So different color transforms can be used to improve the separation of diseased portions. An assessment of the influence of color dimensions HIS,CIELAB and YCbCr in recognition of diseased portion is conducted. Moreover they calculate threshold through Otsu method and perform image smoothing through Median filter. [18]

In this paper [19] authors proposed a methodology which is based on image-processing and includes following steps; (1) Image segmentation through K-Means, after this the segmented images are passed to already train neural network. The dataset is collected from Al-Ghor area in Jordan. They test their system on five diseases which are: (1) Early scorch,(2) ashen mold, (3) tiny whiteness, (4) late scorch and (5) Cottony mold with the accuracy of 93% approximately.

The system proposed by Aakanksha Rastogi, Ritika Arora and Shanu Sharma is majorly divided into two phases i.e. 1) Plant recognition (2) Disease detection. The plant is identified using leaf features whereas this phase is consist of (1) Pre-processing, (2) Feature extraction and model training based on ANN. The second phase contains (1) separation of defected area by K-Means, (2) Extracting the multiple features of identified defected portion and (3) classify the disease using ANN. After these actions disease grading is performed on the basis of disease severity. [20]

In this paper author provides survey of different plant leaf disease classification strategies which may be used for plant disease detection. They used an algorithm for segmentation of image for computerized detection and classification of plant leaf diseases. They work for banana, jackfruit, beans, lemon, sapota, potato, tomato, and mango are some of the ten species on which proposed set of rules tested. Therefore, associated diseases for these plant leaves had been taken for identity. With very few computational efforts the greatest consequences were acquired, which indicates the performance of proposed algorithm in recognition and classification of the leaf diseases. Some other benefits of this technique are the plant diseases may be recognized at early stage or the initial degree. To enhance recognition fee in category technique good judgment and hybrid algorithms are used. [21]

According to the paper [22] Segmentation of image by Ostu is less accurate than K-Means and extraction of features from shape and color features. In classification there always segmentation. After that there is extraction of no of features by some classifier. At the image segments are classified by Support Vector Machine (SVM).

Developed system is used to classify and detect the "Pomegranate Foliar Disease" spots. Preprocessing methods are used for image enhancement. By using k-means system will perform segmentation on these enhanced images and it performs segmentation based on thresholding to extract the diseased portion. By applying first-level Haar it extracts set of visual features from ROI. Wavelet Transform method is used for accuracy. Using this feature set, a classifier based on Fuzzy Logic identifies disease. After this treatments are provided to alleviate the disease. [23]

In this paper, two diseases of grapes, namely Powdery Mildew & Downy Mildew are considered. Image dataset was constructed from the farms of Nasik city, India. Image enhancement was performed. Features extracted includes color characteristics: grey levels of red, green & blue channels of spots. Morphological & Geometrical characteristics: ratio of principal axis length, center of gravity, moments of inertia, orientation, and eccentricity. For disease classification, ANN classifier is used. Segmentation is based on similarity and discontinuity.[24]

In this paper, a technique to identify plants diseases based on pairwise-based classification, color histograms and transformations is proposed. A database comprising of pictures of disease symptoms related to different 82 stresses (abiotic & biotic) due to which leaves of twelve distinct plant species are affected. A comparison of given proposed algorithm with other algorithms is also given. [25]

Following two are tables of details of research papers on Plant Leaf Identification and Plant Disease Identification respectively

Title	Preprocessing	Simple Background	Targeted Crops	Region	Conversions	No. of Features Extracted	Classification Approach	Accuracy Rate
A Leaf Recognition Algorithm for Plant Classification Using Probabilistic Neural Network[?]	A. Converting RGB image to binary image B. Boundary Enhancement	No	32	Egypt	-	12	Probabilistic Neural Network(PNN)	90%
A Novel Method of Automatic Plant Species Identification Using Sparse Representation of Leaf Tooth Feature[?]	1.Extraction of image corner 2.The removal of abnormal image corners	No	General	China	RGB to grayscale image	4	a sparse representation based classifier	76%
Automatic classification of plants based on their leaves[?]	1. Leaf Segmentation 2. Image normalization	Yes	14	Pakistan	RGB image to greyscale image	6	Multilayer Neural Network with back propagation	96.00%
A Computer Vision System for Automatic Plant Species Identification [?]	1. Removing False Positive Regions 2. Removing the Stem	untextured background	184	Washington DC	1.RGB image converted to saturation value space 2.Saturation value space image converted to segmented using EM	-	Nearest Neighbors	96.80

Plant Species Identifcation Using Computer Vision Techniques[?]	"1. Image denoising 2. image content enhancement 3. segmentation"	Yes	General	Germany	-	27	-	-
Leaf Classification Using Shape, Color, and Texture Features[?]	Segmentation using adaptive threshold	yes	32	USA	For RGB color space, the three features are extracted from each plane R, G, and B.	8	PNN	93.75%
Leaf Identification Using Feature Extraction and Neural Network[?]	1- Resizing 2- Grayscale to binary 3- Scaling and Rotation of Image 4- Removing noise using wavelets	Yes	8	India	RGB to Binary	7	ANN	98.80%
Feature decision-making ant colony optimization system for an automated recognition of plant species[?]	Each digital leaf image is resized and converted to a grayscale image, which follows the application of a threshold based on the graylevel histogram to obtain a binary image.	No	2	Malaysia	RGB to Binary	19	SVM	96%

Embedded portable device for herb leaves recognition using image processing techniques and neural network algorithm[**?**]	-	Yes	20	Malaysia	RGB image to grayscale image	-	BPNN	99
Legume Identification by Leaf Vein Images Classification [**?**]	segments the veins using the Unconstrained Hit-or-Miss Transform (UHMT) and adaptive thresholding.	Yes	3	Argentina	-	39	Random Forests	95

Table 2.1: Comparison of research papers on basis of Plant Leaf Detection and Identification

Title	Preprocessing	Simple Background	Targeted Crops	Targeted Diseases	Region	Conversions	No. of Features Extracted	Classification Approach	Accuracy Rate
Image-based phenotyping of plant disease symptoms[29]	-	Yes	General	General	General	-	18	-	-
Detection of unhealthy region of plant leaves and classification of plant leaf diseases using texture features[15]”	Color Transformation: RGB to HSV Masking and Removing Green Pixels	Yes	30	General	Tamil Nadu	RGB to HSV	6	Min distance criterion and then SVM classifier	94.74
”Detection of Plant Leaf Disease Using Image Processing Approach[24]”	- Transformation to HSI - Analyzing Histogram of Intensity to get the threshhold - Adjust the intensity of image by applying thresholding	Yes	1	2	Nasik City, India	Defected Image to HSI	6	Artificial Neural Network	-
Detection of plant leaf diseases using image segmentation and soft computing techniques[26]	1.Clipping of the leaf image is performed to get the interested image region 2.Then image smoothing is done using the smoothing filter.	No	10	6	India	RGB to HSI	4	First min distance criterion and then SVM classifier is used	95.71

Image Processing Based Leaf Rot Disease, Detection of Betel Vine (Piper BetleL.)[31]	Leaf Sample was cropped into smaller dimension of size 16x20 sq. cm to save storage space and increase computing	Yes	1	1	Darah Village, Chhatis-garh India	RGB to HSV	1	Not Needed for a single disease of a single crop	-
Image Processing based detection of Fungal Diseases in Plants [33]	-	Yes	13	7	Univeristy of Agri-cultural Sciences, Dharwar and University of Horti-cultural Sciences, Bagalkot India	RGB to HSV	8	Fruits: ANN, Nearest Neighbour. Vegetables: SVM, K-NN Commercial Crops: Mahalnobis distance, PNN Cereals: SVM, Nearest Neighbour.	90
Identifying multiple plant diseases using digital image processing[25]	Guided Active Contour Method to segment the leaf from background	Yes	12	82	Brazil	RGB to HSV, CMYK, Lab	3	Pairwise based Classification Approach	58
Classification of diseased plant leaves using neural network algorithms[35]	-	No	2	-	India	-	4	(FFNN), (LVQ) ,(RBF)	90.67
Leaf Disease Detection using Image Processing[30]	-	No	1	General	Vellore	RGB to HSI	-	K means and SVM	-

Plant Leaf Disease Detection and Classification Using Image Processing Techniques[14]	1.Create color transformation structure and convert color values 2.Apply K means clustering 3.Masking of green pixels 4.Remove the masked cells inside the boundaries of the infected cluster.	No	3	13	Pune, India	RGB to HSI	4	BPNN, SVM, Radial basis functions, K-nearest neighbours	95
Detection and Classification of Disease Affected Region of Plant Leaves using Image Processing Technique[34]	1.Enhance the contrast of the image using histogram equalization method 3.Remapping function is used to obtain the equalized intensity of image.	Yes	-	4	Punjab, India	RGB color (ROI) image into grey scale image	10	Support Vector Machine	97.22
Detection of unhealthy region of plant leaves using Image Processing and Genetic Algorithm[21]	-	No	9	9	India	-	-	Suggested an algorithm for automatic detection and classification of plant leaf	-
Detection of unhealthy plant leaves using image processing and genetic algo using arduino[9]	1) Conversion from RGB to HSI format 2) Masking the green-pixels 3) Removal of masked green pixels	Yes	3	2	India	RGB to HSI	5	Genetic Algorithm	-

Color Transform Based Approach for Disease Spot Detection on Plant Leaf[18]	Image color transformation to CIELAB, YCbCr, HSI and Image smoothing by Median filter	Yes	10	6	India	RGB to HSI ,YCbCr, CIELAB	-	-	-
A Framework for Detection and Classification of Plant Leaf and Stem Diseases[19]	RGB to Gray , HSI	Yes	General	5	Al-Ghor (in Jordan)	RGB to HSI	10	Neural Networks for Recognition	92.70
Leaf Disease Detection and Grading using Computer Vision Technology & Fuzzy Logic[20]	1)Resize Image 2)Filter Image 3)Segment Image 4)Crop Image 5)Conversion from RGB to Binary and L*a*b space	No	2	2	India	RGB to Binary , L*a*b space	18	(1) Training Phase: Artificial Neural Network (2) Testing Phase: K-means Classification	-
Plant Disease Detection Using Leaf Pattern: A Review[27]	1) RGB image acquisition 2) convert the input image into color space 3) Segment the components	No	General	General	India	RGB to HSV	-	K means, SVM	-
Plant Disease Diagnosis System for Improved[23] Crop Yield	Image resize and image filtering respectively with standard resolution of [512 512] & filtered to remove any noise content present in the image	No	1	1	India	RGB Color Space to L*a*b* Color Space	2	K Means & Thresholding Firstlevel Haar Wavelet Transform fuzzy classifier	-

An Overview of the Research on Plant Leaves Disease detection using Image Processing Techniques[14]	1. Image Enhancement 2. Colorspace conversion 3. Image segmentation	No	General	General	India	RGB to HSV, YCbCr	-	BPNN, SVM, K-means clustering, and SGDM	-
Identification of diseases in leaves using machine vision	-	No	2	General	Hyderabad, India	RGB to GrayScale	14	Otsu, K Means Segmentation, SVM	-
Agricultural Plant Leaf Disease Detection and Diagnosis Using Image Processing Based on Morphological Feature Extraction	Initial step is the enhancement, which includes HSI transformation, histogram analysis, and intensity adjustment.	Yes	General	General	Pune,India	RGB to HSI	10	Fuzzy C Means ANN Classifier	-

Table 2.2: Comparison of research papers regarding Plant Disease Detection and Identification

2.2 Study of Existing Systems

Plantix [37] app's major working is on Mobile, while on Website, it contains library section and further details about usage of app. Following are the facilities of plantix app

- Library section
  - Search by Crop
  - Search by Disease
- Complete info regarding disease and its treatment.
- Automatic detection of disease through image.
- Local Weather information.
- Community support
- Online availability

PictureThis Plant Identification[38] is a mobile app which Identifies plants, flowers and trees And has few following facilities for its users

- Community support
- History tracking
- Online availability
- Plant care tips and watering reminder

Plant Net[39] is a mobile app and it can be used on website too. It facilitates its users in following ways

- Identifies plants, flowers and trees
- Allow contribution to increase plant image dataset

Pest Scan [43] is a mobile app and it facilitates its users in following ways

- Pesticides Monitoring System
- Farmer Training Program
- Complaints
- Pest Warning Activities
- Reporting
- Pest Scouting
- Status of Pesticides Cases

Crop Doctor [44] is a Mobile app and it facilitates its users in following ways

- Questioner based diagnosis

- Single item diagnosis or multiple combination of diagnosis of pests
- Nutrition disorders diagnosis
- Crop disease diagnosis
- English & Hindi language support

Crop Diagnosis [41] is a Mobile app and it facilitates its users in following ways

- Questioner based pest recognition
- Product Recommendation
- Product application guide

Name	Type	Facilities	Plants Species	No. of Diseases	Latest Update
Plantix[37]	Mobile App, Website(just contain library section)	•Library section α Search by Crop α Search by Disease •Complete info regarding disease and its treatment. •Automatic detection of disease through image. •Local Weather information. •Community support •Online availability	350	578	July 20, 2018
Picture-This Plant Identification[38]	Mobile App	•Identifies plants, flowers and trees •Community support •History tracking •Online availability •Plant care tips and watering reminder	4000	N/A	July 5, 2018
Plant Net[39]	Mobile App, Website	•Identifies plants, flowers and trees •Allow contribution to increase plant image dataset		N/A	July 20, 2018

CropsIT[40]	Mobile App	•Identifies plant disease •Product suggestion(remedy) •History tracking •Search disease occurring nearby •Provide guide for proper growth of crops	N/A	N/A	Feb 23, 2018
My PestGuide Diseases[42]	Mobile App	•Provide disease information on tag search or questioner-based search •Provide disease reporting to experts if not found in search.	N/A	N/A	Dec 18, 2017
Pest Scan[43]	Mobile App	•Pesticides Monitoring System •Farmer Training Program •Complaints •Pest Warning Activities •Reporting •Pest Scouting •Status of Pesticides Cases	N/A	N/A	May 7, 2018
Crop Doctor[44]	Mobile App	•Questioner based diagnosis •Single item diagnosis or multiple combination of diagnosis of pests •Nutrition disorders diagnosis •Crop disease diagnosis •English & Hindi language support	N/A	N/A	July 13, 2018
Crop Diagnosis[41]	Mobile App	•Questioner based pest recognition •Product Recommendation •Product application guide	N/A	N/A	July 2, 2016

Table 2.3: Details of Existing Systems

2.3 Current State of art

Most of the image based existing systems only identifies plant(s) but not their health status and mostly identification is inaccurate i.e. have low accuracy rate. PlantNet is one which identifies all plants correctly but does not contain feature of plant disease identification. Some apps have large response time as well as connection problems and become unresponsive sometimes. Some apps are complicated to use i.e. not much user friendly. Moreover, some applications provide questionnaire based disease search which is time consuming and difficult for the users who are less experienced.

Name	**Type**	**QB**	**IB**	**Module 1**	**Module 2**	**Module 3**
Plantix [22] July 20, 2018	Mobile app Website(just contain library section)	No	Yes	Yes	Yes	Yes
Plant Net [24]July 20, 2018	Mobile App Website	No	Yes	Yes	No	No

PictureThis Plant Identification [23] July 5, 2018	Mobile App	No	Yes	Yes	No	No
Pest Scan [26] May 7,2018	Mobile App	Yes	No	N/A	Yes	Yes
Crop Doctor [27] July 13, 2018	Mobile App	No	Yes	N/A	Yes	Yes
Crop Diagnosis [25] July 2, 2016	lobiMe App	Yes	No	N/A	Yes	Yes

QB->QuestionnaBre iased**, IB-**> Imaga Based**, Module 1-**>Plant Identification**, Module 2-**> Disease Diegnosis**, Module 3-**> Recommendation System

2.4 Conclusion from Literature Survey

Literature review is the real backbone of the system's development. From it , we get to know about the previous systems which are developed in the same field and about all those systems' scopes. So by it , it became easy to decide the scope of system. And by the research on development work , we get to know about technology advancements in our field and also about how these technologies are working. So overall literature review was the start of system's work and the real backbone of it. By it we learned about all the work which is done in our field and then on its basis , we decided about the scope of our project and all the work which we have to do and how to do all of it.

Chapter 3

Datasets

3.1 Existing Datasets

For plant detection and identification, "100 Leaves Plant Species" is the dataset which we used at start of our project for testing of any phase of our project. It is really helpful dataset which contains 100 plant leaf species with 16 images of each. So collectively, it contains 1600 samples of images. Each image is digitally photographed image with white background. And it is converted to binary images as they are more used in the project. For plant disease detection and identification, "Plant Village". It contains 38 classes of both healthy and diseased images. So we have to train our system to identify healthy or diseased. Collectively, it contains 21917 images. It contains digitally photographed images. But it does not contain binary images. Further, we have searched a lot many datasets, and based on their specifications, we chose the above mentioned datasets. Let's have a look at the specifications of each of our searched dataset.

Name	No. of Images	No. of Diseases	Resolution	Image Format	Source	Region	Associated Research Papers
PlantVillage	54,306	26	20.2 MP	.JPG	Penn Sate University, US and EPFL Switzerland	USA	An open access repository of images on plant health to enable the development of mobile disease diagnostics by David P. Hughes & Marcel Salathe
“leaf” dataset	340	30 Species	720×920 pixels	.TIFF	`https://www.ics.uci.edu`	California	“leaf” dataset BY Pedro F. B. Silva, Andre R. S. Mar¸cal and Rubim Almeida da Silva on February 2014
Swedish Leaf Dataset	1125	15 species	1423×2508 pixels	.tif	`https://liu.se/?l=sv`	Sweden	Soderkvist, O.: Computer Vision Classification of Leaves from Swedish Trees. Master thesis, Linkoping University. 2001.
Flavia	1907	33 species	1600×1200 pixels	.jpg	`http://flavia.sourceforge.net/`	China	Stephen Gang Wu, Forrest Sheng Bao, Eric You Xu, Yu-Xuan Wang, Yi-Fan Chang and Chiao-Liang Shiang, A Leaf Recognition Algorithm for Plant classification Using Probabilistic Neural Network, IEEE 7th International Symposium on Signal Processing and Information Technology, Dec. 2007, Cario, Egypt
ImageCLEF2012	11572	126 species	random	.jpg	`https://www.imageclef.org/`	France	The ImageCLEF 2012 plant image identification task, CLEF 2012 working notes, Goëau H., Bonnet P., Joly A., Yahiaoui I., Barthelemy D., Boujemaa N., Molino, ImageCLEF 2012 working notes, Rome, Italy.
MEW (Middle European Woods) 2014	15074	200 species	2024×2799 pixels	.png	`http://zoi.utia.cas.cz`	Czech Republic	P. Novotny and T. Suk, Leaf recognition of woody species in Central Europe, Biosystems Engineering, vol. 115, no. 4, pp. 444–452, 2013.

Table 3.1: Details of Existing Datasets

3.2 Local Datasets

Dataset for project is collected from Botanical Garden , GCU Lahore in Jinnah Park Lahore. Pictures of 14 leaf species Bair, Bitter Orange, Black Plum, Guava, Kachnaar, Lemon, Mango, Nayazbo, Neem, Orange, Patajan, Peepal, Rose, Sweet Lime are collected, and 2 diseases common in these species ”Leaf Spots and Early Scorch” ar5e focussed for disease detection and identification module.At start healthy images of all mentioned species are collected and then diseased images of them and in total 1083 leaves were collected.Image format for dataset is .jpg and Dimension for each image is 600×800.Following is the details about our local dataset

Guava

Psidium guajava

Kachnaar

Bauhinia variegate

Lemon

Citrus × limon

Mango

Mangifera indica

Nayazbo

Ocimum tenuiflorum

Neem

Azadirachta indica

Bair

Ziziphus Mauritiana

Bitter Orange

Citrus × aurantium

Black Plum

Syzygium Cumini

Orange

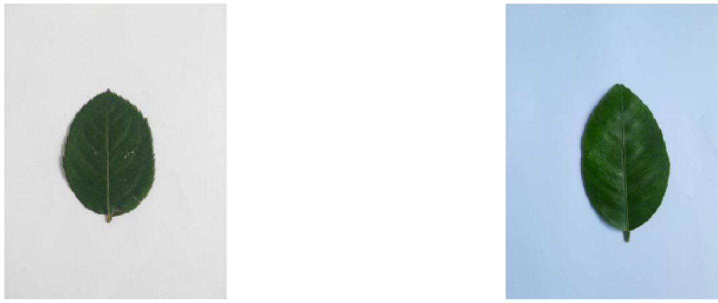
Citrus reticulate

Patajan

Putranjiva roxburghii

Peepal

Ficus religiosa



Rose — Rosa

Sweet Lime — Citrus × Aurantiifolia

Figure 3.1: Dataset info of Leaf Species

3.3 Species Details

1. **Name:** Bair
   Scientific Name: Ziziphus Mairitiana
   Seasons: December to April
   Importance:

- Improves Bone Strength.
- Soothes Anxiety.
- Regulates Blood Pressure.
- Regulates Blood Circulation.

Figure 3.2: Bair

2. **Name:** Bitter Orange
   Scientific Name: Citrus reticulata
   Seasons: December to April
   Importance:

- Improve your brain health.
- Maintain a healthy blood pressure.
- Improve the heart's health.

Figure 3.3: Bitter Orange

3. **Name:** Black Plum

   Scientific Name: Syzygium cumini

   Seasons: February to March, July to August.

   Importance:

- Black Plum are low on calories, which makes them the perfect healthy snack.
- Black Plum juice has bioactive phytochemicals that minimize the risk of liver disease and cancer.
- They are also known to be effective in treatment of diabetes.
- Boosts Immune System.

Figure 3.4: Black Plum

4. **Name:** Guava

   Scientific Name: Psidium guajava

   Seasons: Nov. to March and April to August

   Importance:

- Supports Weight Loss.
- Helpful for Diabetics.
- Lowers Risk of Cancer.
- Boosts Immune System.
- Improves Digestion.
- Promotes Healthy Skin.
- Improves Eyesight.
- Provides Dental Care.

Figure 3.5: Guava

5. **Name:** Kachnaar

Scientific Name: Bauhinia variegate

Seasons: March to April

Importance:

- Treatment of Hemorrhoids
- Purification of Blood
- Treatment of Digestive System Problems
- Healing Internal Wounds
- Anti-cancerous properties
- Antidote for snake bites
- Cure diarrhea due to indigestion
- Ease burning sensation
- Controls blood sugar

Figure 3.6: Kachnaar

6. **Name:** Lemon

Scientific Name: Citrus limon

Seasons: Late winter to early summer

Importance:

- It promotes hydration
- It supports weight loss
- It aids digestion
- It freshens breath
- It helps prevent kidney stones

Figure 3.7: Lemon

7. **Name:** Mango
   Scientific Name: Mangifera indica
   Seasons: May to September
   Importance:

- High in Antioxidants.
- Boost Immunity.
- Support Heart Health.
- Support Eye Health.
- Improve Hair and Skin Health.
- Help Lower Your Risk of Certain Cancers.

Figure 3.8: Mango

8. **Name:** Nayaz Bo
   Scientific Name: Ocimum tenuiflorum
   Seasons: Summer
   Importance:

- It helps combat a plethora of serious ailments like cancer, diabetes, and heart disease.
- It also fights inflammation. Most of the benefits are medicinal, which means it can be used as a medicine as well.
- Controls blood sugar

Figure 3.9: NayazBo

9. **Name:** Neem
Scientific Name: Azadirachta indica
Seasons: May-June
Importance:

- Useful in Leprosy,
- Reduce Eye disorders,
- Reduce Intestinal worms,
- Reduce Loss of appetite
- Helpful in Skin ulcers,
- Improve Cardiovascular disease,
- Beneficial in Diabetes
- Useful in Liver problems

Figure 3.10: Neem

10. **Name:** Orange
Scientific Name: Citrus reticulata
Seasons: December to April
Importance:

- Improve your brain health.
- Help maintain a healthy blood pressure.
- Help improve the heart's health.
- Help individuals fight infections.
- Great for the hair and skin's appearance.

Figure 3.11: Orange

11. **Name:** Patajan

Scientific Name: Putranjiva Roxburghii

Seasons: All Seasons

Importance:

- The hard, white seeds of the fruit are threaded into necklaces and also used for rosaries. Necklaces made from the seeds are traditionally given to children as a protection from disease
- An olive-brown, fixed oil is obtained from the seed. It is used for burning
- An essential oil is obtained from the seed
- The grey wood is close-grained, moderately hard. The wood is sometimes used for construction, turnery, tool handles
- Controls blood sugar

Figure 3.12: Patajan

12. **Name:** Peepal

Scientific Name: Ficus religiosa

Seasons: Summer and Rainy season

Importance:

- It helps with fever.
- It treats asthma.
- It treats eye pain.
- It is good for oral health.
- It helps with nosebleeds.
- It can treat jaundice.
- It helps with constipation.
- It treats heart diseases
- Controls blood sugar

Figure 3.13: Peepal

13. **Name:** Rose

Scientific Name: Rosa

Seasons: March to May and September to November

Importance:

- Soothes skin irritation.
- Soothes sore throats.
- Reduces skin redness.
- Helps prevent and treats infections.
- Contains antioxidants.
- Heals cuts, scars, and burns.
- Enhances mood.
- Relieves headaches.
- Controls blood sugar

Figure 3.14: Rose

14. **Name:** Sweet Lime

Scientific Name: Citrus aurantiifolia

Seasons: July, August and November to March

Importance:

- Promotes consumption of water.
- Helps improve diet.
- May aid digestion.
- Reduces cancer chances.
- Improves skin quality.
- Promotes weight loss.
- Improves immune system.
- Reduces risk of heart disease.
- Ease burning sensation
- Controls blood sugar

Figure 3.15: Sweet Lime

3.4 Diseases And Treatment

1. **Name:** Leaf Spot

   Causing Agent: Fungus or Bacterial

   Symptoms:

   Spots are mostly Brownish but also can be Black or Tan. Dark Margin around the spots.

   Fertilizers(Recommended):

- Kuside from Fatima Fertilizer Company.
- Kumulus from Fatima Fertilizer Company.
- Tilt from Syngenta.
- Intracol from Bayer.
- Hatio from Bayer.
- Defeater from Kanzo.

   Precautions:

- Use fungicides regularly.
- Use appropriate amount of fungicide but don't use it in an excess amount.

Figure 3.16: Early Scorch

2. **Name:** Early Scorch

   Causing Agent: Bacteria

   Symptoms:

   Affected leaves starts curling and then branches begin to drop and die.

   Fertilizers(Recommended):

   1. Kasumin from Arysla.
   2. Cordate from Kanzo

   Precautions:

   - Deep watering.
   - Keeping minimum defects from pests/insects.

Figure 3.17: Leaf Spot

Chapter 4

Methodology

4.1 Proposed Solution

The proposed system aims to reduce the agricultural loss within Pakistan. For this, an automatic plant identification and diagnosis system will be built using image processing and machine learning techniques. This system overcomes the problems of cost, time, efficiency, limited accuracy and area because of traditional manual methods or naked eye observations for diagnosing plants. The proposed methodology includes three major modules i.e. Plant Identification, Disease Identification, and Recommendation system. Such automatic systems have been built previously but they usually have low accuracy or they don't handle a wide variety of plants. Also, the recommendation module is rarely found in these systems. Moreover, the work done on such systems is scarce in Pakistan and needs considerable attention. Therefore, the proposed system is constrained to some limitations and challenges.

4.1.1 General Proposed Model

Let's have a look at general methodology of our project

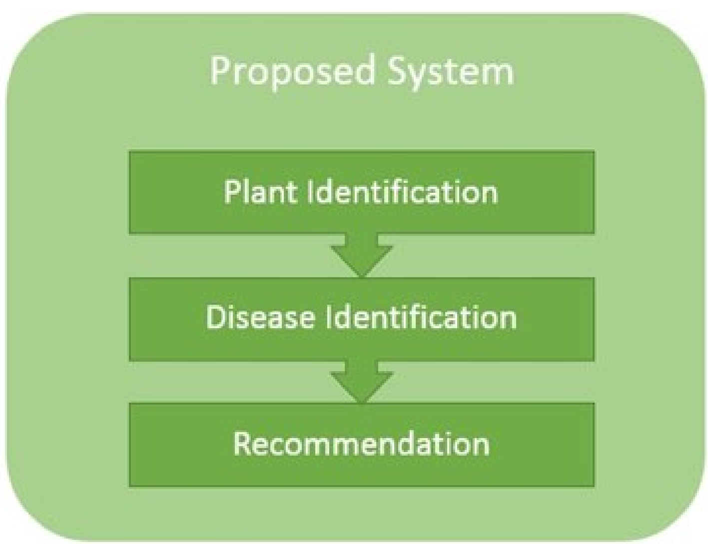


Figure 4.1: General Methodology View of Project

4.1.2 General Flow

One of the main deliverables of the proposed system is the Android mobile application. The primary reason is to benefit more and more users of the local community of Pakistan. According to the stats, 85.53%[6]. Hence if the end user wants to know about the plant or diagnose the plant disease and get proper treatment recommendation. Then as illustrated in the above figure, the user takes an image of the plant leaf containing the diseased portion(s) if any. Uploads it to the mobile application of the proposed system. The mobile application then makes a call to the WEB API for processing which is deployed to the Azure Server. The API then sends back a response to the mobile application and the results are displayed on a mobile screen of the user. The results displayed to the user includes identified plant name along with its description, detected plant disease if any and the corresponding treatment recommendations including fertilizers. Using these recommendation users can save the affected plants and protect them from further damage.

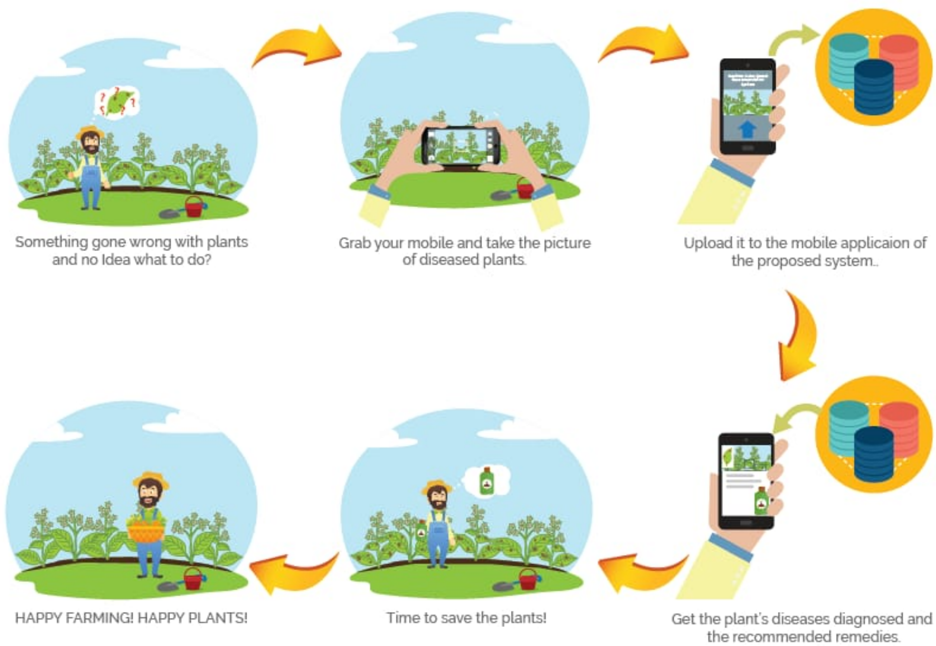


Figure 4.2: General Flow of Proposed Solution

Now see each module of our project in a more detailed view.

4.1.3 Leaf Detection

The objective of this submodule is to detect whether the input image contains leaf or not. For this purpose, the gist descriptors of the dataset images are computed. The dataset used includes 150 leaves and 150 non-leaves images. To compute the gist descriptors LMgist function within Matlab is used and a training file is generated. The training file is then used to train the classification model. Since the proposed project is developed using C#, so the three models each for SVM, Decision Tree & Naive Bayes are trained using the Accord.Net Library and the training file obtained from computing gist descriptors. For the testing purpose, Matlab code is called from C# to get the gist descriptors of the test image and results are displayed to the user. This submodule is part of increasing the efficiency of the proposed system so that no processing takes place when the input image does not contain a leaf. Therefore, the integration of this submodule into the deliverables of the proposed system is included in future work.

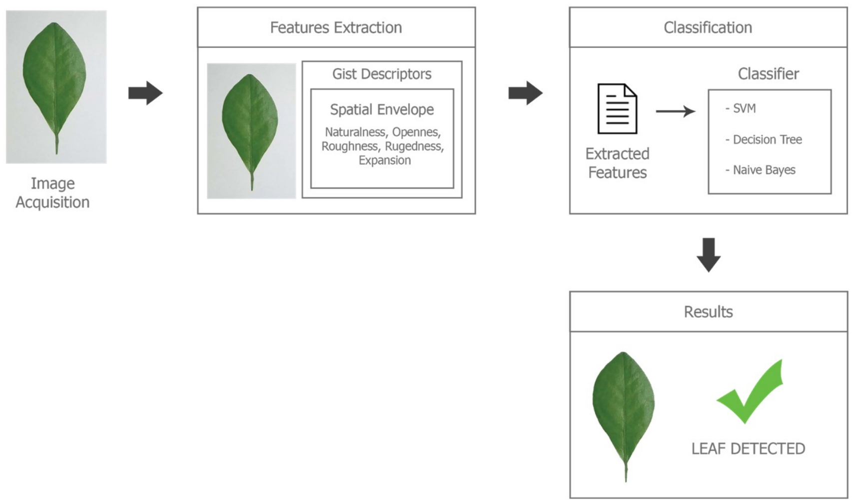


Figure 4.3: Leaf Detection

4.1.4 Plant Identification

This sub module is designed to identify species of uploaded image within the span of dataset. After successful detection of leaf image preprocessing is performed. In preprocessing leaf image is converted to gray scale and then to binary. Binarized leaf image is then passed to feature extraction module. In feature extraction different features are calculated including area, eccentricity, aspect ratio, axis, circularity, convex hull and so on. A feature file is made after calculation of all 21 features and that file is passed to trained classifier SVM, Naive bayes or Decision tree. Classifier return the result in the form of predicted plant name hence leaf is successfully identified.

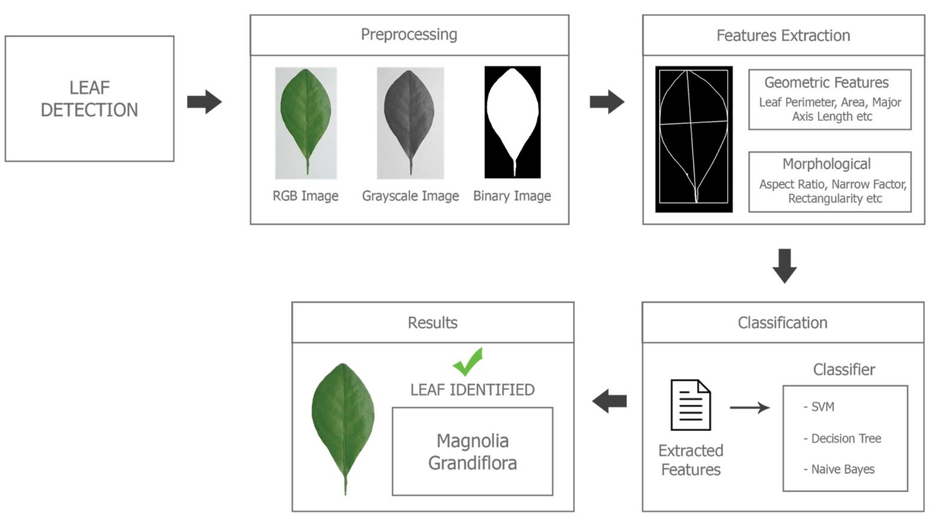


Figure 4.4: Leaf Identification

Descriptor	**Explanation**	**Formula**
Major axis length L	Line segment connecting the base and the tip of the leaf	
Minor axis length W	Maximum width that is perpendicular to the *major axis*	
Area A	Number of pixels in the region of the organ	Contour Area
Perimeter P	Summation of the distances between each adjoining pair of pixels around the border of the organ	Contour Perimeter
Centroid	Represents the coordinates of the organ's geometric centre	
Aspect ratio	Ratio of *major axis length* to *minor axis length*—explains narrow or wide leaf or flower characteristics	$AR=L/W$
Roundness R	Illustrates the difference between an organ and a circle	$R=4\pi A/P^2$
Compactness	Ratio of the perimeter over the object's area; provides information about the general complexity and the form factor, it is closely related to roundness	$C=P^2/A$; $C=P/\sqrt{A}$
Rectangularity N	Represents how rectangle a shape is, i.e., how much it fills its minimum bounding rectangle	$N=A/LW$
Eccentricity E	Ratio of the distance between the foci of the ellipse (f) and its major axis length (a); computes to 0 for a round object and to 1 for a line	$E=f/a$
Perimeter ratio of diameter	Ratio of the perimeter to the diameter	$P_D=P/D$
Perimeter ratio of Major axis length	Ratio of the perimeter to the major axis length	$P_L=P/L$
Perimeter ratio of Major and Minor axis length	Ratio of object perimeter over the sum of the major axis length and the minor axis length	$P_{LW}=P/(L+W)$
Convex Hull Area	The convex hull of a region is the smallest region that satisfies two conditions: (1) it is convex, and (2) it contains the organ's region	
Perimeter convexity PC	Ratio of the convex perimeter PCH to the perimeter P of the organ	$P_C=P_{CH}/P$
Entirety(AC1)	Normalized difference of the convex hull area and the organ's area	$A_{C1}=(CH-A)/A$
Solidity (AC2)	Ratio between organ's area and area of the organ's convex hull	$AC2=A/CH$
Equivalent diameter DE	Diameter of a circle with the same area as the organ's area	$D_E=\sqrt{4*A\pi}$
Elongation	Measuring the length of the object.	$1-\frac{minor\ axis}{major\ axis}$

Table 4.1: Feature Matrix

4.1.5 Disease Diagnosis

This module is designed to detect whether the leaf is healthy or not. If it is diseased, then it tells the details about the detected disease. For this purpose color space conversion is performed on input image to detect weather leaf is diseased or not. If the leaf is diseased one then different statistics like diseased part concentration w.r.t position, area of diseased parts etc are calculated to identify its disease type.

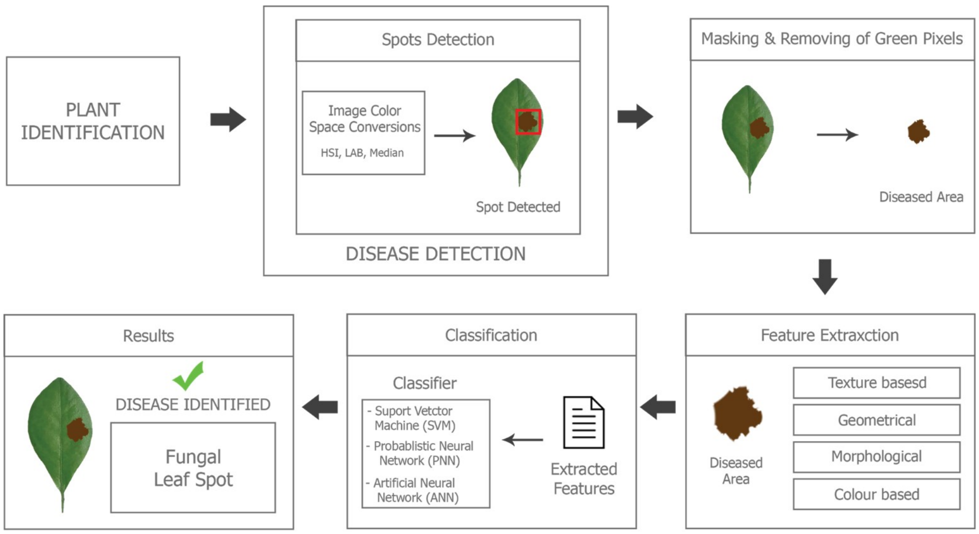


Figure 4.5: Disease Diagnosis

4.1.6 Recommendation

Recommendation module is designed to suggest the remedies regarding the identified disease and tells complete treatment process to make it healthy. This module uses statistic calculated in previous module and recommend fertilizer based on those statistics.

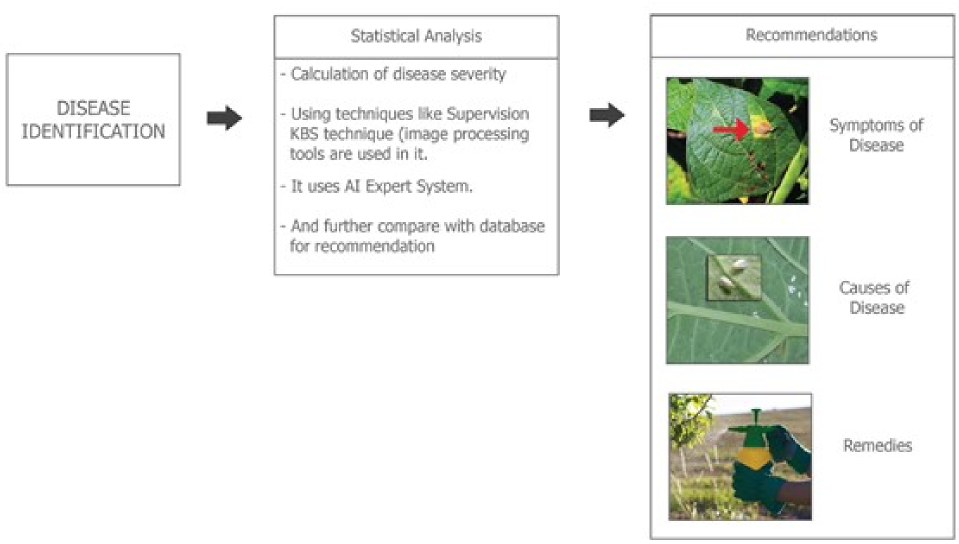


Figure 4.6: Recommendation

Chapter 5

Implementation and Results

5.1 Implementation

The proposed methodology includes three major modules i.e. Plant Identification, Disease Identification, and Recommendation system. Detailed Implementation of these modules is discussed below:

5.1.1 Plant Identification

Leaf Detection is done by SVM model trained on Gist descriptors. For Leaf identification first we calculate 21 features mentioned in section 4.1.4 for our input dataset and generate training file in CSV format. After file generation SVM model is trained.

5.1.2 Disease Identification

It is done by converting the input image to HSI color space from RGB color space. After this thresholding is applied on H component i.e. Hue component of image to get diseased parts of leaf. If the leaf is diseased one then we proceed further to identify disease.

1. **Disease Detection**

   Color Space Conversion to detect any spot region

Figure 5.1: Segmentation of diseased parts

2. **Disease Identification**
   Targeted Diseases: Early Scorch and Leaf Spot
   Identify disease using rule based approach on different features like: disease pixel intensity with respect to position

Figure 5.2: Disease Identification (Leaf Spot)

Figure 5.3: Disease Identification (Early Scorch)

5.1.3 Fertilizer Recommendation:

Based upon Leaf specie and Disease classified, products available for its treatment along with precautions and complete treatment process are suggested by system. Info related to Leaf Spot disease:

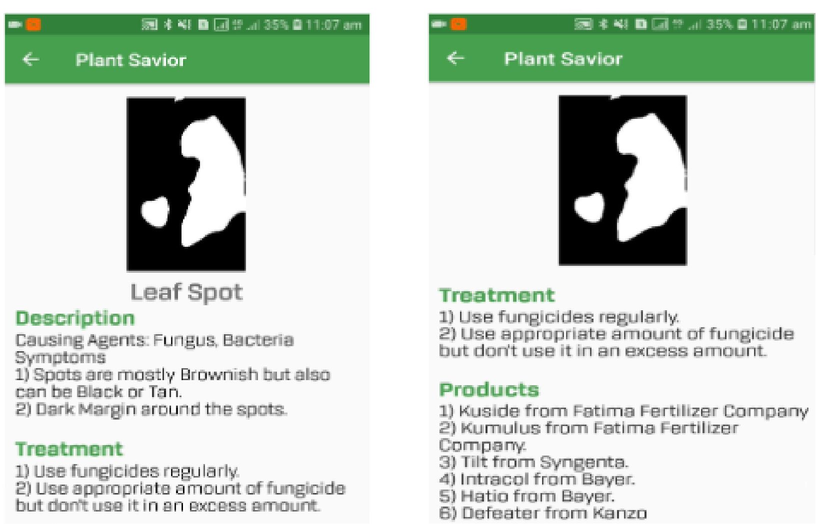


Figure 5.4: Info related to Leaf Spot disease

Info related to Early Scorch disease:

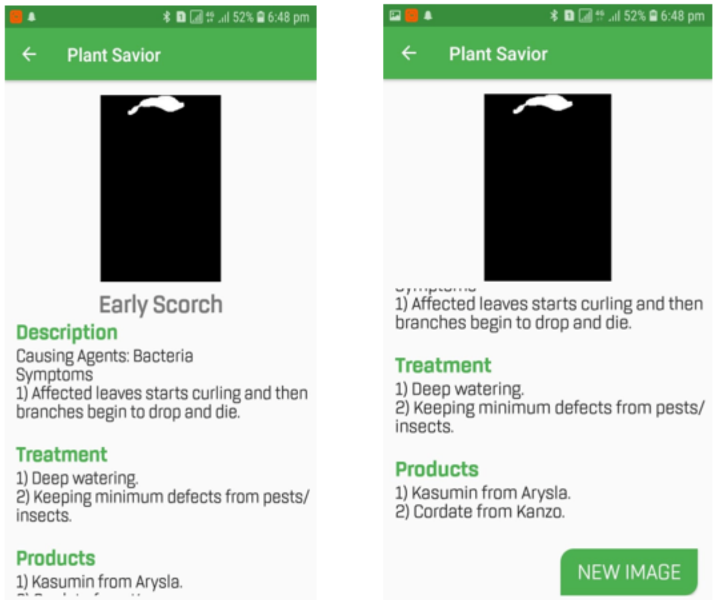


Figure 5.5: Info related to Early Scorch disease

5.2 Details of functionalities:

Mobile application communicates with API and server for processing and to get information. The communication between application and database is important to access data.Mobile Application sends signal to backend API and there all the backend work is performed for all the modules of system and then after findimng the result, the result signal is sent back to mobile application , where it is shown to the user.

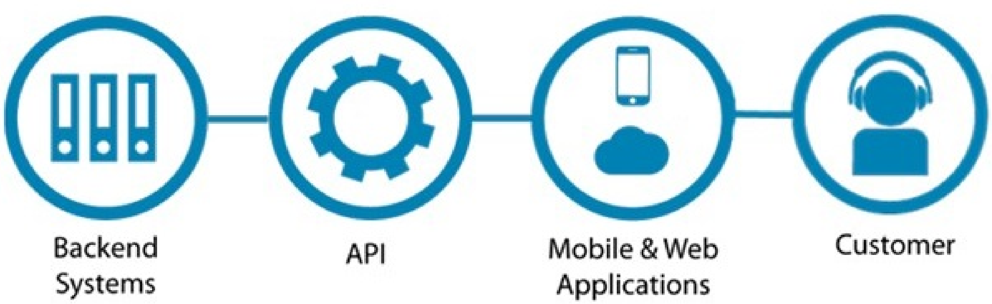


Figure 5.6: Communication b/w API and Mobile app

5.3 Communications Interfaces

The different parts of the system depend on each other so the communication between them is important. However, in what way the communication is achieved is not important for the system and is therefore handled by the underlying operating system for the mobile application. Using internet connection mobile application communicates with build API and web server.
Following is the details about API commands of the system

Title	Identify Plants
URL	https://plantssavior.azurewebsites.net/api/Web/testImage
Method	POST
Content Type	application/json; charset=utf-8
Data Type	Json
Data Params	Input plant leaf image "img":"base64 string of the input image"
Success Response	The status code on success should be 200.
Error Response	The status code 401 for unauthorized.
Return Params	Plant Name in string format
Sample Call	$.ajax(type: 'POST', url: 'https://plantssavior.azurewebsites.net/api/Web/testImage', data: JSON.stringify(img: image base64 string), contentType: 'application/json; charset=utf-8', dataType: 'json', success: function (data) console.log(data););

Title	Disease Detection
URL	https://plantssavior.azurewebsites.net/api/Web/diseaseInput
Method	POST
Content Type	application/json; charset=utf-8
Data Type	Json
Data Params	Input plant leaf image "img":"base64 string of the input image"
Success Response	The status code on success should be 200.
Error Response	The status code 401 for unauthorized.
Return Params	An object obj which contains two parameters obj.result in string format which contains Healthy if plant image is healthy or Diseased if plant image is unhealthy obj.img plant leaf image in base64 string in which diseased part of leaf is highlighted
Sample Call	$.ajax(type: 'POST', url: ' https://plantssavior.azurewebsites.net/api/Web/diseaseInput', data: JSON.stringify(img: image base64 string), contentType: 'application/json; charset=utf-8', dataType: 'json', success: function (data) console.log(data.result); console.log(data.img););

Title	Disease Identification
URL	https://plantssavior.azurewebsites.net/api/Web/diseaseIdenficationCall
Method	POST
Content Type	application/json; charset=utf-8
Data Type	Json
Data Params	Input plant leaf image "img":"base64 string of the input image"
Success Response	The status code on success should be 200.
Error Response	The status code 401 for unauthorized.
Return Params	An object obj which contains five parameters obj.name in string format which contains disease name obj.symptoms in string format the symptoms of the disease which will appear on plant leaf obj.precautions in string format the precautions which will be helpful to get rid from plant disease obj.fertilizers in string format the fertilizer name which cure the plant obj.img plant leaf image in base64 string in which diseased part of leaf is highlighted
Sample Call	$.ajax(type: 'POST', url: ' https://plantssavior.azurewebsites.net/api/Web/diseaseInput', data: JSON.stringify(img: image base64 string), contentType: 'application/json; charset=utf-8', dataType: 'json', success: function (data) console.log(data.img); console.log(data.name); console.log(data.causingAgents); console.log(data.symptoms); console.log(data.precautions); console.log(data.fertilizers););

Title	Petiole Detection
URL	https://plantssavior.azurewebsites.net/api/Web/petioleDetection
Method	POST
Content Type	application/json; charset=utf-8
Data Type	Json
Data Params	Input plant leaf image "img":"base64 string of the input image"
Success Response	The status code on success should be 200.
Error Response	The status code 401 for unauthorized.
Return Params	Base64 string of output image in which petiole is highlighted in red color

Sample Call	$.ajax({
	type: 'POST',
	url:
	'https://plantssavior.azurewebsites.net/api/Web/petioleDetection',
	data: JSON.stringify({
	img: image base64 string }),
	contentType: 'application/json; charset=utf-8',
	dataType: 'json',
	success: function (data) {
	console.log(data);
	}
	});

Title	Base Apex Detection
URL	https://plantssavior.azurewebsites.net/api/Web/baseApex
Method	POST
Content Type	application/json; charset=utf-8
Data Type	Json
Data Params	Input plant leaf image “img”:”base64 string of the input image”
Success Response	The status code on success should be 200.
Error Response	The status code 401 for unauthorized.
Return Params	Base64 string of output image in which petiole is removed and base apex is highlighted in red color.

Sample Call	$.ajax({
	type: ’POST’,
	url: ’ https://plantssavior.azurewebsites.net/api/Web/baseApex’,
	data: JSON.stringify({
	img: image base64 string }),
	contentType: ’application/json; charset=utf-8’,
	dataType: ’json’,
	success: function (data) {
	console.log(data);
	}
	});

Title	Plant leaf Area
URL	https://plantssavior.azurewebsites.net/api/Web/displayArea
Method	POST
Content Type	application/json; charset=utf-8
Data Type	Json
Data aPrams	Input plant leaf image “img”:”base64 string of the input image”
Success Response	The status code on success should be 200.
Error Response	The status code 401 for unauthorized.
Return Params	Base64 string of output image in which area is highlighted

Sample Call	$.ajax({
	type: ’POST’,
	url: ’ https://plantssavior.azurewebsites.net/api/Web/displayArea’,
	data: JSON.stringify({
	img: image base64 string }),
	contentType: ’application/json; charset=utf-8’,
	dataType: ’json’,
	success: function (data) {
	console.log(data);
	}
	});

Title	Display Major and Minor axis of plant leaf
URL	https://plantssavior.azurewebsites.net/api/Web/displayAxis
Method	POST
ContentType	application/json; charset=utf-8
Data Type	Json
Data Params	Input plant leaf image "img":"base64 string of the input image"
Success Response	The status code on success should be 200.
Error Response	The status code 401 for unauthorized.
Return Params	Base64 string of output image in which major and minor axis are highlighted

Sample Call	$.ajax({
	type: 'POST',
	url: 'https://plantssavior.azurewebsites.net/api/Web/displayAxis',
	data: JSON.stringify({
	img: image base64 string }),
	contentType: 'application/json; charset=utf-8',
	dataType: 'json',
	success: function (data) {
	console.log(data);
	}
	});

Title	Display Centroid
URL	https://plantssavior.azurewebsites.net/api/Web/displayCentroid
Method	POST
Content Type	application/json; charset=utf-8
Data Type	Json
Data Params	Input plant leaf image "img":"base64 string of the input image"
Success Response	The status code on success should be 200.
Error Response	The status code 401 for unauthorized.
Return Params	Base64 string of output image in which centroid on the leaf image is highlighted

Sample Call	$.ajax({
	type: 'POST',
	url: '
	https://plantssavior.azurewebsites.net/api/Web/displayCentroid',
	data: JSON.stringify({
	img: image base64 string }),
	contentType: 'application/json; charset=utf-8',
	dataType: 'json',
	success: function (data) {
	console.log(data);
	}
	});

Title	Display ConvexHull
URL	https://plantssavior.azurewebsites.net/api/Web /displayConvexHull
Method	POST
Content Type	application/json; charset=utf-8
Data Type	Json
Data Params	Input plant leaf image "img":"base64 string of the input image"
Success Response	The status code on success should be 200.
Error Response	The status code 401 for unauthorized.
Return Params	Base64 string of output image in which convex hull is highlighted

Sample Call	$.ajax({
	type: 'POST',
	url: '
	https://plantssavior.azurewebsites.net/api/Web/displayConvexHull',
	data: JSON.stringify({
	img: image base64 string }),
	contentType: 'application/json; charset=utf-8',
	dataType: 'json',
	success: function (data) {
	console.log(data);
	}
	});

Title	Display Minimum Bounding Rectangle
URL	https://plantssavior.azurewebsites.net/api/Web/ displayMinBoundingRectangle
Method	POST
Content Type	application/json; charset=utf-8
Data Type	Json
Data Params	Input plant leaf image "img":"base64 string of the input image"
Success Response	The status code on success should be 200.
Error Response	The status code 401 for unauthorized.
Return Params	Base64 string of output image in which minimum bounding rectangle is highlighted

Sample Call	$.ajax({
	type: 'POST',
	url: ' https://plantssavior.azurewebsites.net/api/Web/
	displayMinBoundingRectangle',
	data: JSON.stringify({
	img: image base64 string }),
	contentType: 'application/json; charset=utf-8',
	dataType: 'json',
	success: function (data) {
	console.log(data);
	}
	});

Title	Display Contour of plant leaf
URL	https://plantssavior.azurewebsites.net/api/Web/displayContour
Method	POST
Content Type	application/json; charset=utf-8
Data Type	Json
Data Params	Input plant leaf image "img":"base64 string of the input image"
Success Response	The status code on success should be 200.
Error Response	The status code 401 for unauthorized.
Return Params	Base64 string of output image on which contour is highlighted

Samale Cpll	$.ajax({
	type: 'POST',
	url: ' https://plantssavior.azurewebsites.net/api/Web/displayContour',
	data: JSON.stringify({
	img: image base64 string }),
	contentType: 'application/json; charset=utf-8',
	dataType: 'json',
	success: function (data) {
	console.log(data);
	}
	});

5.4 Technologies Used

Following are the technologies used in the project

- C#
  - EmguCV
  - Accord .Net
- ASP .NET WEB API
- Azure
- Android
  - Mobile App

5.5 System Requirements

5.5.1 Hardware Requirements

1. Android Mobile
2. Digital Camera
3. Minimum RAM: 2GB
4. Camera : 8MP

5.5.2 Software Requirements

1. Accord .net library
2. Emgu Image Processiag Library
3. C Sharp Compiler
4. Mobile App Framework Developer
5. Server for Backend task performing of apps

5.6 Deliverables

5.6.1 Desktop Application

All services of desktop application of proposed system are available offline. The services provided by desktop application are:

1. Plant identification
2. Disease identification
3. Fertilizer recommendation
4. Library of supported species

Complete functionality of desktop application is discussed below with the reference of screens.

1. **Home Screen**

Figure 5.7: Home Screen (Desktop Application)

(a) **Choose Image:** This button allows the user to select the input image. Plant Identification, Disease Identification and Advance Feature buttons work only after the user has selected input image.

(b) **Plant Identification:** This button open up the Plant Identification screen where user can get information about the identified plant i.e. system displays the results of plant identification.

(c) **Disease Identification:** Using this button user can check the plant's health status. If plant is diseased one then the proper treatment and fertilizer recommendations for the diseased plant are displayed to the user after selecting Disease Identification button.

(d) **Advance Features:** This button navigates to the Advance Feature screen which allow users to draw the various advanced leaf features like area, perimeter/contour, convex hull and minimum bounding rectangle and axis.

(e) **Library:** By selecting this button user can view supported species by the system.

2. **Choose Image:** After selecting "Choose Image" button of Home Page a dialog box will appear and ask user to select an image. When user selects an image following screen is displayed by system.

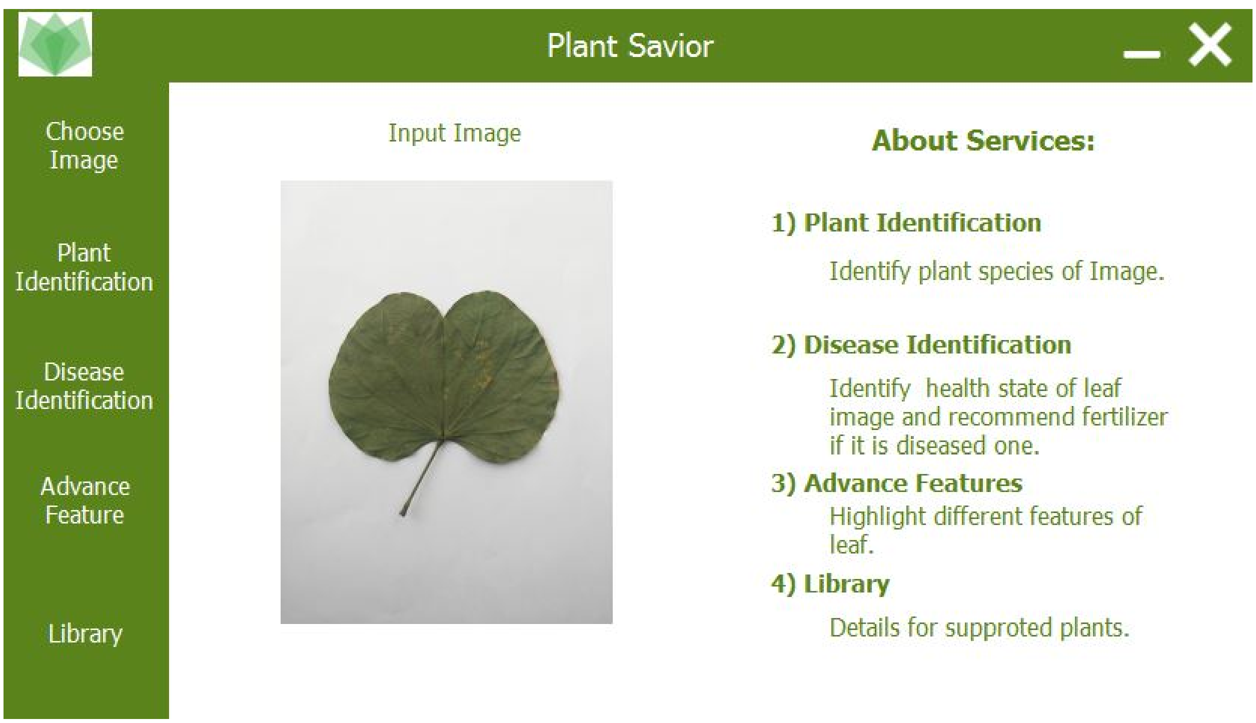


Figure 5.8: Choose Image Screen (Desktop Application)

3. **Plant Identification:** By selecting "Plant Identification" button system identifies plant species and displays results on plant identification screen.
   In this module of system, system shows following details about the leaf picture which user uploaded

   - Name

- Scientific Name
- Season

So in this way user can identify the leaf specie he uploaded.

Figure 5.9: Plant Identification (Desktop Application)

4. **Disease Identification:** By selecting “Disease Identification” button, system checks plant health status and displays results on disease identification screen. User can see diseased parts of leaf by selecting “Show Diseased Parts” button on disease identification screen if leaf is diseased one. Diseased parts are highlighted by white/red color.

   If the health status of leaf is diseased then information related to identified diseased is displayed to the user. For example

   - Disease name
   - Description
   - Recommended Products
   - Complete Treatment
   - Precautions

   The products mainly include list of fertilizers that a user can choose from for the treatment of diseased plant. It may include fertilizers as well as sprays.
   Lets have a look at fertilizer recommendation module of system while dealing with Leaf Spot and Early Scorch Diseases.
   Different health cases are shown in following figures.

Figure 5.10: Healthy Leaf (Desktop Application)

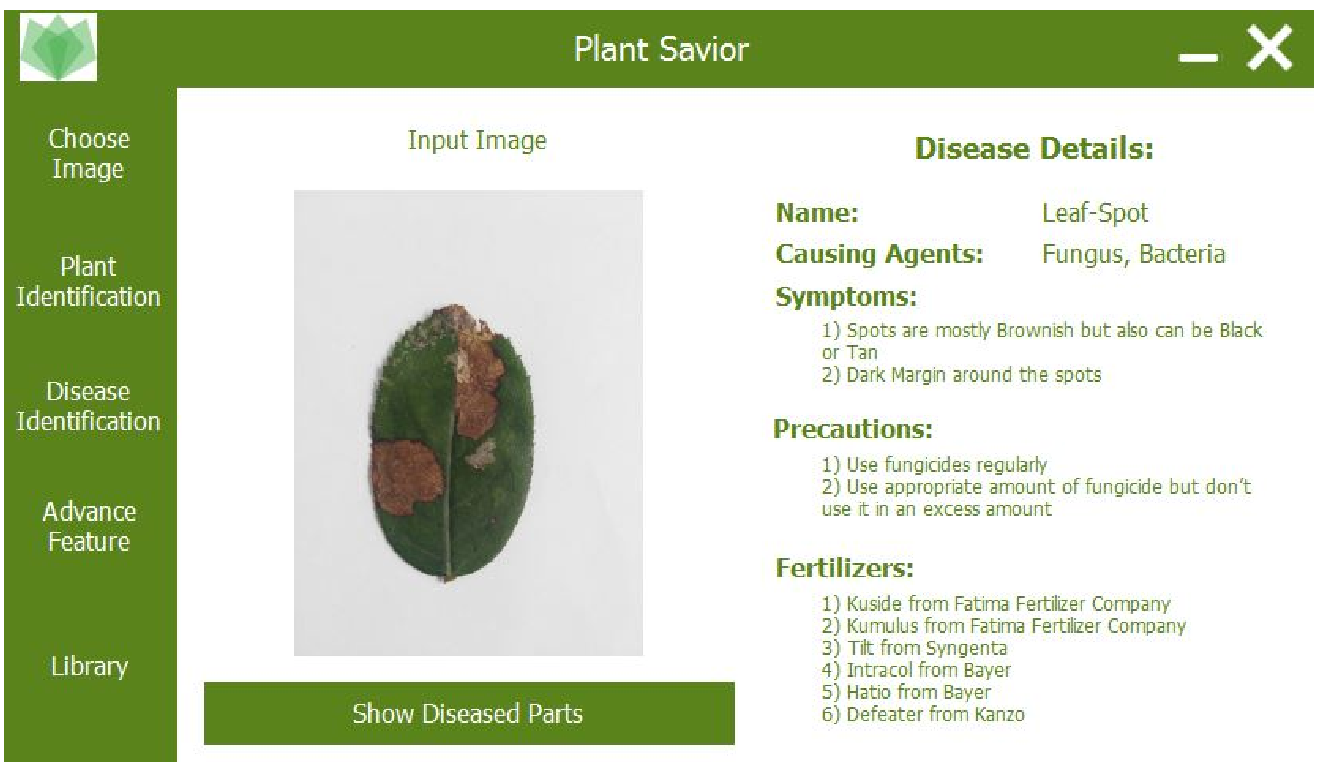


Figure 5.11: Leaf Spots (Desktop Application)

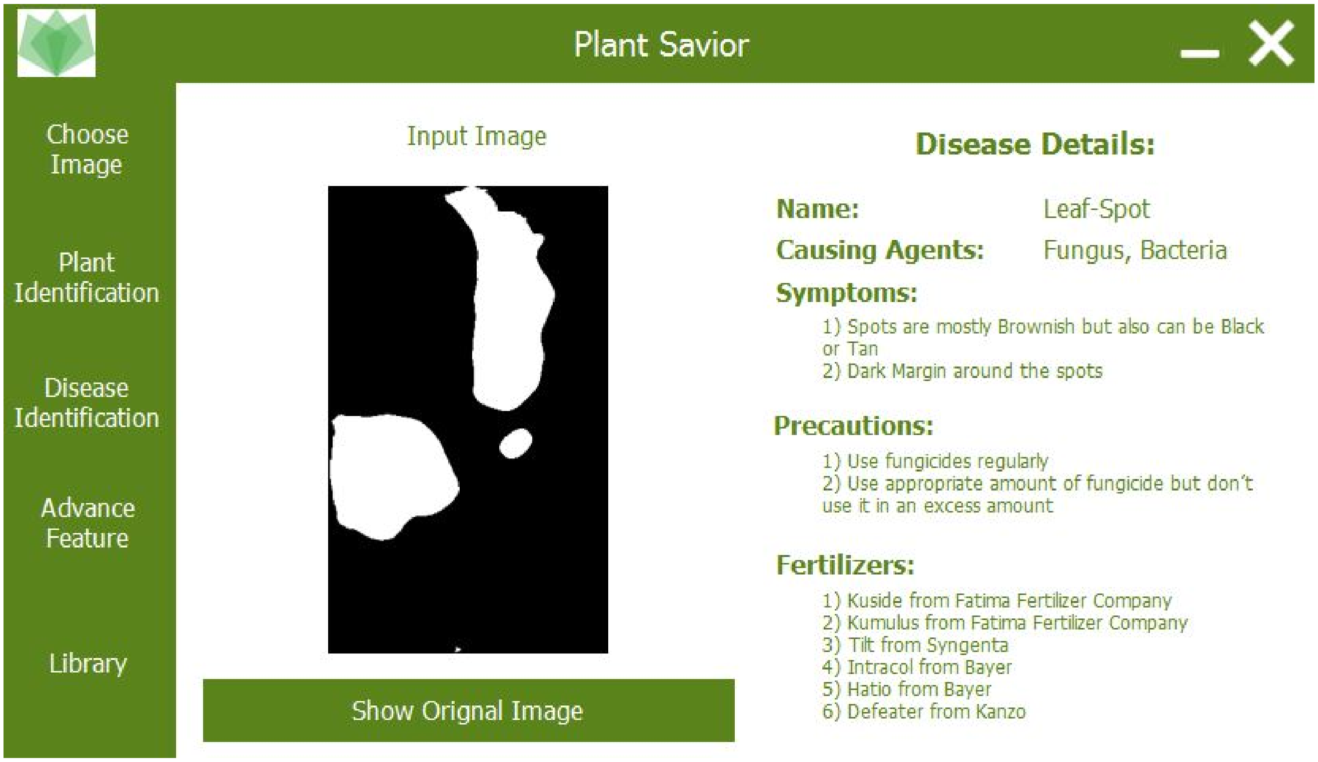


Figure 5.12: Leaf Spots Diseased Parts (Desktop Application)

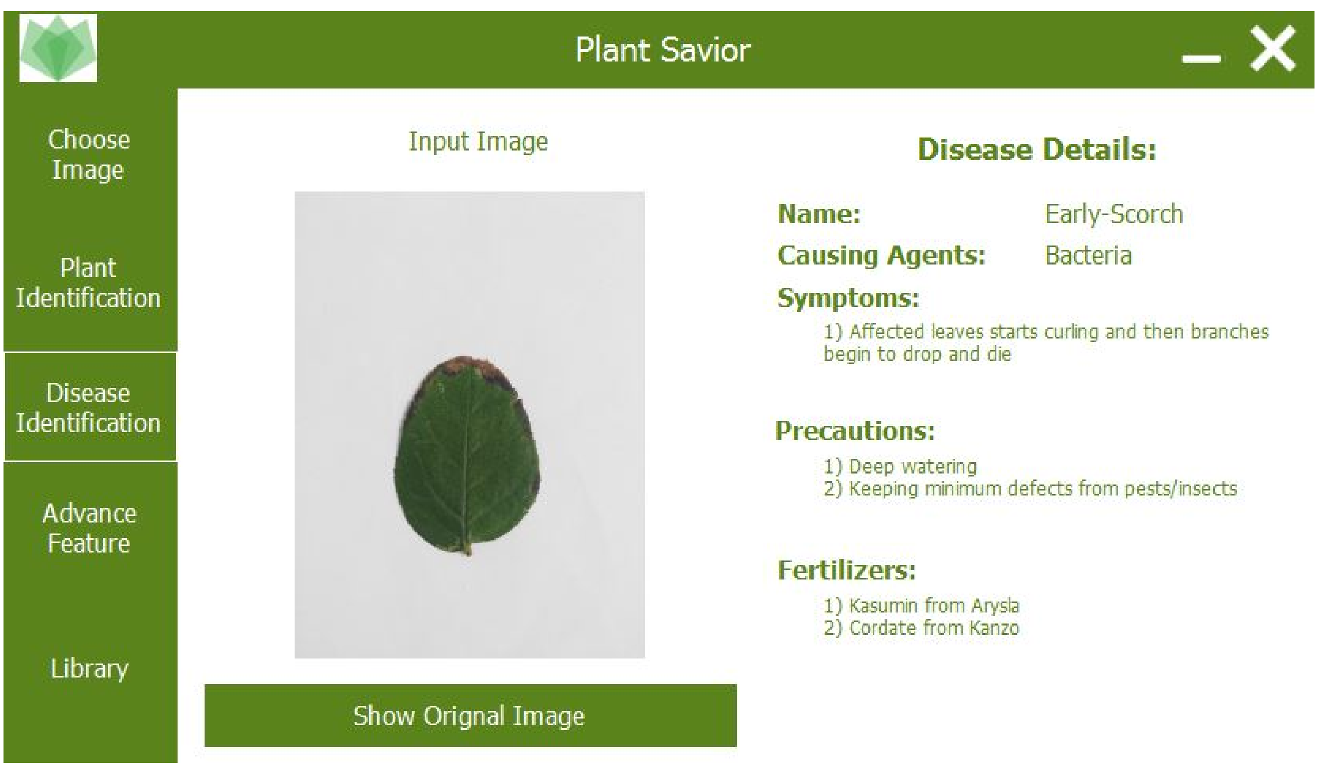


Figure 5.13: Early Scorch (Desktop Application)

Figure 5.14: Early Scorch Diseased Parts (Desktop Application)

5. **Advance Feature:** By selecting "Advance Feature" button, user can draw various advanced leaf features like area, perimeter, contour, convex hull and axis etc.

   (a) **Area**

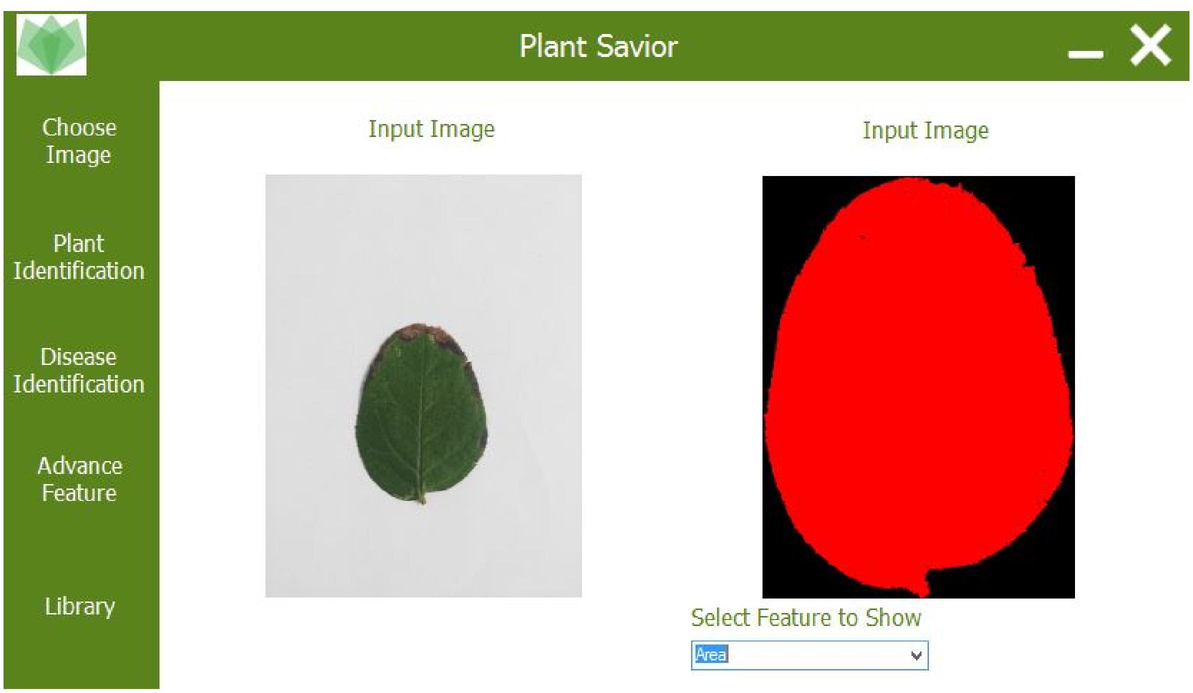


Figure 5.15: Area of Leaf (Desktop Application)

(b) **Axis**

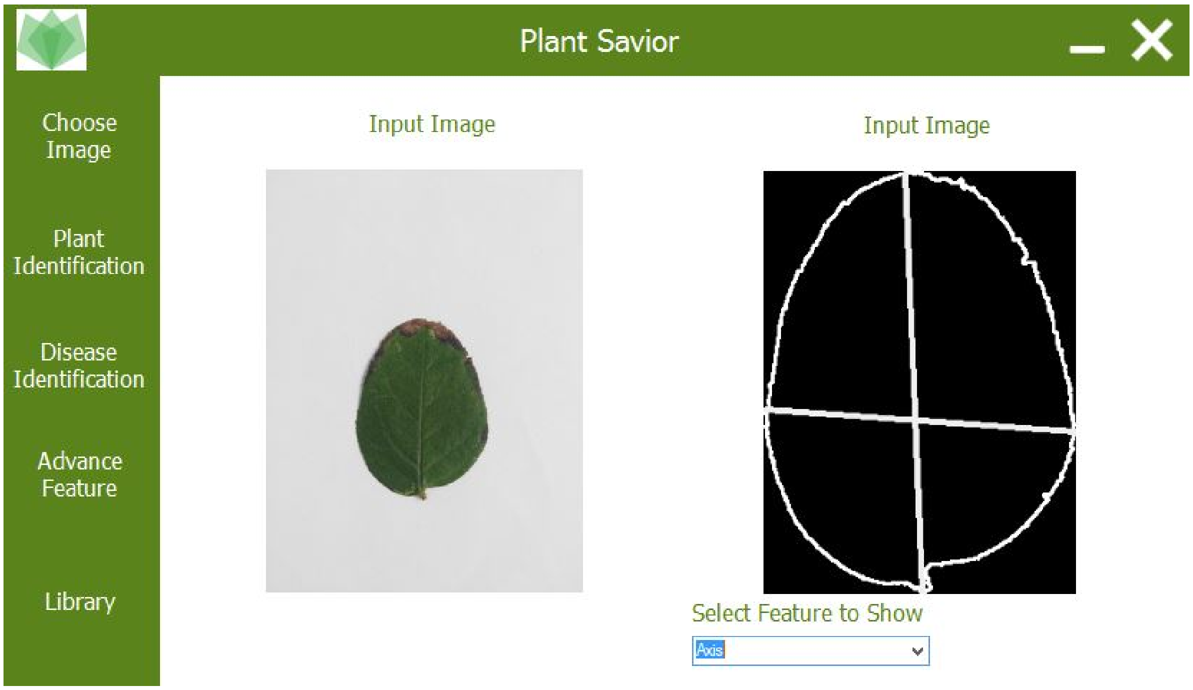


Figure 5.16: Axis of Leaf (Desktop Application)

(c) **Contour**

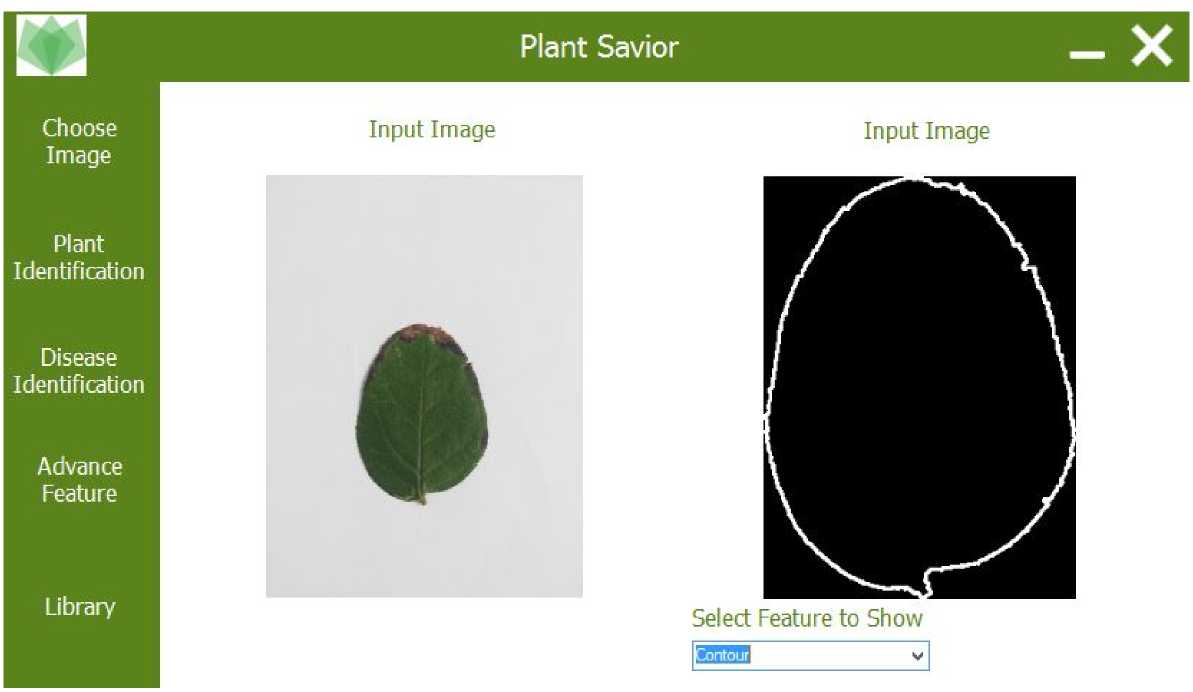


Figure 5.17: Contour of Leaf (Desktop Application)

(d) **Convex Hull**

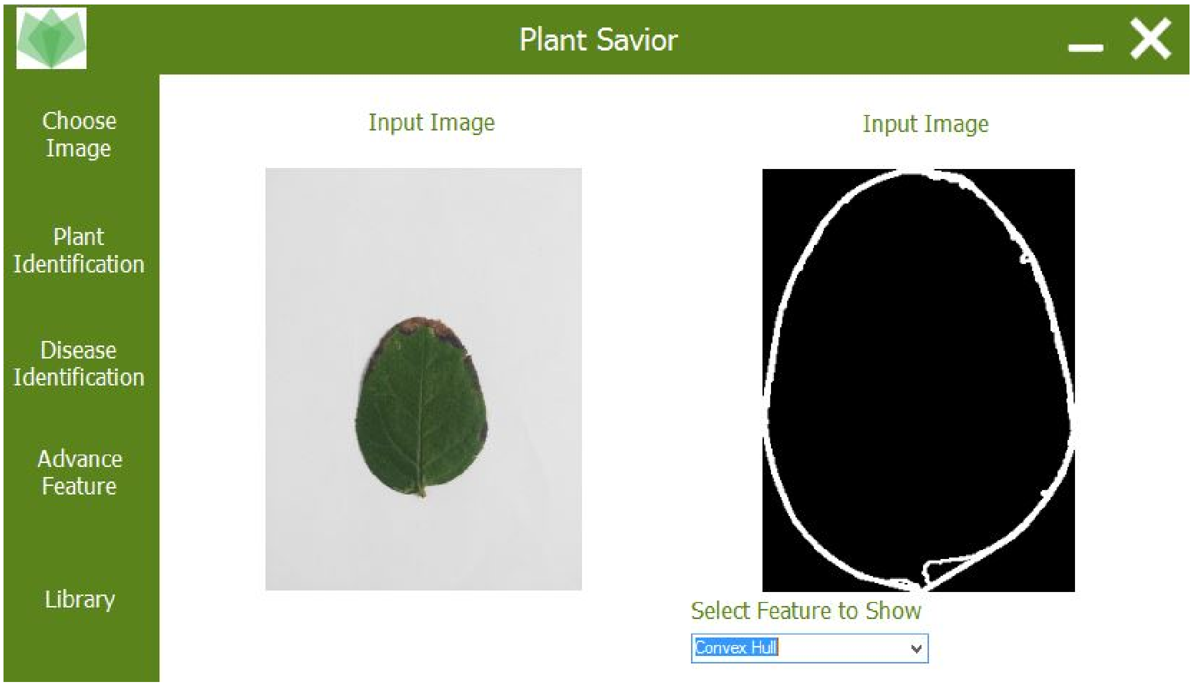


Figure 5.18: Convex Hull of Leaf (Desktop Application)

(e) **Minimum Bounding Rectangle**

Figure 5.19: Mini. Bounding Rectangle of Leaf (Desktop Application)

6. **Library** By selecting "Library" button user can view details of supported species by the system.

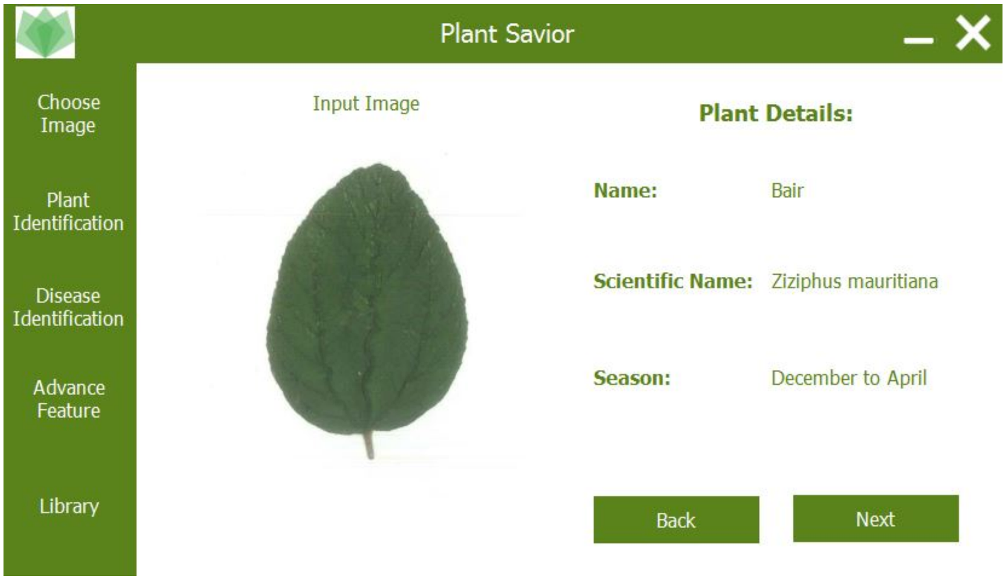


Figure 5.20: Library of supported species (Desktop Application)

5.6.2 Web API

1. **Homepage**

   It's the Homepage of online web API interface. In it, User has different options on the navbar to directly navigate to other sections.

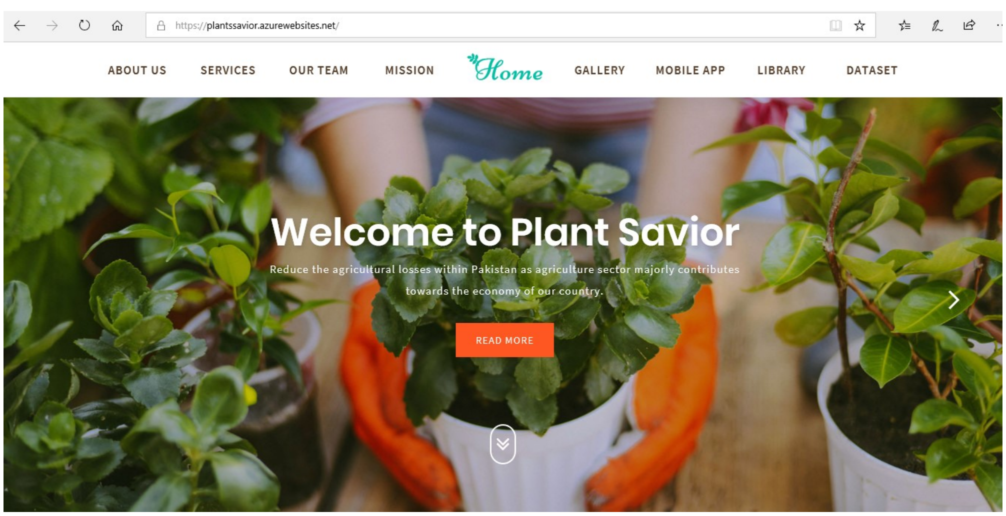


Figure 5.21: Homepage (Web API)

- By clicking on Mobile APP option user can download mobile app directly from play store.

- By clicking on Library option user view or download plant library.
- By clicking on Dataset option user download dataset of leaf images.

Whereas other navbar options like About us, Services, Our Team , Mission etc are related to general info regarding the development team and about the system.

2. **About us Section**

By clicking on About us option or scrolling down user get the details of developers and purpose of building the system.

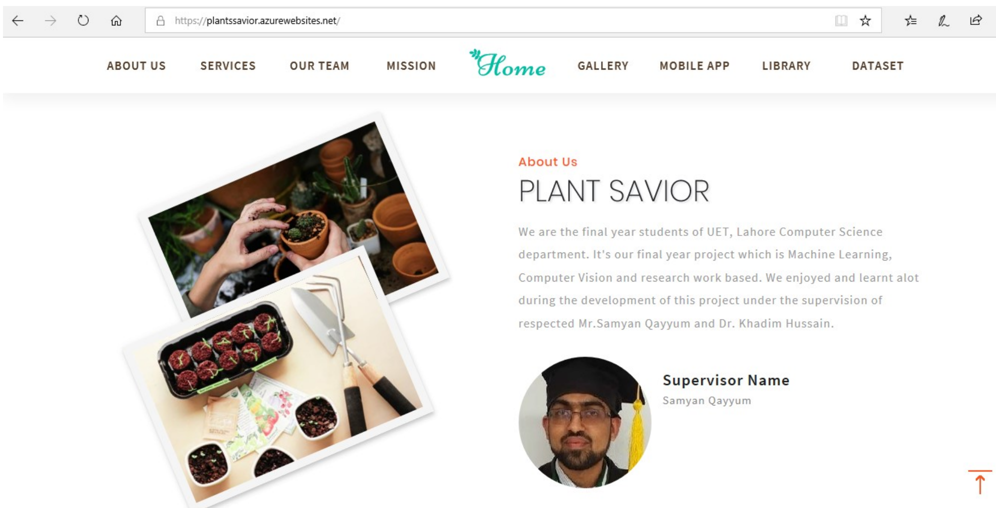


Figure 5.22: About us Section (Web API)

3. **Plant Gallery**

By clicking on Gallery option from navbar or by scrolling down user view the covered plants images and by clicking on leaf image user view the plant name.

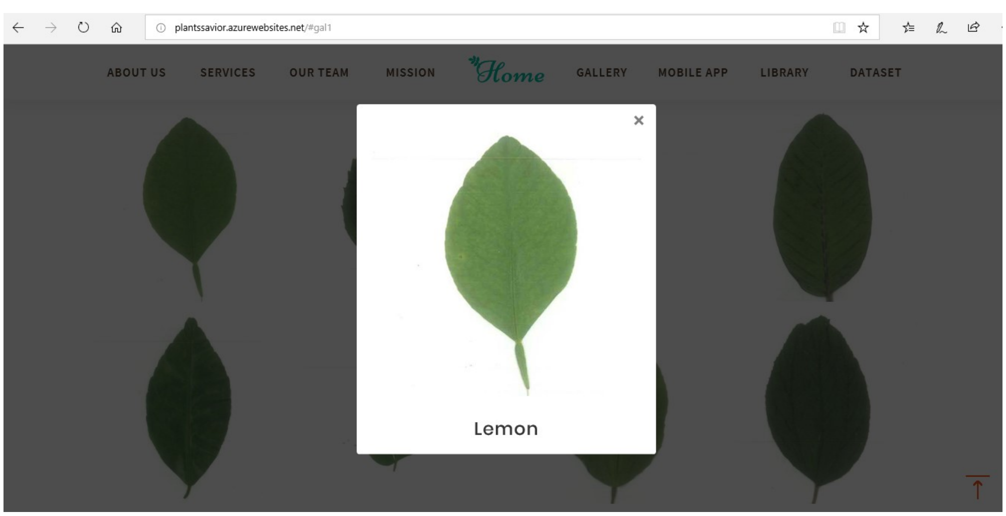


Figure 5.23: Plant Gallery (Web API)

4. **Plant Identification**

   User choose the image from gallery after pressing Choose Image button and then click on "Plant Identification" option then system tell the identified plant name.

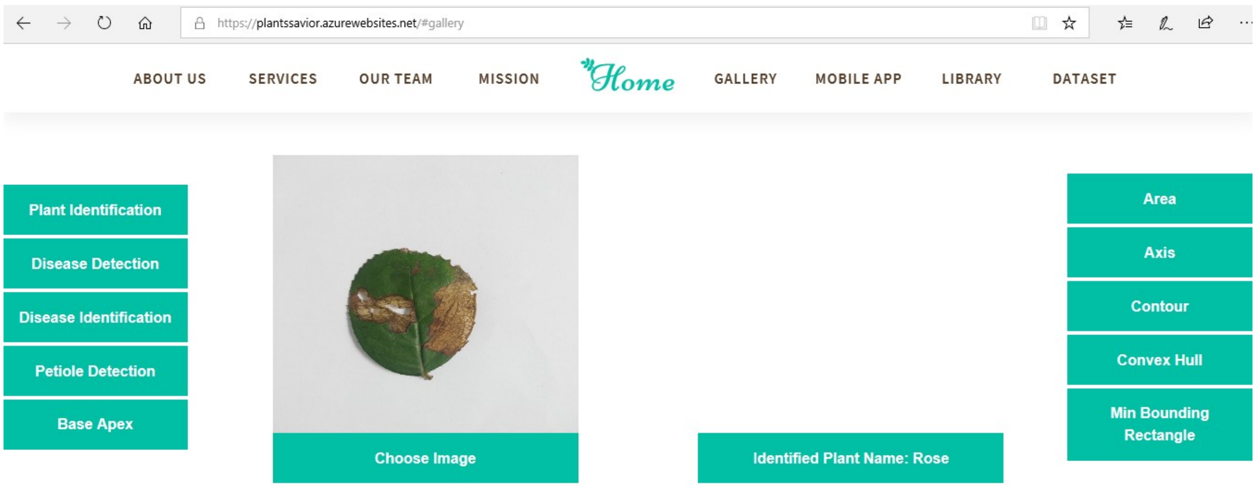


Figure 5.24: Plant Identification (Web API)

5. **Disease Detection**

   User choose the image from gallery and then press the "Disease Detection" button then user view the diseased parts of leafs highlighted in image.

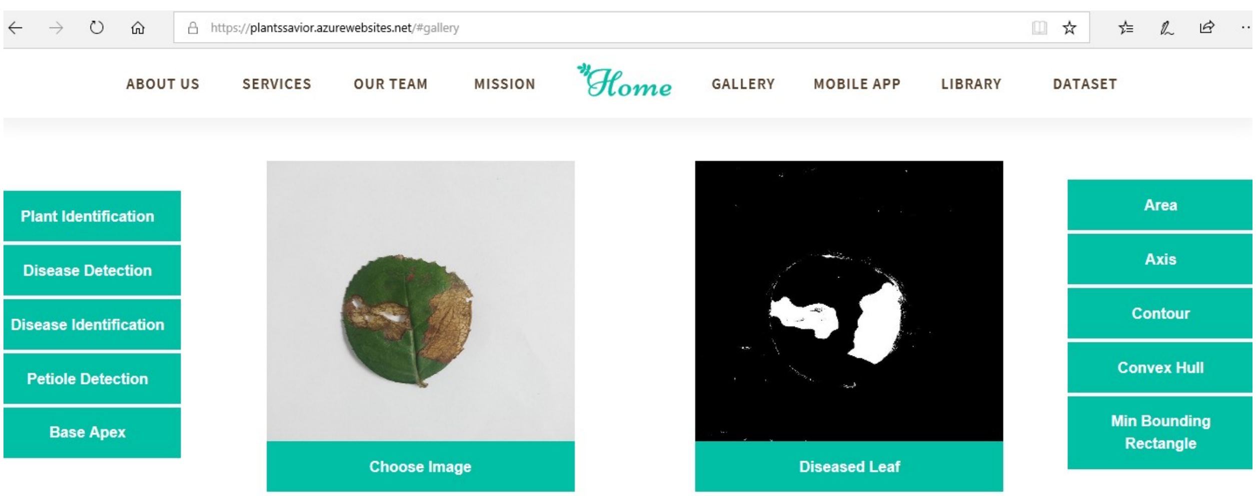


Figure 5.25: Disease Detection (Web API)

6. **Disease Identification and Fertilizer Recommendation**

   User choose the image from gallery and then press the "Disease Identification" button then user view the diseased parts of leafs highlighted in image, predicted disease name, causing agents, symptoms, precautions and recommended fertilizer to cure disease.

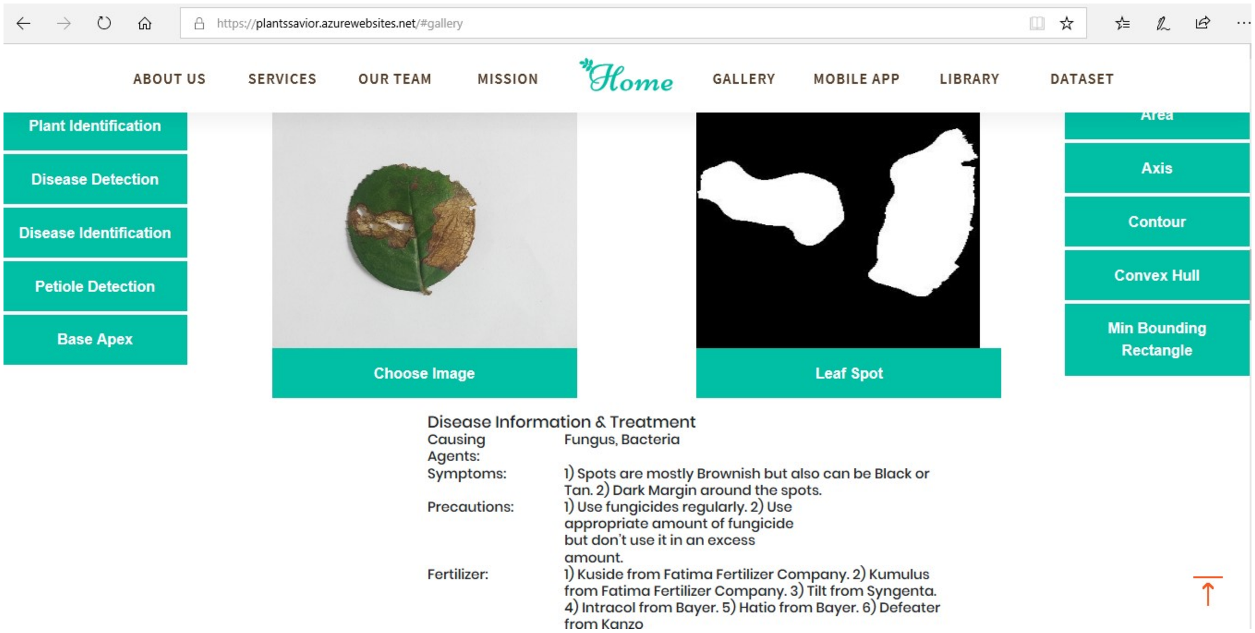


Figure 5.26: Disease Identification and Fertilizer Recommendation (Web API)

7. **Major axis and Minor axis Detection**

   User choose the image from gallery and then draw different features on leaf image if user press the "Axis" button then user view the minimum and maximum axis of leaf highlighted in red color on image.

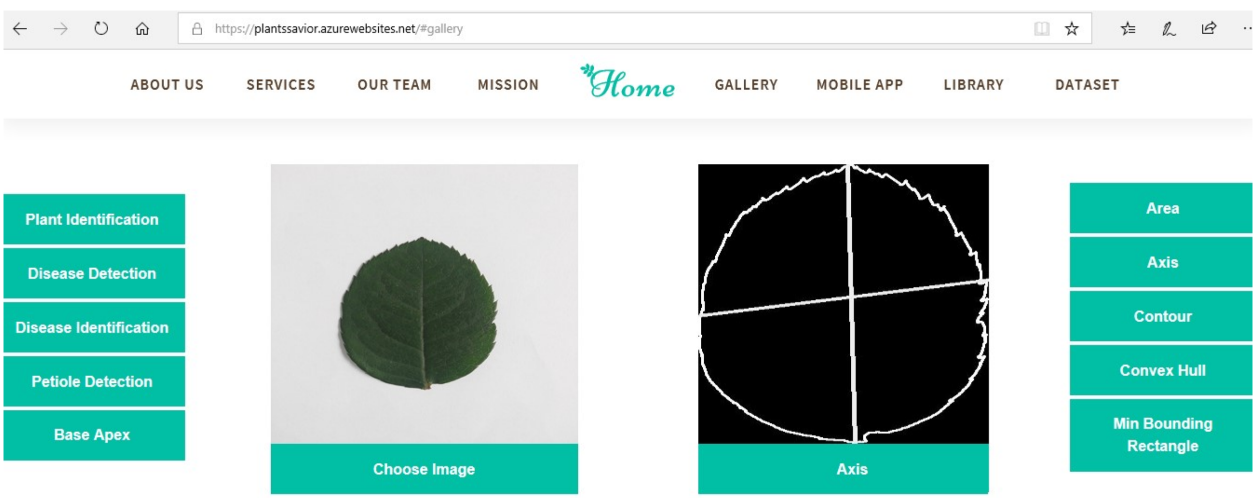


Figure 5.27: Axis (Web API)

8. **Minimum bounding rectangle**

   User choose the image from gallery and then draw different features on leaf image if user press the "Min Bounding Rectangle" button then user view the minimum bounding rectangle of leaf highlighted in green color on output image.

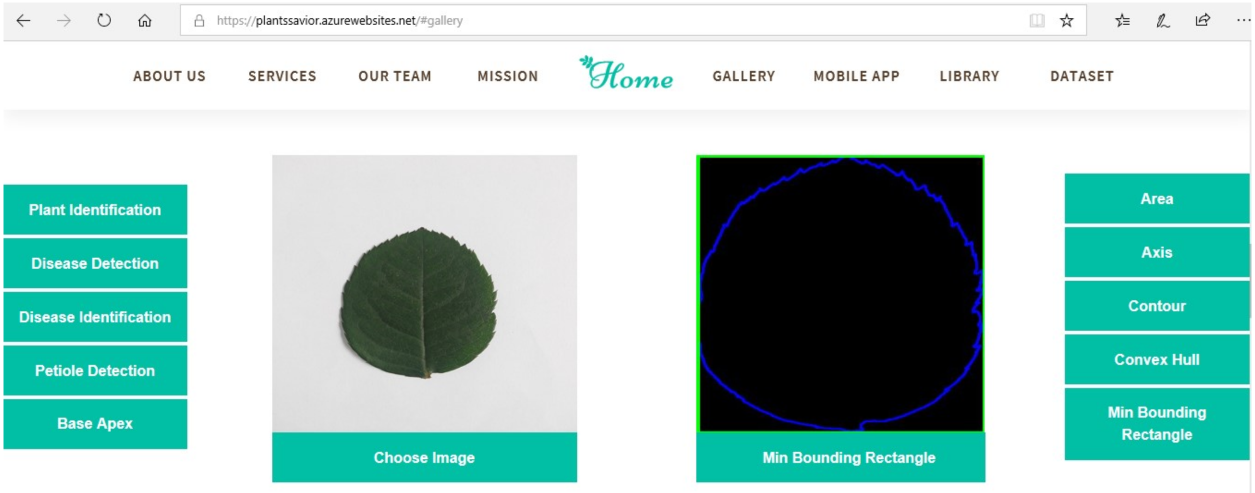


Figure 5.28: Minimum Bounding Rectangle (Web API)

9. **Leaf Contour**

User choose the image from gallery and then draw different features on leaf image if user press the "Contour" button then user view the Contour of leaf boundary highlighted in red color on output image.

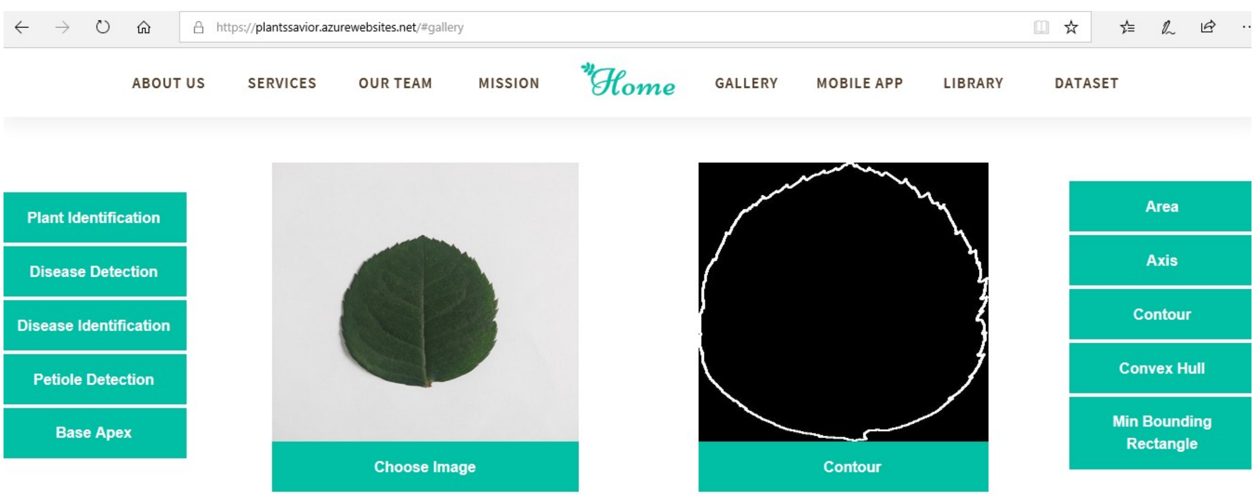


Figure 5.29: Leaf Contour (Web API)

10. **Leaf Convex hull**

User choose the image from gallery and then draw different features on leaf image if user press the "Convex Hull" button then user view the convex hull of leaf highlighted in red color on output image.

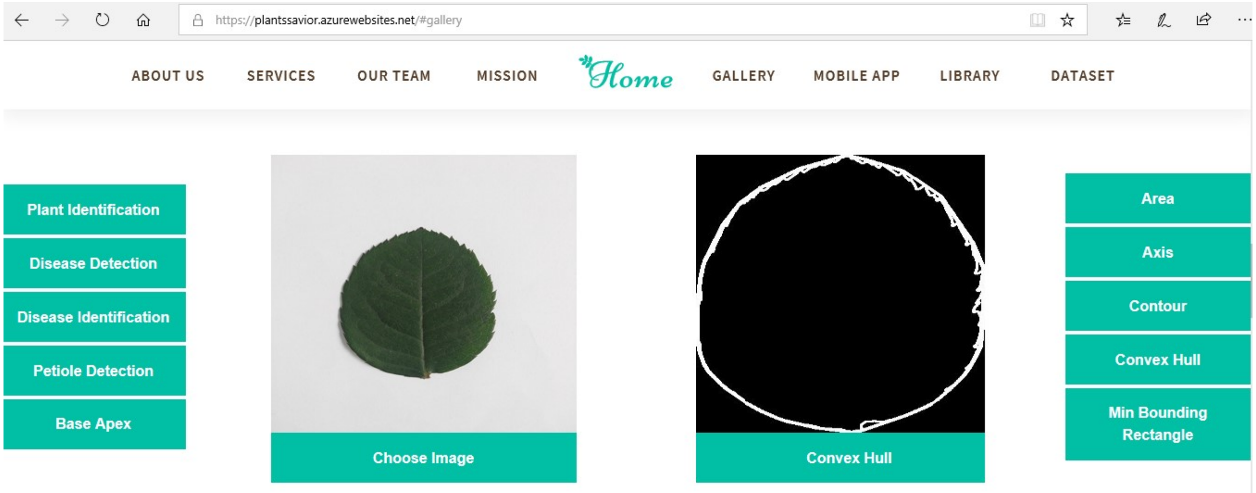


Figure 5.30: Leaf Convex hull (Web API)

11. **Petiole Detection**

User choose the image from gallery and then press the "Petiole Detection" button then user view the petiole of leaf highlighted in red color on output image.

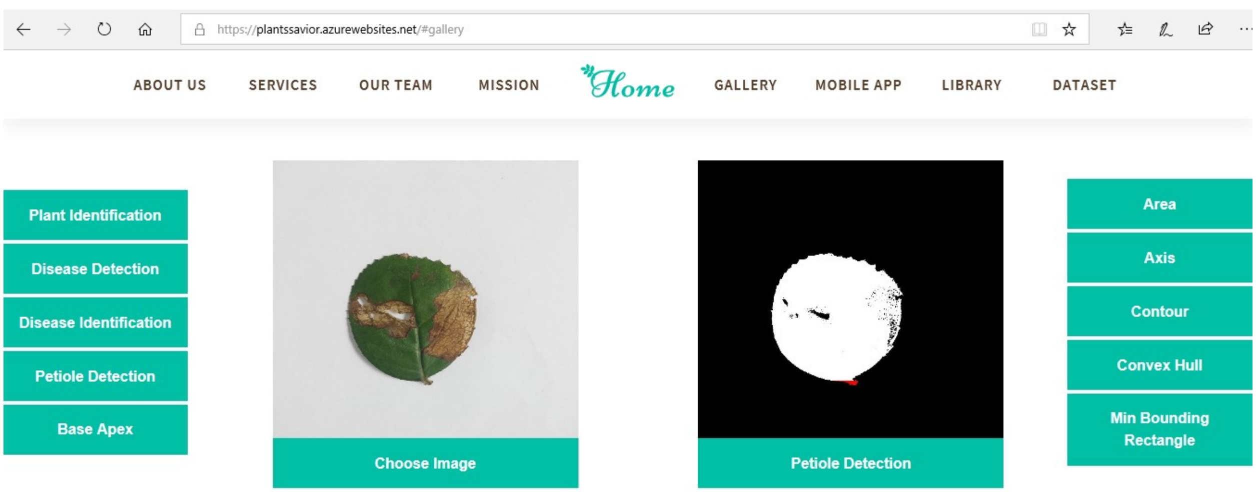


Figure 5.31: Petiole Detection (Web API)

12. **Base and Apex Detection**

User choose the image from gallery and then press the "Base Apex" button then user view the base and apex of leaf highlighted in red color.

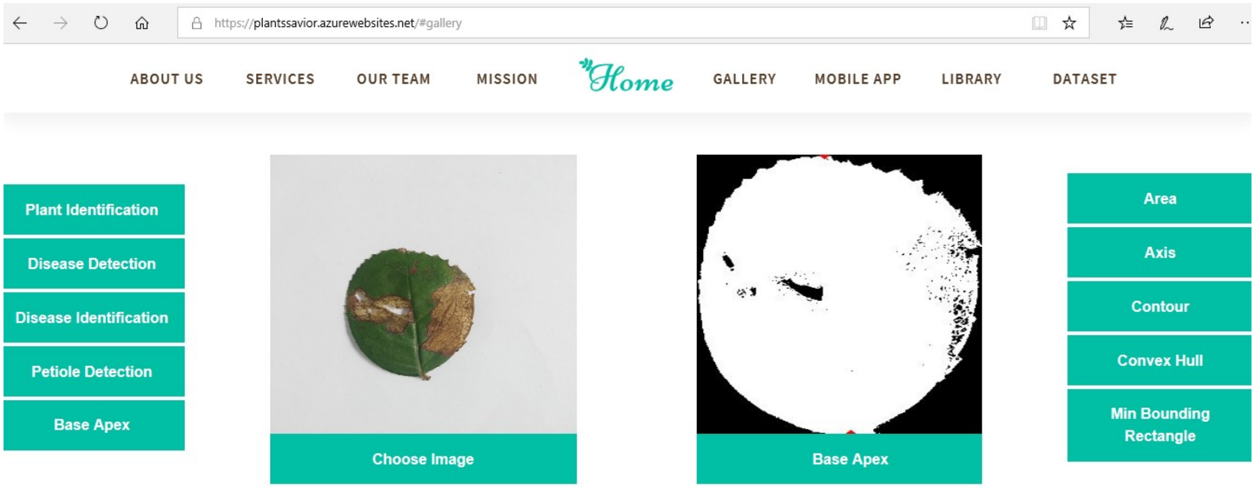


Figure 5.32: Base and Apex Detection (Web API)

13. **Leaf Area Detection**

    User choose the image from gallery and then draw different features on leaf image if user press the "Area" button then user view the area of leaf highlighted in red color.

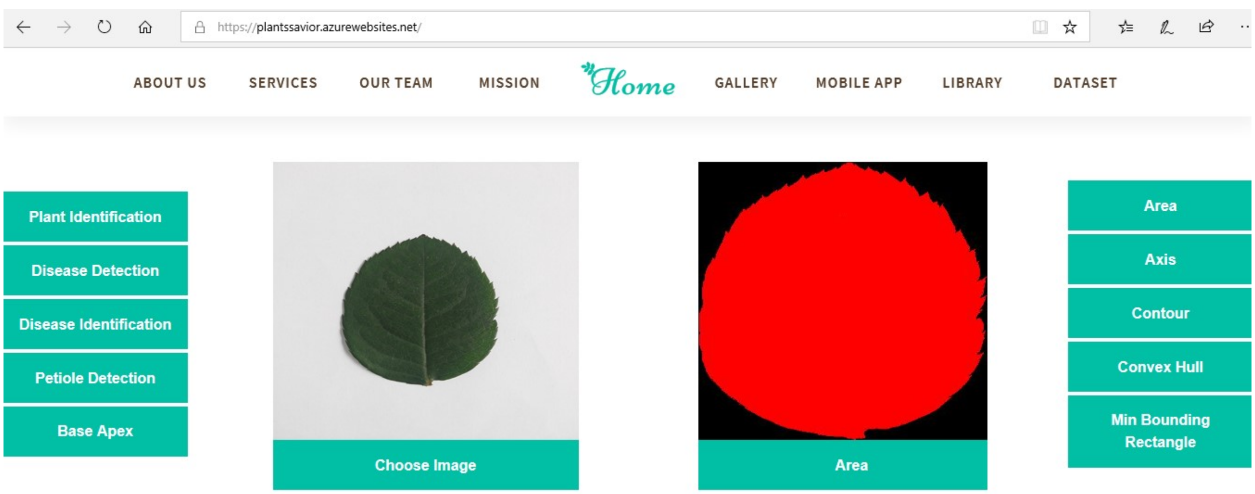


Figure 5.33: Leaf Area Detection (Web API)

5.6.3 Mobile Application

As mentioned earlier in the general flow, to perform any processing Android mobile application of the proposed system makes call to the WEB API of the proposed system. And the response from the WEB API is then displayed as a result on the mobile screen. The major screens included in the mobile application are as follows:

1. **Home Screen**

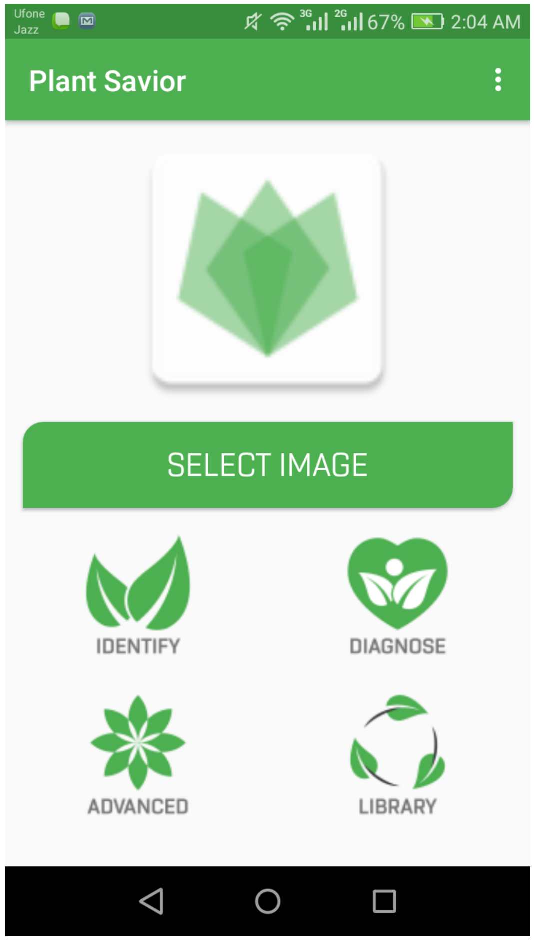


Figure 5.34: Home Screen (Mobile Application)

This is the first screen which appears when the mobile app is opened. The main elements of this screen include:

(a) **Select Image Button:** This button allows the user to select the input image. Identify, Diagnose and Advanced buttons work only after the user has selected input image.

(b) **Identify Button:** This button open up the Plant Identification screen where user can get information about the identified plant.

(c) **Diagnose Button:** Using this button user can diagnose the plant's health status and proper treatment recommendations for the diseased plant. Which is displayed to the user after navigating to the Disease Identification screen.

(d) **Advanced:** This button navigates to the Advanced screen where user gets information not only about identified plant and its health status but also allow users to draw the various advanced leaf features.

(e) **Library:** Using this button user can view a list of the plants supported by the mobile application.

(f) **Menu button:** The 3 vertical dots icon next to the application name at the top bar represents the menu button which mainly includes an option for getting the user feedback.

2. **Plant Identification Screen**

This screen is displayed when a user clicks on the Identify button from the home screen. It displays the input image of the leaf selected by a user from the previous screen. And the identified plant name along with its description is also displayed.

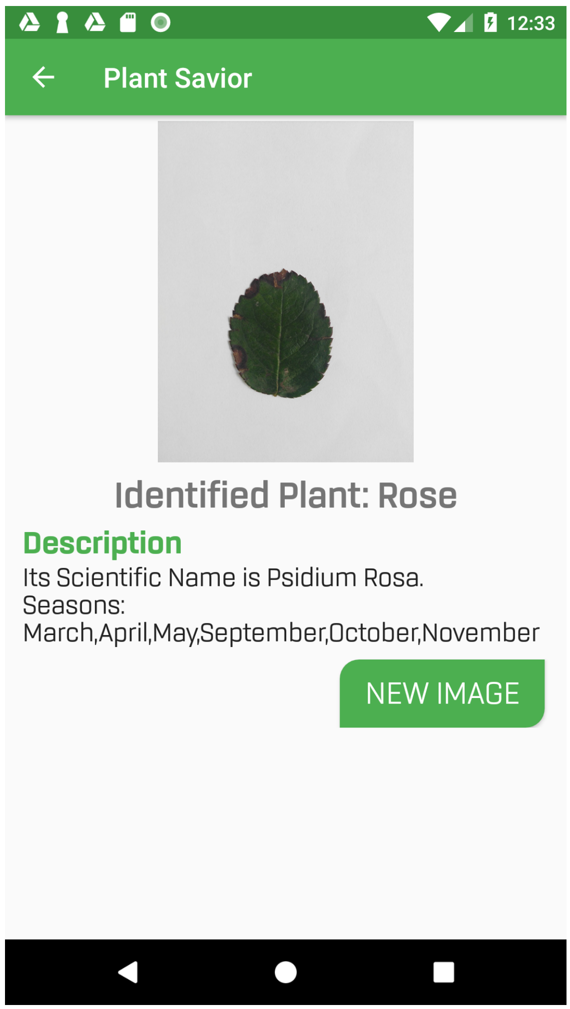


Figure 5.35: Plant Identification Screen (Mobile Application)

There is New Image button available for the user to select another image for plant identification without navigating back to the home screen.

3. **Disease Identification Screen**

When a user clicks on the Diagnosis button available on the home screen, Disease Identification screen is displayed to the user. This screen display a binary image of the plant leaf selected by the user previously. The white area highlights the diseased portion of the leaf image. If there is no disease and plant leaf is healthy then there will be no white portion and the user gets a black image.

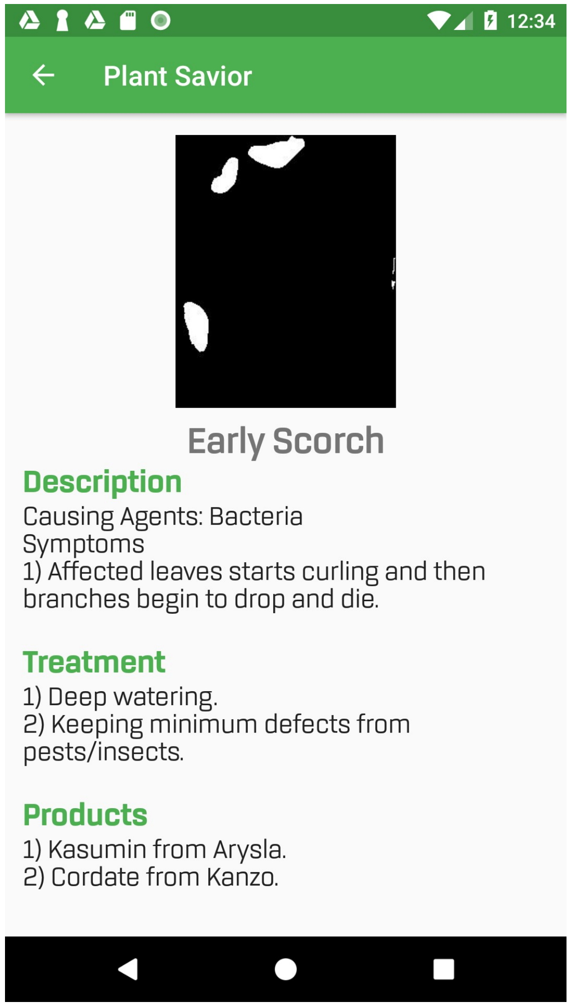


Figure 5.36: Disease Identification Screen (Mobile Application)

If the leaf is diseased then all available information related to identified diseased is displayed to the user. Including disease name, description, recommended treatment and products. The products mainly include list of fertilizers that a user can choose from for the treatment of diseased plant.

4. **Advanced Screen**

Advanced Screen is displayed to the user when the "Advanced" button from the Home screen is clicked. Here the summarized information about a plant is displayed to the user. Which includes the binary image of the plant leaf highlighting the diseased portion if any, identified plant name, leaf's health status i.e. diseased or healthy. The Select Image button at the bottom of the screen, allows user to select a new image for getting information.

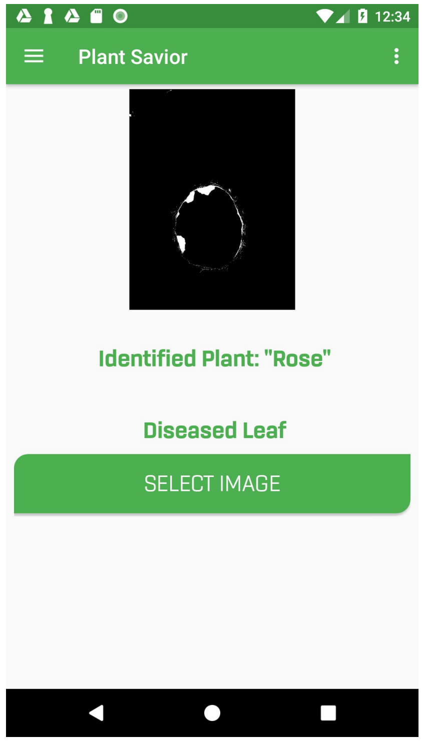


Figure 5.37: Advanced Screen (Mobile Application)

To look at the advanced features of the leaf, user clicks on the top left menu icon.

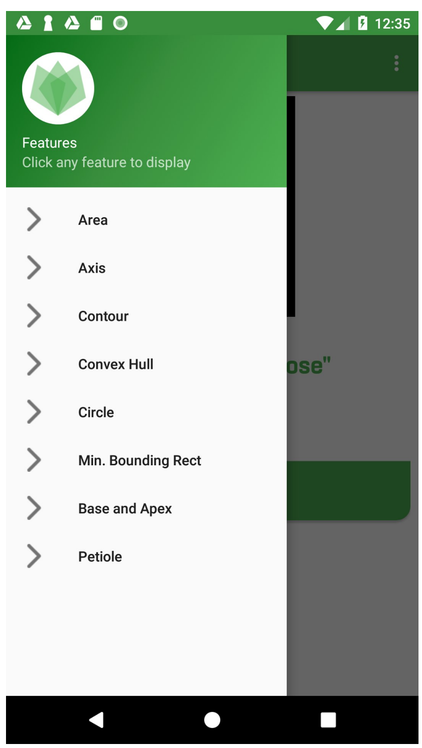


Figure 5.38: Feature menu (Mobile Application)

When a user clicks any of the feature from this navigation drawer menu, it is displayed on the mobile screen. For example the following screen displays axis of the selected leaf image.

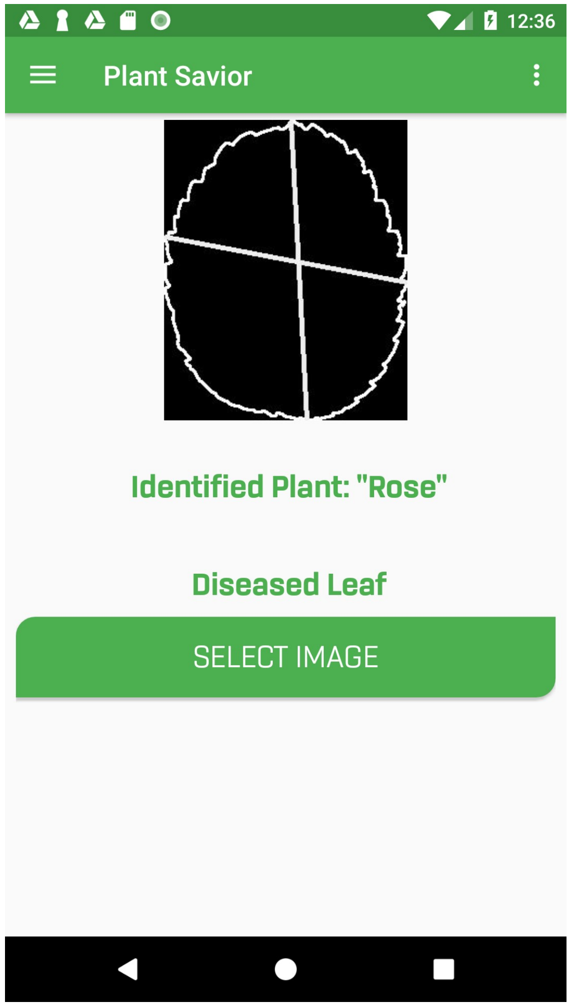


Figure 5.39: Axis of Leaf (Mobile Application)

5. **Library Screen**

   User is navigated to the following screen upon clicking the Library button. It displays a scrollable list of plants supported by the proposed system. Each list item contains following info regarding each specie

   - Plant name
   - Description
   - Image of the respective plant leaf.
   - Season

Lets have a look at Library Section of mobile app of the proposed system

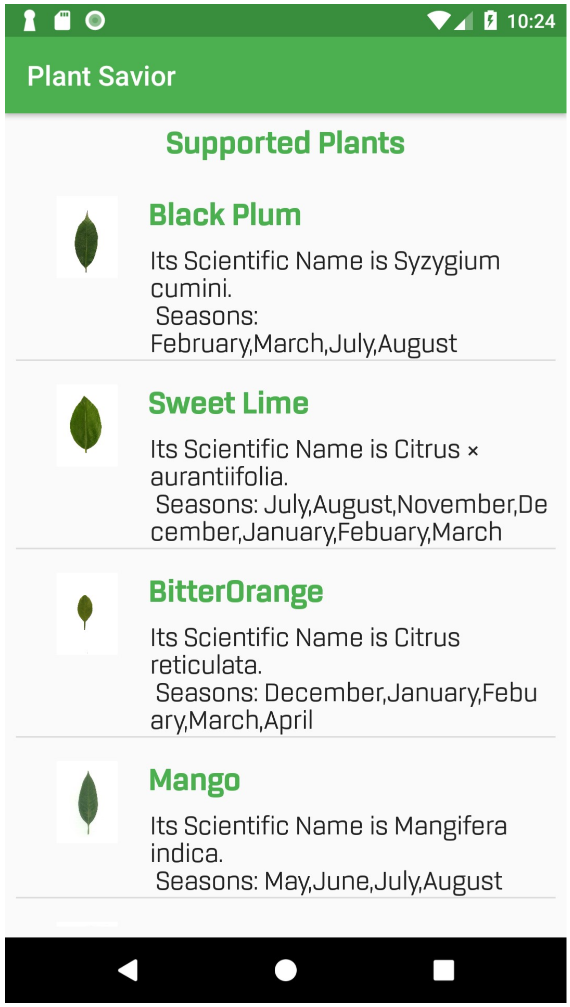


Figure 5.40: Library Sreen (Mobile Application)

Chapter 6

Conlusions and Future Work

6.1 Outputs of Project

The primary output of project is an android application build on Android Studio, which is an interface user friendly enough for any user, whether farmer or anyone else to easily use. While on backend of application, there is an API working which is linked with application. API of the proposed system has built using ASP .NET API framework. It allows us to access the services of our proposed system on various platforms like mobile, web, windows etc. Along with mobile application and web API, Desaktop application of our system is also available.

Focussing on 14 plant species and 2 diseases common in these species i.e. Early scorch and Leaf spot prediction accuracy rate of project comes out to be 90.27% percent. Here's the training image of project and it classifies the dataset.

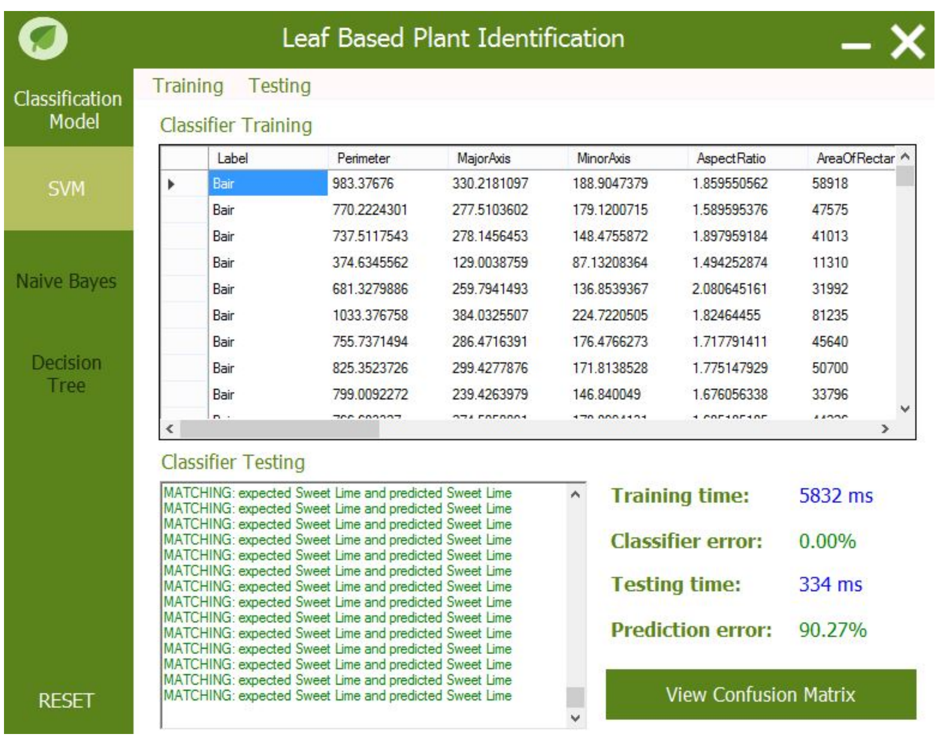


Figure 6.1: Research Utility of Proposed solution for testing and Training

6.1.1 Test Train Results

Training Instances	Testing Instances	Accuracy
715	369	90.27%

Table 6.1: Results of Project

6.1.2 Services of Proposed System

The services which our system provides, include successful:

- Identification of plant
- Diagnosis of plant disease
- Recommendations to cure the plant disease

6.2 Future Work

Future work of project will be to enhance its scope by working on more plant leaf species as well as more plant leaf diseases. Moreover specialized equipments can be made which uses our services for automatic monitoring. Some of future applications of our system are discussed below:

- **Wild plants and Weed Detection by Survival Experts**
  If the proposed system is trained for wild plants and herbs then it will be helpful for the Survival Experts who like to go in forests and must have knowledge about the plants that sustaining of life over a period of time.
- **Disease Detection in Farms**
  Farmers may have to go long distances to contact experts in some developing countries, this makes consulting experts time consuming and expensive. The proposed system will automatically detect the symptoms of diseases as soon as they appear on plant leaves and prove beneficial in monitoring large fields of crops.
- **Research in Botany**
  A botanist, plant scientist is a scientist who specializes in the science of plant life. The study of Botany highly depends upon plants, to search native plants and its diseases is not easy task. Botanist may use the proposed system to identify plants and their diseases for study purposes.
- **Automatic Monitoring**
  If the proposed system is connected with a Drone then it can automate the crop monitoring and landowners can monitor their lands while sitting away from their lands. To increase the agricultural productivity and to promote agriculture, it is important to monitor crop growth, field environment, and farming operations. Although, it is hard to realize these monitoring operations automatically in the agricultural field as it requires the deployment of specialized equipment and the improvement of facilities that require considerable cost, effort and space.

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