Spontaneous Insect Pest Detection and Identification System (SIPDIS)

By

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Submitted to the faculty of Department of Computer Software Engineering,
Military College of Signals, National University of Sciences and Technology, Islamabad,
in partial fulfillment for the requirements of B.E Degree in Software Engineering.

June 2022

In the name of ALLAH, the Most benevolent, the Most Courteous

CERTIFICATE OF CORRECTNESS AND APPROVAL

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under my supervision and that in my judgement, it is fully ample, in scope and excellence, for the degree of Bachelor of Software Engineering in Military College of Signals, National University of Sciences and Technology (NUST), Islamabad.

Approved by

Supervisor

Dr. Ihtesham Ul Islam

Date: ___________

DECLARATION OF ORIGINALITY

We hereby declare that no portion of work presented in this thesis has been submitted in support of another award or qualification in either this institute or anywhere else.

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Allah Subhan'Wa'Tala is the sole guidance in all domains.

Our parents, colleagues and most of all supervisor Dr. Ihtesham Ul Islam without your guidance.

The group members, who through all adversities worked steadfastly.

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ABSTRACT

Insect pests damage crops worldwide. They have a direct impact on agricultural food production by chewing the leaves of crop plants, sucking out plant juices, boring within the roots, stems or leaves, and spreading plant pathogens. They feed on natural fibers, destroy wooden building materials, ruin stored grain, and accelerate the process of decay This problem greatly impacts agricultural products, resulting in low quality and quantity of crops and other agriculture related items like wheat, maize, rice, potatoes, tomatoes etc. It not only destroys the product but also wastes precious time and farmer empowerment. This issue is very critical and has a direct impact on reducing the economy and food security worldwide. However, due to a large number of insect pests and their types throughout the globe we need agriculture domain experts to easily identify these insect pests. It is important because they then must use the right pesticide or chemical to get rid of them. In this project, our aim to is to optimize and manage the agricultural crops from insects and pests by developing an automatic insect pest detection and identification system. This system will be an application that can easily be used by the farmers and other relevant people of this field to identify the pest using captured image through their smart devices. This application will be built using Artificial Intelligence and deep learning techniques. The identification and classification will be done using convolution neural network-based models of deep learning.

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Chapter 1: Introduction

Expert skills built on scientific experimental knowledge and science of numbers style a new division of science known as Engineering. This branch of science is extremely important to society and its elements in many ways, especially the developmental research in the engineering domain that is enhancing the standard of living for mankind.

Engineering is not only limited to the smaller research areas, but it covers entire industrial setups from visual constructions on some software to on-site practical work. Not only this, but this field of science also defines safety policies and evaluation measures. Engineers, who are practicing engineering principles, use their domain knowledge to invent and develop products that solve problems of the society. Either it is an issue of conveyance, medicine, astrology, atmosphere, or entertainment.

With the advancement in engineering knowledge, Artificial intelligence (AI) and deep learning has found a respectful place in the present research interests. It is the process in which computers learn according to the existing events and environment and are programmed in a way to make decisions in the future either by prediction or by the previous trends.

Artificial intelligence and deep learning have completely revolutionized research interests. Where it has been introduced, it has completely changed the on-ground realities. It is no shame to say that it has almost affected every domain of our lives.

The present-day problems demand AI solutions that are efficient. Insect pest problems such as unhealthy crops, or low yield of crops should also be dealt with solutions based on latest technology.

1.1 Overview

Insect pests impair crops globally. This problem critically effects agricultural products and consequently results in low quality and quantity of crops and other agriculture related objects. It not only abolishes the product but also wastes costly time and farmer empowerment. This matter is very critical and has a direct influence on plummeting the economy and food security internationally. In Asia, Pakistan is well-known for exporting agricultural crops in a huge number which greatly contributes 18.9% to the economy. For agricultural 42.3% of labor work force has been used. The remaining population entirely depends on it. The country's population is expanding at the rate of 2.4 % per annum. [1] This speedy growth in population is raising petition for agricultural products. Agricultural products in high quality are mostly imported to other countries. The quality greatly depends on good crops production. To achieve this, the damage from insect pests should be lower at an earlier stage. Products obtained by using wrong pesticides are not healthy and can cause diseases. Insect pests detection and identification in the agricultural fields is one important challenge in a country. However, due to many insect pests and their types throughout the globe people need agriculture domain experts to easily identify these insect pests. It is important because they then must use the right pesticide or chemical to get rid of them, that too in the right amount or quantity. Agricultural pests cause between 20 and 40 percent loss of global crop production every year as reported by the Food and Agriculture Organization (FAO).

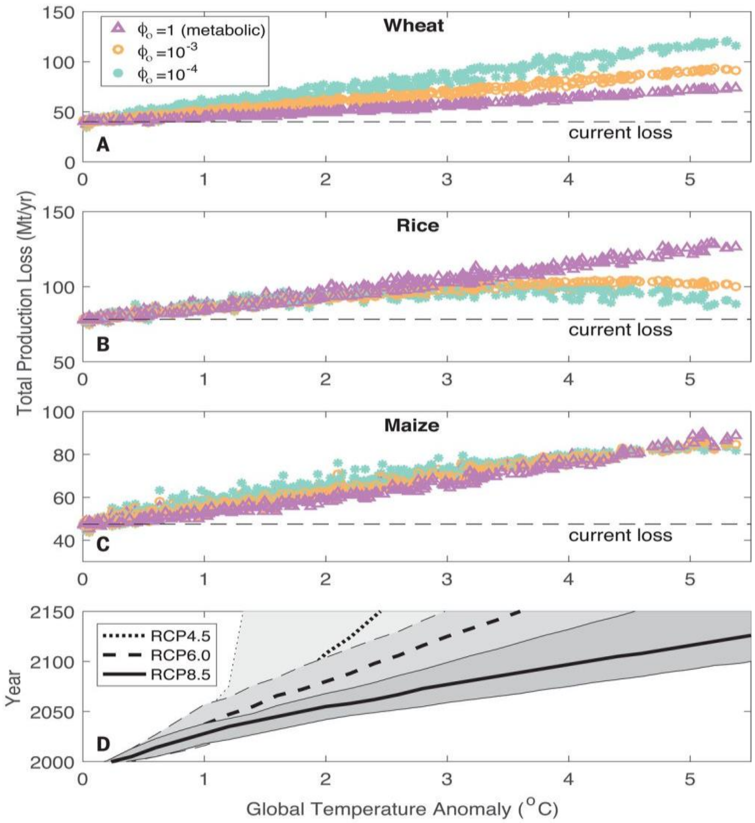

Figure 1.1: Three most important grain crops—wheat, rice, and maize—yield lost to insects will increase by 10 to 25% per degree Celsius of warming climate [2]

Insect pests significantly decrease yields of three essential grains: rice maize, and wheat. Especially in warmer countries like Pakistan, where global warming is already giving rise to more damaged crops by these insect pests. Moreover, the weather conditions are rapidly deteriorating in Pakistan, so to meet the food chain supply demand and to keep the health issues at a low, appropriate measures must be taken to diminish the rise of insect pests damaging the crops in our country.

Therefore, smart agriculture presents the best option for farmers to apply artificial intelligence techniques integrated with modern information to eliminate these harmful insect pests. Consequently, the productivity of their crops can be increased. Hence, this project introduces a new mobile application to automatically classify pests using a deep-learning solution for supporting specialists and farmers.

1.2 Problem Statement

Pakistan is a third world underdeveloped country. Our famers mostly belong to village areas where agriculture education is not considered a pretext in the farming livelihood. At the same time, Pakistan is famous for exporting agricultural products in a large number which greatly affects the economy. For agricultural 42.3% of work force has been employed [1]. The remaining population totally depends on it. This shows how crucial the agriculture sector is for our country. Following are some problems faced by this sector:

1. Lack of agriculture domain experts for education of famers, due to low literacy rate in Pakistan. [3]
2. Health problems caused by wrong usage of pesticide, due to lack of proper guidance and awareness of using pesticides for relevant insect pest.
3. Low yield of crops due to damage by insect pest, by wrong or no usage of insect pesticide.

1.3 Proposed Solution

The major goal of our proposed solution is to give our farmers the agriculture domain knowledge needed for identifying the type of insect pest and consequently suggesting a remedy to getting rid of that pest. This will be done by a average smartphone's camera which can either take a picture or select a picture from the gallery. The proposed model should be able to predict the insect and give a suitable suggestion to get rid of the insect.

1.3.1 Methodology Diagram

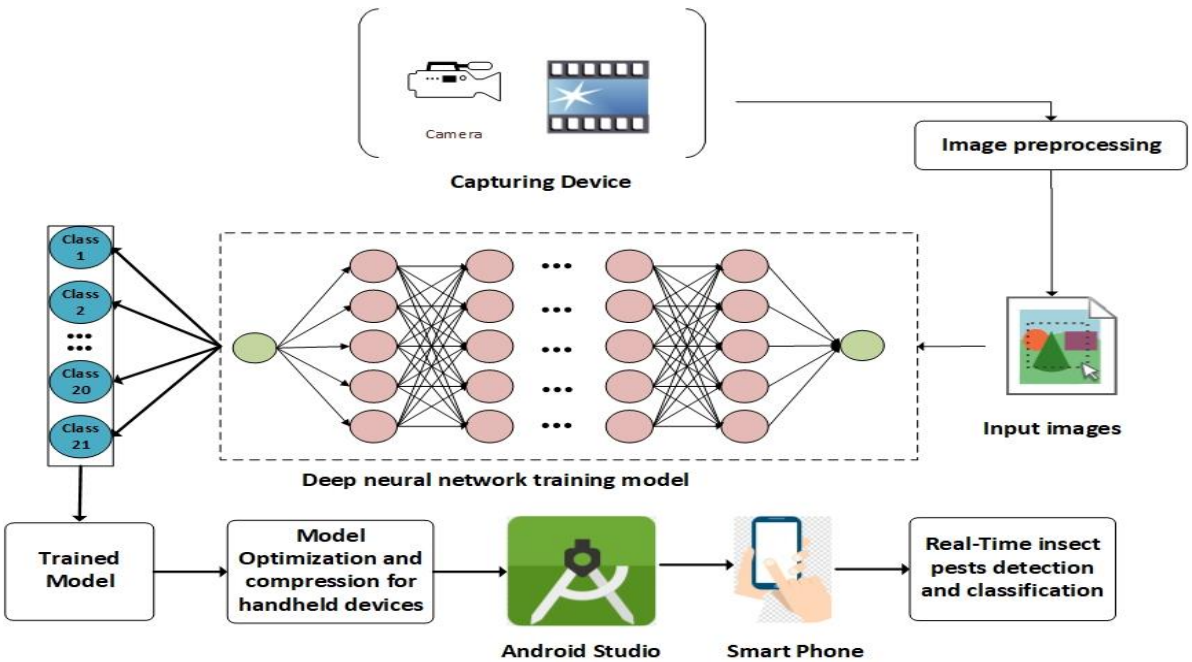

Figure 1.2: Proposed Model for detecting and identifying insect pest through artificial intelligence and deep learning techniques.

1.3.2 Intended Audience

Farmers and crop yielders/stakeholders in agriculture are the intended audience of this project

1.4 Working Principle

The project mainly works on the principles of CNNs (Convolutional Neural Networks) and deep learning algorithms. The project is divided into different modulus and every module is inter-woven with the next module. The list of modules is as under:

- Dataset editing/customizing
- Dataset training and processing
- Decision based upon Output
- Integration with android application
- GUI presentation in application

1.4.1 Dataset editing/customizing:

An integral part of the project is the preparation of datasets. The dataset comprises of images of various type of insect pests.

1.4.1.1 Original Dataset:

IP102 is a large-scale dataset for insect pest recognition by Xiaoping Wu. It contains more than 75,000 images of insect pests belonging to 102 categories. This dataset has a hierarchical classification. The insect pests which mainly mark one specific agricultural product are grouped into the same higher-level class. In addition, it has 19,000 images with bounding boxes for object detection. [4]

1.4.1.2 Customized dataset:

This project uses a custom build dataset of the insect pests only found in Pakistan, from the original dataset IP102. This is done to save time from training of unnecessary images of insect pests, and to save the hassle from predicting classes not found in Pakistan, therefore saving confusion and time. It also serves to save time on training and testing, making the end application lightweight for an average smartphone to handle smoothly without much processing power. The image size is been set as 192x192, with a maximum of 800 images from each of the 26 classes to avoid class imbalance and to make it computationally feasible.

26 classes out of 102 from IP102 dataset were selected and finalized keeping in mind Pakistan's crops and insects. [5] These are:

1. Rice Stem fly
2. Asiatic Rice Borer
3. Brown Plant Hopper
4. Rice Gall Midge
5. Rice Leaf Caterpillar
6. Rice Leaf Roller
7. White Backed Plant Hopper
8. Yellow Rice Borer
9. Cicadellidae
10. Thrips
11. Aphids

12. Army Worm

13. Beet Army Worm

14. Black Cutworm

15. Cabbage Army Worm

16. Corn Borer

17. Large Cutworm

18. Peach Borer

19. Rice Leafhopper

20. Rice Shell Pest

21. Rice Water Weevil

22. Small Brown Plant Hopper

23. Wheat Blossom Midge

24. Wheat Phloeothrips

25. Wheat Sawfly

26. Yellow Cutworm

Figure 1.3: Insect Pest classes selected based on geographical location of Pakistan

1.4.2 Dataset training and processing:

The prepared dataset is used as input to train classification models using deep learning.

1.4.2.1 EfficientNet architecture:

EfficientNet-B4 architecture is a image classification model, used for the training of our customized dataset, it achieves state of the art accuracy, being of smaller magnitude and faster than other architectures. It is computationally power efficient for training as compared to other architectures in the model size vs accuracy comparison.

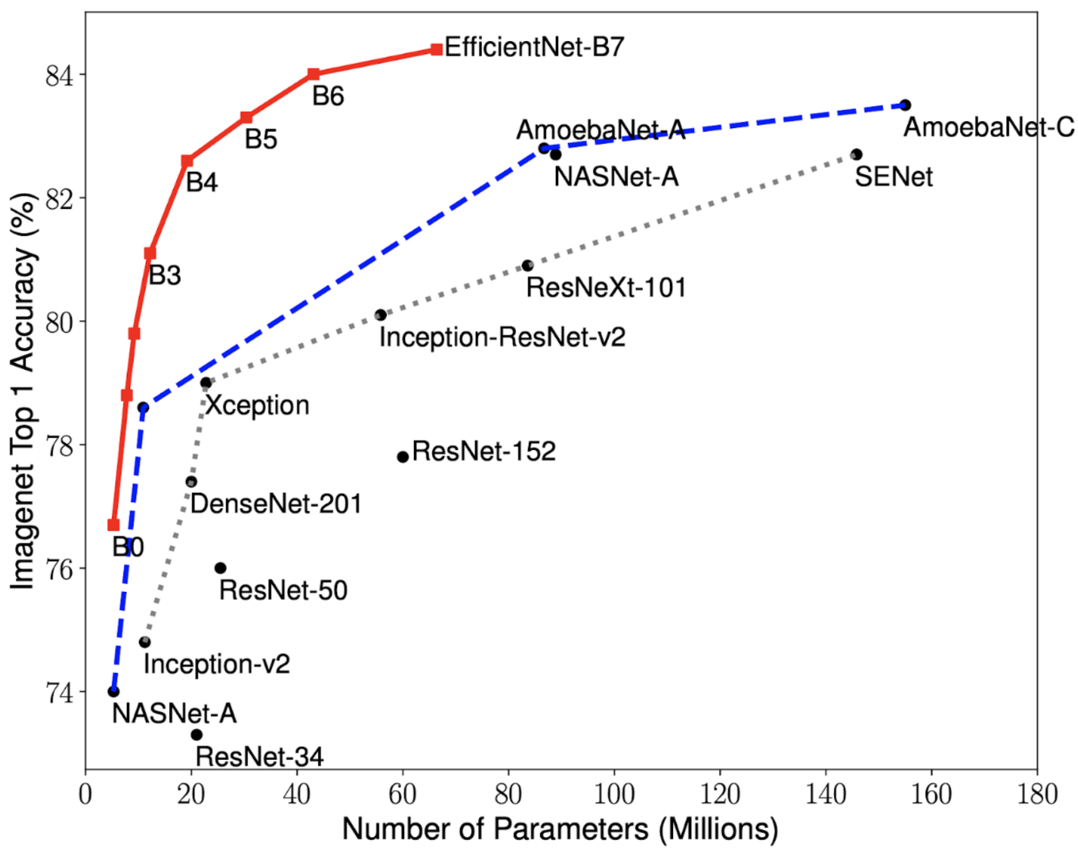

Figure 1.4: Advantage of using EfficientNet architecture for training as compared to other architectures in the model size vs accuracy comparison [6]

1.4.2.2 Training and Prediction

Training results achieved 81% accuracy and 61% validation accuracy, with a batch size of 32 per iterations, and a total of 60 epochs with image size scaled to 192x192, using a 75:15:10 split for training, testing, and validation. The number of trainable parameters achieved is 46,618 with global average pooling with dense layer. And finally, the SoftMax layer uses probability distribution to give final prediction, selecting the highest probability of the 26 classes.

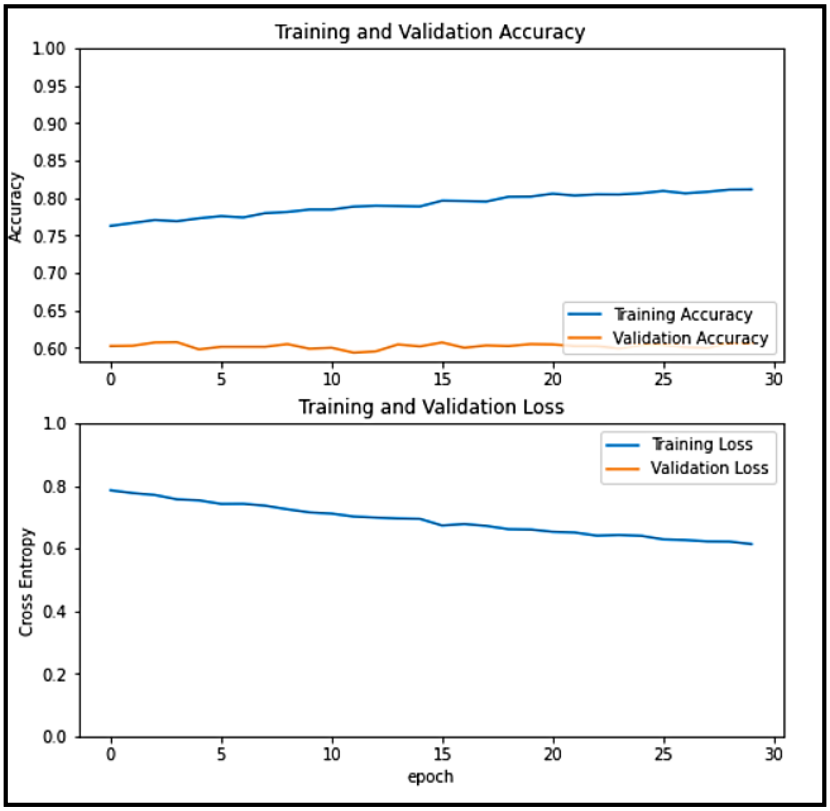

Figure1.5: Training and Validation Accuracy of through EfficientNet-B4 architecture.

Layer (type)	Output Shape	Param #
input_2 (InputLayer)	[(None, 192, 192, 3)]	0
efficientnetb4 (Functional)	(None, 6, 6, 1792)	17673823
global_average_pooling2d (GlobalAveragePooling2D)	(None, 1792)	0
dense (Dense)	(None, 26)	46618

Total params: 17,720,441
Trainable params: 46,618
Non-trainable params: 17,673,823

Figure 1.6: Layers of trained model and number of parameters

1.4.3 Output Extraction:

The outputs are extracted based on features of the insects, leading to detection of the class of the insect pest. Each class of detected crop pests are linked with the standard use of suggested pesticides to guide specialists and farmers.

1.4.4 Integration with Android Application

The different modules are then integrated in to one stand-alone entity in the android application. This stand-alone entity is essential for a compact solution. TensorFlow lite is used for Quantization of trained model to work with smartphones, it is the main tool for integration of the trained model to work with the android application.

1.4.5 GUI presentation in application:

The visual demonstration and end working of the project is done through an android application, where user will be able to take picture of insect pest and get classification and remedy to get rid of that insect pest. TensorFlow lite is used for Quantization of trained model to work with smartphones, with input option from both gallery and the camera app. It predicts the insect pest class and gives remedy. The application has been mainly developed for farmers, so buttons and instructions are Urdu language based, except some inevitable terminologies which are in English. The application has been designed on a friendly GUI basis for ease of use and aesthetics.

1.5 Objectives

1.5.1 General Objectives:

"To build an innovative state of the art software application prototype powered by Deep Learning and Convolutional Neural Network techniques, providing empowerment to farmers to better crop yield , reduce crop damage and health issues caused by infected crops by insect pest."

1.5.2 Academic Objectives:

- Development of Android application which uses CNNs and Deep Learning techniques to curb insect pest damage in the agriculture sector.
- To implement Deep Learning techniques and simulate the results
- To increase productivity by working in a team
- To design a project that contributes to the welfare of society, especially in agriculture sector.

1.6 Scope

In the Asia, Pakistan is famous for exporting agricultural products in a large number which greatly affects the economy. For agricultural 42% of manpower has been utilized. The remaining population totally depends on it., both in terms of food security and GDP as shown in figure 7. Agricultural products in high quality are mostly imported to other countries. The quality greatly depends on good crops production. To achieve this, the damage from insect pests should be lower at an earlier stage. Also, products obtained by using wrong pesticides are not healthy and can cause diseases. Insect pests detection and identification in the agricultural fields is one important challenge in our country. To overcome this damage, effective and systematic measures should be implemented to minimize the usage of chemicals and other pesticides.

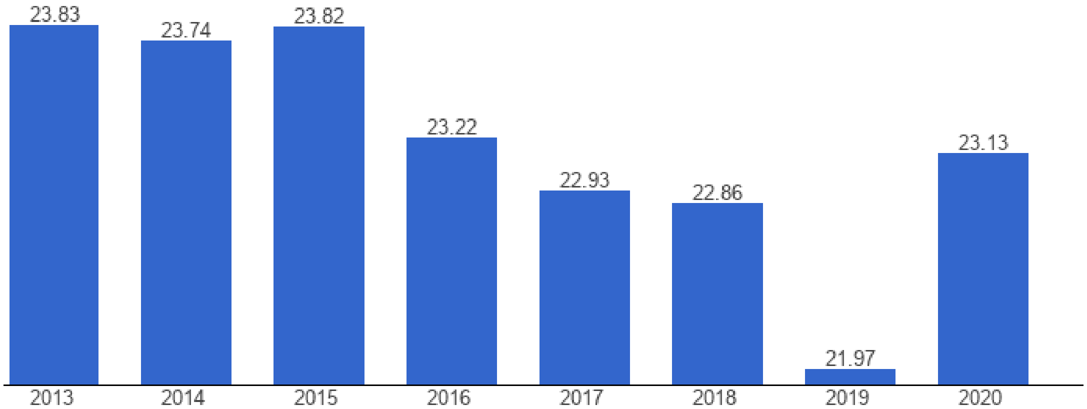

Figure 1.7: Value added in the agricultural sector of Pakistan as percent of GDP from 2013- 2020 [15]

A large literature has been proposed on various insect detection which is limited to computer hardware and can only be deployed on a powerful computer system. Bringing this system to run on a smartphone with low computation power and resources is another challenge. This challenge can be solved by utilizing a deep learning mobile net that allows running a model without any hurdles.

Therefore, automatic insect pests detection and identification advance the monitoring and management of the crops and decrease a farmer's efforts. Manual management and monitoring of crops are heavily manpower dependent, which also requires deep agricultural knowledge and self-analysis. It is a lengthy and cumbersome process still, in the present 21 century of the technological world.

1.7 Deliverables

1.7.1 Classification of Insect pest

It serves to identify and classify insect pest by using a combination of CNNs and deep learning techniques with the help of smart phone camera and a pre-fed data set in real time

1.7.2 Solution for pest removal

It can suggest a remedy for the removal of the Insect Pest when the insect pest class is predicted through the android application in the smart phone.

1.8 Relevant Sustainable Development Goals

The following Sustainable Development Goals (SDGs) are the main aim for this project, along with these other goals and objectives are already discussed in scope of work section.

- **Zero Hunger and food security:**
  This system will help to ensure food security and improved nutrition. Thus, overall leading to promote sustainable agriculture and healthy foods & crops.

- **Decent work and economic growth:**
  Using this system the overall crops and agriculture field of the country will improve. A better and healthy yield of crops will be obtained, which will ensure the inclusive and sustainable economic growth of the country.

- **Responsible production and consumption:**
  Using this system, the production and consumption of crops and agriculture field of the country will improve. A better and healthy yield of crops will be obtained, which will ensure the less wastage of crops.

1.9 Structure of Thesis

- Chapter 2 contains the literature review and the background and analysis study this thesis is based upon.
- Chapter 3 contains the Software Requirement Specification
- Chapter 4 contains System Design and implementation
- Chapter 5 contains the conclusion of the project
- Chapter 6 highlights the future work needed to be done for the commercialization of this project.

Chapter 2: Literature Review

A new product is launched by modifying and enhancing the features of previously launched similar applications and products. Literature review is an important step for development of an idea to a new product. Likewise, for the development of a product, and for its replacement, related to agriculture crops, a detailed study regarding all similar projects is compulsory. Our research is divided into the following points.

- Classical approaches
- Previous Work and their drawbacks
- Research Papers

2.1 Classical approaches

To prevent crops from insect damage on an early basis, the handcrafted method can be used which is heavily time is taken, required expertise and hectic process for many crops field. On the other hand, Artificial intelligence can significantly help us to reduce or prevent the crops from insects and make easy the prevention process on large scale. To detect insect pests in the early stages, various techniques have been used, i.e. static images where the images are scanned first and then processed by using computer vision insect pest detection techniques. [7]. Similar work has been proposed by Shen et al. for the detection and identification of pests by using R-CNN [8] with a custom inception-v3 model. An effective solution has been proposed in [9], which automates the whole process. The proposed system takes a picture of the trapped insects in crops and analyzed them using the proposed Deep Neural Network algorithm and sends alarms in case of detection. Further, the system is fully automated for the whole season. In the end, a report has been generated which effectively decreases the chances of insect attack by taking proper on-time arrangements. The prototype is designed with an embedded platform powered by a small solar panel to achieve an energy-neutral balance. However, this solution is not effective computation cost-wise. With the advancement of the resources various to end the computation limitation various deep learning architecture has been proposed which can be easily run on a handheld mobile device. Xie Et proposed a small robot based on a mobile camera for real-time detection and identification of pyralide species [10]. Insect-like grasshopper has been detected and identified by using a deep learning framework MAESTRO from static RBG images. But the scope of these proposed systems is limited using low number of categories and accuracy parameters. [11] All these proposed architectures required high computation and time and resources to train the model from the scratch and can only be implemented on high processing computers, or need high amount of resources.

2.2 Previous Work And their drawbacks

Previously, a mobile application of agricultural pests recognition using deep learning in cloud computing system has been developed by student of Shaqra University, Saudi Arabia. [12]. It achieves image-based recognition of different classes of crop pests using Faster R-CNN in an intuitive manner. However, utilizing cloud computing services this application can work only online and has many dependencies on the quality and availability of internet, as compared to our project which is aimed at being used in the hands of a farmer who supposedly does not have an internet connection in village areas in countries like Pakistan. Moreover, the dataset used in this project consists of a wide variety of insect pests, as compared to our project which is specifically based on insect pests classes found in Pakistan.

Another similar project based in Department of Science and Technology, India by Author K. Thenmozhi, using machine learning and image pre-processing and image augmentation.[13] Techniques used involved ANN, SVM, KNN, Naive Bayes, and the CNN model. Results from the CNN model provided the highest classification accuracy of the lot, which helps in reducing computation time. Project SIPDIS also revolves around the same technique of using CNNs to achieve higher accuracy in training and testing, but with using Deep learning techniques we can get recognition of multi insects and insect images with different periods of growth in agriculture field crops, and for bigger datasets. This project uses generalized classes of insects, as opposed to using specified classes of insect pests which target a specific country, saving both time and resources for getting desired results.

2.3 Research Papers

A similar project used for research and analysis by Ileladewa Oluwatimilehin Adekunle "Deep Learning Detector For Pests And Plant Disease Recognition"[14]. This paper mentions usage of image preprocessing, RCNN, SDD MobileNet and Deep Learning Techniques, for the detection of plant diseases and consequently integrated into a mobile application, similar to SIPDIS in many ways but instead of detecting and classifying insect pests, this paper aims fully at plant diseases, and does not only aim at recognizing different leaf diseases by using a bulky dataset of images, but also attempts to recognize its position and location for the growth of a real-time system with several light conditions. This research paper has been used for guidance and inspiration for project SIPDIS, in the way how a small application can go a long way to help society and bring opportunities to those who need them..

2.2.2 Data Collection

Project SIPDIS uses IP102 which is a large-scale dataset for insect pest recognition by Xiaoping Wu. It contains more than 75,000 images of insect pests belonging to 102 categories. This dataset has a hierarchical classification. The insect pests which mainly mark one specific agricultural product are grouped into the same higher-level class. In addition, it has 19,000 images with bounding boxes for object detection. [4]

This project uses a custom build dataset of the insect pests only found in Pakistan, from the original dataset IP102. This is done to save time from training of unnecessary images of insect pests, and to save the hassle from predicting classes not found in Pakistan, therefore saving confusion and time. It also serves to save time on training and testing, making the end application lightweight for an average smartphone to handle smoothly without much processing power. The image size is been set as 192x192, with a maximum of 800 images from each of the 26 classes to avoid class imbalance and to make it computationally feasible. The name of the 26 classes is mentioned in the working principle of this document.

Chapter 3: Sotware Requirement Specification

3.1 General Description

Insect pests cause to damage crops worldwide. This problem greatly impacts agricultural products and thus results in low quality and quantity of crops and other agriculture related items. It not only destroys the product but also wastes precious time and farmer empowerment. This issue is very critical and has a direct impact on reducing the economy and food security worldwide. However, due to a large number of insect pests and their types throughout the globe people need agriculture domain experts to easily identify these insect pests. It is important because they then have to use the right pesticide or chemical to get rid of them. In this project, our aim to is to optimize and manage the agricultural crops from insects and pests by developing an automatic insect/pests detection and identification system. This system will be an application that can easily be used by the farmers and other relevant people of this field to identify the pest using camera image through their device.

3.1.1 Product Features

- Faster and less time consuming.
- More accurate in results.
- Easy to access, use and understand.

3.1.2 User Classes

Farmers, food experts, crops yielders/stakeholders

3.1.3 Characteristics

- Quicker to detect insect or pesticide
- Give precise results
- Simple to use.

3.1.4 Operating Environment

Following technologies and skills will be used for this project:

1. Object-Oriented Programming concepts.
2. Python Programming Language.
3. Jupyter Notebook (python; for testing and training of model).
4. TensorFlow model optimization.
5. Django Rest Framework (DRF) for API Building.
6. Flask Framework for mobile-related API.
7. Front-end technologies for application interface development.
8. Android Studio (java; for mobile application development)

3.1.5 Design

Outlines of the design of project are:

- Mobile interface GUI
- Back-end API with CNN model

3.1.6 Implementation constraints

In Implementation constrains we should have to consider the system requirement of that operating device where we want to run it. High processing power is needed so minimum RAM of 1.5 GB will be used in system.

3.1.7 Product Design

Product will be designed as Android App using Python Deep Learning Software , Jupyter Notebook (for testing and training of model, TensorFlow model optimization, Django Rest

Framework (DRF) for API Building., Flask Framework for mobile-related API, Front-end technologies for application interface development, Android Studio for mobile application development.

3.1.8 Dependencies

The product will be dependent on the size and quality of the data-set used. The kinds of images and the quality of those images will decide the result product gives.

3.1.9 Preparing Dataset

Project SIPDIS uses IP102 which is a large-scale dataset for insect pest recognition by Xiaoping Wu. It contains more than 75,000 images of insect pests belonging to 102 categories. This dataset has a hierarchical classification. The insect pests which mainly mark one specific agricultural product are grouped into the same higher-level class. In addition, it has 19,000 images with bounding boxes for object detection. [4]

This project uses a custom build dataset of the insect pests only found in Pakistan, from the original dataset IP102. This is done to save time from training of unnecessary images of insect pests, and to save the hassle from predicting classes not found in Pakistan, therefore saving confusion and time. It also serves to save time on training and testing, making the end application lightweight for an average smartphone to handle smoothly without much processing power. The image size has been set as 192x192, with a maximum of 800 images from each of the 26 classes to avoid class imbalance and to make it computationally feasible. The name of the 26 classes is mentioned in the working principle of this document.

Figure 3.1: Proposed Dataset for training and testing of model

3.2 Specific Requirements/ External Requirements

3.2.1 User Interfaces

- **Home Screen:**

A sample home screen will be displayed which contain the basic header menu i.e. Home, agricultural pesticide detection button.

- **Pesticide detection:**

This page will contain a frame, input image button, and prediction button. The frame will contain the image after a user selects it.

- **Static Image Button Screen:**

This screen contains an input image frame, a select image button, and a prediction button and text label.

- **Input Image:**

This frame will show the image after selecting from the gallery before prediction.

- **Prediction calculation**

Prediction calculation waiting screen.

- **Prediction:**

This button will load the optimize mobile version deep learning trained model and will try to predict the image and display the image in the image frame.

- **Open Camera:**

This button will open the camera and try to start prediction on the prompt of the user captured image.

3.2.2 Hardware and Software Interfaces

- As it will be an android based application, no external hardware would be required other than a smart phone.
- Android implementation will be provided to the users.

3.3 Functional Requirements

In this section the requirements are specified which describe the basic functionality of the Application.

- **Functional Requirement 1**

  IDENTITY: F.R 1

  TITLE: Input of required images.

  DESCIPTION: User should be able to input one required images i.e. image of agricultural crops

  RAT: In order to predict and detect the pesticide of crop.

  DEPENDENCY: none

- **Functional Requirement 2**

  IDENTITY: F.R 2

  TITLE: Input image resize.

  DESCIPTION: User input image should be in predefined size, if the image size will be checked before further processing.

  RAT: To resize the input image for further processing

  DEPENDENCY: F.R 1

- **Functional Requirement 3**

  IDENTITY: F.R 3

  TITLE: Detection if provided images of agricultural crops is completely visible.

DESCIPTION: Provided Images should be tested using image processing techniques to check

if

Crops contain pesticide insect is visible or if there is any kind of distortion in images.

RAT: To verify if provided input is accurate to proceed for further processing.

DEPENDENCY: F.R 1

- **Functional Requirement 4**
  IDENTITY: F.R 4

  TITLE: Predict and classify pesticide.

  DESCIPTION: After providing required input, the input image will be passed on to CNN

  model to

  Evaluate, and predict accurate pesticide insect.

  RAT: In order to predict accurate pesticide insect of agricultural crop.

  DEPENDENCY: F.R 1, F.R 2

3.4 Use case specification

User Case Title	Input Image
Use Case Id	1
Requirement Id	F.R 1
Description: This use case about select and input image for prediction module	
Normal Flow	
1. User can selects an image from gallery. 2. User can select the predict button to start prediction.	

Alternative Flow
1. User select wrong image from the gallery − Application will work normally but no prediction will be showed.
Post Conditions: - Image will be successfully acquired and displayed on the frame box.
Open issues: - if the image size is lower than the normal one then it will cause run time prediction error.
Authority: - Device owner

User Case Title	Resize input image
Use Case Id	2
Requirement Id	F.R 2
Description: This use case is about resizing the image to the desired shape.	
Normal Flow	
1. User will select an input image. 2. System validates the first image 3. User will click on predict button	
Alternative Flow	
1a. User select lower size image instead of normal one − Application will show error message. 1b. User do not select any image − User selects image from gallery − System validates the image	

1c. User only provides one image to the system − System asks user to input second image
Post Conditions: − Image will be resized successfully
Open issues: − No
Authority: - Device owner

User Case Title	Run the application
Use Case Id	3
Requirement Id	F.R 3
Description: This case is about detection if input images is completely visible.	
Normal Flow	
1. Input image will be analyzed and predict 2. User can wait for until the prediction results are output	
Alternative Flow	
1a. Application will get stuck while predicting the input image	
Post Conditions: - This will show the prediction score on the user application text view	
Open issues: - Small amount of RAM on device.	
Authority: - Device owner	

User Case Title	Predict class of image
Use Case Id	4
Requirement Id	F.R 4
Description: This use case is about displaying drawing bound box around the ROI and output the predicted score and class label.	
Normal Flow	
1. User will click on the prediction button. 2. User will wait for the system output response. 3. Data is sent to RCNN model. 4. App moves to waiting state. 5. Model returns image with category. 6. Class of image is shown	
Alternative Flow	
1a. Image have no pesticide insect. - User will be prompted by system to try on different image again. **2a. Values are not returned.** - System will repeat the step 1 so system can get values to show on screen.	
Post Conditions: - Measurements are shown on app screen.	
Open issues: - No apparent issues.	
Authority: - Device owner	

User Case Title	Store the image contain bounding box
Use Case Id	5
Requirement Id	F.R 5
Description: This use case is about storing image with class and remedy.	
Normal Flow	
1. System has generated the image with class and remedy. 3. System prepare the image to be saved 4. System saves the image in local storage	
Alternative Flow	
1. User does not want to save the 3d model 2. User wants to save model but space is full - User will be shown error message and will be asked to free some memory	
Post Conditions: - User will be shown success message after saving image	
Open issues: - None	
Authority: - Device owner	

3.5 Non Functional Requirements

3.5.1 Performance Requirements

The hardware specifications for mobile performance requirements like memory restrictions, cache size, the processor, RAM size, etc. are specified. Which are required for the application to perform functions and make all operations response time effective. These include CPU speed to be at least 2000 MHz, 1.5 GB min RAM, cache size of 500 KB, and internal memory required is between 100 –500 MB for the mobile application to install and run. For the smooth performance of the application and to perform all requirements error handling and response to unexpected situations are encountered.

3.5.2 Security Requirements

The application does not deal with any kind of privacy or security issues. The images that the user will upload will be stored on mobile devices only. And will not be uploaded to any server-side. Along with this, the permissions that the application acquires initially will not be used to get hold of the user's data on a mobile device. Hence, with respect to the user's data security, this application does not pose any security threat.

3.5.3 Reliability Requirements

The application is able to avoid or tackle disastrous actions. Moreover, the app will not crash and is reliable to use.This means that no component or system as a whole will not damage or disturb the functionality of any device component. The system safeguards against undesired events, without human intervention.

3.5.4 Portability Requirements

The application would not be architecture-specific. It would be easily transferable to other different a version of the android system if needed.

CHAPTER 4: System Design and Implementation

4.1 Introduction

The introduction of the Software Design Specification (SDS) document provides an overview of the entire SDS with purpose, scope, definitions, acronyms, abbreviations, and references. The aim of this document is to present, in detail, the functional and non-functional aspects of Spontaneous Insect Pest Detection and Identification System (SIPDIS) which uses image processing techniques and deep learning to detect and identify insect pest. The detailed descriptions and visualizations of Spontaneous Insect Pest Detection and Identification System are provided in this document.

4.1.1 Purpose

This software design document describes the architecture and system design of Spontaneous Insect Pest Detection and Identification System, Version 1.0. The document is meant to provide details about the features design and requirements of SIPDIS, to serve as a guide to the developers on one hand and a software validation document for the potential clients on the other. This document includes classes and their inter-relationships, use cases with detailed descriptions, sequence diagrams and various flow charts.

4.1.2 Scope

In the Asia region, Pakistan is famous for exporting agricultural products in a large number which greatly affects the economy. For agricultural 42% of manpower has been utilized. The remaining population totally depends on it. Agricultural products of high quality are mostly imported to other countries. The quality greatly depends on good crop production. To achieve this, the damage from insect pests should be lower at an earlier stage. Also, products obtained by using pesticides are not healthy and can cause diseases. Insect pest detection and identification in the agricultural fields is one important challenge in a country.

Therefore, this challenge should be considered on priority. To overcome this damage, effective and systematic measures should be implemented to minimize the usage of chemicals and other pesticides. A large literature has been proposed on various insect detection which are limited to computer hardware and can only be deployed on a powerful computer system. Bringing this system to run on a smartphone with low computation power and resources is another challenge. This challenge can be solved by utilizing a deep learning mobile net that allows running a model without any hurdles.

Therefore, automatic insect pest detection and identification advance the monitoring and management of the crops and decrease the man's efforts. Manual management and monitoring of crops are heavily manpower dependent, which also requires deep agricultural knowledge and self-analysis. It is a lengthy and cumbersome process still, in the present 21 century of the technological world. The proposed system can also be enhanced by integrating it into a vehicle robot which further decreases the time cost of monitoring a large number of crop fields.

4.2 System Overview

The main objective of our system is to create Spontaneous Insect Pest Detection and Identification System (SIPDIS). The system will take picture in form of jpg format of minimum 256x256 resolution, or have one uploaded from the gallery rescaled to same resolution. After uploading the image Insect Pest Detection and Identification starts, image pre-processing is applied which includes image resizing, reducing image noise and implement trained model on the resized images. The system is comprised of 5 major modules

I. Image Acquisition module
II. Pre-Processing module
III. Deep Learning module
IV. Insect classification module
V. Visualization module

4.3 System Architecture

This section covers the overall architectural description of SIPDIS. It encompasses the high-level and low-level descriptions of the project including block diagrams of the application and the deep learning model. Moreover, a complete object-oriented description which includes class diagrams, sequence diagrams and others. Finally, the rationale for the design pattern is provided.

4.3.1 Architecture Design

The system uses layered architecture. The modules have a sequential relationship such that the input is dependent on its predecessor module. The image acquisition module will take input and then it will be processed by the Pre-processing module which will resize images and apply pre-processing techniques. Then the model is applied on images for insect pest classification.

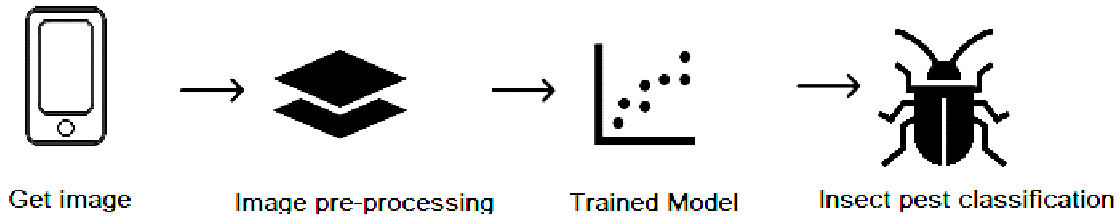

Figure 4.1: Showing the steps in general

4.3.1.1 Block Diagram

This diagram shows the higher-level description of the application. It shows all the modules of the system and their associations and flow of data between modules:

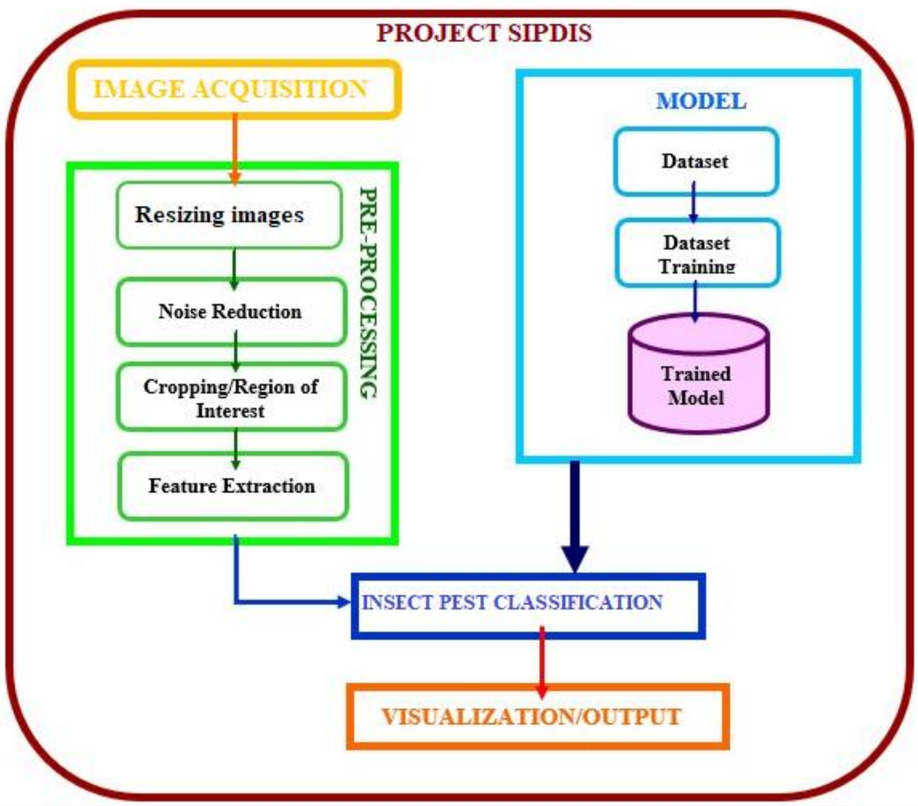

Figure 4.2: Block Diagram representing diagram of a system in which the principal parts or functions are represented by blocks connected by lines that show the relationships of the blocks

- Image Acquisition enables the system to acquire image from the user who will upload it into the application. This image shall be fed into the system for further processing.
- Pre-Processing module involves sending the image to the model where it is resized.
- Model module images shall be analyzed, and features will be extracted from the image.
- Visualization module shall give a final visualization of insect pest in image.

4.3.2 Decomposition Description

4.3.2.1 Component Diagram

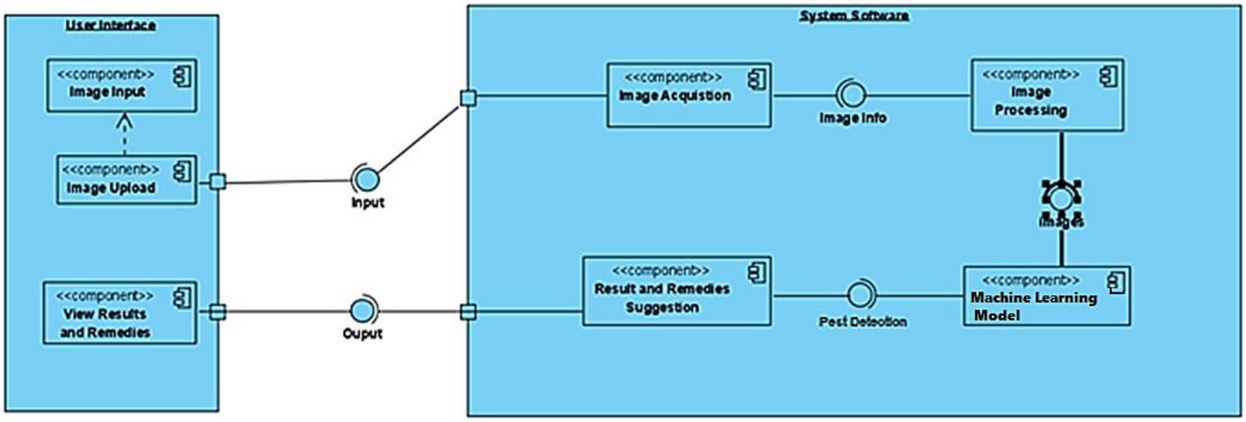

Figure 4.3: Component Diagram describes the organization and wiring of the physical components in a system

4.3.2.2 Class Diagram

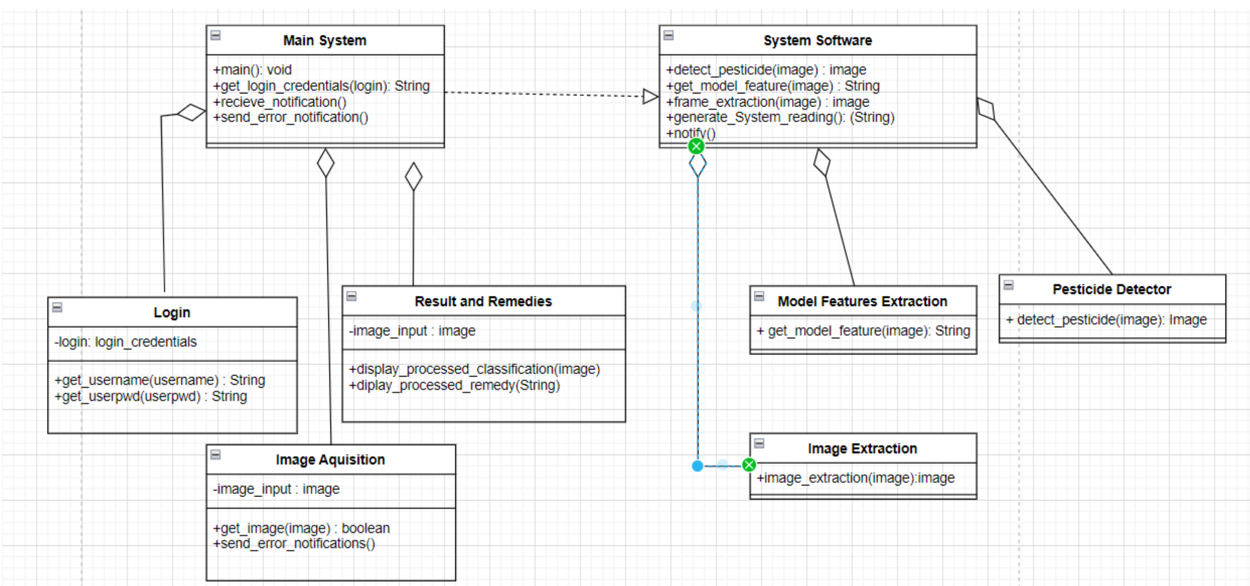

Figure 4.4: Class Diagram is a type of static structure diagram that describes the structure

4.3.2.3 Class Description

Class Name	Description
Login	This will verify the login attributes which are username and password
Android Application	It is the main class that starts when the user interacts with the system. It receives notifications and readings from the system software for pest detection.
Image Acquisition	This class gets image from the user
Result Visualization	This class displays result to the user
Model Features Extraction	This class performs feature selection technique on the images
Pest Detector	This class will classify and implement the image pest detection methods
Image Readings	This class gets readings about the pest detection and saves data
System Software	It receives images from the main system and then uses its methods to detect insect pest

Figure 4.5: Class Description a brief summary of the of the modules of the system

4.3.2.3 Use Case Diagram

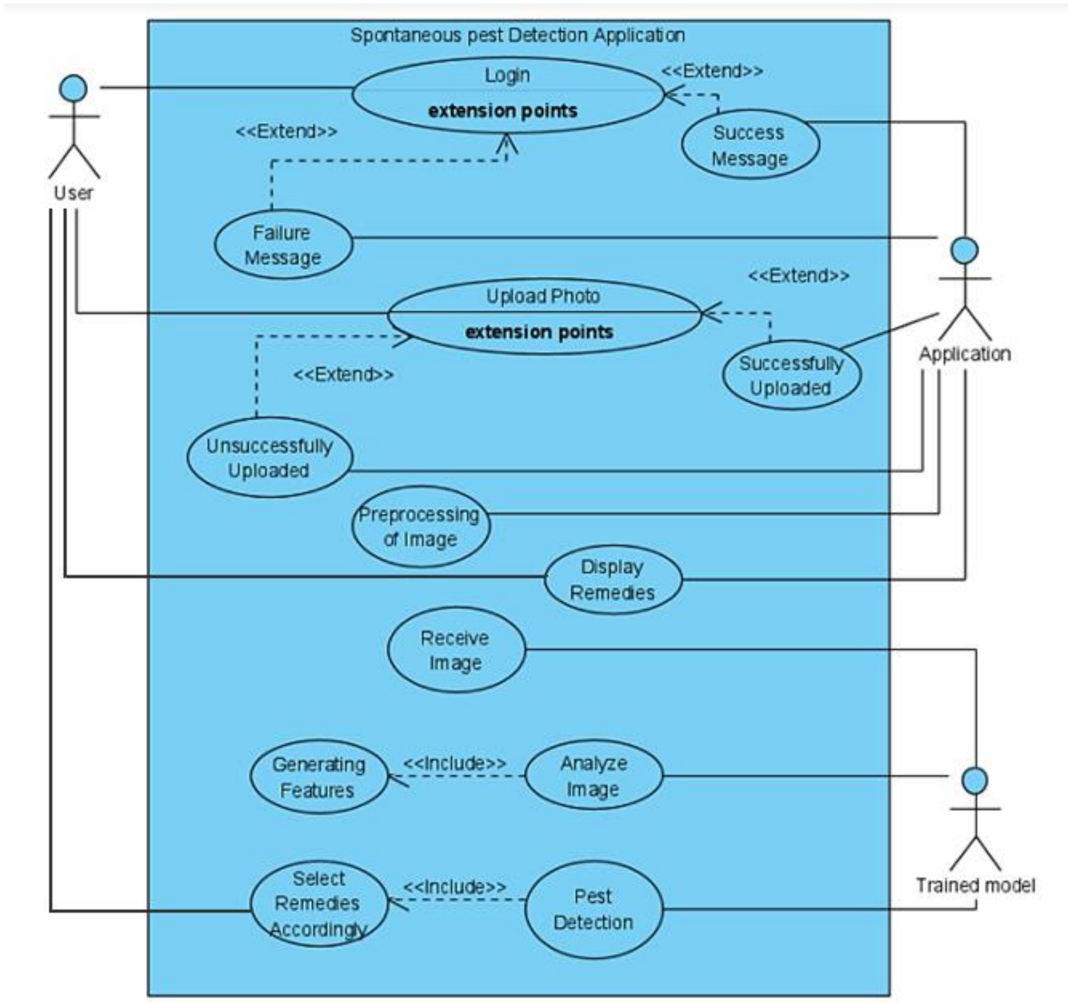

Figure 4.6: Use Case diagram: Graphical depiction of a user's possible interactions with a system

4.3.2.4 Activity Diagram

1. Image Acquisition:

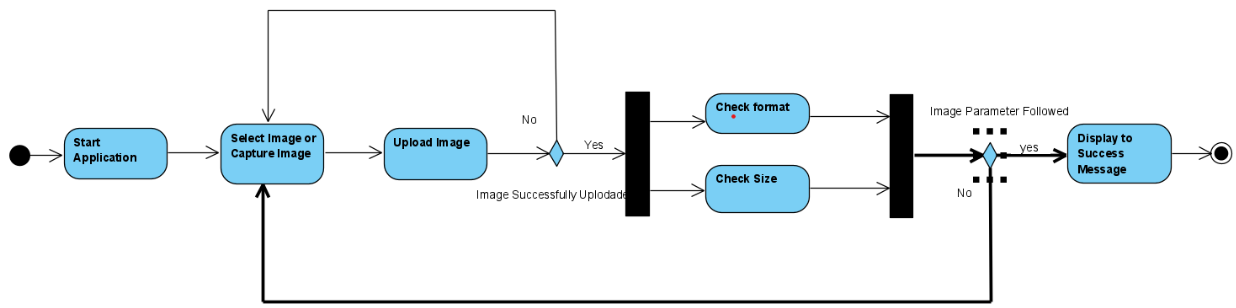

Figure 4.7: Activity Diagram for Image Acquisition

2. Image Processing

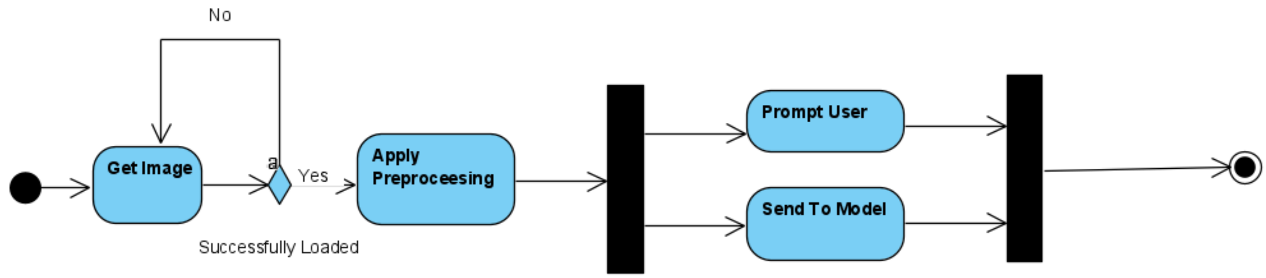

Figure 4.8: Activity Diagram for Image Processing after acquisition

3. Check for insect pest

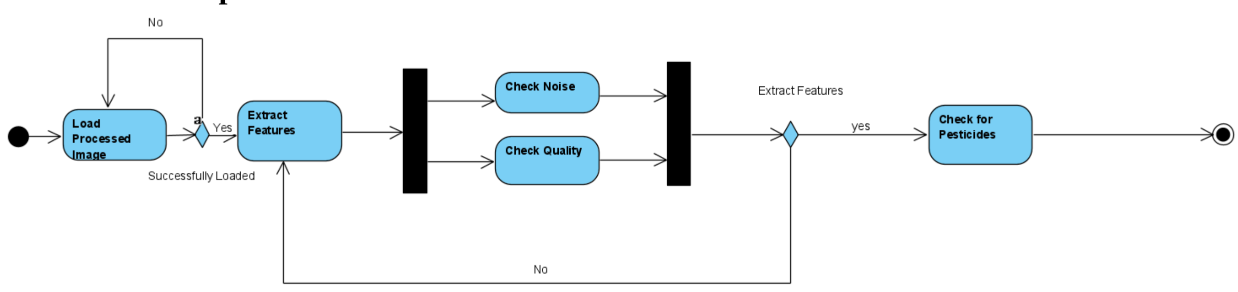

Figure 4.9: Activity Diagram for Classification of pest.

4. **Display remedies**

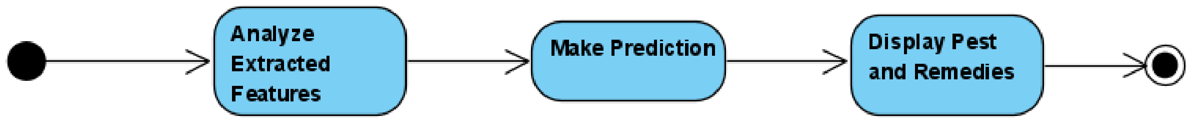

Figure 4.10: Activity Diagram for Displaying pest and remedy after Classification

4.3.2.5 Design Description

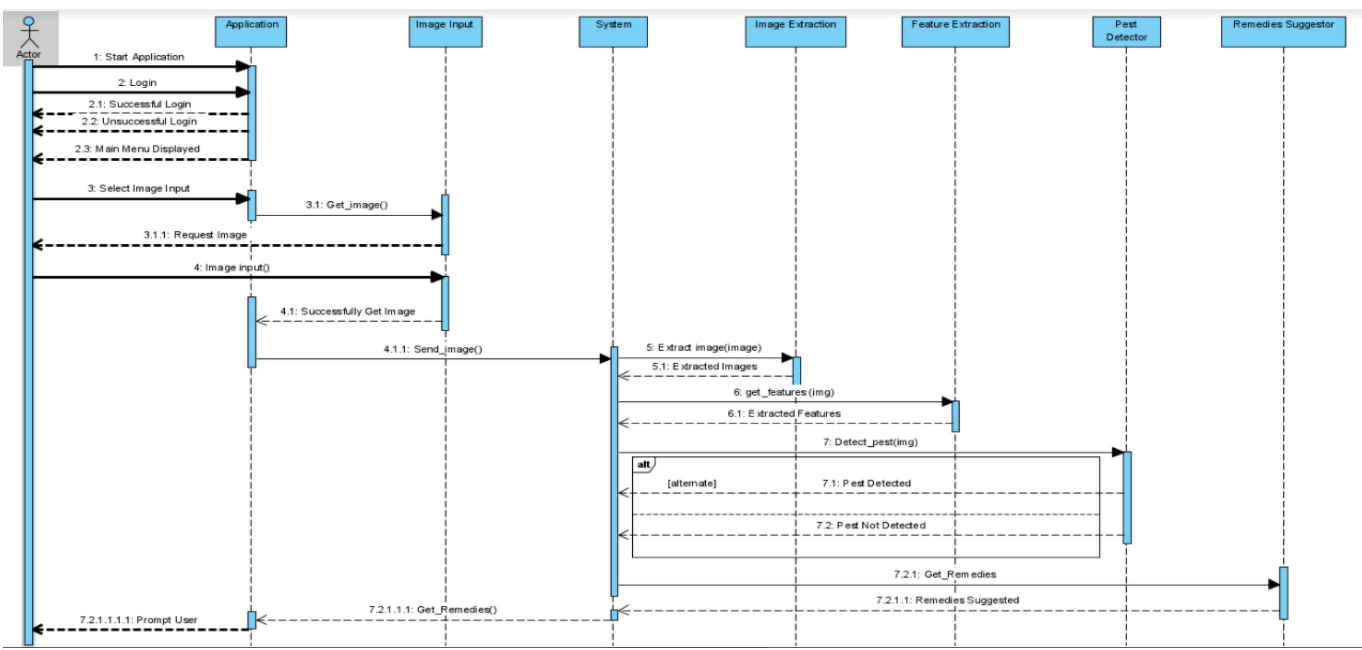

Figure 4.11: Design Description is the process of envisioning and planning the creation of objects, interactive systems

4.3.2.6 State Transition Diagram

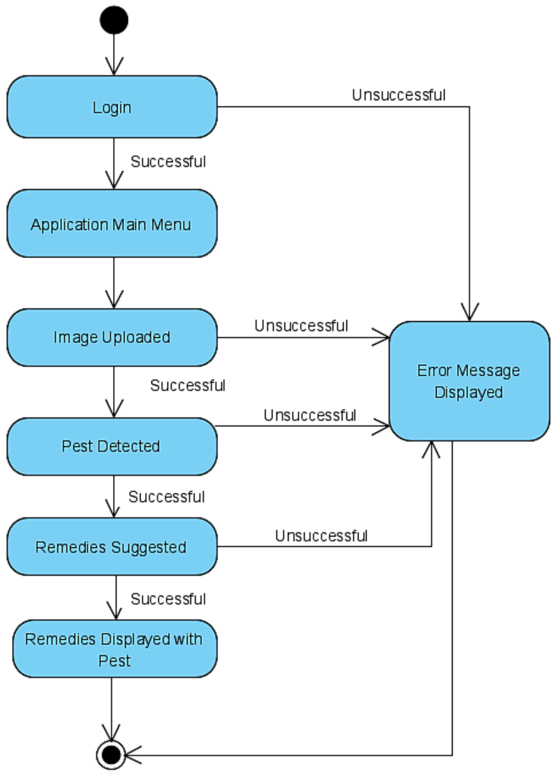

Figure 4.12: State Transition Diagram is a type of diagram used in computer science and related fields to describe the behavior of systems.

4.4 Data Design

4.4.1 Data Description

Project SIPDIS uses IP102 which is a large-scale dataset for insect pest recognition by Xiaoping Wu. It contains more than 75,000 images of insect pests belonging to 102 categories. This dataset has a hierarchical classification. The insect pests which mainly mark one specific agricultural product are grouped into the same higher-level class. In addition, it has 19,000 images with bounding boxes for object detection. [4]

This project uses a custom build dataset of the insect pests only found in Pakistan, from the original dataset IP102. This is done to save time from training of unnecessary images of insect pests, and to save the hassle from predicting classes not found in Pakistan, therefore saving confusion and time. It also serves to save time on training and testing, making the end application lightweight for an average smartphone to handle smoothly without much processing power. The image size has been set as 192x192, with a maximum of 800 images from each of the 26 classes to avoid class imbalance and to make it computationally feasible. The name of the 26 classes is mentioned in the working principle of this document. In addition, special classes targeting Pakistan's Insect pest will be added to the dataset with help from sources from University of Agriculture Faisalabad (UAF). This will bring a generalized dataset to a more customized version for national usage, consequently helping famers from Pakistan on first needs basis.

4.4.2 Data Dictionary

Dataset Name	Details	Source
Aphids	80%– training 20% – testing	https://github.com/xpwu95/IP102/blob/master/README.md
Cicadellidae	80%– training 20% – testing	https://github.com/xpwu95/IP102/blob/master/README.md
Cabbage Army Worm	80%– training 20% – testing	UAF

Wheat Phloeothrips	80%– training 20% – testing	UAF
Yellow Rice Borer	80%– training 20% – testing	https://github.com/xpwu95/IP102/blob/master/README.md

Figure 4.13: Data Dictionary is showing us the classes, their proportion and source from where we have collected the dataset.

4.4 User Interface

- Login screen:

Login screen Contains the space to enter the credentials and login button.

Figure 4.14: Lock Screen

- Home screen:

Home screen contains options to select image either from gallery or camera app.

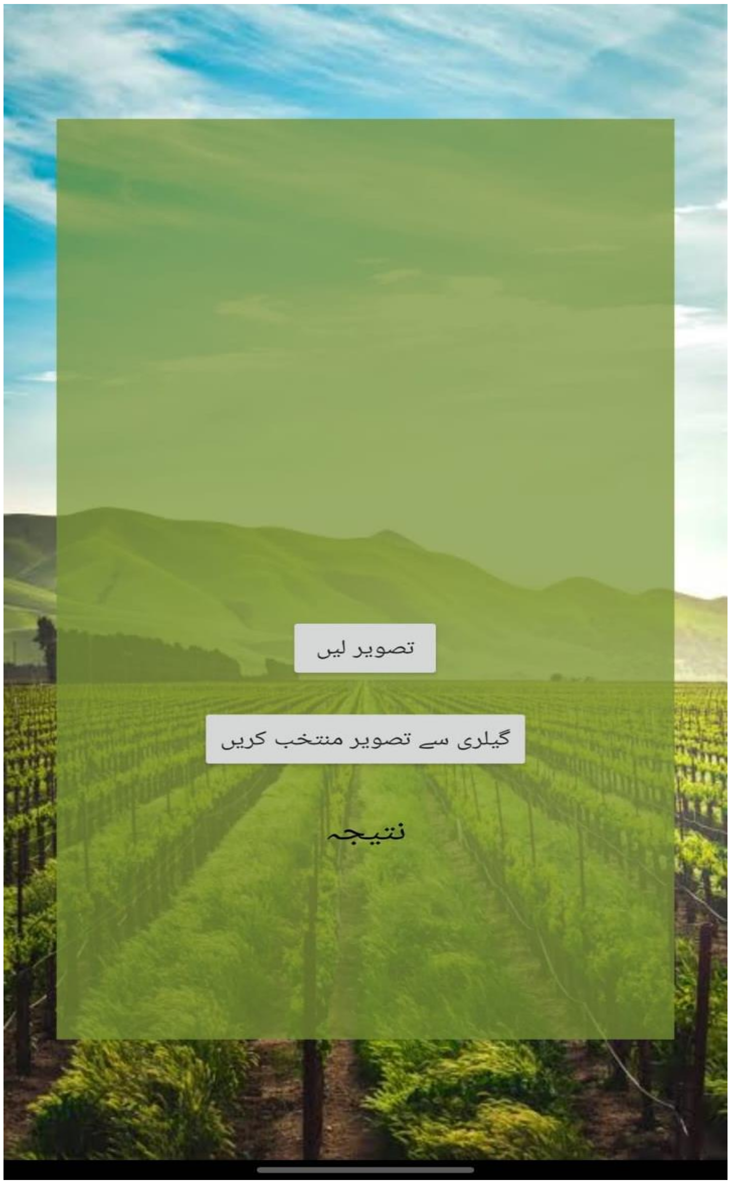

Figure 4.15: **Home Screen**

- Result screen:
Login screen shows the classification of insect pest and the remedy to get rid of it.

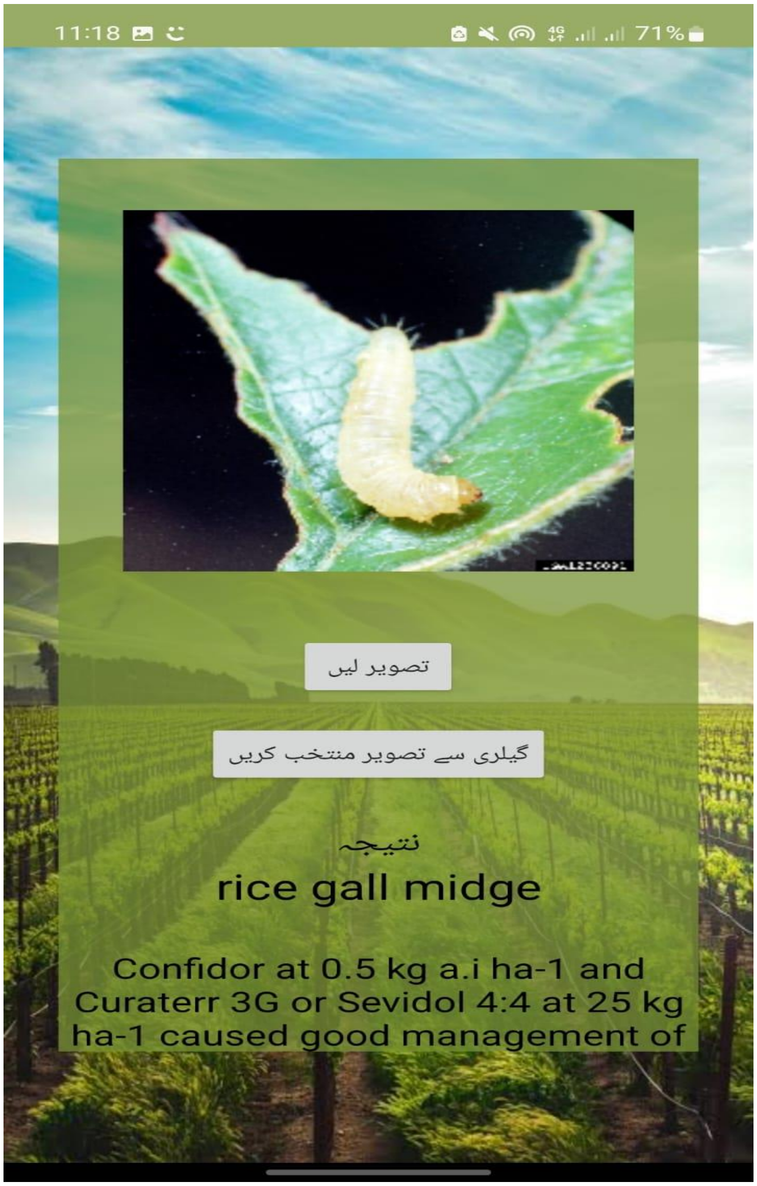

Figure 4.16: Result Screen

4.5 Implementation

- TRAINING

```
import matplotlib.pyplot as plt
import numpy as np
import os
import tensorflow as tf
from tensorflow.keras.preprocessing import image_dataset_from_directory

inputs = tf.keras.Input(shape=IMG_SHAPE)
X = data_augmentor(inputs)
X = input_preprocessor(inputs)
X = base_model(X)
X = tf.keras.layers.GlobalAveragePooling2D()(X)
outputs = tf.keras.layers.Dense(26, activation='softmax')(X)
```

- PREDICTION

```
mg_path = '/home/hamza/pest-classification-26/new_dataset/training/ yellow rice borer/02956.jpg'
preprocessed_img = preprocess_image(img_path, resize=(192,192))
# preprocessed image(numpy array) is given to model for prediction...
pred = saved_model.predict(preprocessed_img)
index = pred.argmax()
predicted_pest = class_order[index]
predicted_pest
```

4.5 Test Cases

Test Case Id	Test Case Description	Test Steps	Test Data	Expected Results	Actual Results	Pass/Fail
TU01	Check Farmers Login with valid Credentials	1. Go to app SIPDIS 2. Enter Username 3. Enter Password 4. Click Login	Username=ali Password=1234	Farmer should Login successfully	As Desired	Pass
TUO2	Check Farmers Login with invalid Credentials	1. Go to app #SIPDIS 2. Enter Username 3. Enter Password 4. Click Login	Username=ali Password 1235	Famer should not be able to log in successfully	As Desired	Pass
TU03	Check the picture from the gallery	1. Access gallery through SIPDIS 2. Select picture 3. Upload picture	Pest .JPG file	Should be able to predict results and remedy	As Desired	Pass
TU04	Take the picture from live input	1. Access camera through SIPDIS 2. Take picture 3. Upload picture	Pest .JPG file	Should be able to predict results and remedy	As Desired	Pass

Figure 4.17: Test Cases and their outcomes are shown

CHAPTER 5: Conclusion

5.1 Project Review

Throughout the development of the project, the chief objective has been to make a mobile based application with a insect pest detector integrated in it to predict and classify the insect pest. This was done using CNN architeture and deep learning techniques.

5.2 Problems encountered

The problems faced were mostly revolving around the type of images in the dataset, leading to lower accuracy rate and validation accuracy than aimed for. A class of insect pest had images from random sources with very different lighting conditions, and location, which caused some problems in the training phase. However, we were able to achieve enough accuracy for the project to work seamlessly. Another issue we faced was the lack of GPU in our computers for training such as large dataset such as the IP102, as average PC's would take a lot of time and online platforms such as collab were not free to use for larger amounts of RAM and GPU. This challenge too was tackled successfully in a way which it came to our advantage. We shortlisted and finalized 26 classes out of the 102 classes of the IP102 dataset, based on research and other sources, to customize our dataset according to Pakistan's need.

5.3 Discussions and Conclusions

In this project, we address insect classification and remedy. In the tangible world, farmers and other agriculture experts go through monotonous and time-consuming processes of visually carrying out examination of agricultural crops such as wheat, corn, fruits, and vegetables which are expected to be pretentious to damage by different insect pest, and does not assure a correct recognition and classification of the insect pest nor its removal. We fundamentally developed a system that effectively recognizes different insect pests and give a solution on how to remove them in the right way and with the right materials. Through this way, we can regulate the damage from becoming uncontainable and endangering food security.

5.4 Potential benefits and impacts

Food security is a topmost worry with the world population growth expected to be more than 9.7 billion by 2050 [16]. Agriculture Crop damage has been a hazard to food security. Thus, precise means need to be adjusted to recognize the insect pests and suitable actions need to be taken to get rid of them. This project makes an accessible, speedy, and accurate model for insect pest detection and removal so that suitable measures can be applied prematurely, therefore putting an end to the question of food security. Moreover, the android based smartphone application established in this project will be a treasured instrument for farmers, particularly for those who reside in parts that are deficient of the proper set-up and have inadequate facilities for the provision of agronomic guidance.

CHAPTER 6: Future Work

Future milestones that need to be achieved to commercialize this project are the following:

- The proposed system can also be enhanced by integrating it into a vehicle robot which further decreases the time cost for monitoring many crop fields.
- The project can have exceptional handling for non-insect/pests images, by throwing an error or recognizing that the input is not correct. Moreover, the training and validation accuracy needs improvement to better recognize the insect pest and reduce computational efforts and increase time of results.
- The mobile based Android application can be made to be run on iOS devices to appeal a larger audience and give further options to end users.
- Furthermore, construction of a wireless motion sensor system for real-time recognition of insect pests will be considered in the future work of our developed mobile-based recognition system.

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