INFORMATICS INSTITUTE OF TECHNOLOGY

UNIVERSITY OF WESTMINSTER

INFORMATICS INSTITUE OF TECHNOLOGY

DEPARTMENT OF COMPUTING

Module: 5COSC009C.2

Software Development Group Project

Module Leader: Mr. Guhanathan Poravi

Paddy Weed Detector

Team Hypesters		
Name	Iit ID	UoW ID
Akila Nanayakkara	2018400	w1742308
Kisal Wedage	2018368	w1742101
Moveen Wijerathne	2018541	w1742328
Amilakelum Kodikara	2018395	w1742107
Danushka Samarakoon	2018382	w1742106
Malshama Perera	2018446	w1742313

Table of Contents

List of Tables 4
Table of figures 4
1. Introduction 6
1.1. Chapter Overview 6
1.2. Problem boundary 6
1.2.1. Example for the problem 7
1.2.2. Problem Definition 7
1.3. Aim 7
1.4. Objectives 8
1.4.1. Research Objective 8
1.4.2. Operational Objectives 8
1.4.3. Academic Objectives 9
1.5. Features 9
1.6. Scope 9
1.6.1. In-Scope 9
1.6.2. Out-Scope 10
1.7. Resource Requirement 10
1.7.1. Software Requirement 10
1.7.2. Hardware Requirement 10
1.8. Document Structure 11
1.9. Deliverables 11
1.10. Chapter Summary 11
2. Literature Review 12
2.1. Chapter Overview 12
2.2 Introduction to Data Science. 12
2.2. Introduction for image processing 13
2.2.1. Image Pre-Processing 14
2.2.2. Image Segmentation 14
2.2.3. Feature Extraction 14
2.2.4. Classification of Images 14
2.3.1. Identification of the scope 15
2.3.2. Isolation of weed from the rest of the plants. 15
2.4. Previous work 19

2.5. Chapter Summary 20
3. Requirement Gathering 21
3.3. Chapter Overview 21
3.4. Selected Methodology 21
3.4.1. Approach 21
3.4.2. Strategy 21
3.5. Interview 22
3.6. Focus group discussion 22
3.7. Survey 22
3.5.1. Questioner Structure 23
3.5.2. Questioners 23
3.5.3. Responses 24
3.8. Rich Picture Diagram 29
3.9. Functional Requirements 30
3.10. Non-functional Requirements 31
3.11. Work Breakdown Structure 31
3.12. Chapter Summary 31
4. Design 32
4.3. Chapter Overview 32
4.2.1. Use Case Diagram 32
4.2.2. Use Case Descriptions 33
4.3. High Level Architecture 42
4.4. Domain Model 43
4.5. Class Diagram 44
4.6. Sequence Diagram 45
4.7. UI / UX Design 46
4.7.1. Activity Diagram 46
4.7.2. UI Wireframes 47
4.8. Chapter Summary 48
5. References 49
6. Bibliography 50

List of Tables

Table 1 Gross Harvested Area, Average Yield and production of paddy 2011/2012 - 2018/2019 Maha Kanna (Anon., 2019) 6
Table 2 Operational Objectives 9
Table 3 Academic Objectives. 9
Table 4 Software Requirement 10
Table 5 Hardware Requirement 10
Table 6 Document Structure 11
Table 7 Deliverables 11
Table 8 Identification of the scope 15
Table 9 Isolation of weed from the rest of the plants 16
Table 10 Strategy Methods 22
Table 11 Use Case Description 1 33
Table 12 Use Case Description 2 34
Table 13 Use Case Description 3 35
Table 14 Use Case Description 4 36
Table 15 Use Case Description 5 37
Table 16 Use Case Description 6 38
Table 17 Use Case Description 7 39
Table 18 Use Case Description 8 40
Table 19 Use Case Description 9 41
Table 20 High Level Architecture description 43

Table of figures

Figure 1 Data Science 12
Figure 2 Techniques of image processing (Rani, 2017). 13
Figure 3 The flow core engine (Mutalib, 2016) 15
Figure 4 Image Capturing and processing (Mutalib, 2016) 16
Figure 5 Input Layer (Mutalib, 2016) 17
Figure 6 Learning Layer (Mutalib, 2016) 17
Figure 7 Weed Vs Normal Plant (Mutalib, 2016) 18
Figure 8 Processing 1 (Mutalib, 2016) 18
Figure 9 Processing 2 (Mutalib, 2016) 18
Figure 10 Processing 3 (Mutalib, 2016) 19
Figure 11 Processing 4 (Mutalib, 2016) 19
Figure 12 Exact Location 24
Figure 13 Grown Area 24
Figure 14 Apply Weedicide 25
Figure 15 Weedicide Cost 25

Figure 16 Increase Harvest 26
Figure 17 Sickness 26
Figure 18 Effects of weedicides 27
Figure 19 Kidney Diseases 27
Figure 20 New Technology 28
Figure 21 New Technology 28
Figure 22 Rich picture diagram 29
Figure 23 Use Case diagram 32
Figure 24 High Level Architecture 42
Figure 25 Domain Modal 43
Figure 26 Class Diagram 44
Figure 27Sequence Diagram 45
Figure 28 Activity Diagram 46
Figure 29 UI Wireframes 47

1. Introduction

1.1. Chapter Overview

This chapter is an introduction to our project. It includes the definition for the problem, through our study of the problem domain and its background. This chapter shows the aim of our project, features of our project, scope of our system and, we have mentioned the operational objectives and academic objectives of our project.

1.2. Problem boundary

"The ultimate goal of farming is not the growing crops, but the cultivation and perfection of human beings.". (Fukuoka, n.d.)

This means even though we grow crops to feed people it should not be an affect the people's health. Our problem is based on weed plants which are grown in paddy fields in Sri Lanka. As an agricultural country, there are so many paddy fields in our country which provides our main food, rice to us. Bellow table shows the average amount of harvested rice paddy from the "Maha Kanna".

MAHA SEASON	GROSS HARVESTED EXTENT		AVERAGE YIELD		PRODUCTION	
	'000 ACRES	'000 HECTARES	BUSHELS PER NET ACRE	Kg PER NET HECTARE	MILLION BUSHELS	'000 MT
2011/2012	1,692	685	86.20	4,444	130.21	2,717
2012/2013	1,832	742	83.04	4,281	136.41	2,846
2013/2014	1,433	580	83.30	4,222	107.15	2,236
2014/2015	1,816	735	84.64	4,364	137.88	2,877
2015/2016	1,835	743	84.34	4,349	139.11	2,903
2016/2017	946	383	83.41	4,301	70.63	1,474
2017/2018	1,532	620	83.43	4,302	114.87	2,397
2018/2019	1,789	724	92.07	4,747	147.26	3,073

Table 1 Gross Harvested Area, Average Yield and production of paddy 2011/2012 - 2018/2019 Maha Kanna (Anon., 2019)

In these paddy cultivations' there are many numbers of weed plants. Some are like exactly the paddy. It's hard a to identify what are weed plants and what are paddy. So, as a solution for this matter, farmers tend to use huge amount of weedicides all over the paddy fields. The problem is, using high amount of chemicals can cause for the people's bad health and it will pollute the ecosystem as well. According to Department of Census and Statistics, Sri Lanka has been applied chemical fertilizers in about 62.5% of the sown extent. Use of both chemical and organic fertilizers was 35.8 % and use of only organic fertilizers was 0.5% of the sown extent. (Anon., 2019)

For this problem we thought of a solution to reduce this massive weedicide usage. If we can identify the exact places where these weeds are and if we could show the locations where the weeds are by using a map, we can use the chemical weedicides only to that area. From that we can reduce the amount of weedicides chemical usage in Sri Lanka.

1.2.1. Example for the problem

Back in the day, basic salt and other metal salts were used as chemical and inorganic weedicides, however these have step by step dropped out and now the farmers are using these high chemical weedicides. Using high amount of these weedicides to the crops can cause to destroy the soil and the small animals in it. Also effect on people as health issues such as

Cancers – while it can be hard to decide the actual reason for disease much of the time in cancers, certain weedicides have been connected to an expanded hazard for malignancy in people. Many chemical weedicides are being embroiled as a conceivable reason for birth imperfections and a large group of other medical issues.,

Respiratory Damage - Whenever breathed, numerous chemical and inorganic weedicides can cause major harm and aggravation of the respiratory system. The nose, throat, lungs and sinuses might be influenced, causing either brief indications or perpetual basic harm. As indicated by researchers can cause nosebleeds, throat consumes and intense respiratory pain disorder. In serious cases, it might cause damage to the throat or prompt aspiratory fibrosis, a perpetual lung sickness. Seriousness of respiratory side effects caused by chemical and inorganic weedicides depends to a great extent on the length and measure of exposure.,

Kidney Damage – A case study has found, together with anecdotal evidence, that the most vulnerable group are men over 40 years of age who has kidney damages are the who have been working as rice farmers for over a decade. A hypothesis has emerged the consistent exposure to weedicides chemicals is the cause for this epidemic.,

Birth defects – A few weedicides may increase the danger for delivery absconds in unborn infants. Similarly, specific beginning imperfections might be difficult to connection weedicides. As indicated by means of the BBC News, infants presented to chemical weedicides in the womb are more than three instances as accountable to revel in the ill outcomes of mental impediment, congenital fissure and different start complications, to the volume of extra hands or toes.

(jaipurbiofertilizers, 2019).

1.2.2. Problem Definition

In our paddy fields, farmers use so much of weedicides in order to control weeds. People get diseases from using extra amount of weedicides and also using extra amount of weedicides generate huge environment pollution. Normally farmers use weedicides to the whole field without concerning only the weed grown areas because they don’t know the exact places where the weeds are, and the weeds are not easy to recognize by farmers in a large paddy field. Our problem is to find a solution to reduce this massive weedicide usage.

1.3. Aim

This project aims to build up system to recognize the weed plants in-between the paddy and to generate the map with location showing where are weeds are.

1.4. Objectives

This section shows the research objective, operational objectives and the academic objectives that we aim to accomplish to fulfill our project.

1.4.1. Research Objective

Focusing on people's health in paddy cultivation areas, reports the highest rate of death and diseases related to using weedicides such as glyphosate. And it's a major problem of using extra amount of weedicides to control weeds. In this research, focusing on how to reduce weedicides introducing new technology to farmers who cultivate paddy fields in Sri Lanka. In addition to that help farmers to introduce low cost weedicide era. Identifying major growing weed "MahaMaruk" in paddy, collect and create a database of the weed and implement a system to identify the "MahaMaruk" weed in the paddy using a drone shoot. The result will generate an image base report to the farmer, where the exact place the weed grown. From that farmer is able to identify the area and use some bit amount of weedicides.

1.4.2. Operational Objectives

Objectives	Description
Objective 1	Validation of the idea and the introduction To gather proper knowledge about the problem. 1. Research on the problem domain. 2. Get the idea validated according to the problem domain. 3. Conducting interviews with domain experts. 4. Distributing a questionnaire to validate the problem.
Objective 2	Literature Review Researching about the problem and its existing solutions. 1. Discovering the existing methods to solve the problem. 2. Comparing the different approaches to solve the problem.
Objective 3	Choosing our approach With the help of the literature review, find out the best approach that we can solve the problem.
Objective 4	Requirement gathering Gather user requirements mainly to come up with functional and non-functional requirements which are necessary.
Objective 5	Designing the system The basic domain models, onion diagram, use case diagrams and its descriptions and class diagrams, use case diagram. This is the basic overview of the system which anyone can understand easily.
Objective 6	SRS Preparing the SRS document with the help of objective three and requirements engineering process.
Objective 7	Proof of Concept

	Initial development stage of the implementation which will include the core functionality and other functionalities depending on what time permits with the help of the best software and hardware which were validated on previous objectives.
Objective 8	Test and evaluate the Proof of Concept 1. Write test cases. 2. Run the tests on the implementation. 3. Record the outputs. 4. Validate them and check if it meets the requirement.
Objective 9	Build up the Proof of Concept and complete the implementation.
Objective 10	Test and evaluate the implementation.
Objective 11	Complete the final documentation.
Objective 12	Conclude the project and submit.

Table 2 Operational Objectives

1.4.3. Academic Objectives

Objective	Description
Objective 1	Using data science and applying image processing. Applying python open cv to do the image processing to identify the weed plants from the paddy field.
Objective 2	Learning python, angular js, weka and matlab and using them to our project.
Objective 3	Learning designing, developing, testing and evaluating
Objective 4	Practicing the software development life cycle To learn and experience the full SDLC and how to manage a software development project. This will give us exposure in all aspects of software development such as requirement gathering, analysis, design, implementation, testing, deployment and maintenance.

Table 3 Academic Objectives.

1.5. Features

- Identifying “Mahamaruk” weed in paddy fields when a photo has been inserted to the system.
- Provide the location through maps showing where the weeds are.

1.6. Scope

1.6.1. In-Scope

- Let the user to insert an image.
- Identifying the “Mahamaruk” weed in paddy fields.
- Analyzing the data in the image and showing the location via a map.
- (If we can get another image data set of these weeds which are not “Mahamaruk”. We can do more weed plant detections.

1.6.2. Out-Scope

- Only English will be considered in the version of this program.
- Only the “Mahamaruk” weed will be identified.
- Other plants will not be detected.

1.7. Resource Requirement

1.7.1. Software Requirement

Angular Js
Angular allows us to build highly responsive web-application. It will be used to build the web-site where the user can upload the image. And then it will give the feedback image and the location to the user.
Python
To do the back-end and the image processing part. Open CV will be used there.
Weka
Weka will be used to test the data set.
Matlab
To analyze the images and to extract the data.
Firebase
Firebase is a real-time database which offers NoSql database with cloud triggered functions.
IntelliJ IDE, PyCharm IDE, Visual Studio Code
To develop, format and to manage and debug the source code.
GitHub
To manage everyone’s code together. Also to keep track of the version history of our code.
Star-UML
To do the design of our system.
Web Browsers – Chrome, FireFox, Internet Explora
To run our web-application.
Google Docs, Forms and Sheets, Microsoft Office
Document and manage different versions of our documentation related to the project.

Table 4 Software Requirement

1.7.2. Hardware Requirement

Core i3 or above processor
To optimize the communication between the computer components. Ans to keep the web browser running smoothly.
4GB of minimum RAM
To run web applications like google chrome, at least this much of ram will be needed.
Drone with a camera
To get a image from above.

Table 5 Hardware Requirement

1.8. Document Structure

Introduction
The introduction chapter consist of background to the identified problem which was the huge amount of paddy weedicide usage. The problem definition describes the problem furthermore. This chapter is also consisted with project aim, objectives, and recourse requirements.
Literature Review
A background study was carried in this chapter about the previous work that has been done regarding this problem domain. Result of this study was used to validate the problem and to learn more about the system and to get help for our implementation.
Requirement Gathering
This chapter was carried in order to get the requirements from the user. The gathered data was analyzed in order to obtain an overview of the system.
Design
The system design was carried out in this chapter which gives a broader view on the system and what technologies are best to use.

Table 6 Document Structure

1.9. Deliverables

The deliverables of our project, in fulfillment of our project, its aim and objectives are as follows.

Domain study and Literature Review
This part consists of our background research on our domain of paddy weed detecting. Our review of existing literature identified through a literature survey on both academic work and existing products in the market.
Software Requirement Specification
The Software Requirements' Specification documents the identification, analysis, and definition of the requirements of our system through our Requirements' Elicitation Process.
Proof of Concept
The implementation of the Recommender System and its associated functionalities, which will be provide recommendations based on a test dataset.

Table 7 Deliverables

1.10. Chapter Summary

This chapter introduced our project by providing a boundary of our problem which is the high usage of weedicides to our paddy fields. A deep study of the problem domain and the background to the problem was discussed in this chapter. Project aim, objectives, features, scopes, requirements are discussed in this chapter. Finally, the chapter concluded with the document structure.

2. Literature Review

2.1. Chapter Overview

This chapter is a review of all the previous work regarding the problem domain, both academic researchers and implementations, related to our problem domain. This help us to compare and understand the approaches taken in the past and how to use them to our approach. Paddy weed detection using image processing is a research area that has been taken place mostly in South-Asian countries. This is because most of the South-Asian countries are depending on an agriculture-based economy. Over ⅓ of this economy is by paddy cultivation. There are so many researchers that are being conducted by various organizations and various individuals. But there is no existing work is done regarding the weed "Echinochloa Crus-Galli" locally (Sri Lanka) known as "MahaMaruk".

2.2 Introduction to Data Science.

Data science is a combination of various tools, algorithms, and machine learning standards which has the ability to discover the hidden properties of raw data. Raw data can be any type, for example text, tables, graphs, scanned data, social network etc. By these data knowledge discovery, pattern matching, and keyword-based search can be done. Converting raw data into information, can extract the value from the collected data. There are data science principles. These principles can be applied to all big and small chunks of data. Theories and techniques from all around the word is used to analyze and converted to information. This help us on industries such as science, engineering (mathematical modeling), statistics (probability), economics, politics and education etc.

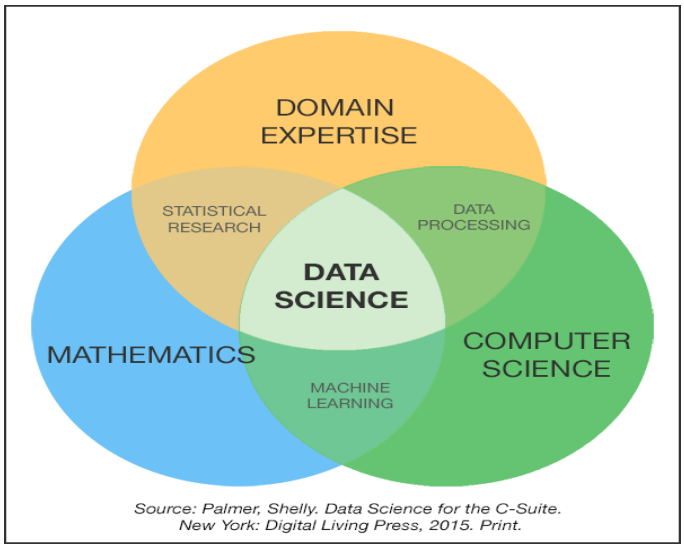


Figure 1 Data Science

2.2. Introduction for image processing

Image processing is basically converting an image to a digital form and extracting useful information from it by doing some operations to the image. This extraction is done by characteristics/ features associated with that image. It is a strategy to change a picture into advanced structure and actualize certain activities on it, so as to make an improved picture or to digest important data from it. The purpose of image processing is following.

1. Visualization: Image processing is utilized to distinguish those items which are not recognizable.
2. Image sharpening and restoration: In image processing, different methods are applied on the image to deliver a superior picture.
3. Image retrieval: By image processing client can identify just that bit of the image which is important to the client.
4. Pattern measurement: Various components in a picture are estimated.
5. Image Recognition: Substances in a picture are perceived.

(Rani, 2017). There are two type of methods use for image processing. They are analog and digital image processing. Analog image processing can be used for hard copies like printouts and photographs. And digital image processing can be used for digital images that are used by digital equipment. In nowadays digital image processing technique is used mostly in the field. There are four type of activities are used in digital image processing. They are “image preprocessing”, “segmentation of image”, “feature extraction” and “classification of images” (Rani, 2017).

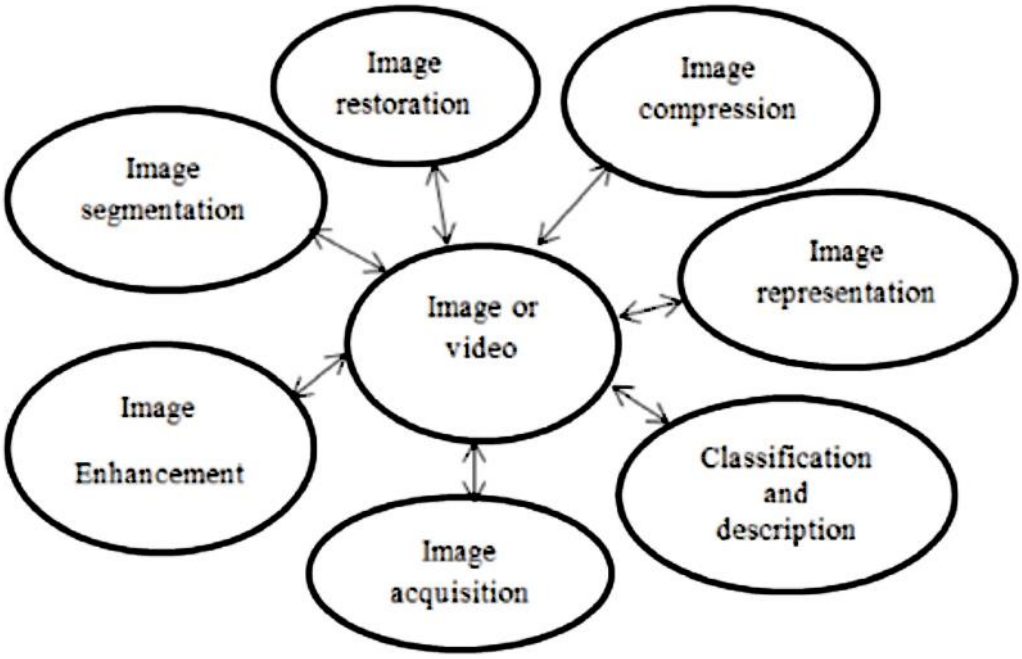


Figure 2 Techniques of image processing (Rani, 2017).

2.2.1. Image Pre-Processing

Pre-processing is a typical name for activities with pictures at the most reduced degree of reflection — both information and yield are power pictures. These notable pictures are of a similar kind as the first information caught by the sensor, with an intensity picture generally spoke to by a grid of picture work esteems. The point of pre-processing is an improvement of the picture information that stifles reluctant twists or upgrades some picture highlights significant for additional handling, albeit geometric changes of pictures are grouped among pre-processing strategies here since comparable systems are utilized. There are several kind of image pre-processing techniques. Convert color images to grayscale to reduce computation complexity, Standardize images, Data augmentation, in some projects you have to remove the background color from your images to reduce the noise and in some projects you require that you brighten or darken your images. Likewise, any adjustments that we do for our data set are considered as image pre-processing techniques.

2.2.2. Image Segmentation

Image segmentation means participation of the image into several parts according to requirement of the user or the problem to be solve. The objective of image segmentation is to improve or change the portrayal of a picture into something that is increasingly significant and simpler to analyze. The result of image segmentation is a lot of areas that together spread the absolute picture or gathering of shapes expelled from the picture.

2.2.3. Feature Extraction

Feature extraction is a process of dimensionality reduction by which an initial set of raw data is reduced to more manageable groups for processing. Feature extraction is the name for methods that select and /or combine variables into features, effectively reducing the amount of data that must be processed, while still accurately and completely describing the original data set. The procedure of feature extraction is valuable when you have to decrease the amount of resources required for preparing without losing significant or important data. Feature extraction can also reduce the amount of redundant data for a given analysis. And by feature extraction we can reduce the time of learning of the machine.

2.2.4. Classification of Images

Image classification refers to the undertaking of extricating data classes from a picture. The subsequent raster from image classification can be utilized to make topical maps. Depending on the interaction between the analyst and the computer during classification, there are two types of classifications. They are supervised and unsupervised classification.

2.2.4.1. Supervised Image Classification

Supervised classification uses the spectral signatures obtained from training samples to classify an image. With the assistance of the Image Classification toolbar, you can easily create training samples to represent the classes you want to extract.

2.2.4.2. Unsupervised Image Classification

Unsupervised classification finds spectral classes (or clusters) in a multiband image without the analyst's intervention. The Image classification toolbar aids in unsupervised classification by providing access to the tools to create the clusters, capability to analyze the quality of the clusters, and access to classification tools.

2.3.1. Identification of the scope

Included a weed checker module in the proposed architecture to identify the paddy fields. This is a commonly used module among data scientists and many researches. This module is used in different plants namely palm and corn. By this module, automatic weed detection can be done too. Some made use of Randarsat's Synthetic Aperture Radar (SAR) data to detect paddy fields by edge detection. (Mutalib, 2016)

By referring previous work done, most of the papers have done the sorting part manually (visual inspection). This is very tedious and inaccurate method. Because of that they proposed a model that uses color and geometrical features as attributes for the core classification. Through this module they achieved a better accuracy and efficiency. (Kuasal, 2015)

Author	Images	Method
(Mutalib et al.,2016)	Close up Photograph	Dedicated wee checker module
(Kausal & More, 2015)	Close up Photograph	Color and geometrical feature analysis

Table 8 Identification of the scope

2.3.2. Isolation of weed from the rest of the plants.

They had built a system to detect the broad and narrow weeds in other plants. They used an algorithm called FFT (Fast Fourier Transform). However, SVM classifier was used on each weed images. There was another research conducted with a weed recognition system with an integrated robot. By this they managed to obtain an accuracy of 92.8% for about 80 samples. (Mutalib, 2016) The flow of core engine is below Figure 1

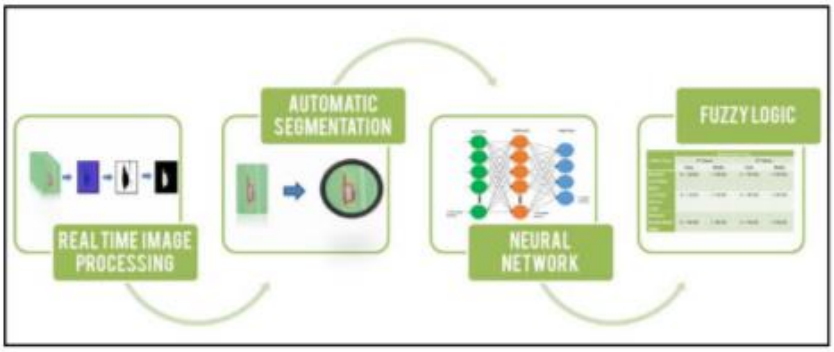


Figure 3 The flow core engine (Mutalib, 2016)

A research team used RADARSAT-2 data that collected by different harvest seasons, namely dual-pol Standard and quad-pol Fine. They used polarimetric radar system to gather data of the seasons. (Hoang, 2011)

There are three stages of consideration which will help us to detect weed.

1. When the paddy is small
2. When the crop size is greater than the weed size
3. When the paddy turns brown

(Viegas et al., 2017)

- When the paddy is small (initial stage)

During the initial stage crop and the weed cannot be separated based on size and color. in this case field is divided into rows that separate the area between the crop. On this strip then color detection in done and the weed can be identified.

- When the crop size is greater than the weed side

In this stage crop size is larger than the weed size. So, weed can be identified based on size detection.

Author	Images	Method
(Mutalib et al.,2016)	Close up photograph	Used a algorithm named FFT
(Hoang, et al., 2011)	Satellite	Polarimetric radar system
(Viegas et al., 2017)	Close up photograph	Size of the crop is considered to sort out

Table 9 Isolation of weed from the rest of the plants

Most of the images are taken by drones which is called aerial photography. That consists of remote sensing and photogrammetry. Also, satellite images and unmanned drones are used to capture images remotely. (Mutalib, 2016)

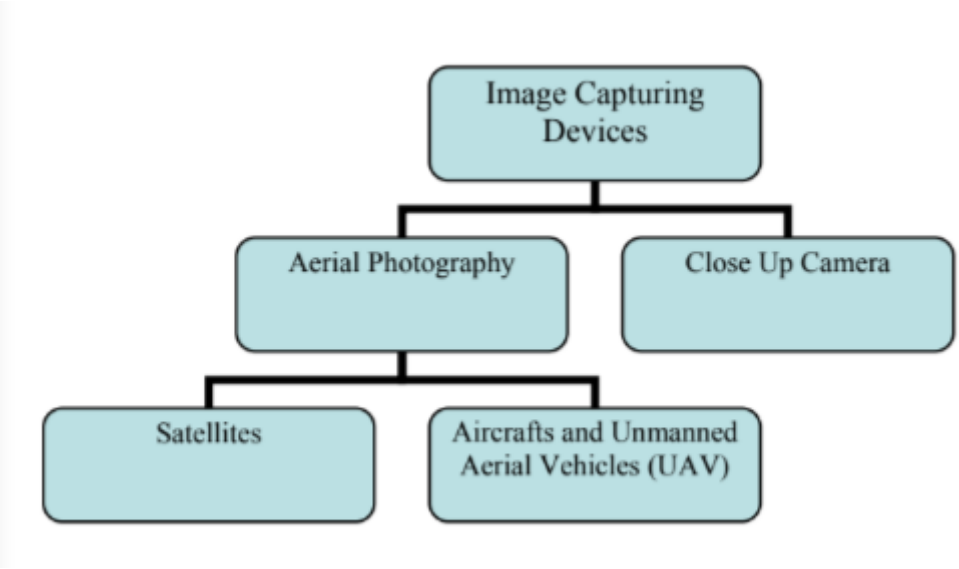


Figure 4 Image Capturing and processing ***(Mutalib, 2016)***

After the capture they divide architecture into 2 layers, namely Input layer and Learning layer.

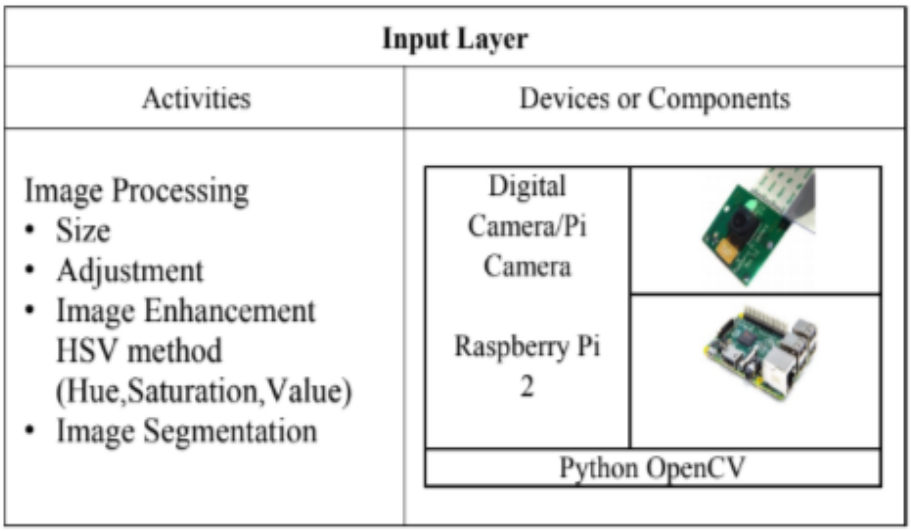


Figure 5 Input Layer (Mutalib, 2016)

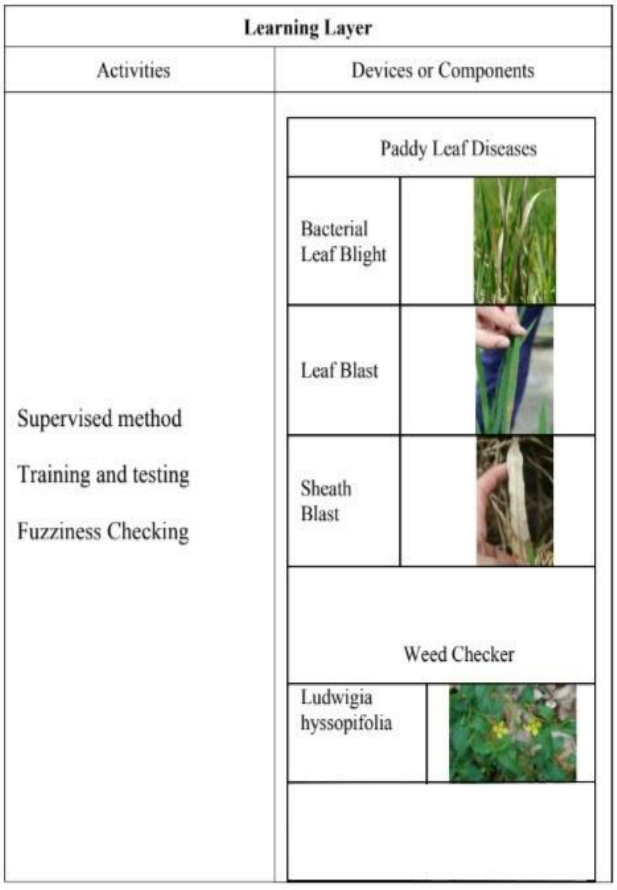


Figure 6 Learning Layer (Mutalib, 2016)

Shape analysis and morphology, texture analysis, noise elimination and pattern recognition are some techniques of image processing. Weed can be detected from the crop by using color or area separation between the weed and the crop.

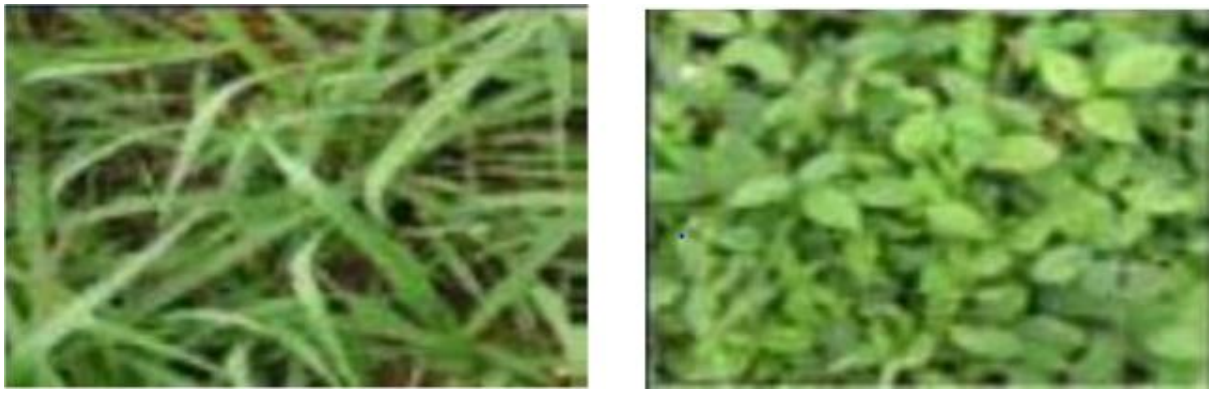
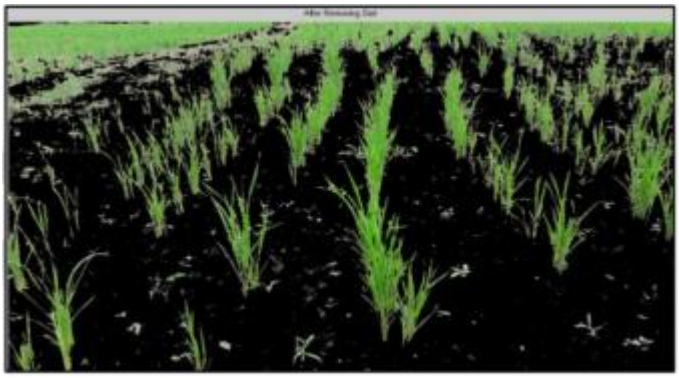


Figure 7 Weed Vs Normal Plant (Mutalib, 2016)

This is the image what they capture and insert to the system. This will now process according to the criteria that they have given to the system.

Figure 8 Processing 1 (Mutalib, 2016)

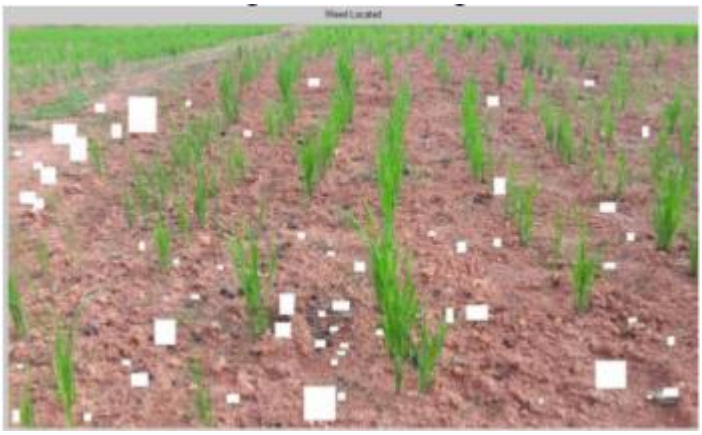


This image shows how the system as identify the soil and the plants. System has removed the soil from the image.

Figure 9 Processing 2 (Mutalib, 2016)

This is the image with not paddy plants. The system as identified the paddy plants and the weed plants. Now it only shoes the weed plants in white color.

Figure 10 Processing 3 ***(Mutalib, 2016)***



After process the as above images weed blocks are shown in white.

Figure 11 Processing 4 ***(Mutalib, 2016)***

2.4. Previous work

With the development of the technology human use IT techniques to all the fields, especially to agricultural field. With the increment of the population needs of the foods also increased. Because of this human find easy ways to increase the cultivations with less effort. So people use machines and modern techniques to these things. In olden day's people removed the weed manually which took more time and energy. In modern agriculture farmers use chemical spraying to remove weeds. Weeds are plants growing in the wrong place which compete with the crop for water and nutrients in the soil. Because of the heavy use of chemicals so many side effects are happen to the humans. Most of them are diseases cause by the chemicals. So people tried to find another way to resolve this problem.

Then they took the help of machines to reduce this pollution. Before, scholastics just used the projection technique with a binary image to figure the weedy regions (Tellaeche, et al., 2010). With the utilization of plant assurance utilizing unmanned aerial vehicle, weed target discovery that depends on unmanned aerial vehicle has pulled in expanding consideration. Weed overlays were procured by means of the projection count technique from unearthly pictures at 30, 60 and 90 meters in maize and sunflower fields (Irene , et al., 2015) In any case, it stays hard to acquire precise data on weed regions from a more minor perspective and to recognize yields and weeds.

As a part of machine learning, deep learning has been generally applied in different fields and has formed into a ground-breaking strategy for image classification (Krizhevsky, et al., 2017), and object recognition (Erhan, et al., 2014) This strategy overcomes the lower area accuracy of the technique for locale arrangement and can adjust effectiveness and exactness in object detection. Object detection algorithms that depend on deep learning have acknowledged enormous upgrades inexactness and speed contrasted with conventional recognition calculations and show higher element extraction execution because of the utilization of convolutional neural system. Commonly, these techniques perform well in object detection; in any case, they require a bounding box that firmly encompasses the object of intrigue. Since rice seedlings and weeds don't have unmistakable limits and can prompt fractional impediments in the constrained space, it will be trying to plainly outline limits of rice seedlings and weeds. The strategy probably won't be feasible for object location at the seedling stage.

Besides, the morphological assorted variety of the development phases of weeds makes exceptional difficulties for utilizing object recognition with a bounding box.

With the advancement of deep learning, a semantic segmentation technique with the SegNet that depends on fully convolutional network (FCN) was proposed. semantic segmentation strategy that depends on fully convolutional network with the SegNet model, which can remove the highlights from initial RGB pictures legitimately and arrange and perceive the pixels that relate to rice, foundation, and weeds in paddy field pictures (Xu MaID, Xiangwu Deng, Long Qi, Yu Jiang, Hongwei Li, Yuwei Wang, Xupo Xing, 2019).

2.5. Chapter Summary

This chapter discussed our study of the previous work done by accredited source within the same domain. Which includes researches and implementations. This chapter help us to get a better understanding on the functionalities we look to fulfill to achieve each requirement we had identified.

3. Requirement Gathering

3.3. Chapter Overview

This chapter shows an overview of methodologies and the requirement's used to design and implementation. For the exact output of weed identifier, these objectives lead us to plan divide and produce step by step.

In the chapter we highly concern about the methodologies used to conduct feasibility of the problem, requirements with identified and unidentified requirements, analysis of gathered data and how it will affect to the problem and its solution with the diagrams.

3.4. Selected Methodology

Methodologies use to focus on its main aspects of a research. Planning, design and implementation strategies stands to gather research related data. Using most suitable methodologies help to increase the efficiency of project. Not only the methodology, but also requirements identify the flow of research problem.

As a working station-based project, in the beginning we decided the approach of the project is different and move forward with most suitable identified an unidentified requirement with the methodologies. (Shymalie, n.d.), (Sheehan, 1986), (statistics, 2018)

3.4.1. Approach

To conduct the research related on weed identifier, used deductive approach in line with qualitative research method. Because the back story of the problem is vas spreader and aligned with health disease. The outcome will be identifying the weed in selected area by image processing can be automated. For that procedure, studying of the problem and gathering related data is possible with deductive and qualitative research approaches.

3.4.2. Strategy

The used strategies are research questions with one to one interview, focus group discussions, surveys and case studies of selected areas. All the interviews, surveys and focus group discussions are qualitative strategy and its outcome is more helpful with feedback and testing.

Method 01	Literature Review
Took a problem and few case studies of existing problem, studied the scenario and analyzed with the possible outcome.	
Advantages	• Understand the problem and solution • Gain knowledge about literature review • Understood the questioners
Disadvantages	• Found few research papers, But the papers and information's are outdated • Time consuming
Method 02	interview
To better understand the problem and solution, conducted interviews with the people who involve with the problem. And also, the experts of cultivation and the medical procedure.	
Advantages	• Got a chance to better obtained the problem and exact situation of the weedicide issue in selected areas

	• Found new technologies to minimize weedicides • Gained knowledge about weeds lifestyle and its nature • Helped to improve our solution with ground level IT technology
Disadvantages	• The viewpoints are different, and some are not stick with the problem and solution • Lack of IT knowledge refuse to cooperate •
Method 03	Focus group discussions
In the selected areas conducted some focus group discussions to gather various information related on topic,	
Advantages	• Able address to the exact people • The feedback and extra information helped add some changes • Collected data are valid and accurate
Disadvantages	• Limited number of responses • Some requests are not related to solution • Requirements are not practical
Method 04	survey
A question paper related in paddy cultivation, weedicide and IT knowledge of farmers. For the purpose of getting positive and negative feedback form the farmers.	
Advantages	• Able to collect valid data and related information • Some suggestions helped to understand the target group needs
Disadvantages	• Unable to respond with understandable manner • Lack of IT knowledge

Table 10 Strategy Methods

3.5. Interview

As a qualitative method, interview used to do a better research with the outcome of clearly understood problem scenario, ground level and experts' feedback of the proposal. From the procedure, got an opportunity to create an image of the people's lifestyle, how they adopt new technologies to their day to day life.

3.6. Focus group discussion

The discussion based on target group of farmers who cultivate paddy fields in Kurunegala, Anuradhapura and Gampaha. These peoples are highly involved with cultivation and weedicides. Not only that having discussion with elder people show newly paths related to the topic, but also gave us an idea about not to touch some areas of cultivation process.

3.7. Survey

Survey was conducted by group members via questionnaire, asked from farmers. The question paper included 10 questions focusing on farmers positive and negative answers. It highly related on farming, using weedicides and its effects and deploying IT solution to the problem. The approach of the survey is to gather farmers experience of detecting weedicides and using weedicides.

3.5.1. Questioner Structure

- Weeds identifying system – the question for collect information about the procedure of detecting weeds among paddy plants
- Applying weedicides – the way farmers apply weedicides to their paddy fields and amount of weedicides
- Side effects from weedicides – to gain information about side effects from weedicides and its nature
- Knowledge related in IT – to apply IT based solution, first need an idea of basic IT knowledge of farmers.

3.5.2. Questioners

1. The research questionnaires are highly focus on farmers answers.
2. How the farmers identify exact locations of weeds are grown?
3. How farmers reach the areas where the weeds are grown?
4. Is it possible to apply weedicides to exact location without spreading everywhere?
5. In the different sizes of paddy lands, how much will cost to weedicides?
6. Do farmers believe that applying weedicides to whole paddy will make his harvest increase?
7. For the farmers, has anyone got sick by weedicides?
8. Do you have any idea about how the weedicides effect to people?
9. Do you know anyone got kidney disease lately work as a farmer?
10. Has any farmer involved with new technology to cultivate of increase the harvest?
11. Will the new technology make a disadvantage to the paddy fields?

3.5.3. Responses

1) How the farmers identify exact location of weeds are grown?

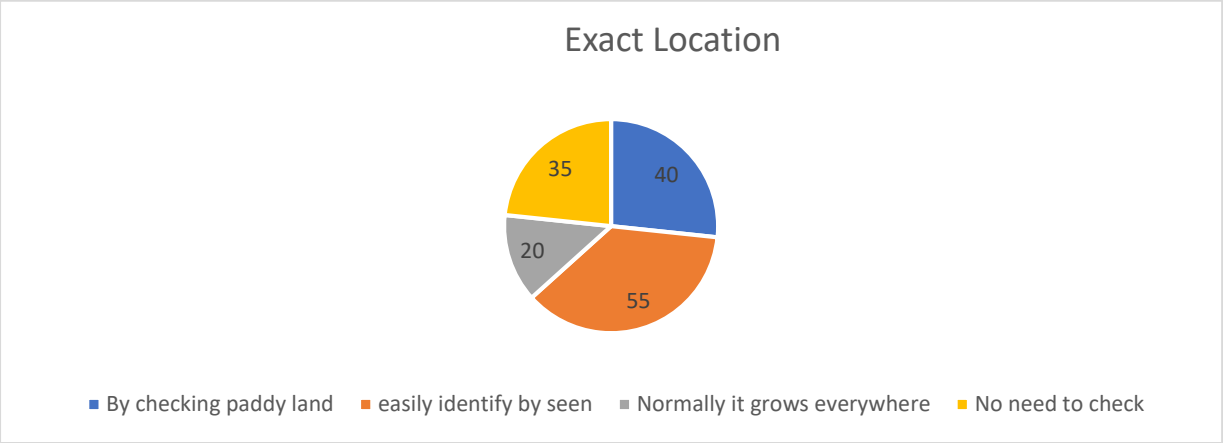


Figure 12 Exact Location

The question asked for get an idea about how the farmers identify grown weeds in their paddy fields. If someone is not a farmer, cannot identify some weed plants from the paddy plant. So, the similarity of the weeds and paddy plants cannot actually identify by first sight. As we got the result was above shown, when in small paddy lands (55) it's easily identifies by seen. According to some farmers (20) were said that weeds are grown in everywhere and they put weedicides everywhere. Some (40) identify by checking the land, (40) are not check and they already know the weeds life circle and they use weedicides. By this result we have understood there are no scientific methods to identify the weeds, so our image identifier should be able to produce exact weeds shown areas to the farmers.

2) How farmers reach the area where the weeds are grown?

Figure 13 Grown Area

This question for get know how they reach to the weeds grown areas. whether they use any technic to reach. Normally weeds are grown not in specific areas. Problem is in some areas hard to reach the weeds grown areas in reason of mud or the size of land area. The purpose of the question is to clarify the proper way, how the farmers are able to use weedicides in the paddy. The 150 farmers answer was they walk through the paddy, check and use weedicides.

3) Is it possible to apply weedicides to exact location without spreading everywhere?

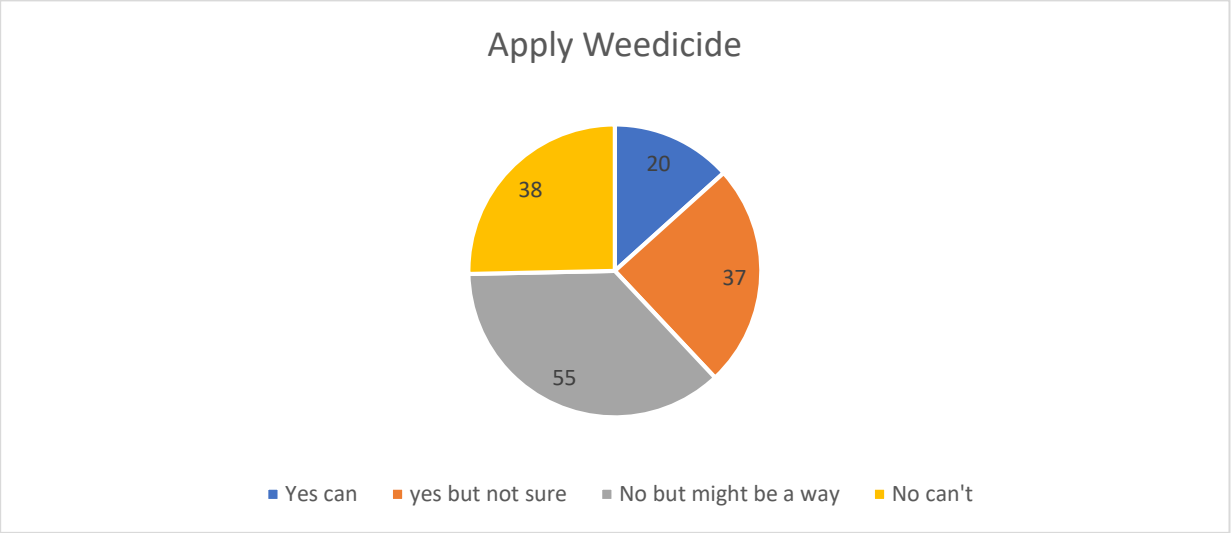


Figure 14 Apply Weedicide

By this question we supposed to get an idea about how normally farmers use weedicides. When they are using weedicides, the farmers who answered as yes but not sure (37), no but might be a way (55) and no can't (38) are using weedicides to everywhere in the paddy without concerning any side effects. The reason for the deceases is using huge quantity of weedicides without concerning weeds grown areas.

4) In the different sizes of paddy lands, how much will cost to weedicide?

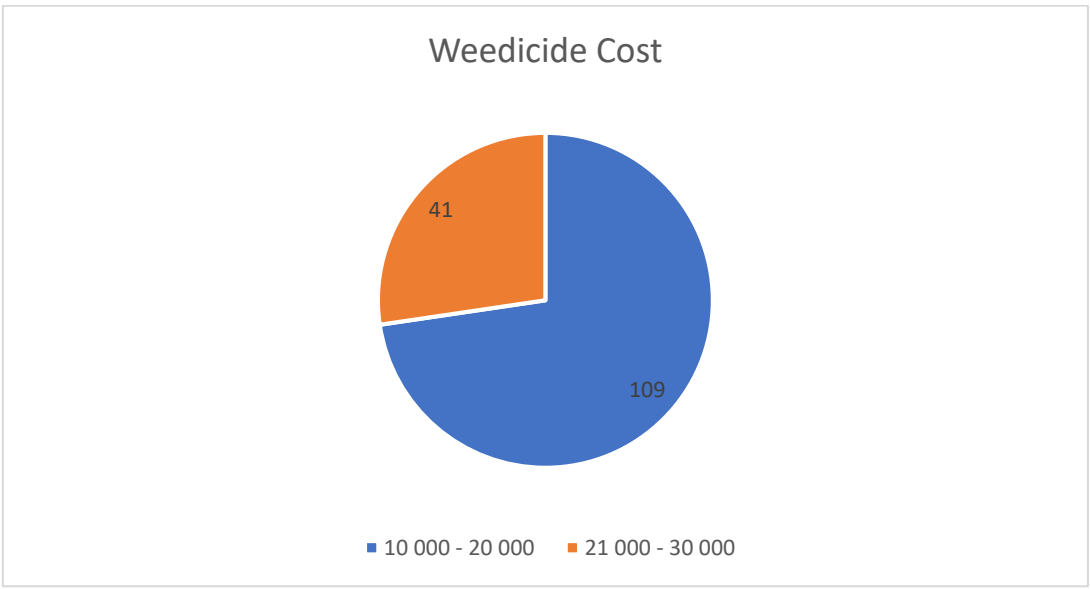


Figure 15 Weedicide Cost

To understand the cost for usage of weedicides per season, the result shown here. Normally 109 farmers are spending approximately 10 000 – 20 000 for average size of paddy. 41 are spending more than 20 000 per season, reason of the size of paddy lands. To help farmers by introducing weeds detecting system able to reduces spending for weedicides.

5) Do farmers believe that applying weedicides to whole paddy will make his harvest increase?

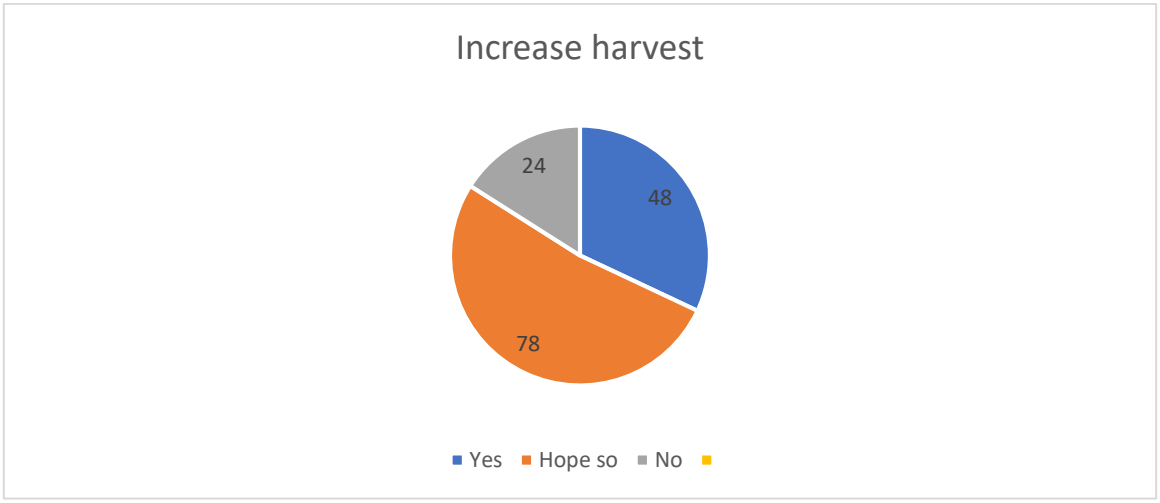


Figure 16 Increase Harvest

This question is for gain the idea of how farmers believe in weedicides. 48 farmers believe that applying weedicides to entire paddy will gain expecting harvest. 78 farmers say they hope somehow it will help to increase their harvest. But 24 farmers say without using weedicides to entire paddy will not help to increase their harvest. We also want to convince to farmers that reducing weedicides will helps to increase harvest.

6) Has anyone got sick by weedicides?

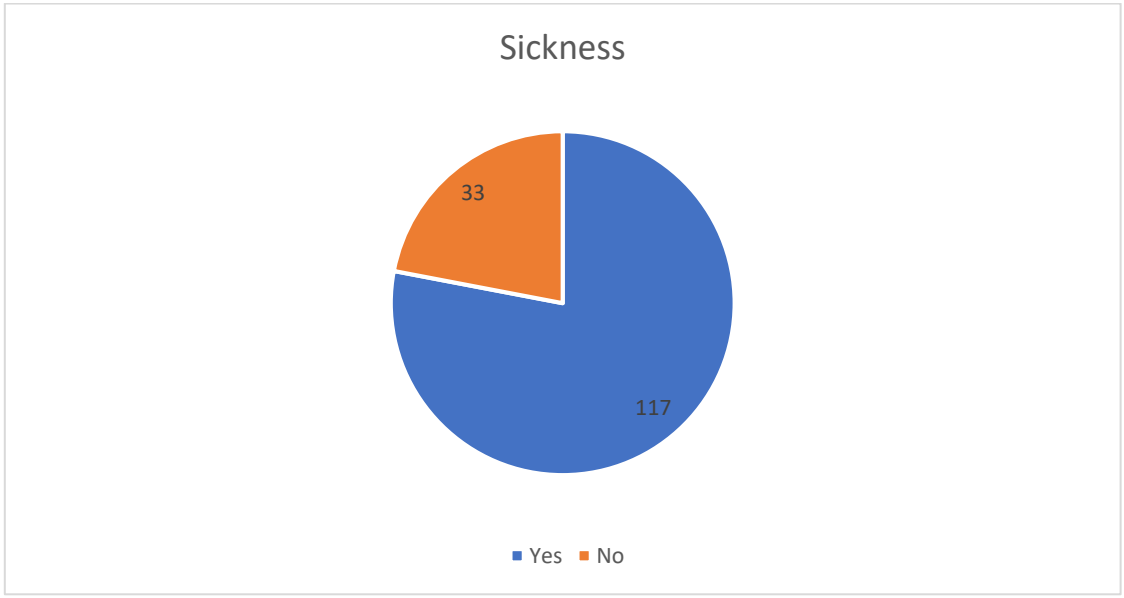


Figure 17 Sickness

The major problems in north central province is kidney disease, and it is spreading by using large number of weedicides for last few decades. The question asked to get an idea about their knowledge of side effects from weedicides. 117 farmers know and some are victims of kidney disease and the side effects such as vomit, headache, faintish. Other 33 scientifically use weedicides with masks and glows. And also the 33 are from Gampaha district.

7) Do you have any idea about how weedicide affect to people?

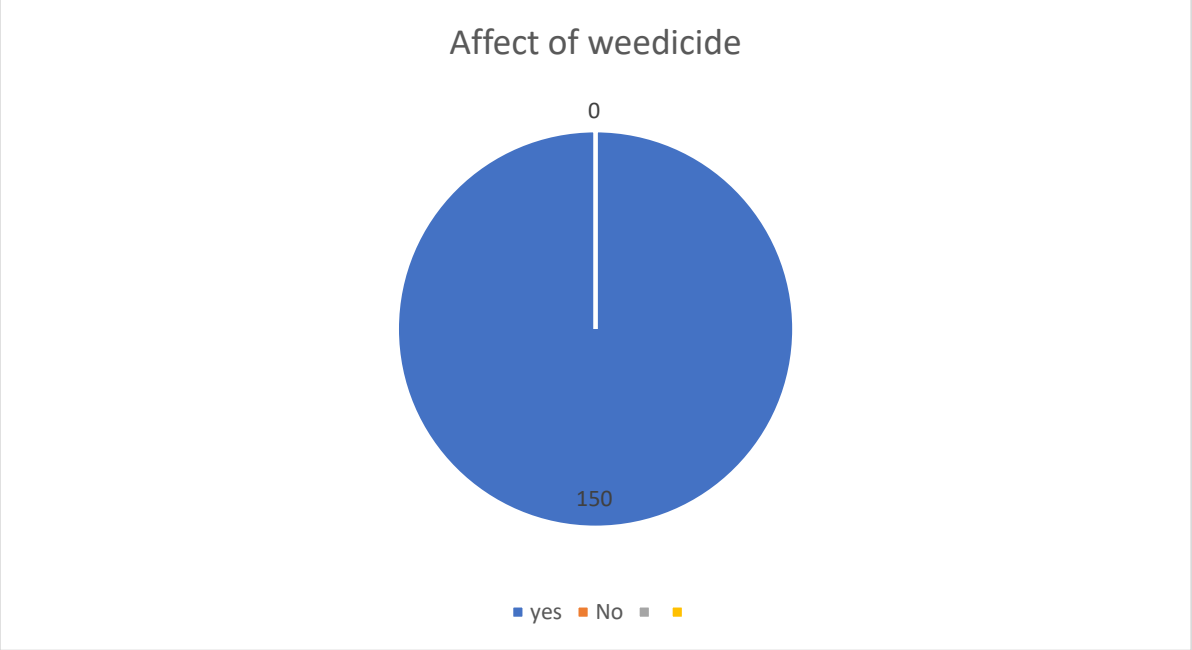


Figure 18 Effects of weedicides

For the idea of major effect, we asked the question and the set of farmers gave one answer and it was they know it will affect, not only the knowledge of the effects, but also they know how to prevent from such side effect.

8) Do you know anyone got kidney disease lately work as a farmer?

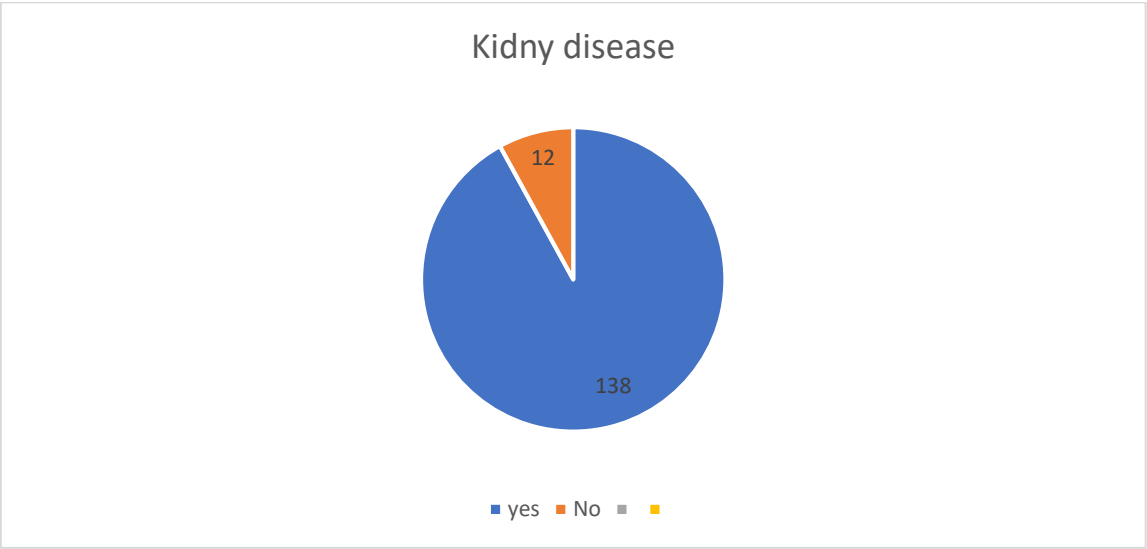


Figure 19 Kidney Diseases

From 150 answers, 138 are directly involved with the people who got kidney disease. Some are from this set show the symptoms of illness. Others 12 are form Gampaha district and don't know anyone who got kidney disease. The data helps us to accurate 100% which area we should cover by the provinces.

9) Has any farmer involved with new technology to cultivate and increase harvest?

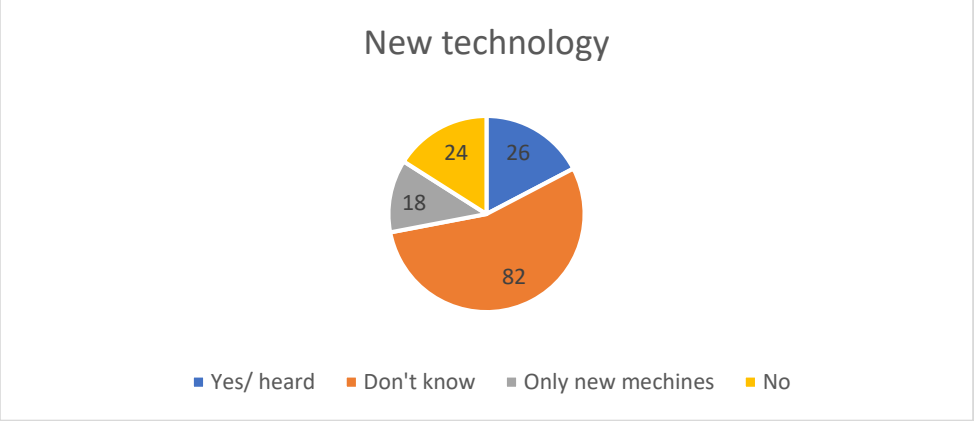


Figure 20 New Technology

To deploy a new system, we should get an idea about farmers knowledge of IT and enrolment with new technology. Form 26 farmers got the answer was they have heard about new technology using in farming and few are using smart phone app as weather forecasting, some are highly concern about new technology also maintain productive relationship with officers of agriculture. Another 82 have not any idea related on technology-based farming. 18 only know about new machines such as “Tsunami”, “Buthaya” using for harvesting. 24 of them don’t know anything about IT.

10) Will the new technology combination of using limited weedicides help to increase the harvest?

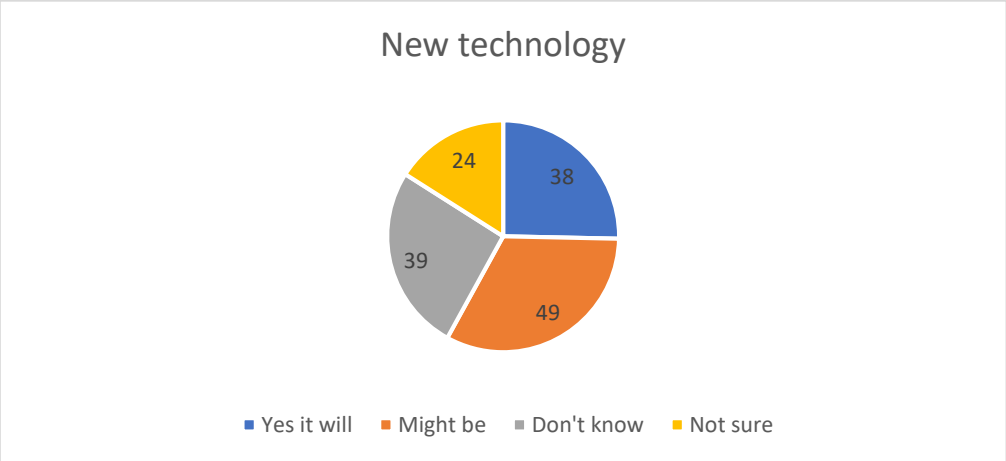


Figure 21 New Technology

From the set 38 farmers believe in that technology-based farming will increase their harvest. 49 believe technology might be increase the harvest. 39 farmers know nothing about that kind of harvesting. Also, they think traditional farming will gain more harvest. 24 farmers do not believe in technology-based farming or machine farming will not increase their harvest. Because of that we got an idea, that we have some believers to farming with new technology. It encouraged us to implement the weed detecting system, for reducing cost to weedicides and its diseases.

3.8. Rich Picture Diagram

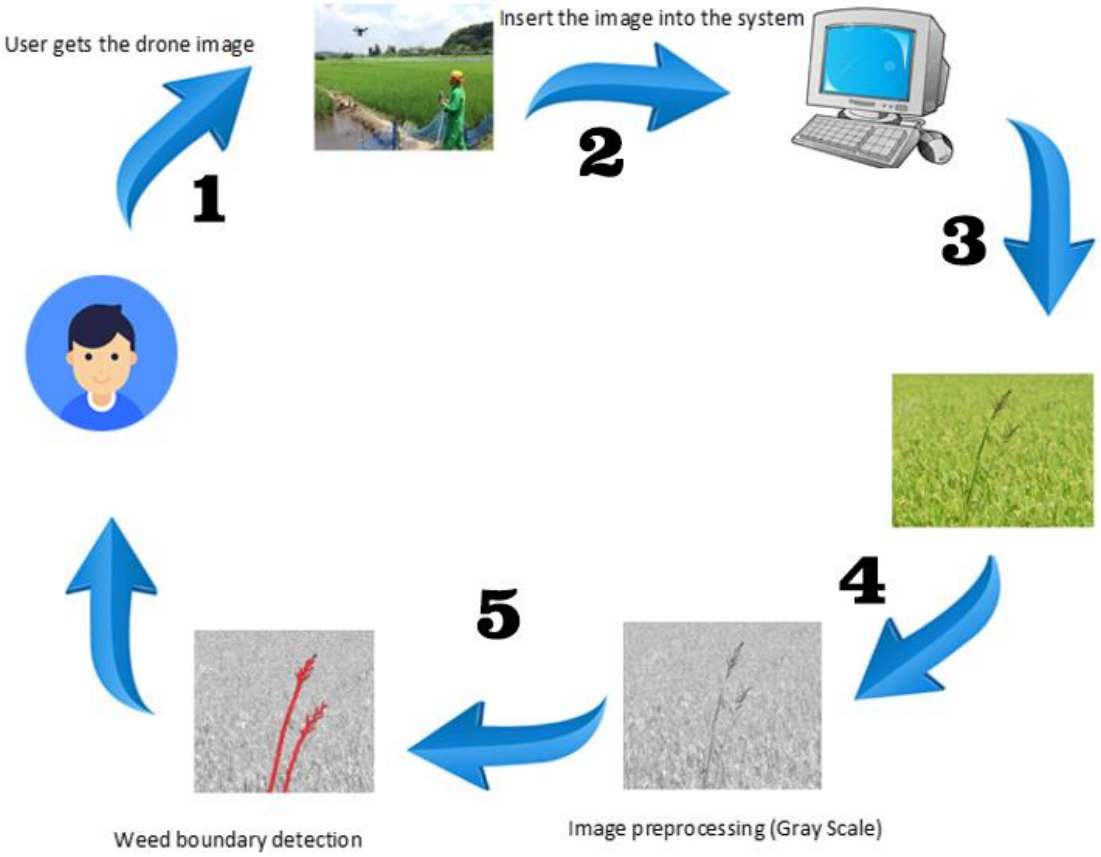


Figure 22 Rich picture diagram

3.9. Functional Requirements

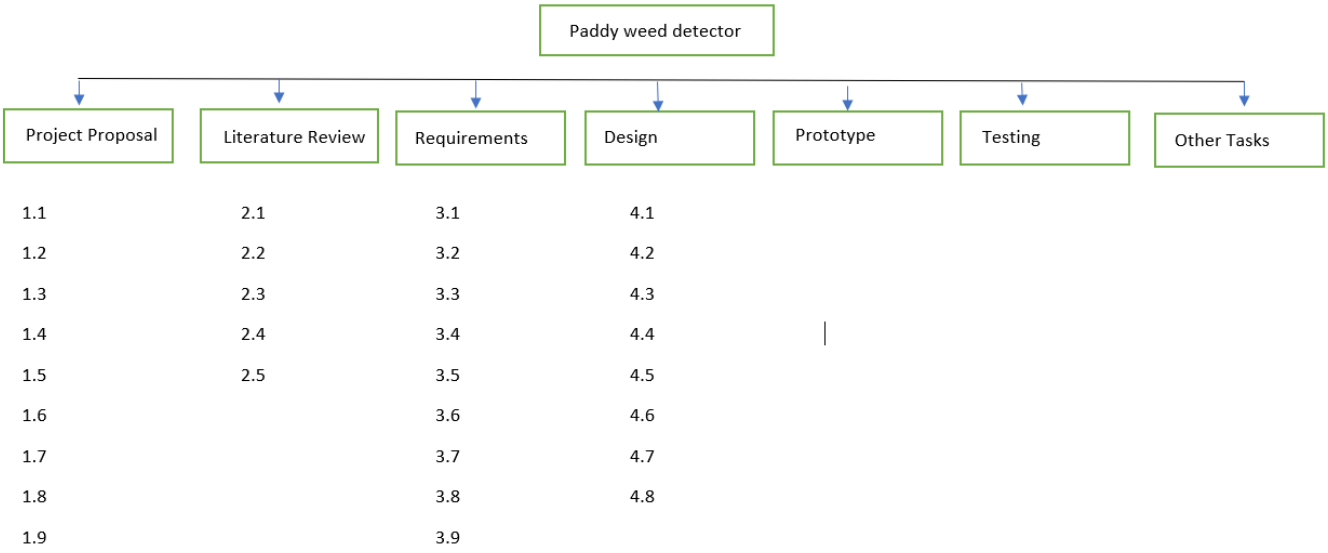
It is important to identify and prioritize the requirements of a system. Both requirements and their prioritization have been verified with our user. Requirements prioritized as “Must Have” are the main features of the system which is main aim of the program. Requirements prioritized as “could have” are the requirements that are not essentially involve to the main aim. The requirements prioritized as “could have” are the requirements that can be implement in the future.

	Requirement	Priority
FR1	The connection between the system and the database.	Must Have
	As this system is based on image processing and data science, the system must always have the connection with the database.	
FR2	The user must be able to put up the drone and snap the paddy field.	Must Have
	User must capture a picture using a drone. The image quality should be at a certain good level.	
FR3	The user should be able to put the snap in to the software.	Must Have
	The system must have an option to get the input image from the user.	
FR4	The system should detect the weed in the paddy field.	Must Have
	Main target of the system is to detect the specific weed that is on the image.	
FR5	The system should give the exact location where the weeds are.	Must Have
	One of the features of our program is to show location where the weeds are. To do that we will extract the location from the image and show it to the user.	
FR6	User Log-in	Should Have
FR7	Identify other weed plants other than the “Maha-Maruk” weedplant.	Could Have

3.10. Non-functional Requirements

- The software should load up soon and then identify the weed quickly.
- Identifying the weed should be accurate.
- The system should improve when it gets more and more images
- Availability –
  The system is a web application, it can be access through a laptop from any location, when the user has a stable internet connection.
- Data retention and backup –
  The system will keep the photos that farmers insert to the system. In the backend, we can use those images and train our system to be more accurate.

3.11. Work Breakdown Structure



3.12. Chapter Summary

This chapter focused on the requirement gathering process which is used to design the core of our project. Chapter commenced with the requirement process which various approaches such as interviews, literature review, questionnaire and brainstorming were used to identify the requirement.

4. Design

4.3. Chapter Overview

The purpose of this chapter is to indicate more about the project by using the diagrams and pictures. These diagrams and pictures can be used to gain more knowledge about the final project. Throughout this chapter, High level architecture, Class Diagram, Sequence Diagram, Activity diagram etc. are included to represent the final project.

4.2.1. Use Case Diagram

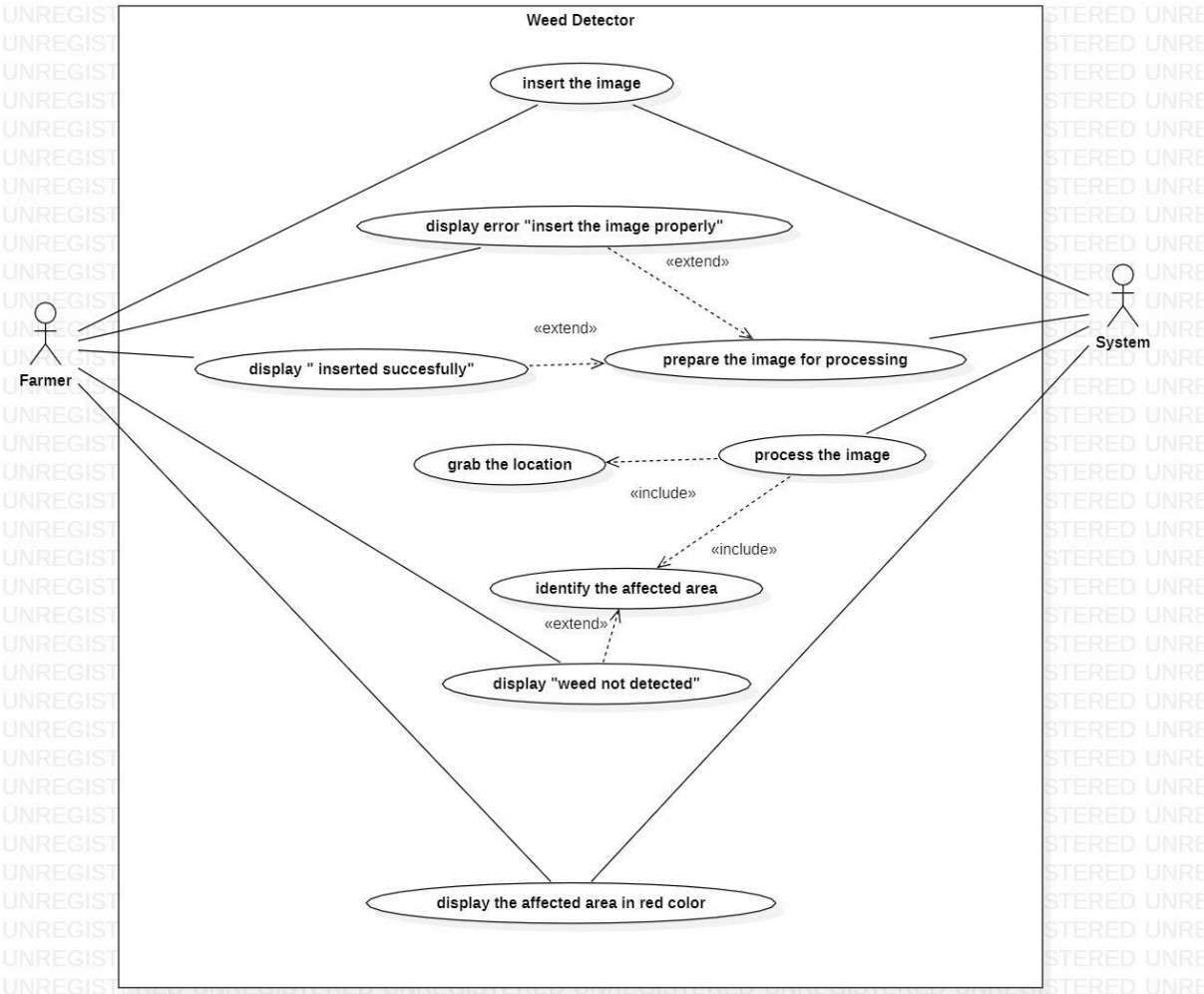


Figure 23 Use Case diagram

According to this Use-Case diagram, the farmer should only insert the high-resolution image to the system and system will process the image in order to detect the weeds in the paddy field. One of the main facts is the farmer has limited things to handle this system. Because the farmers in rural areas are bearing lack of knowledge in technology. Therefore, this system should be generated as a fully automated system in order to be assorted farmers as well.

4.2.2. Use Case Descriptions

Use-Case ID	UC-01
Use-Case Name	Insert an image to the system
Use-Case Description	In this case the farmer has to insert a high resolution image to be detected the weed from paddy.
Actors	Farmer, System
Extended use cases	none
Included use cases	none
Pre-Conditions	A high resolution image of the selected area of the paddy field should already be captured.
Post-conditions	The location of weeds which is represented by the relevant image should be identified.
Path	
Primary Path	1.1 Farmer inserts the image to the system.
Alternate Path	none
Exception Path	none
Assumptions	The image of the area of the paddy field can be clearly identified to the system.

Table 11 Use Case Description 1

Use-Case ID	UC-02
Use-Case Name	Prepare the image for processing
Use-Case Description	When the user enters the image, it should be checked whether it is placed correctly or not.
Actors	system
Extended use cases	1. Display error “Insert image properly” 2. Display “Inserted successfully”
Included use cases	none
Pre-Conditions	The image should be a clear one.
Post-conditions	The location should be extracted from the image.
Path	
Primary Path	1.1 prepare the image for processing.
Alternate Path	none
Exception Path	none
Assumptions	The farmer has inserted the image successfully.

Table 12 Use Case Description 2

Use-Case ID	UC-03
Use-Case Name	Process the image
Use-Case Description	The image should be processed using a tool such as Matlab.
Actors	system
Extended use cases	none
Included use cases	1. Extract the location 2. Identify the affected area with weeds
Pre-Conditions	The image should have properly inserted to the system.
Post-conditions	Display the affected area with weeds, location and recommended herbicide.
Path	
Primary Path	1.1 insert image to the system. 1.2 display the message saying whether it has been inserted successfully or not. 1.3 process the image using a tool such as Matlab.
Alternate Path	none
Exception Path	none
Assumptions	The image has been properly inserted into the system.

Table 13 Use Case Description 3

Use-Case ID	UC-04
Use-Case Name	Extract the location
Use-Case Description	Mobile, tablet, whatever the device,the location should be on.
Actors	system
Extended use cases	none
Included use cases	none
Pre-Conditions	The image should have properly inserted to the system.
Post-conditions	Identify the affected area with weeds.
Path	
Primary Path	1.1 insert image to the system. 1.2 display the message saying whether it has been inserted successfully or not. 1.3 process the image using a tool such as Matlab. 1.4 extract the location.
Alternate Path	none
Exception Path	none
Assumptions	The image can be properly identified.

Table 14 Use Case Description 4

Use-Case ID	UC-05
Use-Case Name	Identify the affected area
Use-Case Description	After processing the image using a tool called matlab, the weed area of the image should be identified.
Actors	System
Extended use cases	none
Included use cases	none
Pre-Conditions	Image should have been processed correctly using matlab.
Post-conditions	The weed area and the paddy area should be differentiated and display it to the farmer in an attractive way.
Path	
Primary Path	1.1 insert image to the system. 1.2 display the message saying whether it has been inserted successfully or not. 1.3 process the image using a tool such as Matlab.
Alternate Path	none
Exception Path	none
Assumptions	The image have already been processed correctly.

Table 15 Use Case Description 5

Use-Case ID	UC-06
Use-Case Name	Display “ inserted successfully”
Use-Case Description	When the farmer enters the image, a message should be displayed to the farmer saying whether the insertion is successful or not.
Actors	System, farmer
Extended use cases	none
Included use cases	none
Pre-Conditions	Farmer has inserted the image to the system.
Post-conditions	If the insertion is not successful, the system should allow farmers to insert the image again to the system. If the insertion is successful, the system will accept the image and process it.
Path	
Primary Path	1.1 insert image to the system.
Alternate Path	none
Exception Path	none
Assumptions	The image has been inserted into the system.

Table 16 Use Case Description 6

Use-Case ID	UC-07
Use-Case Name	Display error “insert the image properly”
Use-Case Description	When the insertion of the image is not accurate, the error message should be displayed.
Actors	System, farmer
Extended use cases	none
Included use cases	none
Pre-Conditions	The image should have inserted to the system.
Post-conditions	The system should allow farmers to insert the image again to the system.
Path	
Primary Path	1.1 insert image to the system.
Alternate Path	none
Exception Path	none
Assumptions	The image has been inserted to the system by farmers.

Table 17 Use Case Description 7

Use-Case ID	UC-08
Use-Case Name	Display error “weed not detected”
Use-Case Description	After processing the image, the system identifies the affected area with weeds. If there is no affected area is identified, the message should be displayed to the farmer.
Actors	System, farmer
Extended use cases	none
Included use cases	none
Pre-Conditions	The image should have properly identified.
Post-conditions	Eject the image.
Path	
Primary Path	1.1 insert image to the system. 1.2 display the message saying whether it has been inserted successfully or not. 1.3 process the image using a tool such as Matlab. 1.4 extract the location. 1.5 identify the affected area.
Alternate Path	none
Exception Path	none
Assumptions	The image has been properly identified.

Table 18 Use Case Description 8

Use-Case ID	UC-09
Use-Case Name	Display the affected area in red color.
Use-Case Description	After differentiating the paddy and weed, the weed area should be marked in red color. Then it is easy to identify for farmers.
Actors	System, farmer
Extended use cases	none
Included use cases	none
Pre-Conditions	The system has been differentiated the weeds and paddy.
Post-conditions	Recommend the weedicides.
Path	
Primary Path	1.1 insert image to the system. 1.2 display the message saying whether it has been inserted successfully or not. 1.3 process the image using a tool such as Matlab. 1.4 extract the location. 1.5 identify the affected area. 1.6 mark the affected area in red color.
Alternate Path	none
Exception Path	none
Assumptions	The image has been properly identified.

Table 19 Use Case Description 9

4.3. High Level Architecture

The whole system has been divided into three layers such as presentation layer, logic layer and data & services layer. The interface which is presented to the user (farmer) has been included in the presentation layer while the logic functions are included in the logic layer.

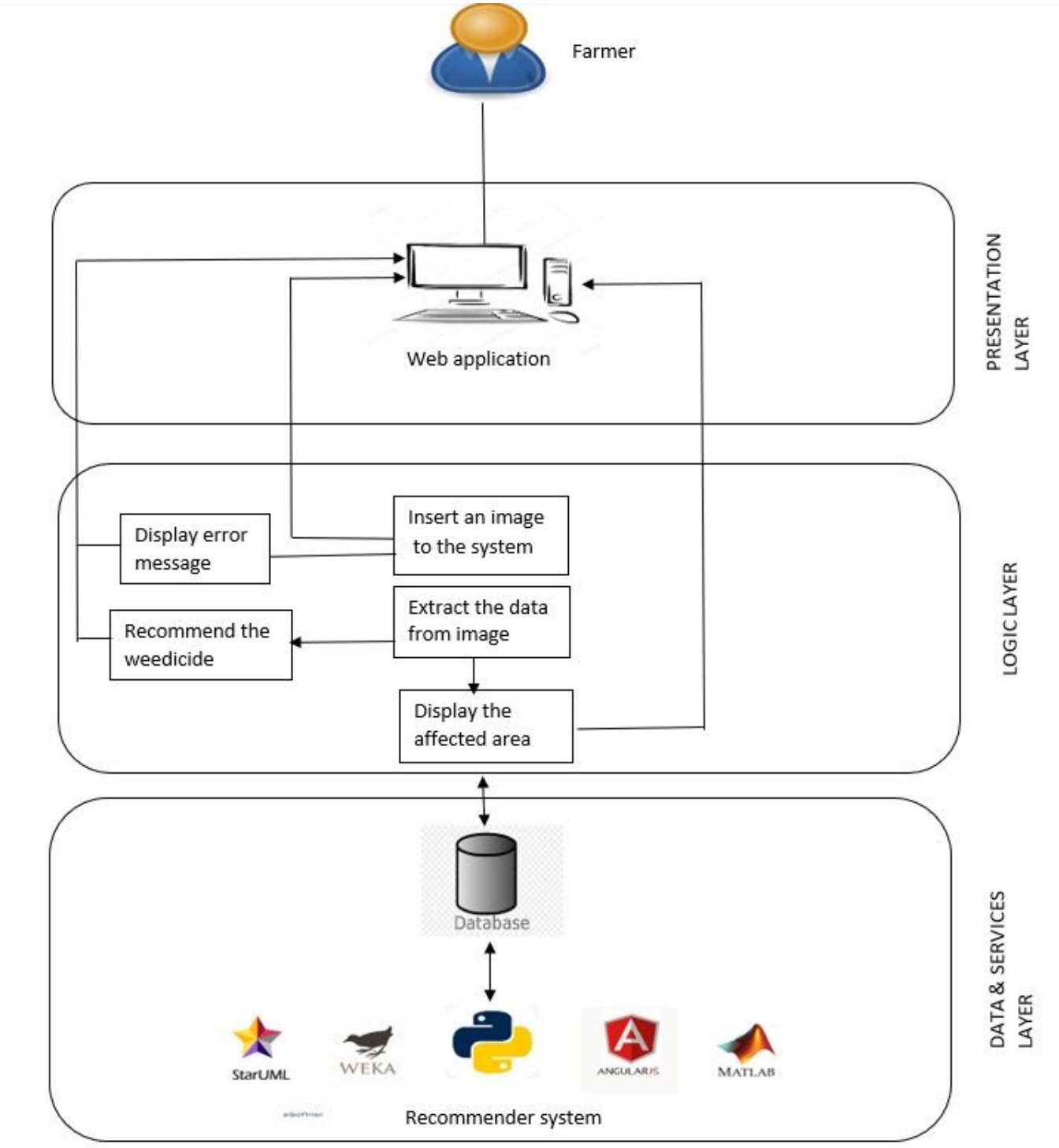


Figure 24 High Level Architecture

Function	Explanation
Insert image to the system	The user should insert a proper image to the system.
Display the affected area	The system will be properly displayed the location which has been affected with weeds.

Table 20 High Level Architecture description

4.4. Domain Model

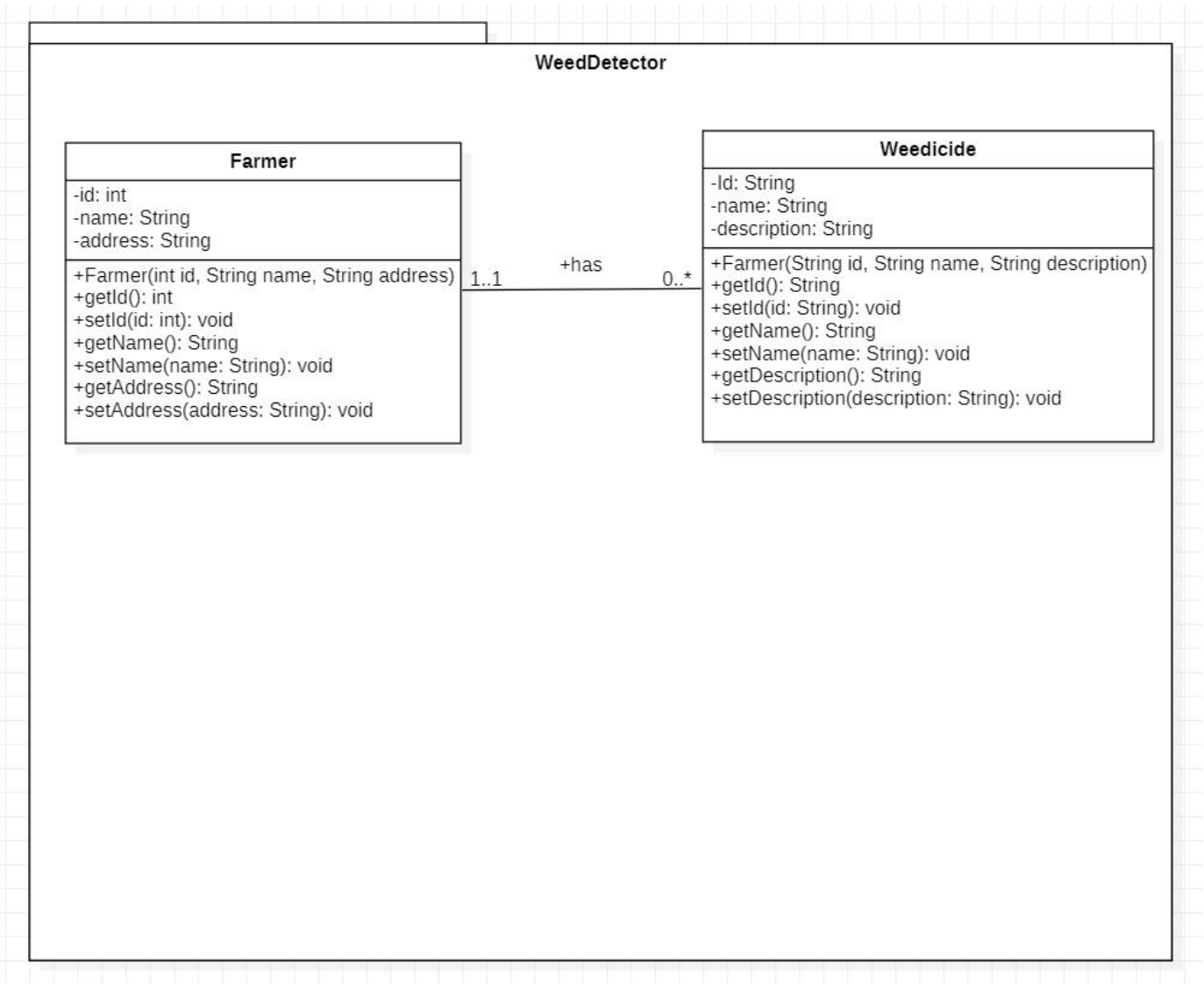


Figure 25 Domain Modal

4.5. Class Diagram

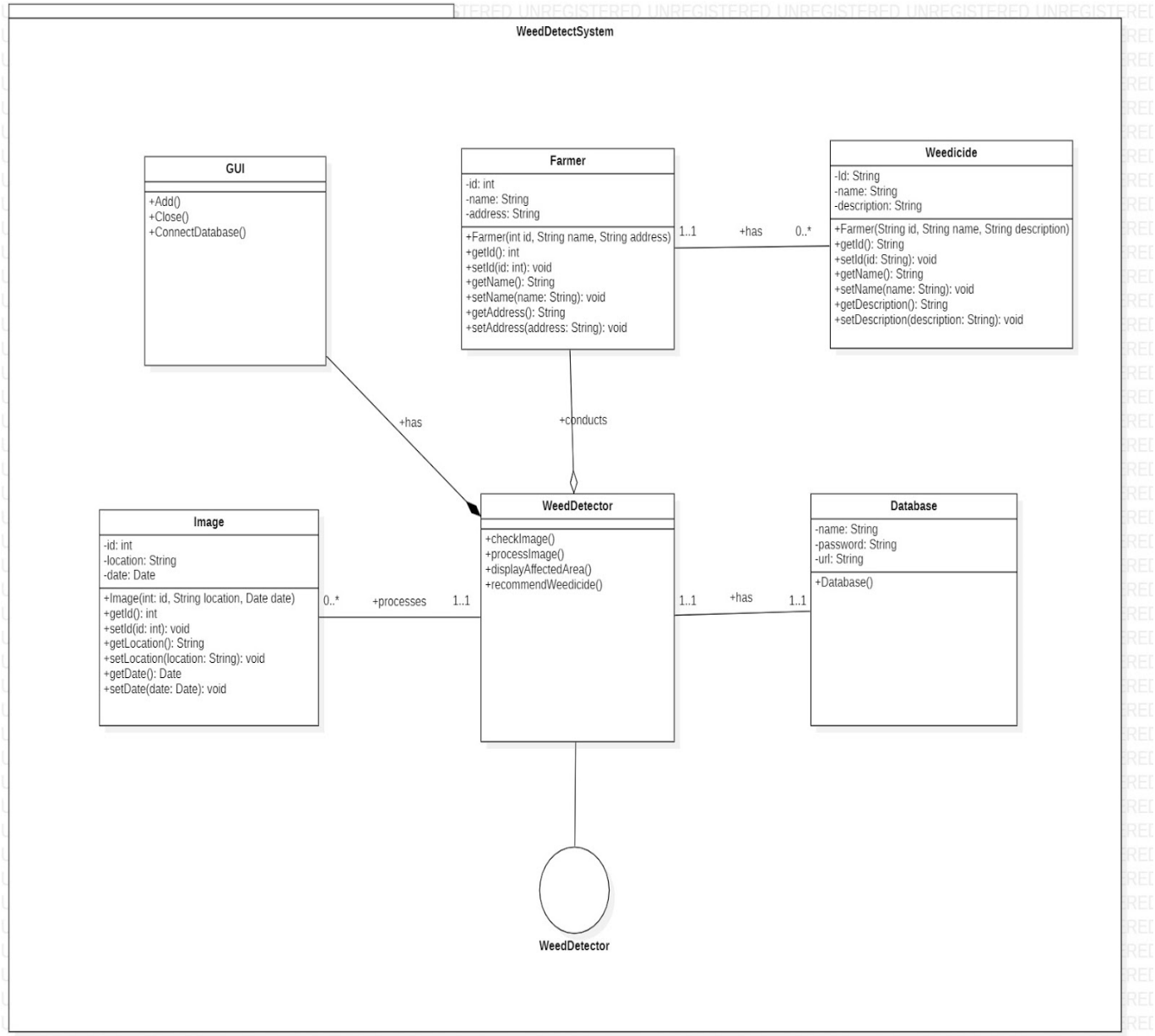


Figure 26 Class Diagram

4.6. Sequence Diagram

The diagram below represents the flow control of the weed identifier sequence. This diagram belongs to the back end of the application. In this case farmer wants to get a high-resolution picture by a good camera. And that photo have be send or input to the weed identifier application or to the website. By the website or the system gather all the information of the picture. According to the weed identifier it gathers all the information of weeds by that photo include. After processing that picture by the system, it gives a small message about picture and it gives all the locations of weeds that appear in that picture.

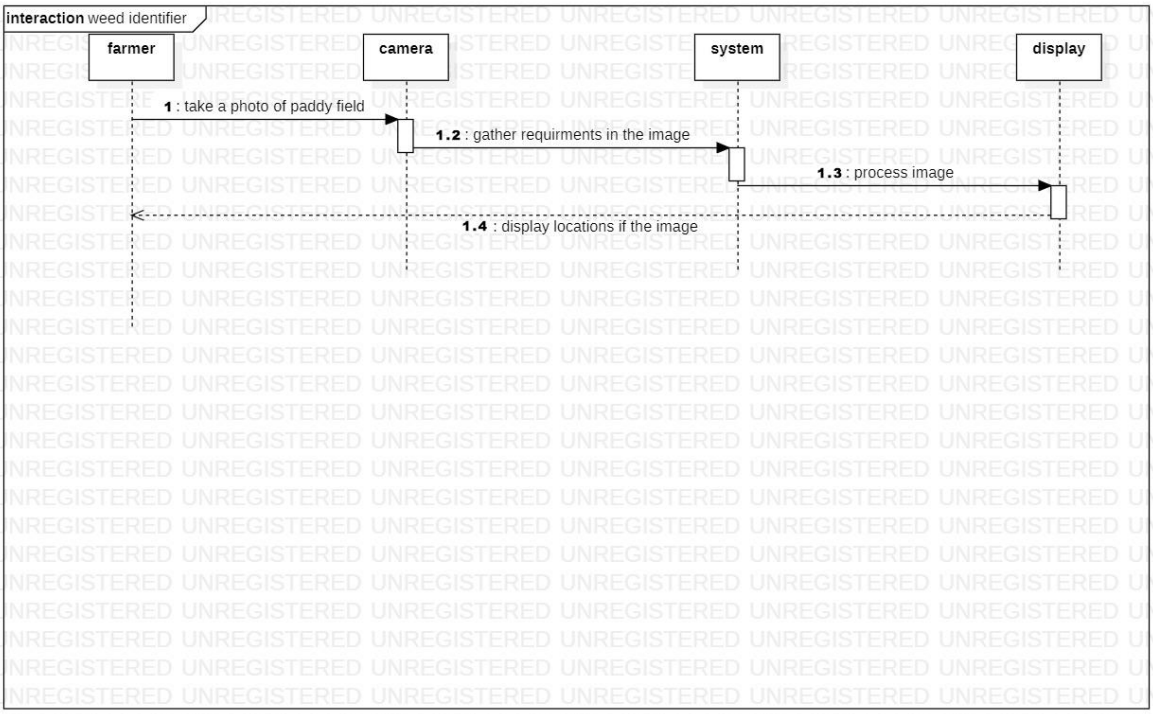


Figure 27Sequence Diagram

4.7. UI / UX Design

4.7.1. Activity Diagram

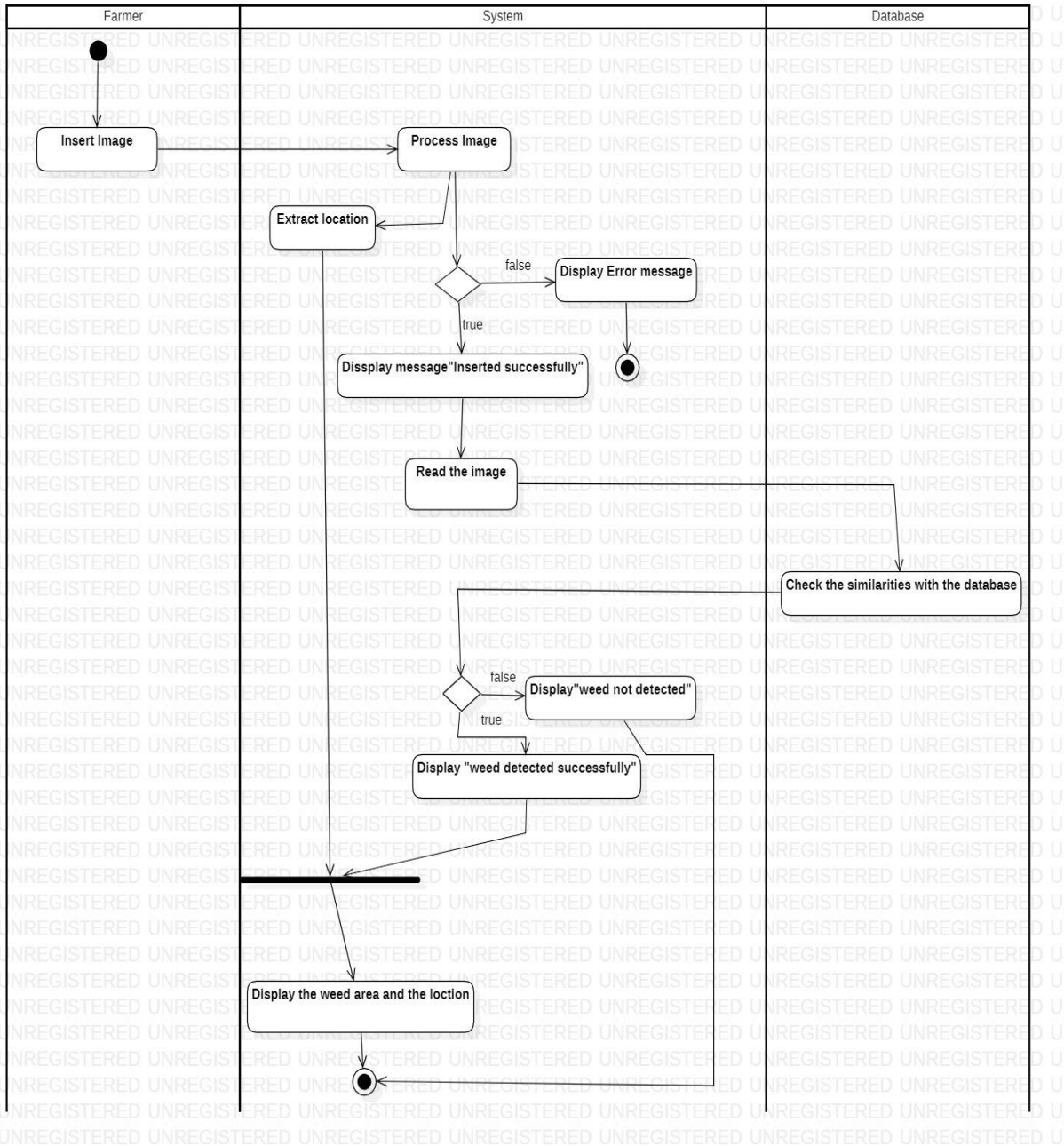


Figure 28 Activity Diagram

This activity diagram indicates the procedure of the weed detection system and its flow. This system has been done for all the farmers around the country and its simplicity will be helpful to conduct this application for any kind of farmers. This diagram shows the complete flow of the system. When considering about the knowledge level of farmers, farmer should have limited things to do with this system. Therefore, farmer should only insert a proper image to the system. Methodically the system will prepare the image to process and grab the location of the affected area from the picture. The system differentiates the weed and the paddy. The image will be read using image processing methods which has been already discussed in the Literature Review.

4.7.2. UI Wireframes

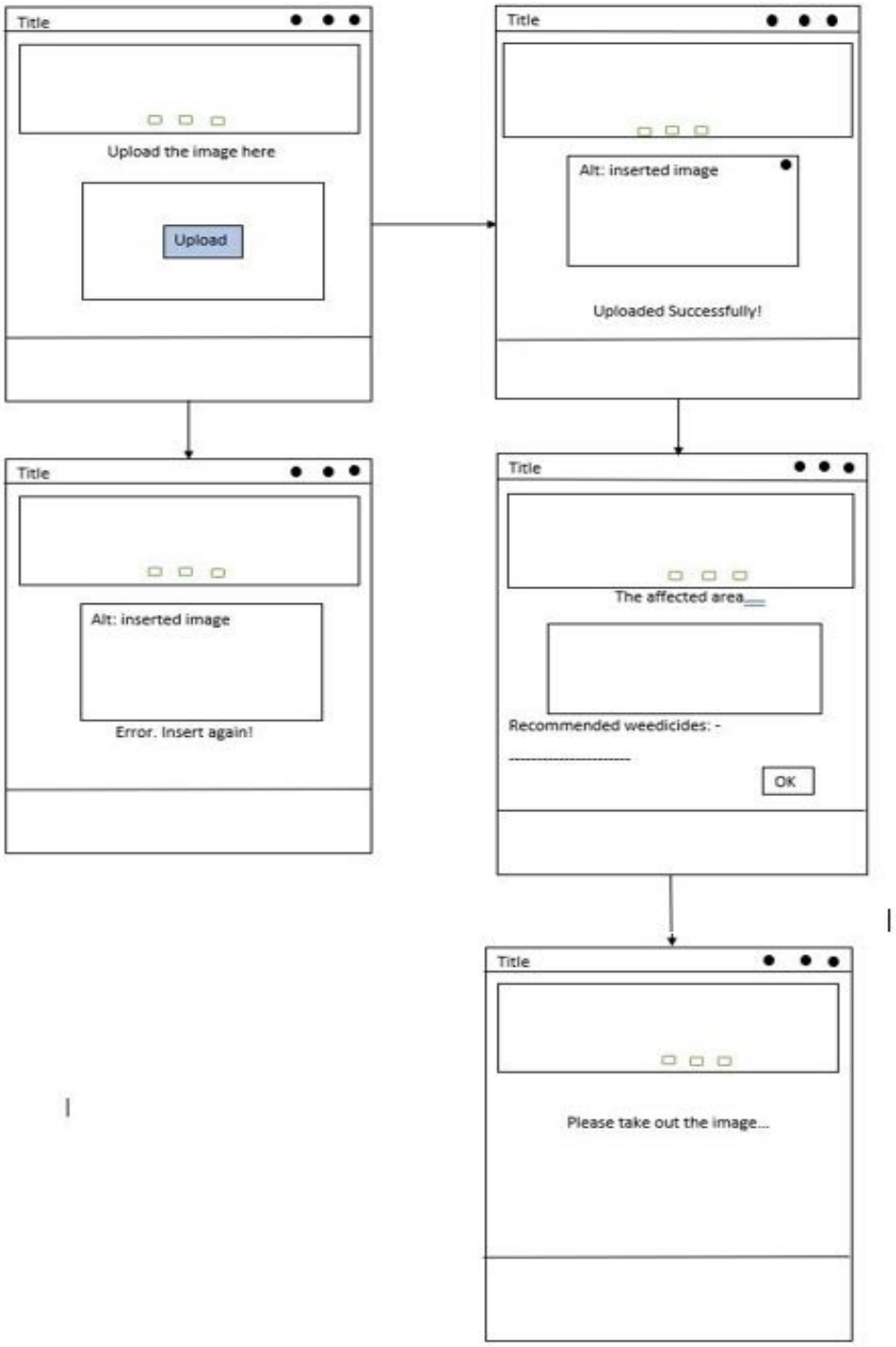


Figure 29 UI Wireframes

The first interface is for uploading the image to the system. After uploading the image, the second interface will display gradually whether the upload is successful or not. If the upload couldn't be identified, the error message should be displayed properly, and user can be uploaded the image again. In the third interface, the area which has been affected with weeds should be marked in red color and the system should recommend the herbicide for that. When the user clicks the OK button in the third interface, it should be shifted to the fourth interface which displays the message saying, "Please take out the image".

4.8. Chapter Summary

This chapter mainly focuses on the facts of system designs and functions of our weed detection application. It is consisted with both high-level designs and low-level designs. The technical overview is also included in this chapter. All these designs represent the summary of the whole project.

5. References

1. Anon., 2019. *PADDY STATISTICS 2018/2019 MAHA SEASON,* s.l.: DEPARTMENT OF CENSUS AND STATISTICS Sri Lanka.
2. Erhan, D., Szegedy, C., Toshev, A. & Anguelov, D., 2014. *Scalable Object Detection using Deep Neural Networks,* s.l.: IEEE Conference on Computer Vision and Pattern Recognition.
3. Fukuoka, M., n.d. *wise old sayings.* [Online]
   Available at: https://www.wiseoldsayings.com/farming-quotes/
   [Accessed 25 11 2019].
4. Gaunker, N. M., 2017. *weed detection using image processing,* s.l.: s.n.
5. Hoang, k., 2011. *CLASSIFICATION OF RICE FIELDS IN A COMPLEX LAND-USE WATERSHED IN NORTHERN VIETNAM USING RADARSAT-2.* Quebec, espace.
6. Irene , B.-S.et al., 2015. *Spatial Quality Evaluation of Resampled Unmanned Aerial Vehicle-Imagery for Weed Mapping. sensors,* s.l.: s.n.
7. jaipurbiofertilizers, 2019. *The Harmful Effects of Weedicides and Their Negation.* [Online]
   Available at: https://jaipurbiofertilizers.wordpress.com/2018/01/02/the-harmful-effects-of-weedicides-and-their-negation/
   [Accessed 25 November 2019].
8. Krizhevsky, A., Sutskever, I. & E, G., 2017. *ImageNet Classification with Deep Convolutional Neural Networks,* s.l.: COMMUNICATIONS OF THE ACM.
9. Kuasal, S., 2015. *Review on Identification and Classification of.* Pune, International Journal of Science and Research..
10. Mutalib, S., 2016. *A Brief Study on Paddy Applications with Image.* Melaka, IEEE.
11. Rani, N., 2017. *Image Processing Techniques,* Himachal Pradesh: www.chitkara.edu.in/publications.
12. Sheehan, J., 1986. *Aspects of research methodology,* s.l.: Logman group UK ltd.
13. Shymalie, H. W., n.d. *Cost Analysis of weed management in tea lands,* s.l.: tea research institue of sri lanka.
14. S, M., 2015. *A Brief Study on Paddy Applications with Image.* Melaka, IEEE.
15. statistics, D. o. c. a., 2018. *Paddy Cultivation2017/ 2018 Maha Season,* Colombo: Department of census and statistics.
16. Tellaeche, A. et al., 2010. *A computer vision approach for weeds identification through Support Vector,* s.l.: ELSEVIER.
17. Xu MaID, Xiangwu Deng, Long Qi, Yu Jiang, Hongwei Li, Yuwei Wang, Xupo Xing, 2019. *Fully convolutional network for rice seedling,* Guangzhou: PLOS ONE.

6. Bibliography

1. Honga, N., Xuanb, T., Eijib, T. and Khanhc, T. (2003). Paddy weed control by higher plants from Southeast Asia. aFaculty of Crop Science, Thai Nguyen University of Agriculture and Forestry,.
2. Olsen, A., Konovalov, D. and Philippa, B. (2019). DeepWeeds: A Multiclass Weed Species Image Dataset for Deep Learning. [online] Scientific Reports. Available at: https://doi.org/10.1038/s41598-018-38343-3 [Accessed 1 Dec. 2020].
3. Karim, R., MAN, A. and SAHID, I. (2004). Weed problems and their management in rice fields of Malaysia: An overview. [online] Research Gate. Available at: https://www.researchgate.net/publication/227946980_Weed_problems_and_their_management_in_rice_fields_of_Malaysia_An_overview [Accessed 17 Dec. 2019].
4. Desai, R., Desai, K., Solanki, Z. and Patel, D. (n.d.). Removal of weeds using Image Processing: A Techni- cal Review. International Journal of Advanced Computer Technology (IJACT).
5. Madhavanavar, S. (2017). A Survey on Weed Detection using Image Processing. Bagalkot: International Journal of Engineering Research & Technology (IJERT).
6. Reddy, R., Laasya, G., Sowmya, T., Sindhuja, P. and Basha, M. (2017). Image Processing For Weed Detection. International Journal of Engineering Technology, Management and Applied Sciences.
7. Sakthi, P. and Yuvarani, P. (n.d.). Detection and Removal of Weed between Crops in Agricultural Field using Image Processing. Electronics and Instrumentation Engineering M. Kumarasamy College of Engineering Karur, India.
8. Tellaechea, A., Pajares, G., Burgos-Artizzub, X. and Ribeiro, A. (2010). A computer vision approach for weeds identification through Support Vector Machines. Spain: Dpto. Ingeniería del Software e Inteligencia Artificial, Facultad Informática, Universidad Complutense, Madrid 28040, Spain.
9. Vikhram, R., Agarwal, R., Uprety, R. and Prasanth, V. (2018). Automatic Weed Detection and Smart Herbicide Sprayer Robot. Chennai: International Journal of Engineering & Technology.
10. Weis,, M. and Gerhards, R. (n.d.). Detection of weeds using image processing and clustering. Germany: Department of Weed Science, University of Hohenheim, Otto-Sander-Straße 5, 70599 Stuttgart, Germany.
11. Wua, X., Xu, W., Song, Y. and Cai, M. (2003). The Detection Method of Weed in Wheat Field on Machine Vision. China: College of Computer and Information, Hohai University, Nanjing 210098, China.