Portable Soil Detection System Based On Image Processing For Agriculture

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Abstract

Portable Soil Detection System based on Image Processing for Agriculture

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Sri Lanka is a country where agriculture and cultivation is a main form of livelihood of it's natives and a main form of income to the country. Therefore, selecting the best suitable crop for a specific soil type becomes the key factor at the initial stage of the process since it not only provides an anchor for the plants, but since the different properties of soil provides several other physical and chemical factors which affects the plant growth. Traditional farmers tend to cultivate crops which commonly grew in that area whereas the next generation of farmers went one step ahead to go for laboratory testing of the soil before cultivating which was highly time consuming with the distances to those labs and time taken to give the results and the results were also highly subjective due to the soil variability and the results were of low accuracy. Therefore, developing and automated soil detection and crop suggesting system is very applicable for this requirement. The developed system will predict the best suitable crop to be grown in a soil type once a photo of the soil sample is input to the system. Soil data set obtained from different parts of the country has been used to train the developed model. The dataset consisted of several categories of soil and concepts of machine learning were used to analyze the dataset. Data preprocessing techniques have been used to cleanse the dataset so that the accuracy of the results will be high. After that the key attributes of a soil were recognized by the team which have been necessary for training the AI model. Then the collected data were divided considering the previously recognized soil attributes. The system has identified the patterns of soil using analyzed data and then trained the model for prediction. We have a mobile application to use these final results efficiently.

Keywords – Soil Classification, Deep Learning, Crop Prediction

Acknowledgement

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Other than them, we need to thank all our batch-mates who helped us to research about image processing techniques and soil sample collection process, other technologies and methodologies that we have to use when implementing the system.

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Introduction

1.1 Introduction And Background

Agriculture could be considered as the key livelihood of Sri Lanka. For the inhabitants in Sri Lanka especially in the dry zone their daily income depends on the harvest they obtain from their cultivations. Hence their cultivations should have a profitable harvest. One of the major reasons for the lack of yield in their plantations is the incapability of the farmers to select the best crop which suits their land. Due to this reason, there is a rapid drop in the number of people who are engaged in the agricultural sector. By the year 2020 the percentage of farmers whose main occupation is agriculture was reported as 23.73%. [1] Therefore, it is important to introduce a technique for the cultivators to select the best and the most profitable crop to be cultivated in their land.

Soil is an important influence to plants as it not only provides an anchor for the plants, but the different properties of soil which also provides several other physical and chemical factors which affects the plant growth. Among such factors are the porosity, moisture content, cation exchange rate, electrical conductivity, pH level etc. [2] These factors are manually identified using several chemical processes. If these factors could be identified precisely, easily and accurately, by combining these factors the best suitable crop/plant for a specific soil type can be determined.

Determining the properties of soil to estimate the strength of soil is one prime objective of geotechnical engineering. For this a range of traditional lab testing methods have been employed. But the data obtained from these tests are highly subjective, which even further complicates the existing variability of soil. [2]

Image processing has been incorporated with agriculture since recently and is widely expanding. Therefore, through the proposed Portable soil detection system we are planning to use image processing techniques to analyze a soil sample and suggest the best suitable crop for a given soil type.

1.2 Problem To Be Addressed

Even to date agriculture contributes to the national economy of our country at large scale. Cultivation of tea, coconut, paddy, vegetables and fruits, oilseed crops, spices etc. are among the most cultivated. When selecting a crop to be grown in a specific land most farmers tend to select a crop which commonly grows in the surrounding. This might lead to poor growth of that crop, pronging the crop to various deficiencies, reduction of harvest and they're by spending money to overcome these problems result in extra expenditure, wastage of resources and time and overall, a loss.

To minimize these problems farmers are educated to test their soil sample and determine the best suitable crop for that soil type as the variety in soil is immeasurable. The traditional testing methods used up to date in Sri Lanka are laboratory mechanical testing which occurs when the farmer takes a soil sample to the lab. For an example in order to determine the ph. value of a soil sample the amount of hydrogen ions were calculated. And in order to find the electrical conductivity of the soil sample the salinity value was found by using an electrical conductivity meter. [2] But these methods are expensive, time consuming, involves much labor and also can be error prone as it's a mechanical process and is not very accurate. Hence the need of a method to make this process simple, more convenient and accurate for the farmers is seen as a gap.

1.3 Scope

There's a huge variety of soil types in Sri Lanka. One or many of these soil types can be found in one or many of the Provinces, Districts and Grama Niladhari Divisions of the country. Therefore, in this project we are targeting the soil types of North Central Province. And the system and application will be developed to cover the soil types and crop types in Sri Lanka.

1.4 Objectives Of The Project

Most farmers now have access to a mobile phone with a camera. If they can take a photograph of the soil sample and if the crop is suggested by the app at that instance itself, much time and effort in taking them to a lab will be saved, accuracy of the result will be higher, the extra expenses which have to be borne in selecting an unsuitable crop will not have to be spent and overall increase the harvest and profit for the farmer.

The main aim of this project is to develop a mobile application to address the above problem so that once the farmer takes a photo of the soil, it automatically analyses the soil and suggests the most suitable crop to be grown in that soil so that the problems mentioned above are minimized.

We plan to fulfill this aim under two objectives using digital image processing and deep learning.

1. Determine the type of soil by analyzing the soil sample
    - I. Determine the soil type using color
    - II. Determine the soil type using grain size
    - III. Determine the soil type using moisture
2. Suggest the best suitable crop for that soil type instantly.

1.5 Summary

There's a huge variety of soil types in different provinces, districts and grama niladhari divisions of Sri Lanka. Identifying the proper soil type and cultivating the suitable crop for that soil type is compulsory to obtain a good harvest and higher profits. The proposed system analyses and predicts the most suitable crop for a soil type instantly. This system helps make a correct decision on crop selection for a given soil type within few minutes.

Literature Review

2.1 Introduction

To predict soil type accurately has been a challenging task with the vast variety of soil types in different regions. Many researchers have tried to overcome this challenge by carrying out research for implementing system for soil type prediction. However, there are still

some limitations on their findings to provide an accurate prediction. In order to achieve the objectives mentioned in chapter 01, a literature survey is conducted to identify existing methods of soil type prediction. A large number of research papers on this topic have already been published previously. In this chapter it gives a brief description such project ideas found out through the survey and the basic methodologies used by them.

2.2 Literature Survey Based On Background Related Researches

The literature review has done depend on the project objectives. We have categorized the literature review according to the objectives of our project.

Determine The Soil Type Using Color

Research done by scientists Pengcheng Han, Daming Dong, Xiande Zhao, Leizi Jiao, Yun Lang had developed a Smartphone-based soil color sensor for soil type classification. In this research they mainly compared and analyzed the roles of the visible spectrum and machine vision adopted in soil classification. They directly used the CMOS device of the mobile phone as the sensor and the flashgun of the phone as the light source. In this method they used peripheral components included external lens, shading devices, and color calibration card, which were assembled on the phone directly. The colors of soil and proofread cards were acquired by the smart phone and converted into RGB signals. With RGB signals, after simple processing, they achieved rapid soil classification. But for image acquisition of machine vision, they used D7000 SLR (Single Lens Reflex) kit (Nikon Corporation, Japan) in their experiment. After they captured pictures, the pictures of each soil type were treated with the Matlab7.0 as their data set. By doing more spectral curves they obtained the visible reflectance spectral curve of each soil type. Different types of soils were different in the visible spectrum characteristics. Using these visible spectrum reflection characteristics, they managed to detect the soil colors of each soil type. [3]

Within this study the researchers have used the Munsell soil chart to categorize the initial images which were collected to create the database. In the proposed research study, the Munsell chart will be used to categorize the soil types in terms of color. However, as peripheral devices are used to capture the image, when experimenting (Shading bucket, external lenses, calibration card are attached to the smart phone) it is not convenient for a farmer to use these devices when obtaining the images in their cultivating land. Hence the objective of this research is not efficient in the practical aspect. Also, in this research visible Spectroscopy method was used to classify the soil types. And also, as mentioned in their research paper this method is not suitable for the rapid classification of soil samples.

Shima Ramesh Maniyath, Mr. Ramachandra Hebbar,Dr. S Rama Subramoniam, Akshatha K N, Architha L S had developed a method to detect the soil color using digital image processing. The authors bring some information about the background of the problem and they use the Munsell chart to compare the soil colors using image processing. According to this research they had generated a database about the soil colors using soil Munsell chart. And this literature shows that even the comparing soil sample image was not clear which means that it contains noises, that they had used median filter as their noise removing filter and used thresholding segmentation to do the segmentation. And they used K-Nearest Neighbor (KNN) as their soil color classification algorithm. It is a supervised machine learning technique. KNN considers the k nearest cases from an instance and decides which the most frequent class in the set is. The most repeated class is assumed to be the class of that instance (x), KNN system adopts a distance metric in order to determine nearest instance. Various distance metrics can be adopted including Euclidean which is used at this research as it gives the best results. KNN classifier could be taken as a successful technique to detect the soil color because of its simplicity and it is relatively speed. [4]

According to this research study the researchers have used the Munsell soil chart to categorize the initial images which were collected to create the database. In the proposed research study, the Munsell chart will be used to categorize the soil types in terms of color. Also, in this study a mobile phone camera was used to take the images which will enhance the practical usability of the objective of this research. A mobile phone camera is used in the proposed system as well to elevate the convenience of the user to use the application. Another plus point which was observed in this research methodology was that the median filter was used here as the best filter to remove the salt and pepper noises. However, in order to identify the most suitable crops to be cultivated in a farmer's land which is the indirect practical objective of this research cannot be achieved by identifying the color alone. Several other characteristics of soil such as porosity, moisture and grain size also effect the growth of a crop.

Fitri Utaminingrum and Ihwanudien Hasan Robbani had proposed an algorithm to detect the soil color using image processing, The Soctect Algorithm which means soil color detection algorithm. This research paper shows that this algorithm is consisting of five main steps, namely, creating database, first filtering process, segmentation, and second filtering process and color matching process. In this algorithm they create a database and they used mode of RGB values to get representation data. A median filter method is used to get the clear image. And they segmented the image by using K-means segmentation method. Furthermore, the segmented image will be filtered again by using median filter method. In this method they have used Euclidean distance to match the layers of image soil with the color in the database. They use this algorithm to detect the soil colors of different layers in soil sample. [5]

In this research the researchers have used the Munsell soil chart to categorize the initial images which were collected to create the database. In the proposed research study, the Munsell chart will be used to categorize the soil types in terms of color. Also, in this study a mobile phone camera was used to take the images which will enhance the practical usability of the objective of the research. A mobile phone camera is used in the proposed system as well to elevate the convenience of the user to use the application. Another benefit which was observed in this research methodology was that the median filter was used here as the best filter to remove the salt and pepper noises. Nevertheless, the result of this technique is highly dependent on the original image, as when obtaining images from different cameras the results will differ and if the images are collected using the same camera a higher accuracy could be reached. Also, as there are two filtering processes this approach is highly time consuming and larger neighborhoods might make the image blurry.

Determine The Soil Type Using Grain Size

The scientists G.H.A. Janaka J. Kumara, Kimitoshi Hayano and Keita Ogiwara has conducted a research study under the title of Image Analysis Techniques on Evaluation of Particle Size Distribution of Gravel. The researchers have adopted a methodology where the particles were arranged on a transparent sheet without touching or overlapping each other. Then the images were captured using a Nikon D7000 camera. The experimental procedure of this research study was done in two approaches. In the first approach 100 particles were placed on a white color sheet and in the second approach the particles were placed on a black color sheet. Shadow effect on the gradation curves were examined comparing the results of the first and second approaches. An alternative approach is used in the first approach as well. That is by using a transparent sheet to eliminate shadow effects. Then the images were analyzed by using the ImageJ software. Initially the pixel values are converted to millimeters using a scale factor. Then the images were converted into binary images and image processing techniques such as erode, dilate and fill holes were applied on the images respectively. Area, minor and major axes and shape characteristics such as roundness, perimeter and circularity were measured in the image analysis. The volume of the particles was determined by the results of the image analysis. [6]

In this research the morphological operations such as erosion and dilation were used to extract the image components. These techniques will be used in the proposed research study when determining the grain size of the soil particles. As this research is done by using an experimental apparatus that is not a practical approach for a farmer to determine the grain size of their soil samples. The farmers should consult an image processing expert to find out the grain size of that soil sample. Hence it is not a convenient method. Also, in this method the individual gravel particles are arranged in a white and black sheet in order to obtain the photograph to be analyzed. But in most of the soil samples it cannot be done practically. Furthermore, in order to identify the most suitable crops to be cultivated in a farmer’s land which is the indirect practical objective of this research cannot be achieved by identifying the grain size alone. Several other characteristics of soil such as porosity, moisture also effect the growth of a crop.

Determine The Soil Type Using Moisture

In a research study which was conducted by Gheorghe C., Dean T.A. and Filip N. under the title of Image processing techniques used in soil moisture analysis the researchers have adopted a methodology by which they have obtained several pictures of a large field located nearby Cluj - Napoca city through a quadcopter and processed them in MATLAB software. The intensity of the original RGB image was determined by using MATLAB codes and that was compared with the black and white image pixel's intensities. In this methodology the researchers have converted the original RGB image to a gray scale image and that image was converted to a high contrast gray scale image. Then the coordinate matrices were obtained from the above images and the intensity level was set on the z axis using image processing algorithms. By applying this algorithm on the MATLAB software, the researchers have obtained a surface plot with three axes, x (number of pixels on the length), y (number of pixels on the width), z (number of pixels in the height). From the plotted graph the researchers were able to observe that the number of pixels in z was higher as the color of the image is brighter. Hence it was concluded that when the number of pixels in z is lower that places contain dry soil and when the number of pixels in z is higher the soil is wet as the grass is grown in the moist soil and that is the green color which is giving a higher number of pixels in z. It was also found out that the contrast enhanced black and white images can produce easier to see results at first glance and also the contours of the grass parcels are better defined in this image than in the other two images. [7]

According to this research study it was found out that the black and white images have a pixel distribution and a contour higher than the RGB images. Hence that finding will be used in our research study when applying the image processing techniques. As in this research a drone is used to take the aerial view of the soil it is not practically supporting the agriculture in general as the farmers does not possess a drone to take aerial images and they have to go to an expert to analyze the soil moisture content of their land. This is not a convenient method to the farmer and also is time consuming. Furthermore, in order to identify the most suitable crops to be cultivated in a farmer's land which is the indirect practical objective of this research that cannot be achieved by identifying the moisture alone. Several other characteristics of soil such as porosity, grain size also effect the growth of a crop.

Yuanjun Zhu, Yungiang Wang, Mingan Shao and Robert Hortan has published a research article under the title of Estimating soil water content from surface digital gray level measurements under visible spectrum. The researchers have adopted a methodology where the soil samples were initially passed through a 2 mm sieve and dried at 108 ^{0}C. The soils were then packed into small cylinders and water saturated. The images were taken using a digital camera. The packed soil samples were allowed to dry. At selected times during drying, the samples were weighed to determine the soil water content and surface images were obtained. Two color checkers of black and white were used in two corners of the image when taking the digital photograph to minimize the effect from the background light. All the images taken were converted to gray scale images and the gray level was determined. It was observed by the researchers that in dry soil the surface gray level is increased and in the wet soil the gray level is very less. For saturated soil the gray level is at its minimum. In this research statistical characteristics of the surface gray levels were described by using different mathematical models and formulas. [8]

In this methodology they have dried a soil sample and has saturated it with water and allowed them to dry and has taken the photographs of it. This approach could be used in the proposed research study as well. However, in the proposed research study it was not planned to saturate the sample at once but gradually saturate it by increasingly adding 20 ml of water until it is saturated. These researches have also adopted a technique to minimize the effect of the background light in the images that are taken. Here they have used two black and white checkers. Hence that technique will also be helpful in the proposed research study to minimize the effect of the background light. However, in this study the soil sample has to be packed in a cylinder with 3 cm diameter and 1.5 cm deep. This cannot be practically found by the farmers. Also, as this study has used a mathematical basis to find the moisture level of soil the farmer has to consult an image processing expert to determine the moisture level of the soil. This is not a convenient and a practical method for a farmer.

2.3 Organization of the dissertation

The dissertation explains the major tasks followed in the process of achieving the aim and objectives of the project. This provides detail descriptions about the analysis, designing, implementing and evaluating phases which we have performed. In the first chapter discussed about the project introduction and background, then about the problem that has identified. It also consists of project scope and the objectives of the project.

The second chapter of the dissertation consists of the background related researches addressed to the project idea. It consists of the past research works conducted to the same problem and also include the recent findings of the information about the same problems. Further this includes the techniques used in these previous works that address the same problem.

In the third chapter, it describes the software components of the project. Also, it includes the description about system architecture, objects and communication and about tools and techniques which we used to develop the soil type prediction system.

In the fourth chapter, it describes the system integration of the developed system.

Fifth chapter discuss results and some outputs of the developed system.

Sixth and final chapter describes the conclusions and the future work that should fulfilled with proposed system.

2.4 Summary

According to the literature survey conducted, most of researches have used machine learning/deep learning techniques, data mining techniques to develop such kind of prediction systems. Also, image processing techniques had been used to get values for different criteria. Among them it could be identified that machine learning/deep learning techniques are most suitable to develop an automated soil type detection system and digital image processing techniques to analyze the properties of soil.

Software Components

3.1 Introduction

In this chapter, it is going to be discussed about the research component of the project. Here, the basic design of the research component is briefly explained.

3.2 System architecture

The software design of the project is based on the software functional components or units of the soil detection system that has been implemented as a system in the project implementation. It basically shows how each of the functional units link with other units of the system in order to perform the functional requirements of the system.

3.2.1 Software design diagram and its components

In order to achieve the objectives stated in chapter one, a system to predict the soil type and the most suitable crop to be grown in that soil was developed by analyzing several soil types taken from several regions of Sri Lanka. First of all, we collected different soil types from different regions of the country and created a database which includes that soil details. Before training the model data are preprocessed. Then that preprocessed data is fed to train the AI model. Using these trained data, it can predict the soil type of the taken photo and further predict the best suitable crop to be grown in that soil. To use these predicted results efficiently, we developed a mobile application. The mobile application could be used by the admin to update soil types and crop types frequently whereas the user can use it to get the soil type and crop type predicted.

Further this soil database can be updated frequently, therefore this is a real time system. Through the combination of these developed software sections altogether, it forms the basic research component in the system.

Figure 1 shows the basic software component diagram of the system. The functioning of each numbered component in the diagram is listed below.

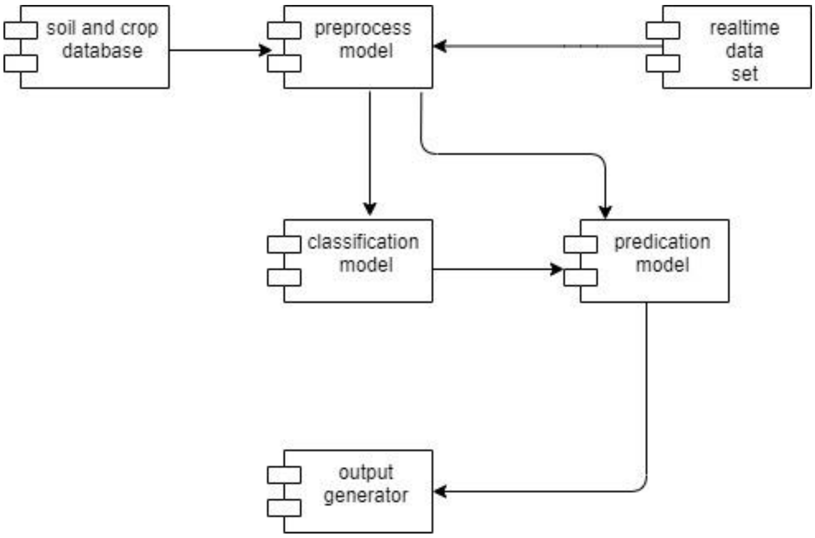


Figure 3.2.1: Component diagram for proposed system

3.2.1.1. Preprocess model

The format of the data has to be changed in to a proper format in order to achieve best result from the AI model. Therefore, prior inserting the data in to the model the data has to be preprocessed. The soil types and their properties in the soil database and the real time data are preprocessed in this module. Preprocessing plays a vital role in AI as the data may contain missing values, null values and some incomplete data. By preprocessing the data will be cleaned and the missing values will be filled. Through preprocessing the key soil attributes could be identified which is useful for model training.

3.2.1.2 Classification model

The classification model will conduct statistical analysis on the dataset and create graphs on the dataset to give a clearer idea. After analyzing the dataset, the patterns and trends of the soil attributes can be identified.

3.2.1.3 Prediction model

In this component the prediction model will predict the soil type using the preprocessed and the classification dataset. For this purpose, the AI model will be trained using the preprocessed and the classification data.

3.2.1.4 Output Generator

With the use of the predicted data of from the predication model, the output generator will generate its output. This output will either be the soil type or suggested crop depending on the result requested by the user and it will be displayed on the screen.

3.2.1.5 Real-time Dataset

The real-time dataset of this application involves with the different soil types and crop types updated to the database by the admin. This will be done occasionally by the admin with the advent of an un existing soil type or crop type in the database.

3.3 Objects and Communication

Sequence Diagram for Select Location

In this sequence diagram, the location selection process is represented. The application initially displays two options to select the location. They are selecting the location manually and through GPS technology. If the user chooses to select the location manually, the application will display the available provinces, districts and divisional secretariat divisions respectively to the user. Once the user selects the location it will be stored in the database. The alternate path is selecting the location through GPS technology. Here the user simply has to switch on the location settings of the mobile device and then the GPS facility of the device automatically detects the location of the user and returns it to the application.

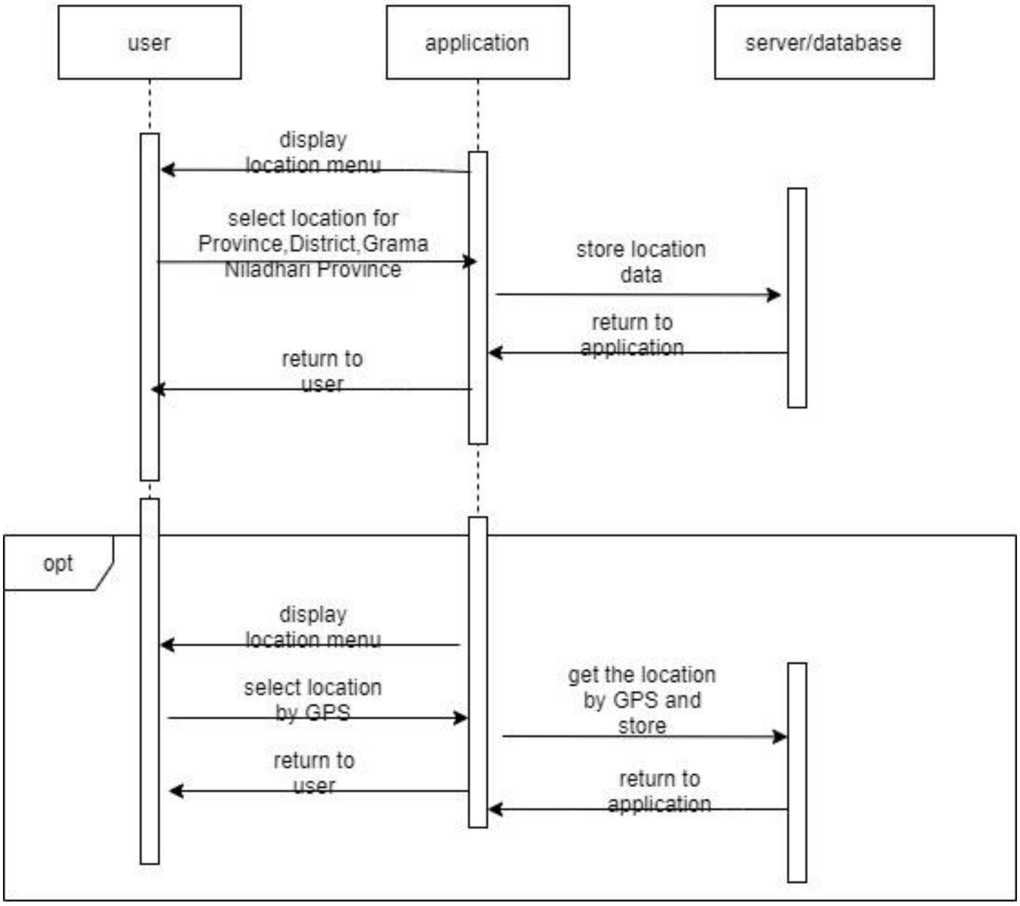


Figure 3.3.1: Select Location

Sequence Diagram for Upload Photo

In this sequence diagram the process of uploading the photograph is represented. The application initially displays two options to upload the photo. They are capturing a photograph through the application and uploading an image already existing in the gallery. If the user chooses to capture a photograph through the application, the user will be directed to the device camera with a square in the middle so that the user will have to capture the soil sample within that square frame. When the photo is successfully taken within the given resolution boundaries it will be displayed in the mobile application screen. The alternative path is to upload an existing image from the gallery. If the user chooses that option, he will be redirected to the gallery interface of the device and the user can select the relevant image from the gallery. Thereafter, the image will be cropped according to the relevant dimensions and if the image is with the required dimension and resolution then the image will be successfully displayed.

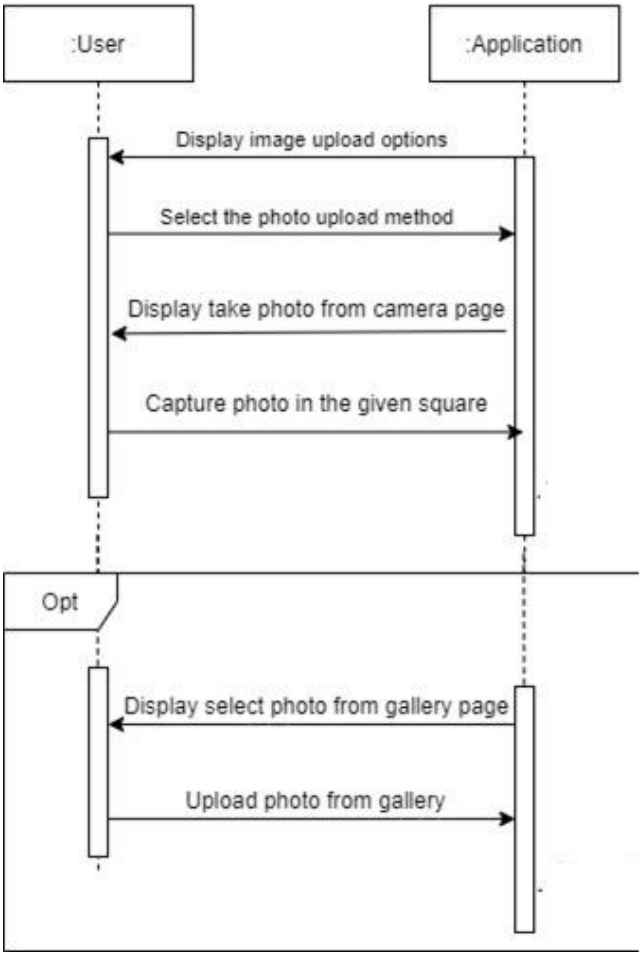


Figure 3.3.2: Upload Photo

Sequence Diagram for Analyze the soil type

This sequence diagram represents the process of analyzing the soil type using image processing techniques. The application will analyze the previously uploaded photo by means of soil color, moisture and grain size. After the photo is being analyzed, the result will be displayed to the user.

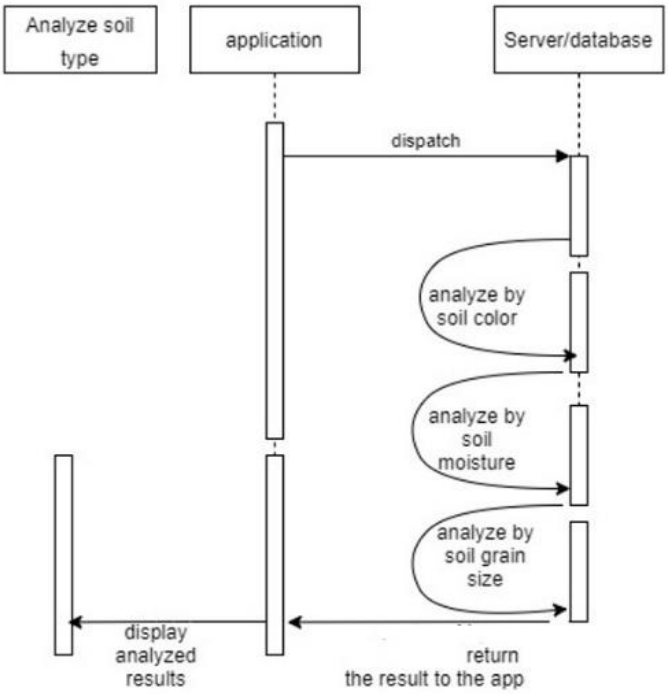


Figure 3.3.3: Analyze the soil type

Sequence Diagram for Display the suitable crop

This sequence diagram represents the process of finding and displaying the most suitable crop to be cultivated in the previously analyzed soil. Here once the application displays the type of the analyzed soil sample, if the user wishes to know the best suitable crop to be cultivated in that soil, then the user must click on the option button to view the suitable crop types. Then the user will be directed to an interface consisting of the suitable crop types after being compared with the database.

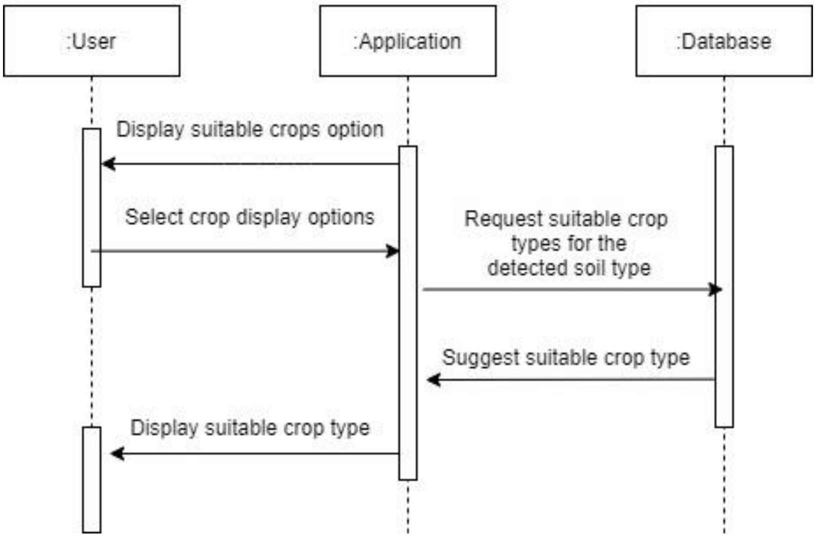


Figure 3.3.4: Display most suitable crop

Sequence Diagram for Login as administrator

This sequence diagram represents the process of logging in as the administrator. The application will initially provide an interface for the administrator to login. Once the administrator clicks on the login option, he will be directed to the login form where he has to enter the username and the password which will be validated through the application. If the data is successfully validated the application will display a login success message.

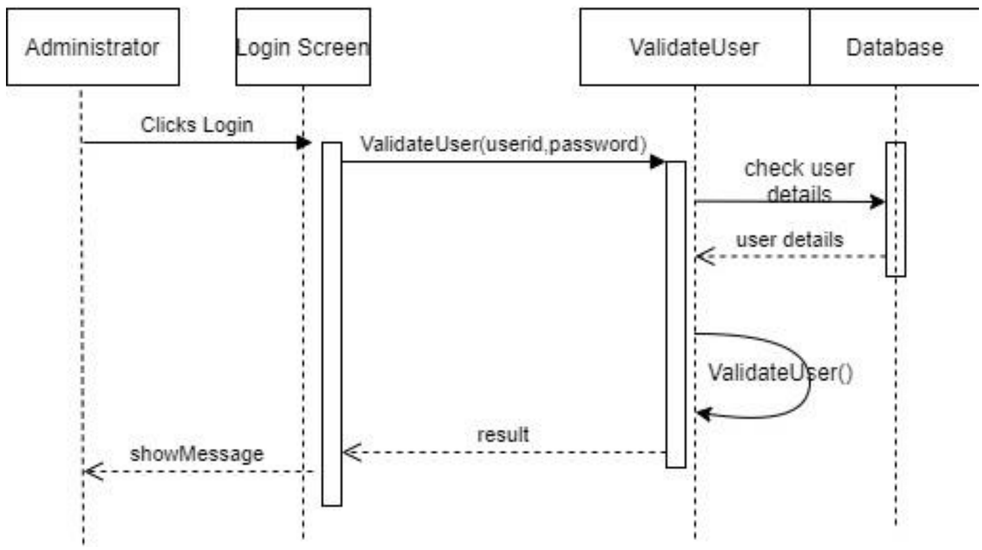


Figure 3.3.5: Login as administrator

Sequence Diagram for Update database

This sequence diagram represents the process of updating the database. In order to update the database, the administrator must initially login to the system. There after the administrator can either update an existing record in the database or can add a new record. The update database process involves either updating or adding a crop type or soil type.

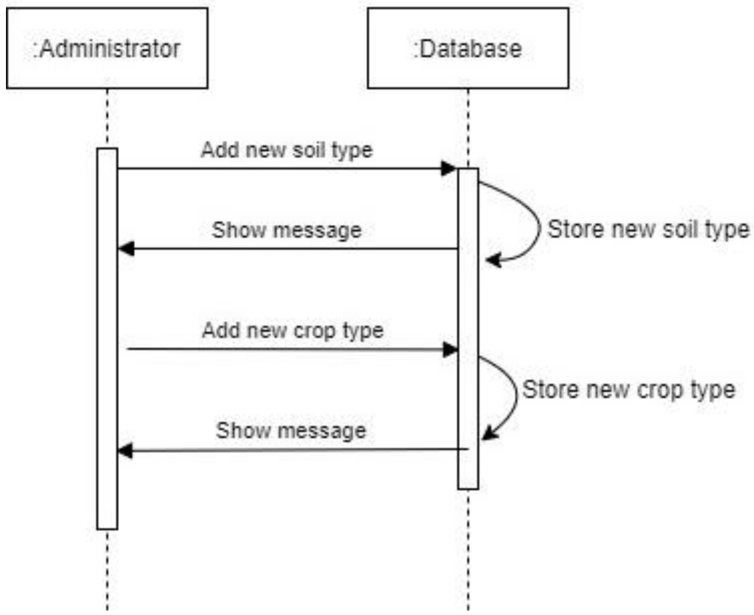


Figure 3.3.6: Update Database

3.4 Tools and techniques used

Microsoft Visio

Microsoft Visio is software for drawing a variety of diagrams. These include flowcharts, org charts, building plans, floor plans, data flow diagrams, process flow diagrams, business process modeling, swim lane diagrams, 3D maps, and many more. Visio can be used in a variety of setting to create professional-looking diagrams. Visio includes a big library of shapes/symbols used in dozens of diagram types. Using Visio, we use for drawing sequential diagrams and flow chart.

Python

Python is an interpreted, interactive, object-oriented programming language. It incorporates modules, exceptions, dynamic typing, very high-level dynamic data types, and classes. We hope to use python as our implementing environment.

Deep Learning

A Convolutional Neural Network (CNN) is a Deep Learning algorithm which can take in an input image, assign importance (learnable weights and biases) to various aspects/objects in the image and be able to differentiate one from the other. CNN is a type of artificial neural network used in image recognition and processing that is specifically designed to process pixel data. We have used some deep learning approach to build our AI model.

Open CV

OpenCV (Open-Source Computer Vision Library) is an open-source computer vision and machine learning software library. OpenCV was built to provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in the commercial products

3.5 Summary

This chapter basically describes about the component diagram and describes its functions. Further it includes sequence diagrams for some functions of the system and also about the tools and techniques which are used to develop.

System Integration

4.1 Introduction

Mainly there are 2 major components in this soil analysis prediction system. It includes a mobile application to enter soil and crop details by the admin and for the user to get the output and also convolutional neural network, deep learning model to predict the type of soil and most suitable crop for that soil type.

4.2 Deep learning model

Supervised deep learning used for this system since both inputs and outputs used to train the model. Among the supervised deep learning models convolutional neural network used since it gives a more accurate results for image classification processes. When the user uploads a photo of the soil sample and chooses the location as inputs model will predict using the previous data and gives the name of the soil type and the best suitable crop to be grown in that soil type as outputs.

4.3Mobile application

Mobile application was developed using Android JDK. Mobile application can be used by both the admin and farmers. The admin can login with their username and password whereas the farmers can use it without any such login.

4.3.1Select location

There are two buttons in the select location screen. One to select the location by GPS and the other to select the location manually. If the user selects the GPS mode, user is directed to another screen with two buttons where the user can automatically set his location and the upload that detected location using the other button. If the user selects the manual button, he gets three drop-down menus to select the Province, District and Grama Niladhari Division accordingly.

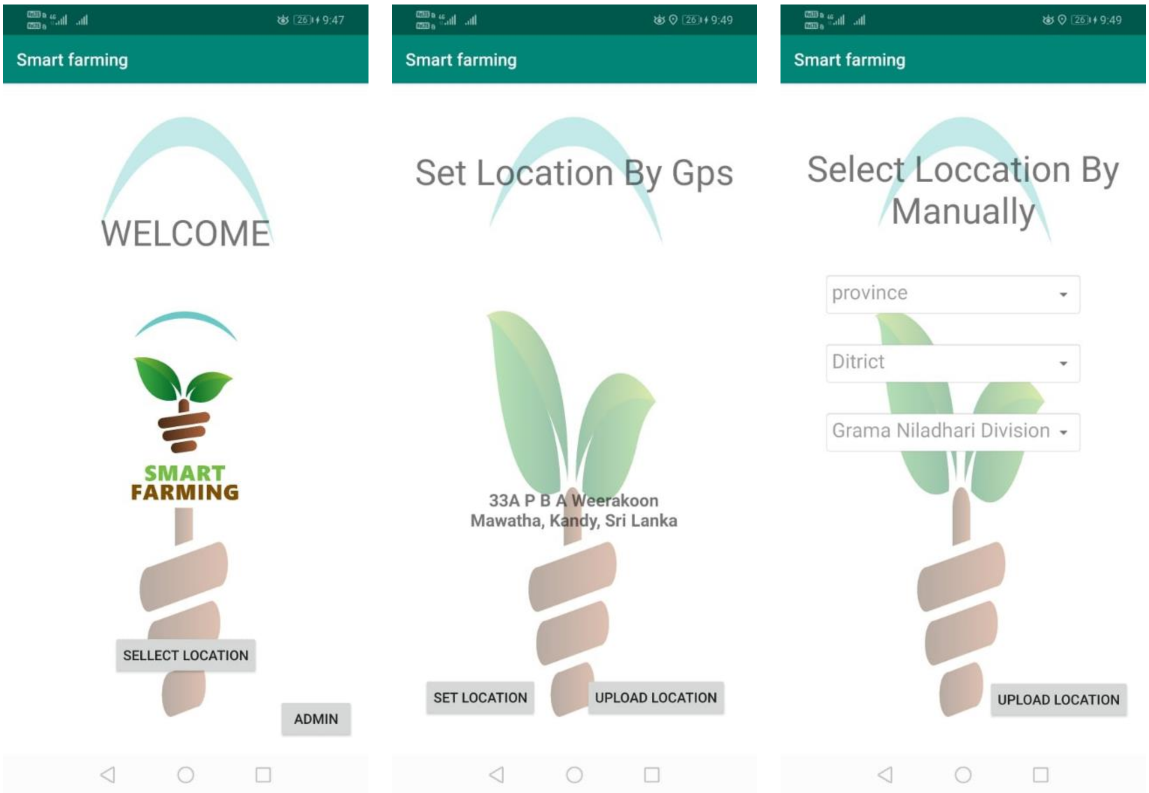


Figure 4.3.1: Select Location

4.3.2Upload Image

There are three buttons in this interface. One to get the image spontaneously using the camera, second to select the image from the gallery and a third predict button to upload the selected image and get the prediction. If the user selects the camera button an alert message with instructions is displayed on the screen before capturing the photo. If the gallery button is selected it is directed to the gallery to choose and image. Either way once an image is selected it will be displayed in the upload image screen and when predict button is selected the soil type will be displayed in the same interface with details such as moisture level, precited value and grain size. By clicking the next button user can move forward.

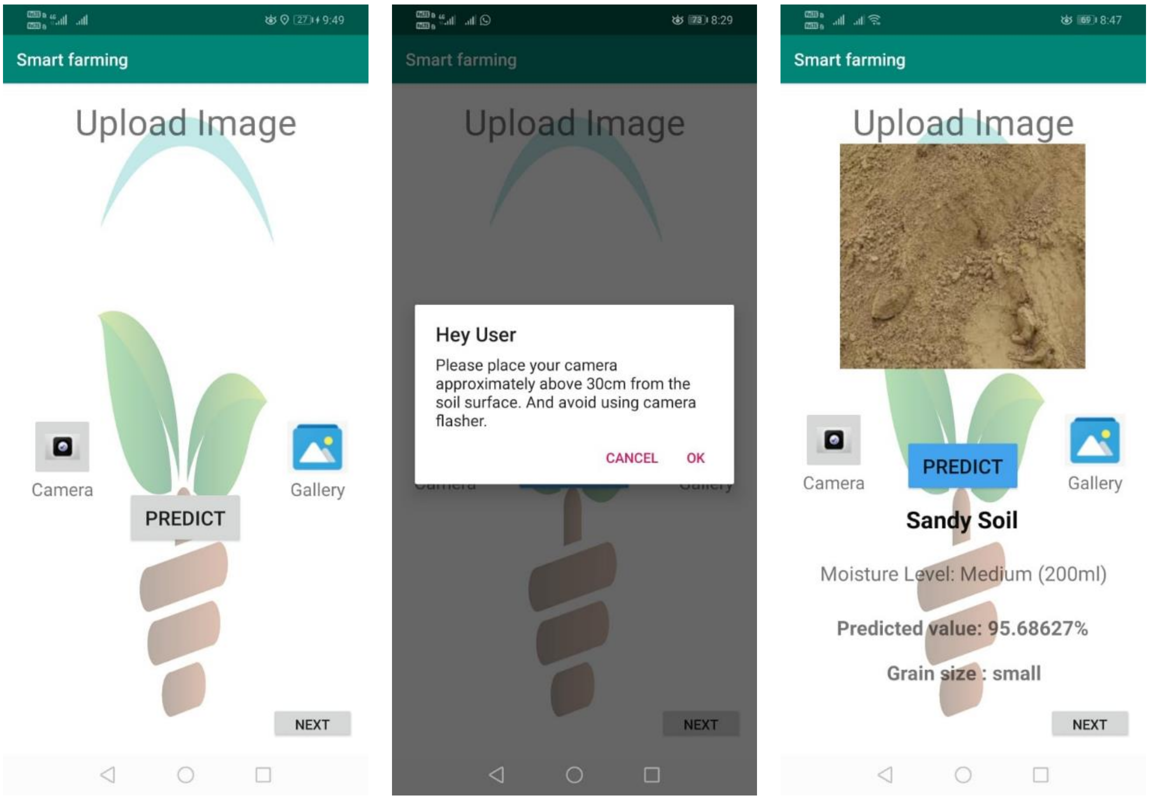


Figure 4.3.2: Upload image

4.3.3 Suitable crops

This interface has a display crop button so with the predicted soil type once the display crop button is selected the best suitable crops for this soil type will be displayed along with an instruction message on how to add water to this soil type depending on its grain size value.

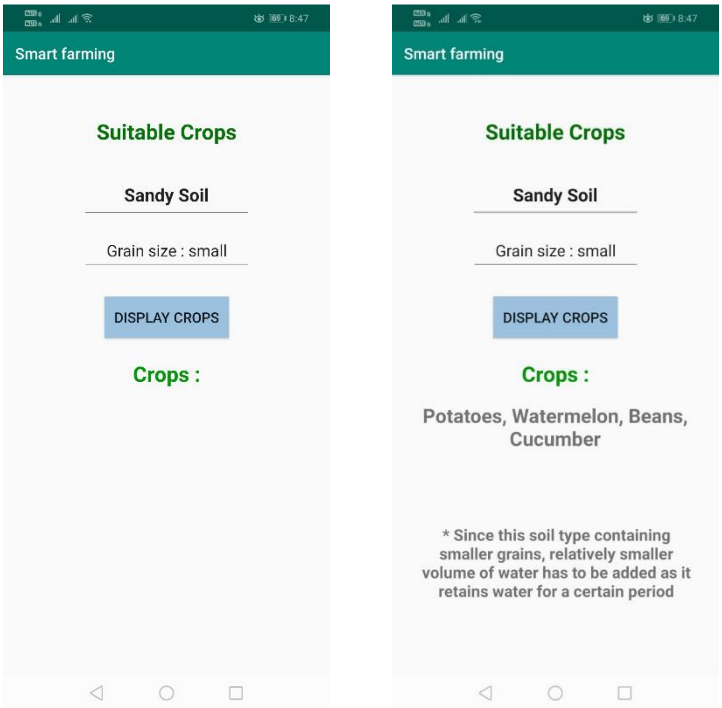


Figure 4.3.3: Display suitable crops

4.3.4 Admin Login

Admin can login using his username and password and clicking the Login button. Only the authorized admin can be logged into the system.

4.3.5Admin Menu

Admin has two options in this interface. One to insert data and two to update data. He can pick any based on his requirement.

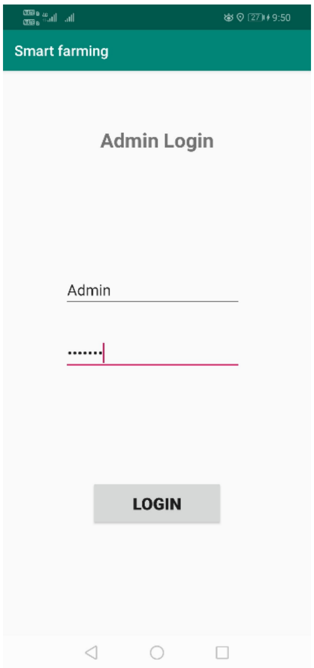


Figure 4.3.4: Admin Login & Admin Menu

4.3.6 Insert Data

In this interface the admin can type the new Soil Name and new crops suitable to that soil and press the Input Data button to input new soil types or crop types to the database.

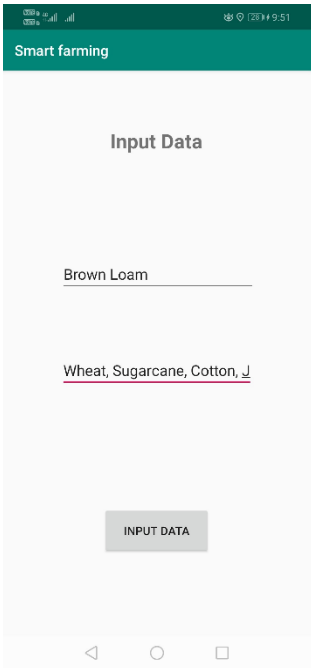


Figure 4.3.5: Admin insert data

4.3.7 Update Data

In this interface the admin can type the Soil Names and crop names and press the Update Data button to change or update any soil type or crop type in the database.

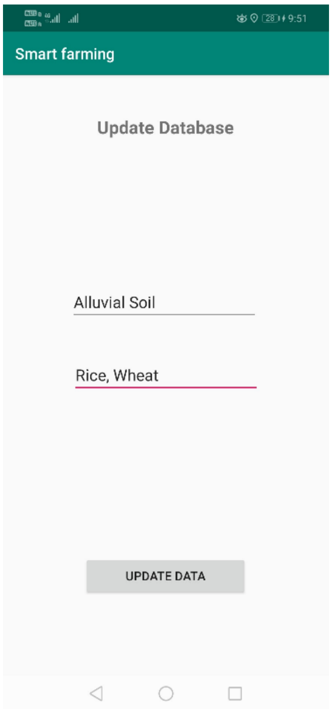


Figure 4.3.6: Admin update data

4.4 Summary

This contains about the integration of two major components in the system and further it includes interfaces of the mobile application.

Results and Discussion

5.1 Introduction

This chapters basically describes about the all the possible results of the developed methodology. It includes possible results with convolutional neural network model and mobile application.

5.2 Results with deep learning model

5.2.1 Model Training

Convolutional Neural Network (CNN) model has been used for soil color classification since it is one of best applied algorithm for image and video classification. CNN is specially designed to process pixel data. The model consists with 3 convolutional layers, 2 max pooling layers, 2 dropout layers and 2 dense layers. Created a dataset of different types of soil sample images for the training purpose and split that data into train data and testing data. For that 80% of data were used as train data and other 20% used as test data.

For the moisture classification of the soil image, same model is being used since it also detected using image color. Created a separate dataset of soil sample images for moisture classification training process.

```
model = Sequential()
model.add((Conv2D(noOfFilters, sizeOfFilter1, input_shape=(imageDimensions[0],
                                                           imageDimensions[1], 1),
                                                           activation='relu')))
model.add((Conv2D(noOfFilters, sizeOfFilter1, activation='relu')))
model.add(MaxPooling2D(pool_size=sizeOfPool))
model.add((Conv2D(noOfFilters // 2, sizeOfFilter2, activation='relu')))
model.add((Conv2D(noOfFilters // 2, sizeOfFilter2, activation='relu')))
model.add(MaxPooling2D(pool_size=sizeOfPool))
model.add(Dropout(0.5))
model.add(Flatten())
model.add(Dense(noOfNodes, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(noOfClasses, activation='softmax'))

model.compile(Adam(lr=0.001), loss='categorical_crossentropy', metrics=['accuracy'])
return model
```

Figure 5.2.1: Convolutional Neural Network Model

The models were tested using the test data of their own models. Soil color classification model achieves an accuracy of 89% and the soil moisture classification model achieves an accuracy of 71% according to their own testing data. And the test accuracies of the models were shown in below figures.

```
#### EVALUATE USING TEST IMAGES
score = model.evaluate(X_test, y_test, verbose=0)
print('Test Score = ', score[0])
print('Test Accuracy =', score[1])

Test Score =  0.3170274496078491
Test Accuracy = 0.8945147395133972
```

Figure 5.2.2: Color classification model test data accuracy

```
#### EVALUATE USING TEST IMAGES
score = model.evaluate(X_test, y_test, verbose=0)
print('Test Score = ', score[0])
print('Test Accuracy =', score[1])

Test Score =  0.9171807765960693
Test Accuracy = 0.715976357460022
```

Figure 5.2.3: Moisture classification model test data accuracy

The main two objectives of this developed system are how to predict the soil type according to the soil color, grain size and moisture level and to display the suitable crop types according to the predicted soil type. The accuracy of the predicted results was successfully verified during the user acceptance testing done with the involvement of an external user. The models were tested using external soil sample images which are captured using mobile phone camera and higher accuracy was established for the samples falling under the categories of the samples in the data set.

```
To enable them in other operations, rebuild TensorFlow with the
appropriate compiler flags.
class: Red Laterite  ,  Prediction : 90.19243717193604
[Finished in 22.1s]
```

Figure 5.2.4: color classification prediction results

```
To enable them in other operations, rebuild TensorFlow with the
appropriate compiler flags.
Moisture Level: Medium (200)  ,  Prediction : 91.42985939979553
[Finished in 10.6s]
```

Figure 5.2.5: moisture classification prediction results

5.3 Results with image processing techniques

Image processing techniques were used to determine the grain size of the soil sample. The selected soil sample image has been converted to a black and white image. And the image was thresholded using scikit-image threshold Otsu function. The areas of thresholded image which were highlighted were labeled. The equivalent diameter of the labeled areas was calculated using measure library from scikit-image. The values obtained for the equivalent diameter of the labeled areas were categorized in to two categories. From the number of areas falling into each of these categories the category into which the majority of the areas are falling is considered as the grain size of the soil.

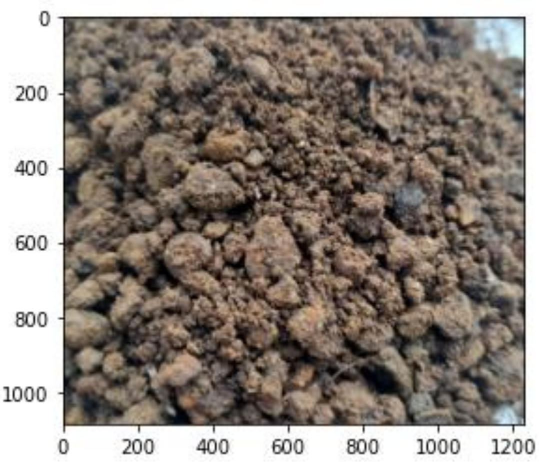


Figure 5.3.1: Original image of a soil sample

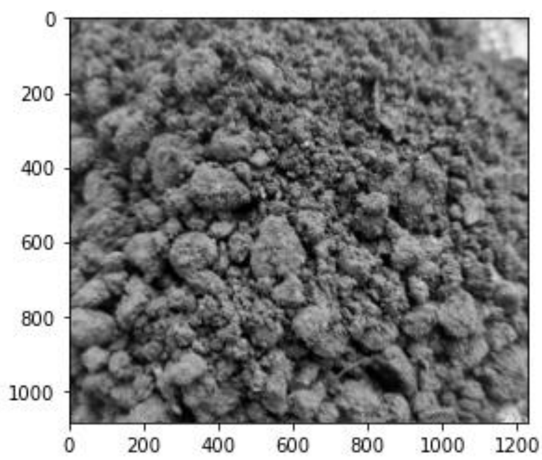
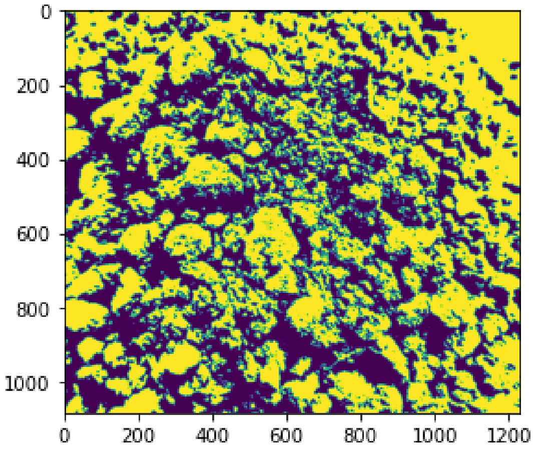


Figure 5.3.2: Black and white image



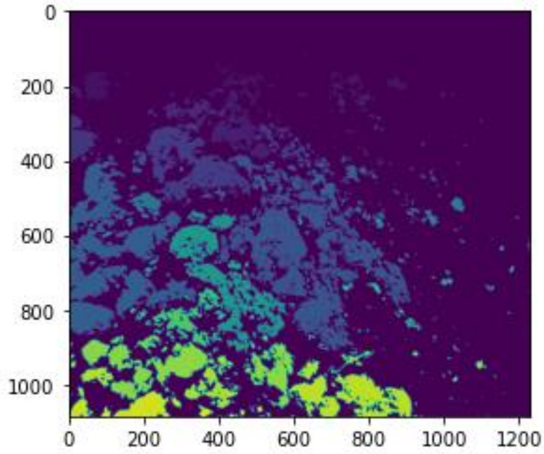


Figure 5.3.3: Thresholded image

Figure 5.3.4: Labeled image

5.4 Get predicted results using mobile application

The application gets the location of the end user through GPS technology or by manually entering the location. The user can upload the image of the soil sample using the camera of the mobile phone or by uploading a photo from the gallery. The predicted results could be viewed by the user by selecting either the predict soil type option or the predict crop type option. When displaying the soil type moisture level and the grain size of soil is also displayed. When displaying the suggested crop types the amount of water to be added is also displayed according to the grain size.

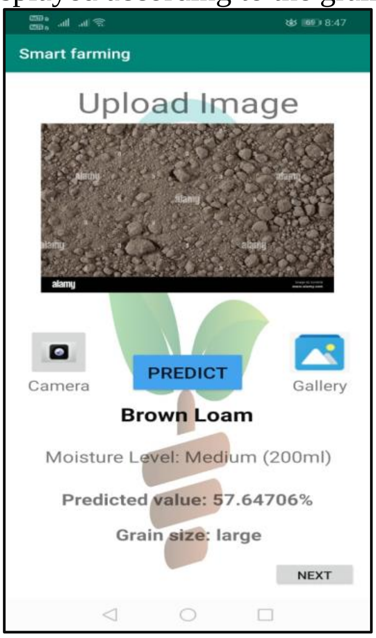


Figure 5.4.1: Soil type and the predicted results shown in the mobile application

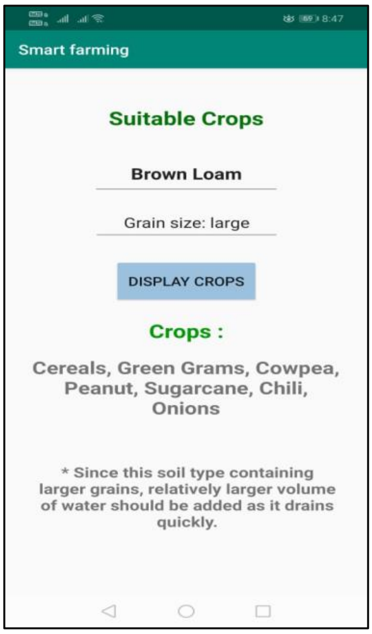


Figure 5.4.2: Suitable crops results shown in the mobile application

By observing the prediction time, it statistically proved that the time taken for the prediction is considerably low. Following figure will show that the time taken for the system to predict the soil type.

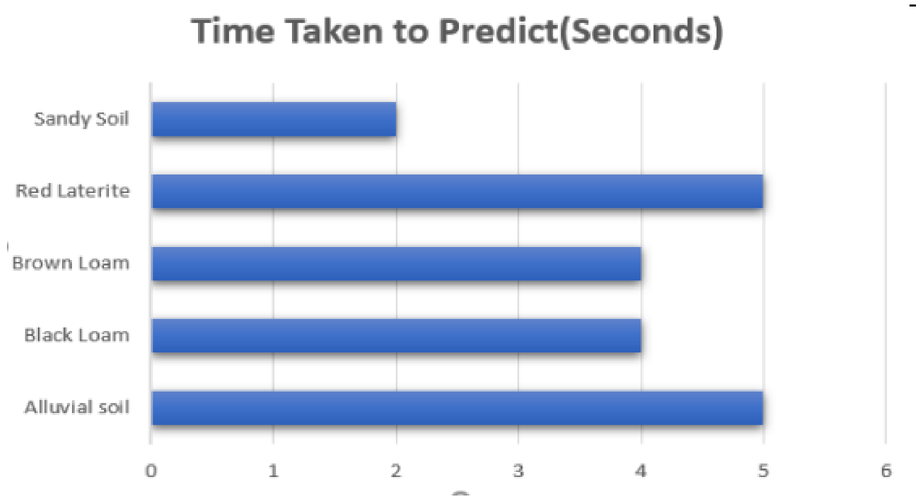


Figure 5.4.3: Bar chart of time taken to predict the soil type

Following figure will show that the time taken for the system to predict the crops types.

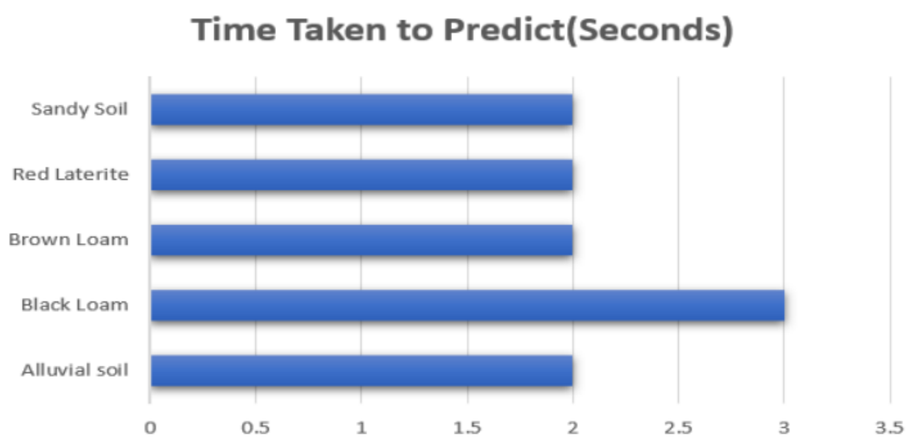


Figure 5.4.4: Bar chart of time taken to predict the crop types

Conclusion and Future Work

6.1 Introduction

This chapter basically describes the discussion of the project. It includes the achievements in the project, impact to the society and limitations. Further, this describes the future work that could be carried out further through this project idea.

6.2 Discussion, achievements and impact to the society

The project was implemented to the farmers in Sri Lanka. The main aim is to suggest the best suitable crop to a soil type instantly to the farmer so that the cultivation will ultimately bring profit.

Considering the social impacts, Agriculture contributes to the national economy of our country at large scale. When selecting a crop to be grown in a specific land most farmers tend to select a crop which commonly grows in the surrounding. This might lead to poor growth of that crop, pronging the crop to various deficiencies, reduction of harvest and they’re by spending money to overcome these problems result in extra expenditure, wastage of resources and time and overall, a loss. To minimize these problems farmers are educated to test their soil sample and determine the best suitable crop for that soil type as the variety in soil is immeasurable. The traditional testing method used up to date in Sri Lanka is a laboratory mechanical testing which occurs when the farmer takes a soil sample to the lab. But this method is expensive, time consuming, involves much labor and can be error prone as it's a mechanical process and is not very accurate. To reduce the above explained gap a portable soil detection system based on image processing for agriculture was developed. Using the developed system, the farmers could minimize the problems described above and by using our system to detect the soil type, the farmers can save their valuable time and money. This system is a very efficient system for the farmers in their day-to-day life

6.3 Assumptions and limitations

The system should provide expected outcomes as mention in this document. However, there are few limitations when considering the system.

The main assumption is that the android version of the user's device is above 6.0 (Marshmallow version). There's a huge amount of soil type variation in Sri Lanka. So, the location had to be initially taken from the user to filter out the soil types belonging to that area first to give a more accurate result.

This system is limited only to few provinces of Sri Lanka, as the data set collection and analysis was been able to be performed only for soil types in Sri Lanka. The location selection option only allows a user to select a location in Sri Lanka. And we are only using color, moisture and grain size to determine the soil type. We were only able to develop the system to be compatible with the android operating system.

6.4 Future work

As future developments for this system the researchers are expecting to increase the parameters from which the soil type is detected which will result in increasing the accuracy of the output. Furthermore, they hope to consider the weather details as well when suggesting the suitable crop types. Another development that the researchers are expecting to do is to enhance this system to be compatible with other operating systems such as iOS. Also, they expect to increase the size of the data set by collecting more sample images from different parts of the country to enhance the scope of the application.

6.5 Summary

In this chapter we discussed what is impact for the society from the soil detection system, the assumptions and limitations and also the further improvement for the system.

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