SMART PLANT DISORDER IDENTIFICATION SYSTEM USING COMPUTER VISION TECHNOLOGY

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Dissertation submitted in partial fulfillment of the requirements for the Bachelor of Science in Information Technology, Specializing in Software Engineering

Department of Computer Systems Engineering

Sri Lanka Institute of Information Technology
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DECLARATION

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ABSTRACT

The soil composition around the world is depleting at a rapid rate due to overexploitation by the unsustainable use of fertilizers. Streamlining the availability of nutrient deficiency and fertilizer related knowledge among impoverished farming communities would promoter environmentally and scientifically sustainable farming practices. Thus, contributing to several Sustainable Development Goals set out by the United Nations. The most direct solution to the inappropriate fertilizer usage is to add only the necessary amounts of fertilizer required by plants to produce a significant yield without nutrition deficiencies. Facilitating this solution can be segregated as: A Smart Nutrient Disorder Identification system which identifies nutrient deficiencies using image processing techniques, recommends the best remedy using Machine Learning, and a blockchain based network establishing means of secure and streamlined communication between cultivators and agricultural experts. This solution is prospectively offered to regional agricultural research institutes and departments, enabling them to maintain a streamlined ledger of nutrient deficiencies with adequate solutions and to also further communicability with cultivators in the field. This research investigates the devising of this solution in an ICT centric approach to transforming agricultural science.

Keywords - CNN, RCNN, Nutrient deficiency, Machine learning, Blockchain, Image processing

ACKNOWLEDGEMENT

We would like to express our appreciation and full-hearted gratitude to our supervisor **Dr. Janaka Wijekoon** and co-supervisor **Dr. Dharshana Kasthurirathna** who guide us to success this research and for sharing the experiences and expertise with the project matters. We extend our gratitude to the Sri Lanka Institute of Information Technology (SLIIT) for giving an opportunity to carry out this research project. A special thanks to the Agriculture department for providing datasets and our friends and family, who helped us and gave suggestions for our research. We would like to appreciate the guidance given by other supervisors as well as the members of the panel.

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LIST OF ABBREVIATION

API	Application Programming Interface
CNN	Convolutional Neural Networks
FAO	Food and Agriculture Organization
ICT	Information Communication Technology
ITU	International Telecommunications Union
MDG	Millennium Development Goals
MT	Machine Translation
R-CNN	Region-based Convolutional Neural Networks
SDK	Software Development Kit

1. INTRODUCTION

Sri Lanka is an island nation with 66,000 sq km of land area with prehistoric settlements dating back to 125,000 years. The accurately documented history of Sri Lanka is at around 3000 years, of which agriculture is the prominent livelihood [16]. In recent years, predominantly during the latter stages of, and after the Civil War; Sri Lanka has shown one of the highest GDP growth rates per capita in South Asia, rising from US$859 in 2000 to US$3,256 in 2013 [18]. Sri Lanka has also attained the most Millennial Development Goals (MDG) amongst South Asian countries, with a GDP growth which has been pro-poor, with the consumption of the bottom 40% being at 3.3% in comparison to the 2.8% of the other 60%. Agriculture is the foremost contributor to poverty reduction, with a 5.7% increase in Agriculture related wages [16]. With the evolving technological landscape in Sri Lanka and the devolving interest in scientifically backed agricultural practices, the need for a technology-oriented and driven communicability solution to promote availability of information and precision agriculture is evident.

According to the World Bank [13], agriculture is a major contributor of poverty reduction and welfare in Sri Lanka with over 1.65 million smallholder farmers operating in less than 2 hectares of cultivable land. Although agriculture is not as prominent as it was, it is a major driving force of the country’s economy. In a local context, several key factors have been identified as contributors to the stunted growth of agriculture-related industries in Sri Lanka [13]:

- Weaknesses in agricultural strategies and policy implementation.
- Public sector regulatory interventions are considerably heavy in commodity markets.
- Service delivery is weak in rural areas.
- The destructive impact of 3-decade long civil war and the 2004 Tsunami disaster.

While such policy and governance-related complexes do raise concern, the lack of literacy and awareness among farmers is also a major drawback for the agricultural sector. In the Indian Subcontinent, most farmers remain illiterate and impoverished. They operate in isolation, with little or no bargaining capacity and lack high-quality agricultural practices that could improve their productivity.

After the ‘4th Industrial Revolution’ (4IR) [14], the accessibility of farmers to technological solutions has enhanced, evolving from low impact Information Communication Technologies to technological solutions offering productive, competitive, and sustainable outcomes. In Sri Lanka, the need for such technological innovations is only becoming more evident. The yield of agriculture products in Sri Lanka have stagnated at unsatisfactory levels, even when considering the factor of it being a developing country [14]. Considering the Total Factor Productivity (TFP) growth in the South Asian region [15], Sri Lanka is performing very poorly and the TFP growth of the country is also witnessing a steady decline, as shown below:

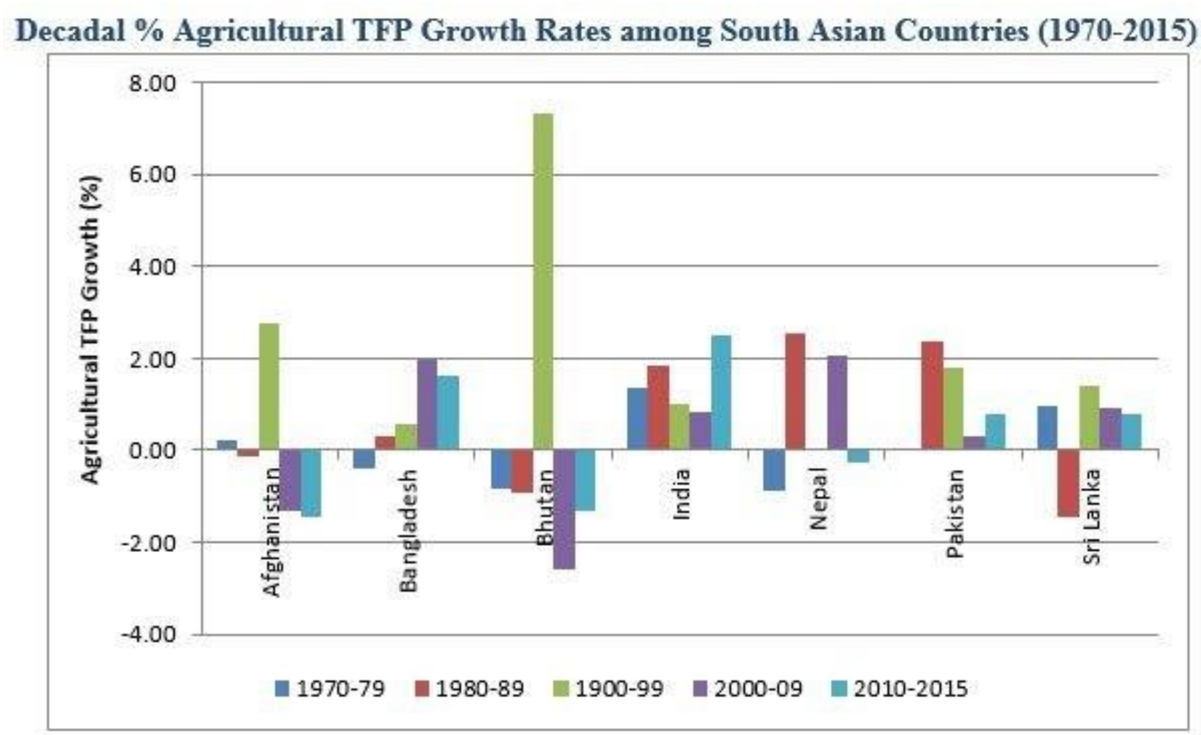


Figure 1.1: Agricultural TFP growth [15]

With the technologically adept youth gradually losing interest in pursuing agriculture as a way of life and with heuristic practices adversely affecting yield and the environment, a technologically sustainable ‘Smart Farming’ approach is best suited. As such, the e-agricultural strategy of Sri Lanka [16] offers the following deliverables:

- Food crop self-sufficiency, saving foreign exchange on imports of these food items
- Enhance abundance of safe food by promoting eco-friendly practices and curtailing agro chemicals and pesticides in food crop production
- Ensure food security via appropriate buffer stock management
- Introducing agro-ecological regional food crop cultivation programs
- Increase the productivity of crop production via technological innovations
- Establish proper coordination among all agricultural stakeholders in the local food production process and connect all schools, civil organizations and general public to the program
- Provide quality inputs for production and establish proper marketing mechanism for their products
- Ensure building a healthy nation.

The practice of eco-friendly agro-chemical administration was identified as a key objective and an efficient solution can be offered by means of an effective technological innovation. The potential of this solution to extend to providing an efficient and verified marketing mechanism for agro-fertilizer, which is a key constituent in agricultural inputs, would encompass a crucial deliverable of the e-agriculture strategy as well.

The production of oilseeds and fruits plays a vital role in the economy of Sri Lanka. According to Statistics in 2020, the total production of oilseeds and fruits were 349,000 MT [43] and 540,000 MT [28] annually. Groundnut is considered a “King” of oilseeds [37]. Groundnut (Arachis Hypogaea L.) is the 6th major oilseed crop in the world [31]. As shown in Fig. 1.2, it is one of the crops which contributes highly to the economy of Sri

Lanka. It is grown mainly in Kilinochchi, Moneragala, and Mulathivu. Groundnut production is a vital source of economy and employment in Sri Lanka and also it's an essential component of Sri Lankan rural income. In the Fruit production Banana, guava, papaya, and lemon continue to impact prominently in the economy. Among those plantations, Guava and lemon seem to have been in an important place in the market [34]. The estimated Sri Lankan production for guava and lemon in 2019 was 81.74K metric tons and 5.56K metric tons [44].

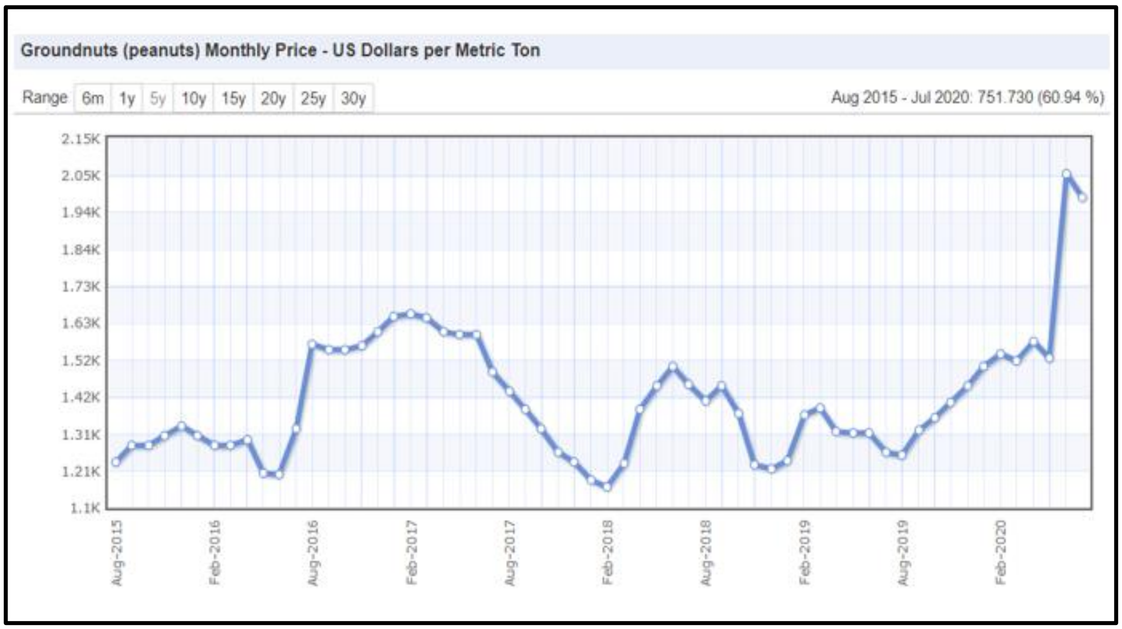


Figure 1.2: Groundnut monthly price range

In the agriculture sector, there are many unsolved things related to cultivation. The farmers are facing lots of problems to get quality and quantity output of the cultivation effectively. Mainly they're facing problems in identifying nutrient deficiency in an early stage because different plants have different nutrient deficiencies and most of the nutrient deficiency symptoms are very similar. Usually, nutrient deficiencies will cause diseases to spread faster [8].

From the Background literature on plant nutrient deficiencies has mentioned that Nitrogen (N), Potassium (K), Phosphorus (P), and Sulfur (S) deficiencies are recorded mostly in the production of groundnut, lemon, and Guava plants. Due to the various factors such as environmental weather conditions, seasonal variation, and the spread of diseases, these plants have been found to be extremely susceptible to infection [8].

1.1 Background Literature

The nutrition available in soil moves through a cycle. Moving from plants, to the organisms that devour plants until it returns to the soil through the decomposition of the bodies of the organisms that used plants as a source of food. These food sources nourish and sustain the organisms through the nutrients trapped within the plants. A lack of nutrition in soil will fail to sustain life. This is the overall impact of nutrition within soil.

However, as highlighted in the introduction the soil nutrition levels are directly interlinked with farming practices around the world. A closer look at the current status on the usage of technology in this regard shows several key findings.

Firstly, an excess or deficiency in soil nutrients causes a severe loss in yield. Therefore, early and accurate diagnosis of plant nutrition disorders is a vital part of managing a farm [5]. Managing plant nutrition disorders can be divided into several activities. These are, identification of a nutrient disorder, identification of the degree of the said disorder, analyzing the soil composition to determine the reason behind such disorders and finally, to provide the most suitable remedies to the farming community. While the first three have issues directly involving field practices within farming the final activity arises out of work and interactive practices within the farming community.

The current methods used in identifying plant nutrition disorders is very expensive and highly cumbersome for field use. Currently satellite imagery and expensive Chlorophyll-meters are used for the identification of such nutrition disorders [5]. These methods require high funding which most of the farming communities cannot afford. For example, 49% of the population in Sub-Saharan Africa live on less than 1$ a day, 10 years back [6]. Sub-Saharan Africa accounted roughly of a third of the overall growth within the period of 1993 – 2005 [6] showing how heavily involved the country’s labor force is in the agricultural industry. Expecting farmers from such regions to use the existing systems for identification of plant nutritional disorders is far from being pragmatic.

Meanwhile, the current methods in use to identify the degree of nutrition deficiency in plants are mainly tissue analysis and soil analysis [7]. These require laboratory expertise and is also time consuming. Thus, both methods and soil composition evaluation methods used are not practical in managing a farm by most of the farming community.

Finally, upon researching on the interactions of the farming community in agriculture related activities a severe problem identified was that of information asymmetry which results in middle actors capturing a margin [4] while sustainable suggestions made by the agricultural researches being neglected. This statement was further confirmed by the discussions held with soil experts at the Kahagolla Agri-research Institute of Bandarawela, Sri Lanka.

While the current status regarding the above four main factors are as above this research project aims in finding solutions for them using Information and Communication Technology techniques such as image processing, machine learning, block-chain and IoT. The subsequent sections will identify the research gaps existing in using such technologies, the research problems to be addressed while doing so, objectives and the methodology required to achieve such objectives.

According to Jayamala.K, Patil, Raj Kumar paper titled “Advances in image processing for detection of plant disease” [45]. This paper explains the methods which are available to study plant diseases using image processing. These methodologies were proposed by the human professionals in detecting the plant diseases to increase the throughput. The paper mainly focuses on speed and accuracy which were the main characteristics of plant disease detection using machine learning. There is space for the development of fast, effective interpreting algorithms which could help plant scientist in detecting the disease. The algorithm uses color space and co-occurrence matrix to extract short disease spot texture features and BP neural network is applied as a classifier with an accuracy of 98 % [45].

When using an image processing technique for classifying the absence of nutritional disease that occurred in oil palm leaves can only be investigated by the leaves' surface [6]. This technique is functioning as a guide for fertilization because the trees show rapid reaction to the used fertilizers. Extreme use of fertilizers will cause harm to the trees. So, the use of fertilizers must be controlled. To examine the leaves' surface of oil palm leaves needs high-end digital imaging devices. Based on the texture and color of the disease type, feature extraction will progress. The feature vectors will be reached acting as inputs to a fuzzy classifier [6].

The degree of a nutrition disorder requires in identifying the severity of the disorder at a certain stage. In plants the amount of nutrition required varies amongst different growth stages [8]. In order to identify the degree of a nutrition deficiency, currently soil analysis or leaf analysis is carried out [8] in the field. Both soil analysis and leaf analysis require expert training to conduct and laboratory facilities [8]. Furthermore, they are both time consuming and cannot be practically applied in the field by most independent farmers. In this case, farmers usually add fertilizers based on the instructions provided during field trials etc [12].

Apart from this the nutrient deficiency degree has been identified in several works of research carried out with the use of image processing and machine learning. However, it must be noted the amount of research carried out on plant nutrition disorder identification using image processing and machine learning is relatively low. The research works identified have usually been done to identify a nutrition deficiency from a set of deficiencies within one plant. Thus, the overall research work done to analyse the severity of a nutrition deficiency is substantially lower.

The research on identifying macronutrient deficiencies on the development of tomato plant using Convoluted Neural Network (CNN) in forecasting and classifying [15] has used Inception-ResNet v2 architecture with autoencoder and ensemble averaging as a means of validation. While ensemble averaging is a technique used to improve the performance of machine learning [14], the autoencoder is used to train the neural network [15]. All plants were grown in a green house environment and the accuracy of rates were 87.273%, 79.091% and 91% for the Inception-ResNet v2 model, the autoencoder and ensemble averaging respectively.

In the Sri Lankan economic backdrop, it is evident by the preceding section that agriculture is of vital importance. With the contribution agriculture related industries make toward empowering the segment of the less benefited population [16], it is paramount that more feasible and penetrable solutions should be offered for the issues faced by farming communities. the corresponding concern with regards to availability of actionable information to the farming communities is also significant [19]. This literature survey would take a multi-pronged approach as it would analyze the current status quo of input management in agriculture i.e. fertilizer practices, the lack of information penetrability to the farming communities, and a comparison of current approaches made to mitigate this issue and also an overview of how ICT has been employed in agriculture and in real time knowledge sharing. According to the FAO-ITU E-Agriculture Strategy Guide for Asia-Pacific region [16], improving the capability of farmers to access knowledge-banks, and institutions via Information and Communication Technologies (ICT) improves their productivity and profitability. Availability of right information, at the right time, in the right format, and through the right medium, influences and affects the livelihoods of many stakeholders involved in agriculture through enhanced decision-making capabilities. Furthermore, recommendations made by e-Agriculture strategy guide encourages awareness-raising, effective engagement of key stakeholders and action to resolve issues of ICT access, especially in rural areas [16].

Sighting illiteracy as a contributing factor for lack of information access [10], it is also noted that the unstructured nature of rural farmland and agriculture also contributes to uneven distribution of information. Governing bodies for agriculture, specifically in developing countries where farming is a major contributor to the GDP, have significant setbacks in structuring rural agriculture in a feasible manner. As such, according to William M. Rivera [11], knowledge-driven frameworks exist for agricultural purposes which are mostly institution based and do not consist of readily available information systems for farmers to rely on. Such institution-based frameworks cater for the requirement of specific communities under obligation to these institutes, and do not offer a universal solution. Furthermore, such frameworks have only been made accessible to a fraction of the community. This fraction does not represent the general farming community and their requirements by any proportion. It is also recommended that such frameworks should be adapted into 'Agriculture innovation systems' and 'Agricultural Knowledge and Information Systems', adapting technological advancements for the benefit of the agriculture community and that these systems should be inculcated into a growingly technologically aware farming community [14] by the mediation of government entities as well as regulatory and governing bodies.

An analysis of existing products in the market emphasizes the need for a system similar to CropMedic Plus and the competitive advantage it holds over other products in the market:

Table 1.1:Comparison between exiting products

Features	BFN – Under development	Govi Mithuru	Soil Test Results E-Service	Plant Production E-Service	CropMedic Plus 2.0
Nutrient deficiency Identification through plant leaves	✓	✓			✓
Identification of nutrient deficiency degree					✓
Suggesting Fertilizer				✓	✓
Soil nutrient Analysis	✓	✓	✓		✓
Secure communication between Farmer, vendor and Experts		✓			✓

1.2 Research Gap

The main research gap identified in the project is the unavailability of an accurate early detection ‘smart’ system using Information and Communication Technologies (ICT) to identify nutrition disorders in plants and provide suitable recommendations that benefit farmers in carrying out sustainable agricultural practices.

In the past, several researches have conducted for identification of diseases with machine learning and image processing techniques but few researches has done to identify the nutrient deficiency. There are nutrient deficiency identification researches that were done by researches still don’t predict the degree of the nutrient deficiency which is most needed to identify. There is research that contains using leaf color images to identify nitrogen and potassium deficient tomatoes [23]. It is focusing only on the nutrition deficiency of the plants but those are not suggesting any solution for the crops to cure the disorder.

It is clearly indicated in the introduction that there exists a problem where soil nutrition levels are receding rapidly and the need for more sustainable practices in agriculture which don’t exploit the soils. Through the literature survey however, it can be easily seen the solution to this problem is impractical and infeasible. Moreover, the current research work 5 done is to predominantly study the techniques of image processing and machine learning in identifying the disorders rather than provide a practical solution. Adding only the necessary amounts of nutrients into the soil to sustain the plant nutrient requirement is the solution to the overall problem at hand. This can be possible only if the nutrient disorders with the relevant stage is identified to recommend the most appropriate remedy. While the literature survey above shows none of the academic research recommending a suitable remedy, this research project aims in doing so by identifying the relevant stage of the disorder by taking the plant growth stage and the soil composition into consideration. The soil composition will be analysed and the outputs will be provided for this component by another researcher handling it separately.

Developing countries such as Sri Lanka have decisively backed an approach toward e-agriculture [14] since utilizing ICT for the purpose of ‘smart farming’ is a sustainable approach. However, while theoretically feasible, a practical implementation of such nature remains a considerable challenge. Regardless, a country with a high literacy level such as Sri Lanka should ideally benefit from such an approach. RAS enabling food security and sustainable farming services [22] tallying with decisive, accurate and timely information retrieval could be a major contributing factor towards enhanced and farming practices and yield in Sri Lanka. Deviation from the centralized approach and adaptation of a decentralized system [23] could be the driving force of any relevant success.

Research conducted on fertilizer management and application have not reached far beyond controlled development stages [8] and have not been deployed in ground-level circumstances for ensuring food security. Fertilizer administration is a segment of farming which requires specific information. Farmers require specific information on 'when, how and what' to administer in the case of requiring fertilizer for their crops. If this information is not readily available or easily accessible for the common farmer, as constituents of a trust-driven industry [24], they would be quick to rely on the intermediary vendor for instructions as well. Such a trust-driven ecosystem for fertilizer procurement has long been established but is not advisable as this lack of social sustainability has a direct effect on the degradation of soil conditions in Sri Lanka. At present nearly 18% of the overall landmass in Sri Lanka has been depleted due to the adverse effects of unsustainable agricultural practices [13].

Blockchain can be utilized to uplift economic and social performance in the agriculture industry. This can be achieved due to the distributed nature of a blockchain and the transparency encouraged by it. Yet, a majority of blockchain related research has been centric to traceability and economic performance. S. Saberi et. al clarifies interactive information management to be a feature of social performance [24]. The justification of doing so is: any approach made toward a distributed information system linking farmers with relevant professionals is culturally contextual with a broad subjectivity. It could be argued that this matter has social sensitivity [24] as better fertilizer administration would have a pragmatic effect on the environment and would also eventually bestow toward enhancing profitability and livelihood of the farming community, contributing to attaining Millennium Development Goals (MDG) setup by the United Nations [16].

Hence, as evident; no research has been conducted in adapting a knowledge-driven system in a universal context, to streamline fertilizer procurement by assisting the farmer to make the most well-informed decision. Therefore, this research is being conducted to introduce a solution for the beneficiaries i.e. the farmers, to be used in real-time field conditions. As related previously, fertilizer administration is a knowledge intensive and knowledge specific domain which has to weigh in a social context as well. As such, this component is intended on constructing a decentralized system for streamlined and informed fertilizer procurement for farmers, resolving any pre-existent complications through an ICT-driven approach.

1.3 Research Problem

The main research problem identified is the divided into four main sections. These are:

- The inability to detect a plant with a particular nutrition deficiency specifically amongst a number of deficiencies based on symptoms appearing on the leaf. The inability to detect nutrition deficiencies in this manner amongst a variety of plants subsequently is the first main research problem identified.

- The inability to detect the degree of a plant identified to contain nutrition deficiency accurately and analyse the reason for such a deficiency using several variables. The inability to carry out the above function and recommend a suitable remedy for the deficiency are all part of this same research problem.

- The inability to measure and analyse the soil composition data by means of an IoT device that is practically usable in the field. The unavailability of a solution to provide these values to be used for further analysis on the amount of fertilizer required in a short time with a significant accuracy.

- The inability to provide farmers with verified information by researches on the best fertilizer to be used at a given time without being influenced by the vendors.

1.4 Research questions

Several research questions stem from the four main research problems identified above. These are;

- Investigating the best machine learning and image processing techniques to be used to select for identification of the nutrition disorder and its degree.
- Investigating the plant nutrition deficiency symptoms and the relevant magnitude of nutrient deficiency in soil.
- Investigating the best method to be used to set up a control experiment to analyse the above variations
- Investigating the use of Arduino in assessing soil composition.
- Investigating the most practical method to be used to vary soil composition and obtain a usable measure to analyse and use the data on soil composition
- Investigating the use of block-chain technologies in creating a system for the interaction of stakeholders.
- Investigating the attitudinal manners in promoting this system to be used by the stakeholders.

The investigation of the above criteria will ask the researches the relevant research questions needed to be answered to solve the relevant research problems listed previously.

1.5 Research Objective

1.5.1 Main Objective

The main objective of this research project is to provide an intelligent solution capable of identifying the nutrition deficiencies in plants, the extent of the nutrition deficiency and recommend the suitable remedy through soil analysis in an agriculture researcher verified system. The main and specific objectives of the separate components are highlighted next.

1.5.2 Specific Objective

I. Identification of nutrition deficiency (amongst N, P and K)

The specific objective of this component is to identify the nutrient deficiency in a plant with speed and accuracy using image processing technique and CNN.

II. Identification of the degree of nutrition deficiency and recommendation of suitable remedy

The primary objective of this component is to identify the degree of the disorder. Secondly, this component aims in using the results obtained from component 3, to recommend the suitable remedy in terms of the application of chemical fertilizer etc.

III. Soil analysis using IoT to provide accurate degree of nutrition deficiency in soil and recommendation

The main expectation of this component is to develop a fully functionally IOT device to measure Nutrient levels (NPK),Organic Matters, EC Conductivity, pH level of selected soil crop and creating inputs for Machine learning algorithm which is created by member 2.

IV. Implement a secure and distributed platform for identifying best commercial product for deficiency based on diagnosis

The primary objective of this component is to identify the most suitable methodology to implement a distributed platform to provide farmer – vendor – agricultural researcher engagement while overcoming information asymmetry. Blockchain has been identified as the most suitable technology for a distributed system as proposed and Hyperledger Fabric module will be employed for implementation.

2. METHODOLOGY

2.1 Methodology

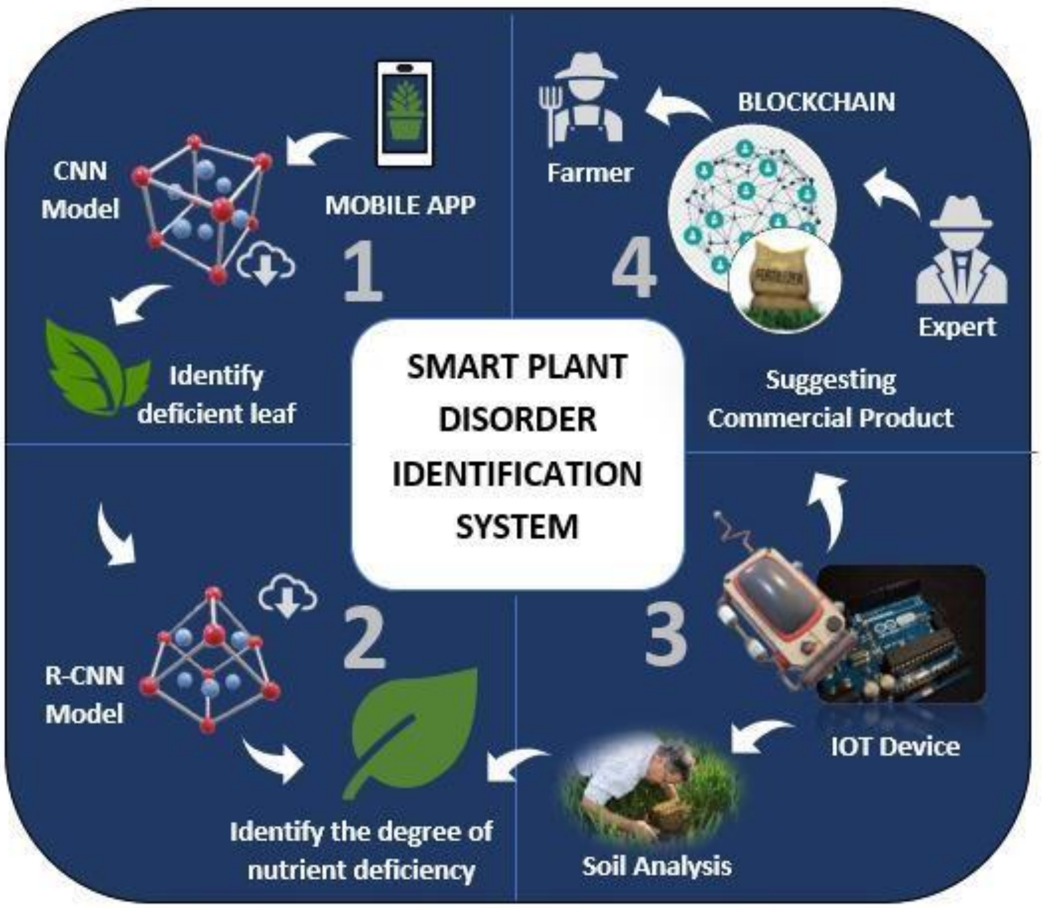


Figure 2.1: System Overview of the Smart Plant Disorder Identification System

The system overview diagram shown above provides information on the overall functionality of the system. It includes four major components. Such as:

1. Identification of nutrition deficiency (amongst N, P and K)
2. Identification of the degree of nutrition deficiency and recommendation of suitable remedy
3. Soil analysis using IoT to provide accurate degree of nutrition deficiency in soil and recommendation

4. Implement a secure and distributed platform for identifying best commercial product for deficiency based on diagnosis

In the first component, image is captured via a mobile device and identified as a healthy or nutrition deficient leaf. This image is then passed onto the next the component which using Image processing and mask R-CNN model to identify the degree of the nutrition deficiency. It then uses the values passed on by component three to analyse the probable reason for such a deficiency and correlates the accurate remedy that ought to be taken. This remedy moves through to component four which is responsible in creating a platform for all stakeholders to interact using only verified data for the aquisition of fertilizers.

Below Fig 2.2 shows the system flow

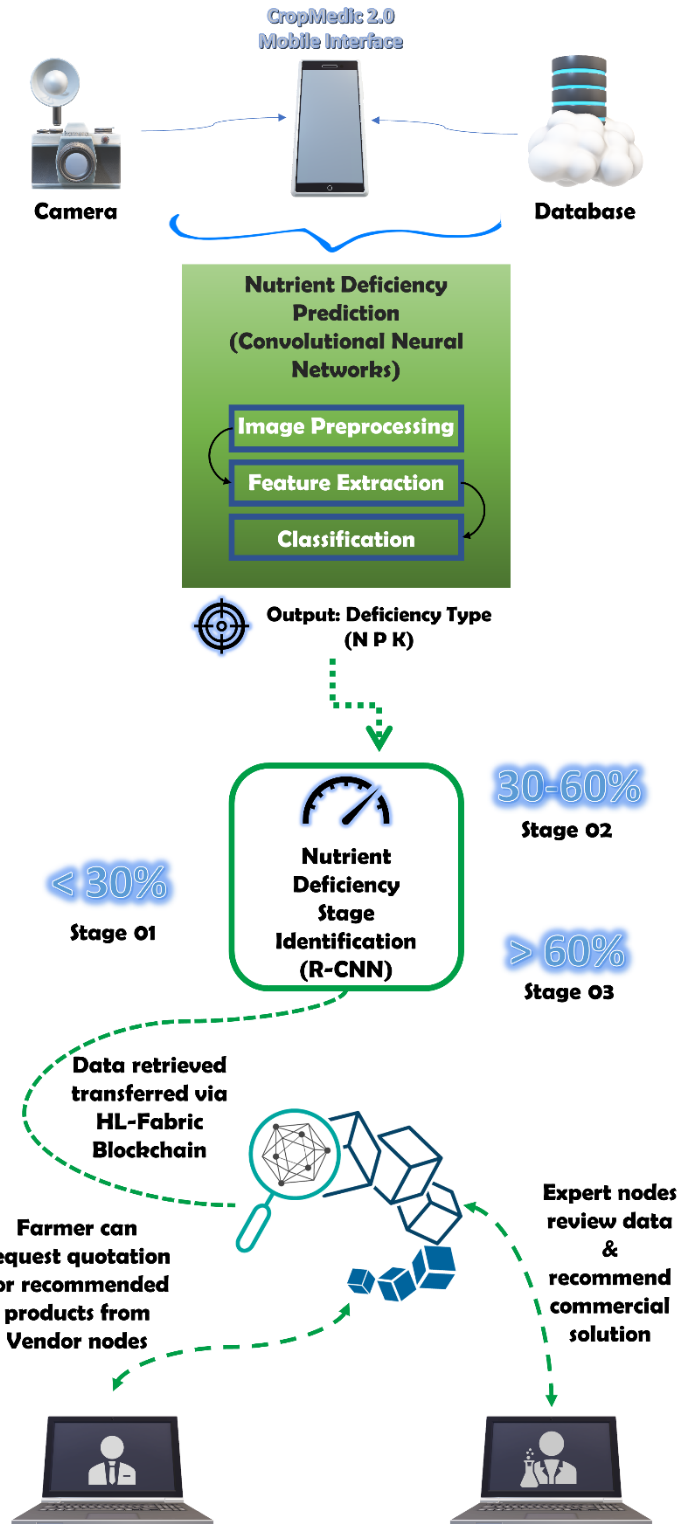


Figure 2.2: System flow diagram

Below Fig. 2.3 shows the System High Level Diagram

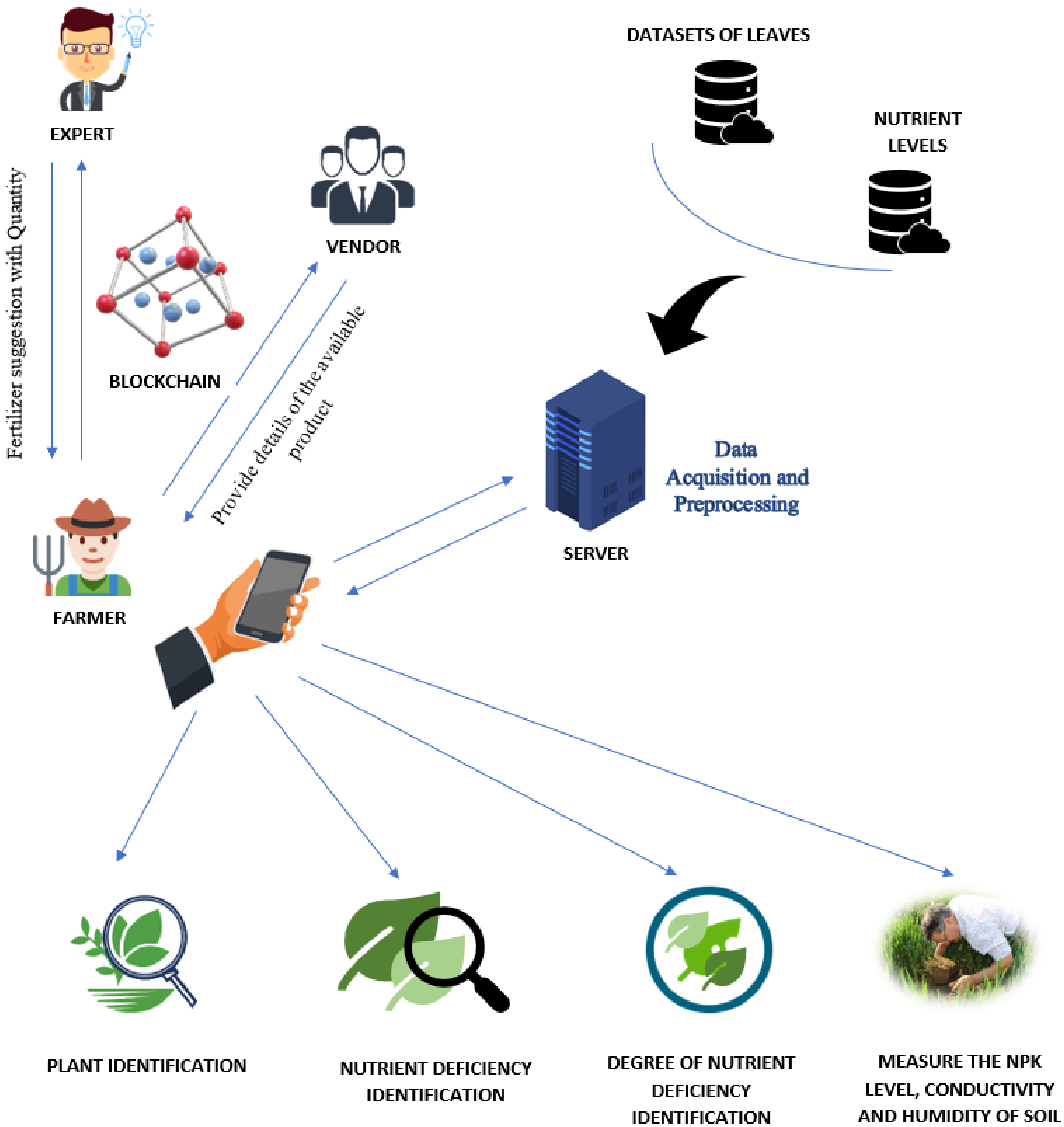


Figure 2.3: System High Level Diagram

2.1.1 Identification of Nutrient deficiency in Groundnut, Guava and Citrus

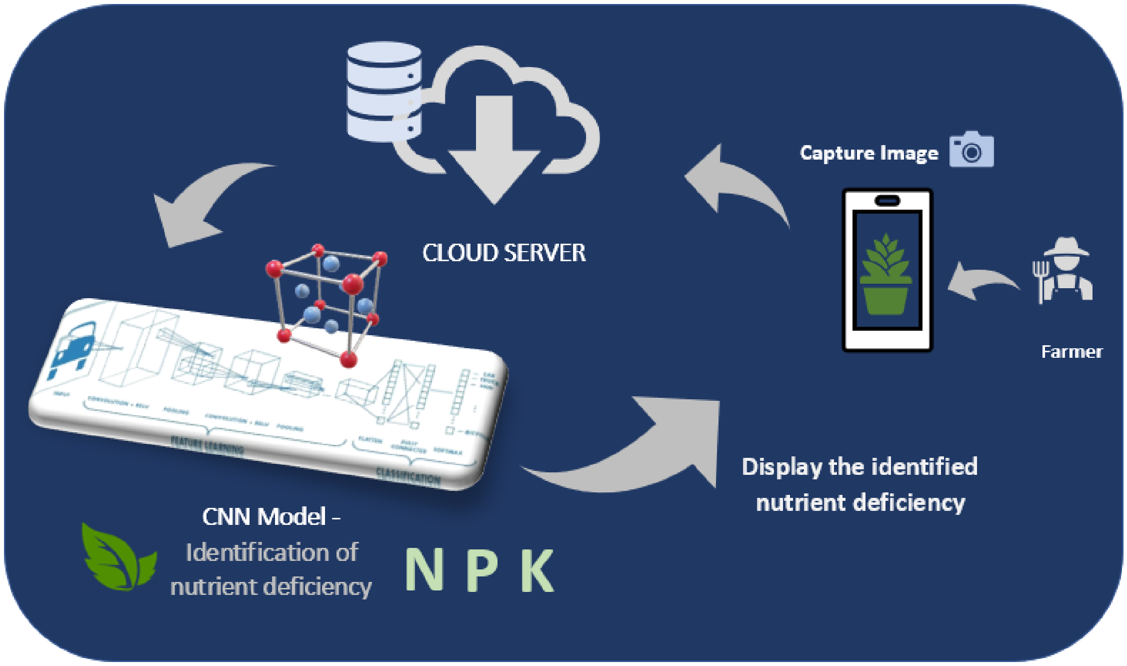


Figure 2.4: Component 01- High level diagram

Farmers face many difficulties in identify the correct nutrient deficiencies through its symptoms via direct observation. And most of the nutrient deficiency symptoms are very similar. So, Farmers randomly apply fertilizers without knowing the correct disorder. It would cause the vast damage to plants and their productivity. This part depends on disorder prediction in groundnut, guava and citrus plants to solve the above mentioned problem.

As shown in the high-level diagram Fig.2.4, any user registered as a farmer is able to upload a captured image of the leaf image through the application. Then the system predicts nutrient deficiency using the constructed CNN model. The inputs are sent to Machine Learning model which will predict exact nutrient disorder using CNN model. For Nutrient deficiency prediction; Nearly 8000 images were collected and augmented for the Guava, Groundnut and Citrus plants, split according to their classes. These classes are N (Nitrogen) deficiency, P (Phosphorous) deficiency, and K (Potassium) deficiency. In the prediction phase datasets are moved with different levels like data normalization, training model, testing model, validating model.

Used datasets

Datasets were collected using different ways such as:

- Downloaded from Online resources.
- Manually captured during the field visits

Algorithms used

- EfficientNetB0
- ResNet50
- VGG-16

2.1.2 Identification of the degree of nutrition deficiency and recommendation of suitable remedy

The degree of nutrition disorder means to simply to identify the extent of the color change in a leaf. Currently, in the field, this is done through a manual rating of the leaves by specialists. However, this method is erroneous due to inter and intra-rater variability [17]. Furthermore, such identification is carried out only by specialists which curtails information being available to the general farming population to take timely action [17]. For this purpose, the deep learning specifically used was convolutional networks with the use of a Mask-RCNN with Resnet101 and Feature Pyramid Network (FPN) backbone architecture. This was used in conducting transfer learning on the COCO weights to ensure high accuracy of the results obtained when the actual data set is used. The Restnet101 was chosen due to its high accuracy and its successful implementation in carrying out instance segmentation and image localization against other models as shown in the image below.

method	top-5 err. (**test**)
VGG [41] (ILSVRC'14)	7.32
GoogLeNet [44] (ILSVRC'14)	6.66
VGG [41] (v5)	6.8
PReLU-net [13]	4.94
BN-inception [16]	4.82
ResNet (ILSVRC'15)	**3.57**

Figure 2.5: Error rates (as a percentage) of ensembles among different methods

Source: Adapted from [18]

The ResNet101 and FPN architectures mainly function in two steps. First the Mask – RCNN scans the image and proceeds with object detection after which in the second stage using bounding boxes and masks it classifies the image. The use of the FPN is to allow the features extracted in the lower and higher levels to be available at all layers [19]. The two images below show the FPN structure and the basic structure of the entire Mask – RCNN.

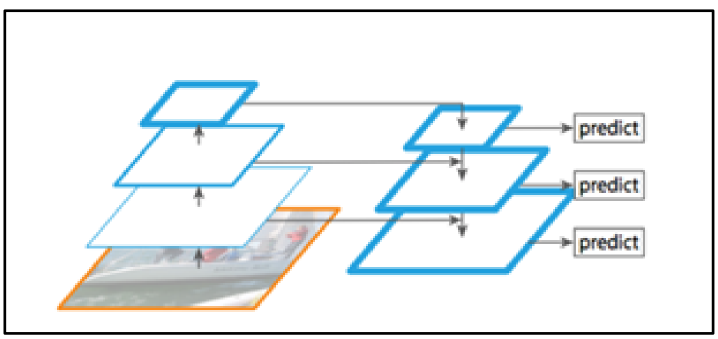


Figure 2.6:Comparison of ResNets,

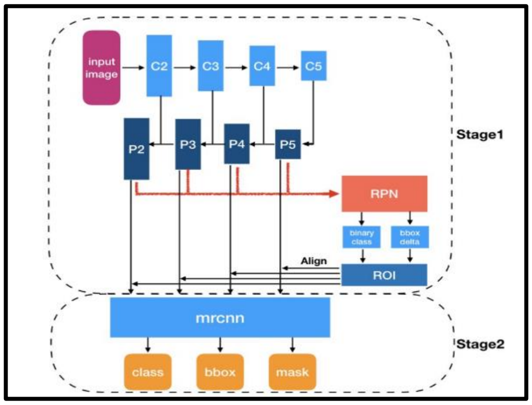


Figure 2.7: FPN structure based on functionality

Using a Region Proposal Network (RPN) and Region of Interest (ROI) pooling in the Mask-RCNN it carries out semantic segmentation by masking and instance segmentation. The following images show the difference between instance and semantic segmentation.

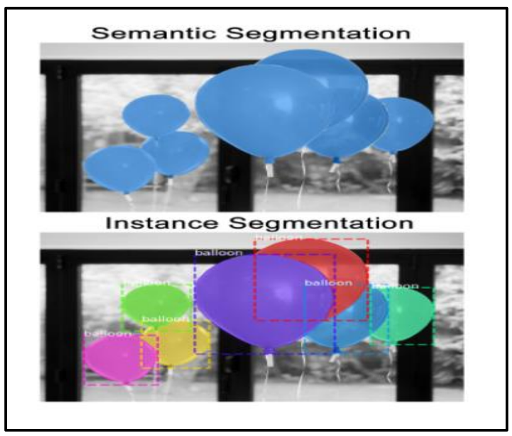


Figure 2.8: Comparison of instance and Semantic segmentation

Meanwhile, the following image shows the basic structures of the ResNet RCNN in block formation. The ResNet101 is of use in this research.

layer name	output size	18-layer	34-layer	50-layer	101-layer	152-layer
conv1	112×112	7×7, 64, stride 2				
conv2_x	56×56	3×3 max pool, stride 2				
		[3×3, 64 3×3, 64] ×2	[3×3, 64 3×3, 64] ×3	[1×1, 64 3×3, 64 1×1, 256] ×3	[1×1, 64 3×3, 64 1×1, 256] ×3	[1×1, 64 3×3, 64 1×1, 256] ×3
conv3_x	28×28	[3×3, 128 3×3, 128] ×2	[3×3, 128 3×3, 128] ×4	[1×1, 128 3×3, 128 1×1, 512] ×4	[1×1, 128 3×3, 128 1×1, 512] ×4	[1×1, 128 3×3, 128 1×1, 512] ×8
conv4_x	14×14	[3×3, 256 3×3, 256] ×2	[3×3, 256 3×3, 256] ×6	[1×1, 256 3×3, 256 1×1, 1024] ×6	[1×1, 256 3×3, 256 1×1, 1024] ×23	[1×1, 256 3×3, 256 1×1, 1024] ×36
conv5_x	7×7	[3×3, 512 3×3, 512] ×2	[3×3, 512 3×3, 512] ×3	[1×1, 512 3×3, 512 1×1, 2048] ×3	[1×1, 512 3×3, 512 1×1, 2048] ×3	[1×1, 512 3×3, 512 1×1, 2048] ×3
	1×1	average pool, 1000-d fc, softmax				
FLOPs		1.8×10^9	3.6×10^9	3.8×10^9	7.6×10^9	11.3×10^9

Figure 2.10: ResNet structures with the different layers used

While the transfer learning was carried out, a dataset was collected. This was annotated manually to identify the healthy and unhealthy areas of the leaf. The tool used for this was the VGG Image Annotator. The 300 images collected were divided into three categories with 100 images each for images showing a deficiency by 30%, between 30 – 70% and greater than 70%. These images were then sent through the Mask-RCNN post transfer learning (obtained through matterport) with configurations as 2 images per GPU, five classes (background, leaf, 30% deficiency, 30 – 70% deficiency, greater than 70%) and a 100 steps per epoch (per training instances) and a minimum detection confidence of 0.9. The input image sizes were set at 1024 x 1024. The images that were classified with the masks were then again used to calculate the percentage of deficiency using OpenCV to provide a numeric value as an output to the user.

2.1.3 Soil analysis using IoT to provide accurate degree of nutrition deficiency in soil and recommendation

As you can see in this diagram farmers has to measure soil parameters with the device. Soil parameters will be sent to farmers mobile app by a sms. Farmer has to enter those parameters to the mobile app. The machine learning algorithm which running on the mobile backend will be predicted NPK level of given soil sample .

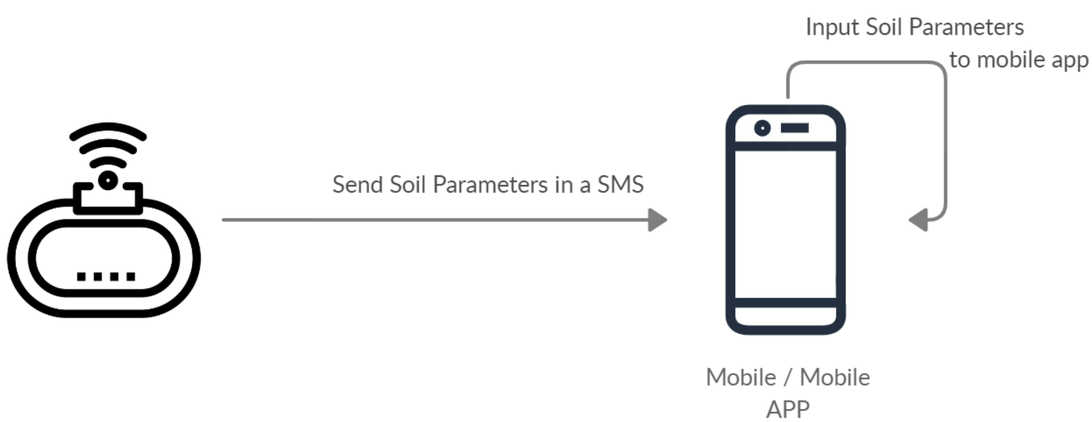


Figure 2.11: System Diagram

Soil temperature sensors arrive in an assortment of structures utilizing thermistors, thermocouples, thermocouple wires, and averaging thermocouples. The electrical signs transmitted from the sensors to information lumberjacks can be changed over to various units of estimation, including °C , °F, and °K. Information lumberjacks are likewise equipped for estimating most financially accessible soil temperature sensors. After gathering all the information all the data s redirecting to cloud using API gateway. Thereafter use relevant machine learning algorithm to predict the results.

In this case we use regression neural network machine learning algorithm to predicate the results with co-relationship.

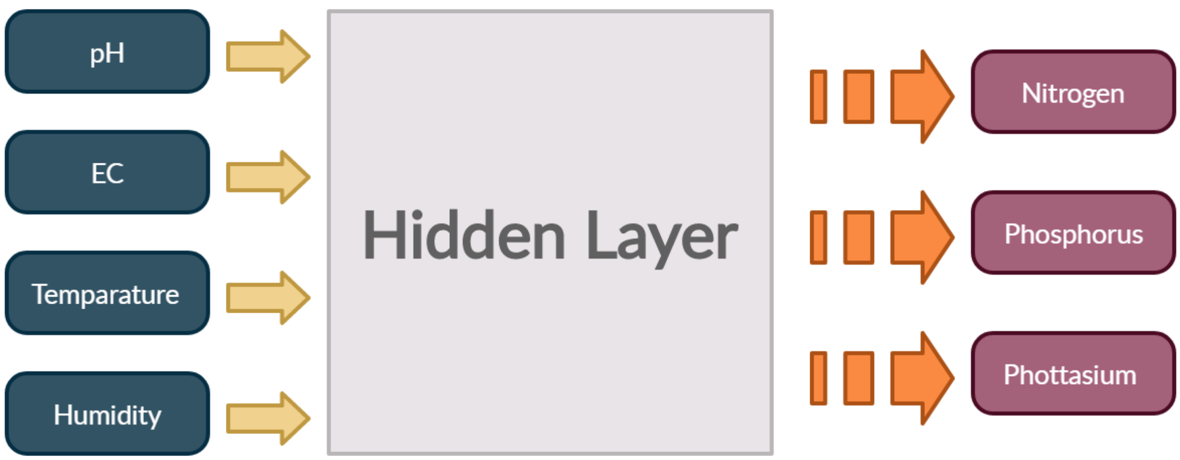


Figure 2.12: Flow through the Hidden layer

<u>Machine learning algorithm which are used.</u>

K-mean in Agriculture:

The K-means algorithm is separation based grouping methods. By applying this algorithm, K group are shaped. In light of Euclidean separation, object is put into the individual group. The k-implies calculation is utilized to characterize soil in blend with GPS. Grouping of plant and soil, reviewing apples before showcasing, Monitoring water quality change, recognizing weeds in accuracy horticulture, and the forecast of wine aging issues can be performed by utilizing a k-means approach.

Neural Networks in Agriculture:

In information mining a factual model known as Artificial Neural Network is a Non-direct prescient model that learns through preparing and looks like natural neural organizations in structure.

The neural network is used in Prediction of flowering and maturity dates of soybean and in forecasting of water resources variables in agriculture.

SVMs in Agriculture:

SVMs are one of the most current regulated AI procedures.

The current examination explored the materialness of help vector machine in horticulture is in the harvest grouping and in the investigation of the environmental change situations

2.1.4 Implement a secure and distributed platform for identifying best commercial product for deficiency based on diagnosis

Blockchain networks are fundamentally based on peer-to-peer communication. There is an agreed consensus process built on smart contracts by which all nodes of the network must comply [23]. The validity of transactions is verified by this consensus process. This agreed automated consensus process is a key factor in implementing blockchain solutions for most interaction-driven systems. An interaction-driven network is typically trust-based [24] where approaches such as human-verification or manually maintained/third-party ledgers would hold any transaction accountable. This brings forth several complications in a compliance context as there is considerable margin for error or deference. A blockchain network uses a ledger-based mechanism with the consensus providing a trust-free alternative which can be relied upon to function seamlessly and in a streamlined manner.

The following workflow would further clarify by this workflow:

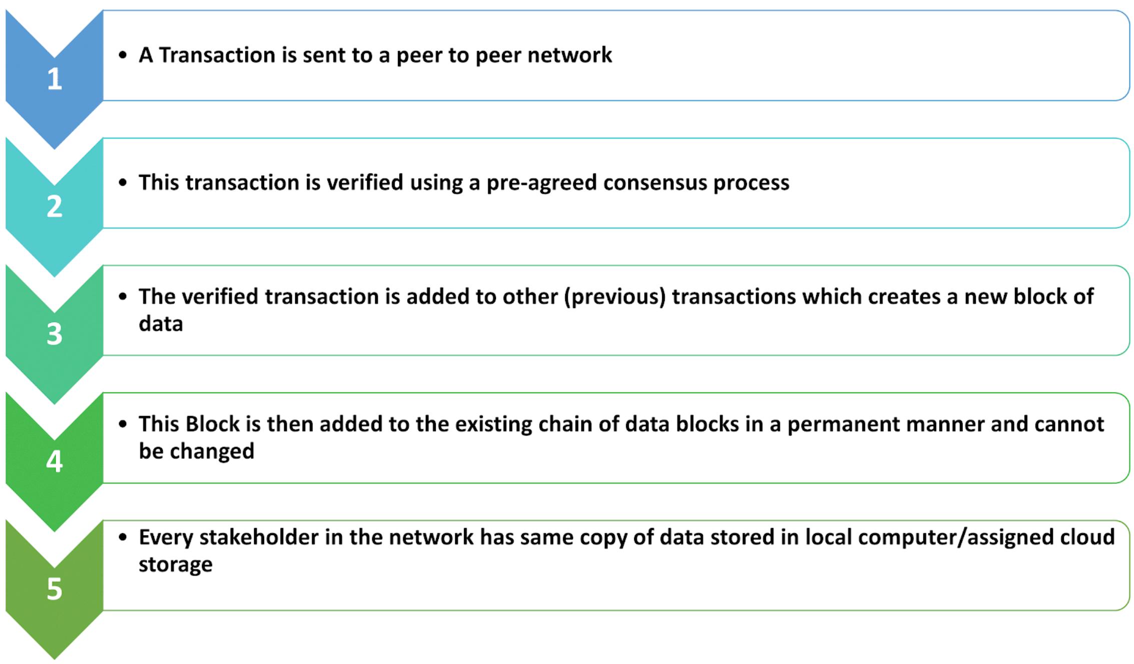


Figure 2.13: Workflow of blockchain

There are three main approaches to Blockchain technology based on data handling and who can join the network. This can be clarified by the following table:

Table 2.1: Blockchain types

Public Blockchain Network	Anyone can participate in this network E.g. Bitcoin

Private Blockchain Network	A Centralized database on networks ideally for banks etc.
Consortium Blockchain Network	Ideal for software and systems handling data of multiple stakeholders with distributed network topology

By the preceding section, it is evident that a blockchain solution is ideal for the relevant research component, based on the identified problems and requirements that should be catered for. Of the three approaches available, a consortium blockchain is best suited for the solution. A re-visit to the requirements would clarify that whichever network is constructed, it should:

- Provide a secure gateway for communication between identified stakeholders
- Initiate confidential communication between farmer and expert
- Marginalize impact of vendors on the ecosystem.

As such, the logic for proposing a consortium blockchain is because it is private and permissioned. It can be used on multiple enterprises while permitting only those with permission to interact with the network for any transaction or make any changes for the blockchain ledger which has been agreed upon by all stakeholders. Accordingly, such a network can provide for requirements of the proposed system, utilizing the key features a consortium blockchain possesses

Hyperledger Fabric

- **Why Hyperledger Fabric**

In Hyperledger Fabric [6], the system can be deployed on several nodes which ensures the integrity of data. The relevant data will not be lost. In a scenario in which one node crashes the system will still be up and running through the other nodes which we have created for our blockchain based system software.

Another key takeaway as to why Hyperledger Fabric is best suited for this system is: in a multiple enterprise ecosystem as the proposed system, we can assign different nodes to different enterprises and also restrict access to some or all of our data from other enterprises in the system and only give access to them on request. This would be an essential factor when establishing the proposed system as it would marginalize the impact a vendor would have, provide other stakeholders ability to monitor his transactions and would also provide a secure channel for the farmer to communicate with the expert and receive timely, relevant information for his fertilization practices. Scalability of a blockchain is an issue discussed in-detail when they are considered to be integrated into enterprise systems. This is another issue which was identified with relevance to any network to be constructed for this particular scenario as there would be numerous stakeholders who would be categorized into the three main segments: farmers, vendors and experts. Hyperledger Fabric offers an architecture which resolves this issue by deploying different nodes in different servers. Accordingly, in the context of this scenario, the three nodes belonging to the segments of farmers, experts and vendors would be in three different servers. This offers the network a considerable and comfortable *'breathing space'* in terms of the scalability and number of peers who would be joining the respective nodes.

While the ability to assign nodes to different organizations is essential to lifting the bias toward the vendor in the fertilizer procurement ecosystem, a key feature in Fabric permits any other stakeholder to monitor and audit any transaction carried out by the vendor node. In Hyperledger Fabric, if some participant performs some action it is saved in the transaction log which gives us a complete view of any transmitted data from beginning to current state, with the keys of the person performing the transaction. As such, any malicious data forgery can easily be tracked-down to the relevant participant responsible for it. Hyperledger Fabric enables restriction of access to certain participants and permits more authority to others. Any entity performing transactions must have the identity keys for performing transactions. An identity key is somewhat similar to an access card. It provides permission for a particular participant of the network with sufficient access to fulfill his responsibilities. In an Information Security perspective, this is somewhat similar to an access control mechanism. These keys are given when a particular participant is added to the network.

When a System is divided into multiple enterprises, a lack of trust originates. In Hyperledger fabric we create an element of trust between enterprises by creating a common business logic agreed by all the enterprises. Any delegated enterprise can also restrict some of its data to others only for its personal use. Also, certain enterprises with elevated control and access can monitor the transactions of other entities. If it is the requirement of the user to trade with a stakeholder which has not been verified or is at a considerable distance, the user would not ideally know whether this entity is trustworthy or not. However, with Hyperledger Fabric, you can track the transaction history from the platform and use smart contracts to automate the payment as necessary, if necessary. As such, it's a 'win-win' situation for any stakeholder involved.

- **Constituents of Hyperledger Fabric**

The main components of the Hyperledger Fabric Network [6] are as follows:

- Peers: Peers are a fundamental element of the network because they host ledgers and smart contracts
- Ordering Service: It handles the transactional flow between peers and in the network.
- Certificate Authority: It issues identity to all the participants of the network so that no malicious actor accesses the network.
- Chaincode: The business logic of the network the structure in which data will be stored in ledger is defined in chaincode.
- Fabric Node SDK: It's basically the API which connects web apps with the chaincodes.

Technologies taken use of when implementing a Hyperledger Fabric Network are:

- GoLang and Javascript to compose the chaincode

- Docker Containers to bring-up the peers, orderer and Certificate authority service
- Node SDK API for interacting with Hyperledger Networks

Workflow of Hyperledger Fabric:

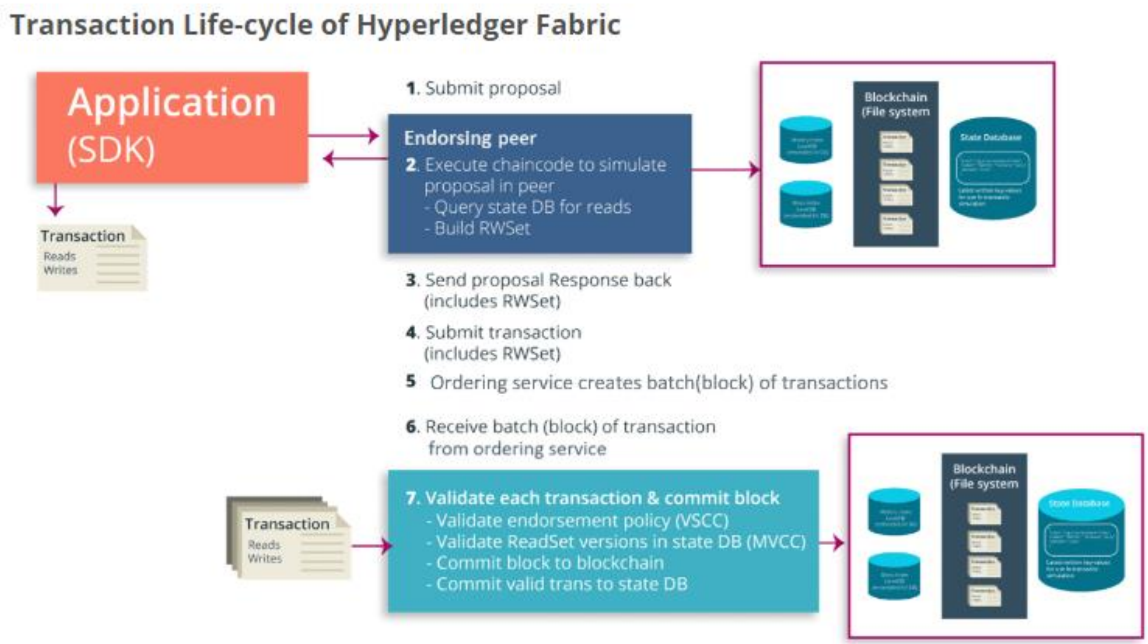


Figure 2.14: Life cycle of Hyperledger Fabric

We can create a three peer network for this system one for the farmer, one for experts and one for the vendor. Farmers will send the image and condition of their crops to experts in-order-to obtain expert advice. After getting a response from an expert they can post a product request for vendors. Experts can view Farmers request and view the crop condition and post a response. They can also rate the product of the vendor. This rating system would be an indicator as to the level of recommendation of a vendor, further improving chances farmers possess toward making the best informed decision.

The System Architecture explains the high-level, overall structure of the system which would clearly indicate that the system meets the requirements and abides by the objectives set-out for this research component:

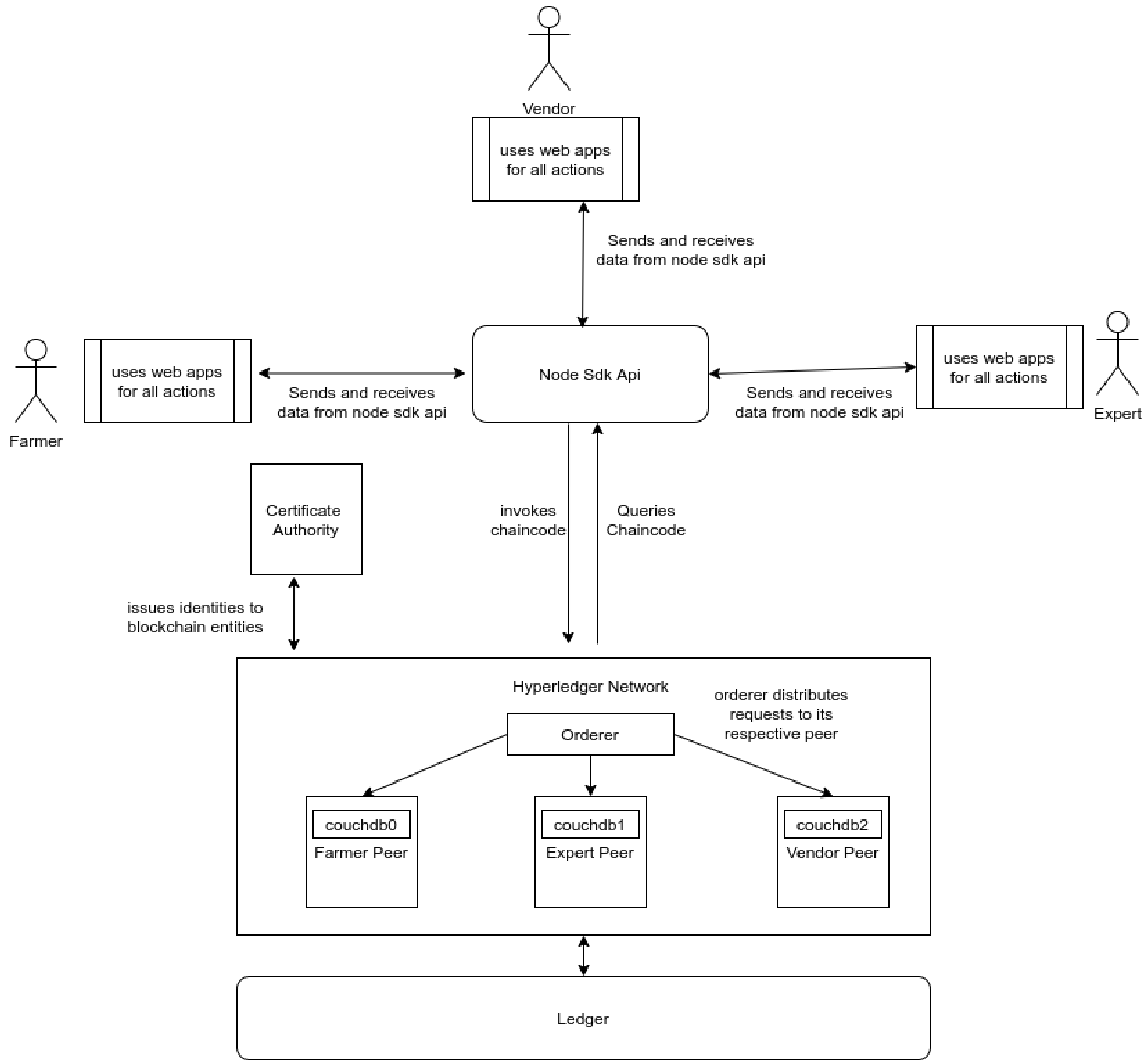


Figure 2.15: Architecture diagram of the component

2.2 Implementation

2.2.1 Identification of Nutrient deficiency in Groundnut, Guava and Citrus

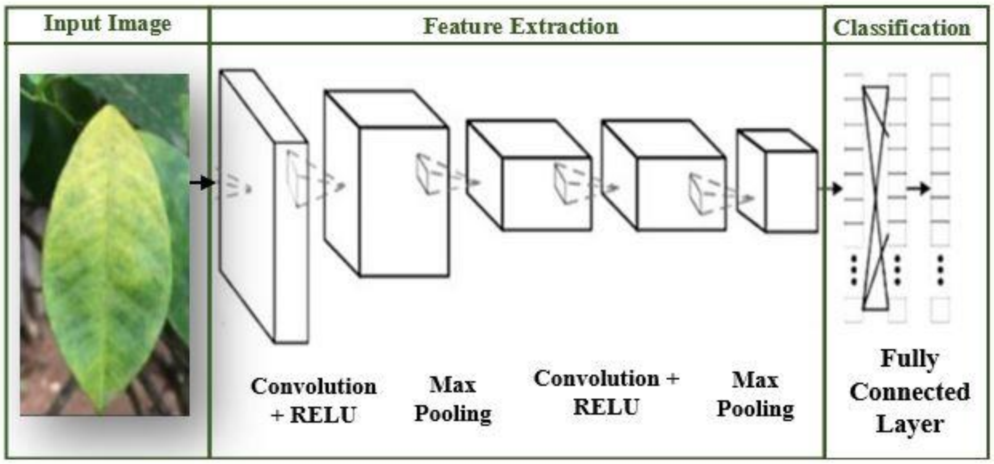


Figure 2.16: CNN Architecture

After collecting the images, to feed these images into the CNN model, it needs to be in standardization form and have clear data. Preprocessing was done to increase accuracy and reduce the complexity of the dataset. While converting the color image to grayscale is an accepted preprocessing technique, we employed Image standardization. For this, first the data has rescaled in the range of 0 to 1. This is called Normalization. Next, each training dataset image pixel should be transferred from 0 to 255. The reasoning for this is: some images in the dataset would have high pixels and some would have low pixels. It is necessary to treat the Images at the same level. We need this data preprocessing. If not, high pixel images can get more loss than low pixel images and it may need more learning ratings. For training the model we divided the dataset in to two parts. 80% for training and 20% for testing purpose.

As shown in the Fig. 2.16, Feature extraction and classification will happen within the CNN model. The main advantage of CNN is, it can do the feature extraction automatically. There are five main operations to build CNN which are Convolution operation, ReLU layer, Max pooling layer, fattening, and fully connected layer. Initially, the input image will be sent to the convolutional layer which helps to perform the extraction of features. For example Color extraction, edge detection, and gradient orientation, etc. Here, ReLU is used to introduce non-linearity. The pooling layer used to get only the needed information from the input leaf image by minimizing the parameters. Finally, a fully connected layer gets the input from previous layers such as the Convolutional layer and the Pooling layer and it flattens the input, classifies the deficiencies as output with the help of the SoftMax technique.

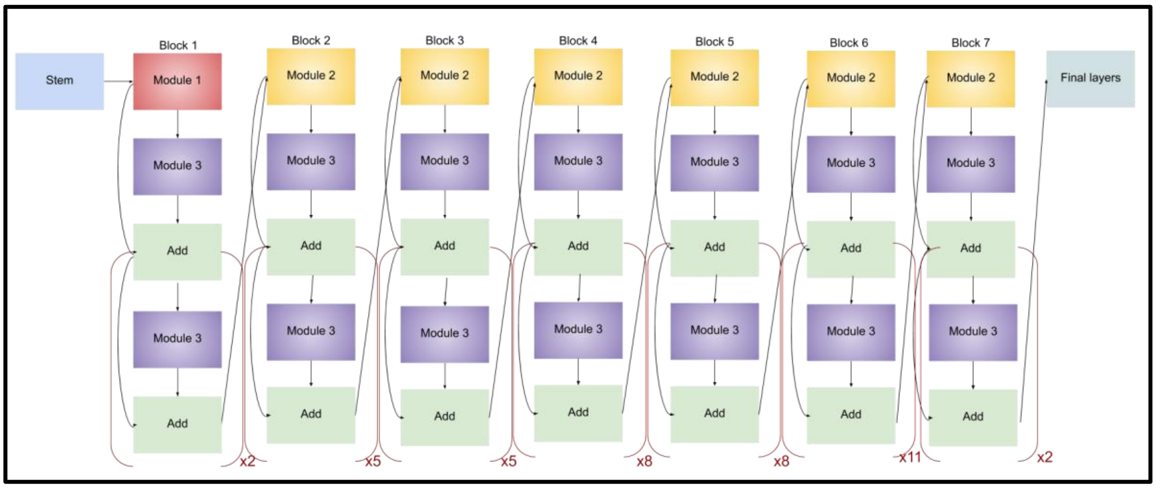


Figure 2.17: EfficientNet Architectural diagram

According to the several background study, there are many CNN architectures used previously for the image classification. Such as EfficientnetB0, Inception-V3, GoogLeNet, ResNet and VGG. According to the comprehensive literature review EfficientB0, ResNet and VGG has stated as top three architecture in CNN[10]. In this research, Comparison has done among ResNet, EfficientnetB0, and VGG architectures and the Model which got highest confidence level has selected to the identification of nutrient disorder in guava, groundnut and citrus plants.

Following Fig. 2.18 shows the EfficientNet training:

```
model1 = efn.EfficientNetB0(include_top=True, weights=None, classes=len(classes))
model1.compile(optimizer='adam',loss='categorical_crossentropy',metrics=['accuracy'])
es = EarlyStopping(monitor='accuracy', mode='min', verbose=1, patience=5)
history = model1.fit(train_generator, epochs=50)
model1.save("/content/drive/My Drive/deficiency classification/efficientnet.h5")

Epoch 1/50
 2/73 [..............................] - ETA: 5s - loss: 3.1023 - accuracy: 0.4062WARNING:tensorflow:Ca
73/73 [==============================] - 251s 3s/step - loss: 2.2499 - accuracy: 0.6279
Epoch 2/50
73/73 [==============================] - 11s 153ms/step - loss: 0.8754 - accuracy: 0.7225
Epoch 3/50
73/73 [==============================] - 11s 152ms/step - loss: 0.8837 - accuracy: 0.7493
Epoch 4/50
73/73 [==============================] - 11s 151ms/step - loss: 0.6845 - accuracy: 0.8040
Epoch 5/50
73/73 [==============================] - 11s 153ms/step - loss: 0.3974 - accuracy: 0.8630
Epoch 6/50
73/73 [==============================] - 11s 152ms/step - loss: 0.3418 - accuracy: 0.8682
Epoch 7/50
73/73 [==============================] - 11s 154ms/step - loss: 0.3001 - accuracy: 0.9107
Epoch 8/50
73/73 [==============================] - 11s 155ms/step - loss: 0.2663 - accuracy: 0.9289
Epoch 9/50
73/73 [==============================] - 11s 156ms/step - loss: 0.1737 - accuracy: 0.9367
Epoch 10/50
73/73 [==============================] - 11s 155ms/step - loss: 0.3730 - accuracy: 0.9341
Epoch 11/50
73/73 [==============================] - 11s 155ms/step - loss: 0.4307 - accuracy: 0.8933
Epoch 12/50
```

Figure 2.18: Training the EfficientNetB0

2.2.2 Soil analysis using IoT to provide accurate degree of nutrition deficiency in soil and recommendation

The machine learning model which is running on the hidden layer build up with following steps.

```
pH=df['pH ']
humidity=df['humidity %']
ec=df['ec ']
temperature=df['temperature']
n=df['n %']
p=df['p %']
k=df['k %']


getData=[pH,humidity,ec,temperature,n,p,k]
list1=[]
for k in range(len(getData[0])):
    i=k
    x=[int(getData[0][i]),int(getData[1][i]),int(getData[2][i]),int(getData[3][i])]
    tot=0
    for j in range(len(x)):
        tot=float(tot)+x[j]
    x=[int(getData[0][i])/tot,int(getData[1][i])/tot,int(getData[2][i])/tot,int(getData[3][i])/tot,getData[4][i],getData[5][i],ge
    list1.append(x)
```

```
"""  Nitrogen  """

list=list1
totPred=0
cp=0
model=None
X=None
Y=None
for i in range(10):
    shuffle(list)
    bigData=pd.DataFrame(list,columns=['','','','','label','t1','t2'])
    target=bigData['label']
    from sklearn.model_selection import  train_test_split
    X_train,X_test,Y_train,Y_test=train_test_split(bigData.drop(['label','t1','t2'],axis='columns'),target,test_size=0.2)
    model = LinearRegression()
    X=X_train
    Y=Y_train
    model.fit(X_train,Y_train)
    pred=model.score(X_test,Y_test)

    if(pred>cp):
        cp=pred
        filename = r'E:\IOT\NPK\NPK/nModel.sav'


        pickle.dump(model, open(filename, 'wb'))

    totPred=pred+totPred


print("")
print("Algorithm : LinearRegression for n")
print("Train Data Count : ",len(X_train))
print("Test Data Count : ",len(X_test))
print("Accuracy :",cp)
```

```
""" phosphorus """

list=list1
totPred=0
cp=0
model=None
X=None
Y=None
for i in range(10):
    shuffle(list)
    bigData=pd.DataFrame(list,columns=['','','','','t1','label','t2'])
    target=bigData['label']
    from sklearn.model_selection import  train_test_split
    X_train,X_test,Y_train,Y_test=train_test_split(bigData.drop(['t1','label','t2'],axis='columns'),target,test_size=0.2)
    model = LinearRegression()
    X=X_train
    Y=Y_train
    model.fit(X_train,Y_train)
    pred=model.score(X_test,Y_test)

    if(pred>cp):
        cp=pred
        filename = r'E:\IOT\NPK\NPK/pModel.sav'
        pickle.dump(model, open(filename, 'wb'))

    totPred=pred+totPred


print("")
print("Algorithm : LinearRegression for p")
print("Train Data Count : ",len(X_train))
print("Test Data Count : ",len(X_test))
print("Accuracy :",cp)
```

```python
""" potassium  """

list=list1
totPred=0
cp=0
model=None
X=None
Y=None
for i in range(10):
    shuffle(list)
    bigData=pd.DataFrame(list,columns=['','','','','t1','t2','label'])
    target=bigData['label']
    from sklearn.model_selection import  train_test_split
    X_train,X_test,Y_train,Y_test=train_test_split(bigData.drop(['t1','t2','label'],axis='columns'),target,test_size=0.2)
    model = LinearRegression()
    X=X_train
    Y=Y_train
    model.fit(X_train,Y_train)
    pred=model.score(X_test,Y_test)

    if(pred>cp):
        cp=pred
        filename = r'E:\IOT\NPK\NPK/kModel.sav'
        pickle.dump(model, open(filename, 'wb'))

    totPred=pred+totPred


print("")
print("Algorithm : LinearRegression for k")
print("Train Data Count : ",len(X_train))
print("Test Data Count : ",len(X_test))
print("Accuracy :",cp)
print("")
```

IOT Device: Hardware Component

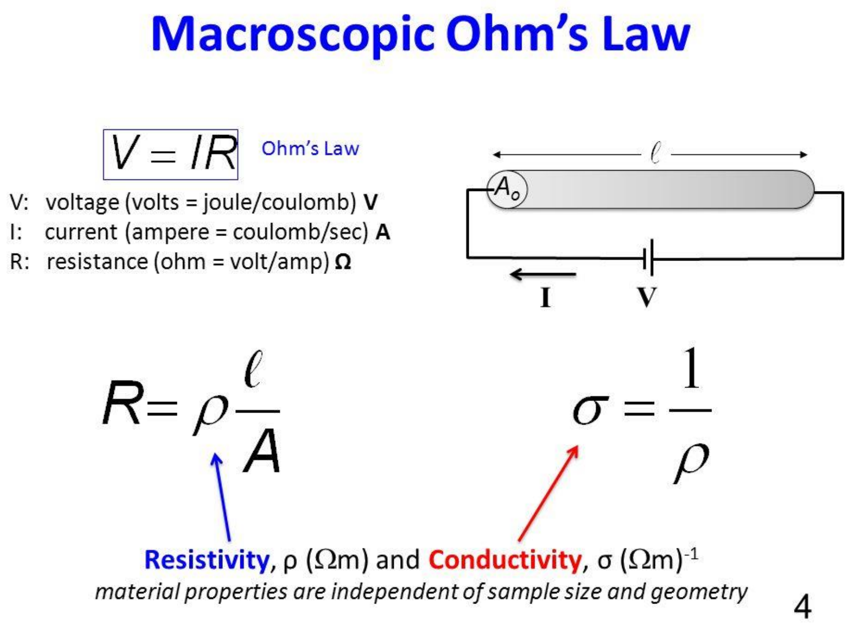
```cpp
int switchpin = 7;
volatile bool last = 1;

int thermoDO = 4;
int thermoCS = 5;
int thermoCLK = 6;
MAX6675 thermocouple(thermoCLK, thermoCS, thermoDO);

int conducpin = A2;

SoftwareSerial Sim800l(10, 11);

int pHSense = A0;
int samples = 10;
float adc_resolution = 1024.0;

int moistPin = A1;
int sensorValue;
int limit = 300;

String to_send = "";

float ph(float voltage) {
  return 7 + ((2.5 - voltage) / 0.18);
}
```

```
      double cons = 0.0059459;
      long conduct = map(analogRead(conducpin),0,473,100000,400000);
      double cv = 1/(double(conduct)*cons);
      to_send += "CV=";
      to_send += String(cv,(unsigned char)'\004');


      Sim800l.write("AT+CMGS=\"+94776612147\"\n\r");
      Sim800l.write(to_send.c_str());
      Sim800l.write(26);

      Serial.println(to_send);

      delay(1000);
    }
    last = state;
  }

}
```

```
int switchpin = 7;
volatile bool last = 1;

int thermoDO = 4;
int thermoCS = 5;
int thermoCLK = 6;
MAX6675 thermocouple(thermoCLK, thermoCS, thermoDO);

int conducpin = A2;

SoftwareSerial Sim800l(10, 11);

int pHSense = A0;
int samples = 10;
float adc_resolution = 1024.0;

int moistPin = A1;
int sensorValue;
int limit = 300;

String to_send = "";

float ph(float voltage) {
  return 7 + ((2.5 - voltage) / 0.18);
}
```

When we are designing the IOT device, measuring the electrical conductivity was a major part. We have developed a sensor to measure the electrical conductivity.

We have used a a container with constant volume. After filling it with soil, withusage of copper clads we are measuring the resistance.



2.2.3 Implement a secure and distributed platform for identifying best commercial product for deficiency based on diagnosis

The orderer service in a Hyperledger Fabric network is responsible for transaction ordering and endorsement of the Chaincode execution. The certificate authority is what provides and defines the accessibility each peer has in a network. Three main peers have been identified for the system as: farmer, vendor and expert. The following snippets are a demonstration of how to define an orderer service, certificate authority and a peer:

```yaml
version: '2'

volumes:
  orderer.example.com:
  peer0.org1.example.com:
  peer1.org1.example.com:
  peer2.org1.example.com:

networks:
  byfn:

services:

  ca.example.com:
    image: hyperledger/fabric-ca
    environment:
      - FABRIC_CA_HOME=/etc/hyperledger/fabric-ca-server
      - FABRIC_CA_SERVER_CA_NAME=ca.example.com
      - FABRIC_CA_SERVER_CA_CERTFILE=/etc/hyperledger/fabric-ca-server-config/ca.org1.example.com-cert.pem
      - FABRIC_CA_SERVER_TLS_KEYFILE=/etc/hyperledger/fabric-ca-server-config/CA1_PRIVATE_KEY
    ports:
      - "7054:7054"
    command: sh -c 'fabric-ca-server start --ca.certfile /etc/hyperledger/fabric-ca-server-config/ca.org1.example.com-cert.
    volumes:
      - ./crypto-config/peerOrganizations/org1.example.com/ca/:/etc/hyperledger/fabric-ca-server-config
    container_name: ca.example.com
    networks:
      - byfn

  orderer.example.com:
    extends:
      file:   base/docker-compose-base.yaml
      service: orderer.example.com
    container_name: orderer.example.com
```

Figure 2.19: Definition of Orderer, Certificate Authority and Peer

```yaml
  peer0.org1.example.com:
    container_name: peer0.org1.example.com
    image: hyperledger/fabric-peer:$IMAGE_TAG
    environment:
      #Generic peer variables
      - CORE_VM_ENDPOINT=unix:///host/var/run/docker.sock
      # the following setting starts chaincode containers on the same
      # bridge network as the peers
      # https://docs.docker.com/compose/networking/
      - CORE_VM_DOCKER_HOSTCONFIG_NETWORKMODE=${COMPOSE_PROJECT_NAME}_test
      - FABRIC_LOGGING_SPEC=INFO
      #- FABRIC_LOGGING_SPEC=DEBUG
      - CORE_PEER_TLS_ENABLED=true
      - CORE_PEER_PROFILE_ENABLED=true
      - CORE_PEER_TLS_CERT_FILE=/etc/hyperledger/fabric/tls/server.crt
      - CORE_PEER_TLS_KEY_FILE=/etc/hyperledger/fabric/tls/server.key
      - CORE_PEER_TLS_ROOTCERT_FILE=/etc/hyperledger/fabric/tls/ca.crt
      # Peer specific variabes
      - CORE_PEER_ID=peer0.org1.example.com
      - CORE_PEER_ADDRESS=peer0.org1.example.com:7051
      - CORE_PEER_LISTENADDRESS=0.0.0.0:7051
      - CORE_PEER_CHAINCODEADDRESS=peer0.org1.example.com:7052
      - CORE_PEER_CHAINCODELISTENADDRESS=0.0.0.0:7052
      - CORE_PEER_GOSSIP_BOOTSTRAP=peer0.org1.example.com:7051
      - CORE_PEER_GOSSIP_EXTERNALENDPOINT=peer0.org1.example.com:7051
      - CORE_PEER_LOCALMSPID=Org1MSP
    volumes:
        - /var/run/:/host/var/run/
        - ../organizations/peerOrganizations/org1.example.com/peers/peer0.org1.example.com/msp:/etc/hyperledger/fabric/msp
        - ../organizations/peerOrganizations/org1.example.com/peers/peer0.org1.example.com/tls:/etc/hyperledger/fabric/tls
        - peer0.org1.example.com:/var/hyperledger/production
    working_dir: /opt/gopath/src/github.com/hyperledger/fabric/peer
    command: peer node start
```

Figure 2.20: Definition of Orderer, Certificate Authority and Peer

Once the docker has been set up after defining orderer, Certificate Authority and peer, it is necessary to configure the ledger specific for the requirements of our network. The ledger is based on a key concept in Hyperledger Fabric. The ledger consists of the current state of proceedings in the platform as journals of transactions. A real-world instance to define a ledger would be a scenario where we check our bank account balance. Apart from knowing the current status, we can also check on the transactions that have been done for the account to evolve to that particular point. This being a key concept of Fabric, is also a primary component which would enable to fulfill the objectives set out for the blockchain component constructed. The coding snippet for the ledger is as follows:

```
- &Org1
    # DefaultOrg defines the organization which is used in the sampleconfig
    # of the fabric.git development environment
    Name: Org1MSP

    # ID to load the MSP definition as
    ID: Org1MSP

    MSPDir: crypto-config/peerOrganizations/org1.example.com/msp

    # Policies defines the set of policies at this level of the config tree
    # For organization policies, their canonical path is usually
    #   /Channel/<Application|Orderer>/<OrgName>/<PolicyName>
    Policies:
        Readers:
            Type: Signature
            Rule: "OR('Org1MSP.admin', 'Org1MSP.peer', 'Org1MSP.client')"
        Writers:
            Type: Signature
            Rule: "OR('Org1MSP.admin', 'Org1MSP.client')"
        Admins:
            Type: Signature
            Rule: "OR('Org1MSP.admin')"

    # leave this flag set to true.
    AnchorPeers:
        # AnchorPeers defines the location of peers which can be used
        # for cross org gossip communication.  Note, this value is only
        # encoded in the genesis block in the Application section context
        - Host: peer0.org1.example.com
          Port: 7051
```

Figure 2.21: Definition of Ledger

These files are run together with fabric binaries by creating a bash script file which will use the fabric binary tools and create certificates for all the components of the Hyperledger network. This snippet is demonstrated below:

```
function createOrgs() {

  if [ -d "organizations/peerOrganizations" ]; then
    rm -Rf organizations/peerOrganizations && rm -Rf organizations/ordererOrganizations
  fi

  # Create crypto material using cryptogen
  if [ "$CRYPTO" == "cryptogen" ]; then
    which cryptogen
    if [ "$?" -ne 0 ]; then
      echo "cryptogen tool not found. exiting"
      exit 1
    fi
    echo
    echo "##########################################################"
    echo "##### Generate certificates using cryptogen tool #########"
    echo "##########################################################"
    echo

    echo "##########################################################"
    echo "############ Create Org1 Identities ######################"
    echo "##########################################################"

    set -x
    cryptogen generate --config=./organizations/cryptogen/crypto-config-org1.yaml --output="organizations"
    res=$?
    set +x
    if [ $res -ne 0 ]; then
      echo $'\e[1;32m'"Failed to generate certificates..."$'\e[0m'
      exit 1
    fi
```

Figure 2.22: Bash Script for Certificate Creation

Once this script file is executed the three-peer blockchain network would be running. Afterwards, it's necessary for the Chaincode to be written.

Chaincode

The Chaincode would be written in ‘Golang’. Importing the Fabric binaries is the first step in implementing the Chaincode:

```go
package main

import (
    "bytes"
    "encoding/json"
    "fmt"

    //"strings"

    "github.com/hyperledger/fabric/core/chaincode/shim"
    "github.com/hyperledger/fabric/protos/peer"
)
```

Figure 2.23: Import Fabric Binaries

It will be able to communicate with the blockchain network using these imports. The 'shim api' is responsible for communication of Chaincode with API and a separate import should be done for the communication of peers.

Afterwards, it is necessary to define a database structure for the system. It is necessary to define how and what will be stored here. As an instance, at first a user amongst the three stakeholders (Farmer, Expert, Vendor) would be stored.

The Chaincode function for posting a product can be defined as follows:

```go
    product_ID := args[0]
    name := args[1]
    amount := args[2]
    price := args[3]
    farmer_ID := args[4]
    vendor_ID := args[5]
    expert_ID := args[6]
    status := args[7]

    // ======Check if product Already exists

    productAsBytes, err := stub.GetState(product_ID)
    if err != nil {
        return shim.Error("Transaction Failed with Error: " + err.Error())
    } else if productAsBytes != nil {
        return shim.Error("The Inserted product ID already Exists: " + product_ID)
    }

    // ===== Create product Object and Marshal to JSON

    objectType := "product"
    product := &Product{objectType, product_ID, name, amount, price, farmer_ID, vendor_ID, expert_ID, status}
    productJSONasBytes, err := json.Marshal(product)

    if err != nil {
        return shim.Error(err.Error())
    }

    // ======= Save product to State

    err = stub.PutState(product_ID, productJSONasBytes)
    if err != nil {
        return shim.Error(err.Error())
    }
```

Figure 2.24: Post function in Chaincode

This defines how a product with the relevant attributes is to be posted on request or when the vendor is willing to do so.

```
func (t *SmartContract) queryProduct(stub shim.ChaincodeStubInterface, args []string) peer.Response {

    if len(args) < 1 {
        return shim.Error("Incorrect number of arguments. Expecting 1")
    }

    status := args[0]

    queryString := fmt.Sprintf("{\"selector\":{\"Type\":\"product\",\"status\":\"%s\"}}", status)

    queryResults, err := getQueryResultForQueryString(stub, queryString)
    if err != nil {
        return shim.Error(err.Error())
    }

    return shim.Success(queryResults)
}
```

Figure 2.25: Get Function in Chaincode

All the get post functions are similar, calling out their respective struct. They are marshalled into JSON structures and then stored in blockchain. Afterwards, the invoke function in which all the get and post methods are defined. When an API communicates with the Chaincode, its request will be received by invoke method and then this method sends it to its respective function. The invoke function is as follows:

```go
func (t *SmartContract) Invoke(stub shim.ChaincodeStubInterface) peer.Response {

    // Retrieve the requested Smart Contract function and arguments
    function, args := stub.GetFunctionAndParameters()
    fmt.Println("Chaincode Invoke Is Running " + function)

    if function == "addExpert" {
        return t.addExpert(stub, args)
    }
    if function == "queryExpert" {
        return t.queryExpert(stub, args)
    }
    if function == "addFarmer" {
        return t.addFarmer(stub, args)
    }
    if function == "queryFarmer" {
        return t.queryFarmer(stub, args)
    }
    if function == "queryFarmerbyID" {
        return t.queryFarmerbyID(stub, args)
    }
    if function == "addVendor" {
        return t.addVendor(stub, args)
    }
    if function == "queryVendor" {
        return t.queryVendor(stub, args)
    }
    if function == "queryVendorbyID" {
        return t.queryVendorbyID(stub, args)
    }
```

Figure 2.26: Invoke function

Deployment

The Chaincode needs to be deployed on the blockchain network in order for it to run the methods for posting and getting data from the ledger. CLI operations need to be executed to deploy the Chaincode file on the network.

In the directory where the blockchain network files are stored we need to execute the following command on CLI to make our Chaincode work:

$ docker exec cli peer Chaincode install -n agri -l golang -p path to chaincode file/agri -v 0.1

This will install the Chaincode on the peers ready for usage.

By this stage the blockchain network backend is running and functional. As per now, all we need is an API to send data to the blockchain.

Node SDK API

For the API, first a user must be enrolled so it can send and receive data from blockchain. For the purpose of demonstration, let us consider the vendor node:

```
        trustedRoots: [],
        verify: false
    };
    // be sure to change the http to https when the CA is running TLS enabled
    fabric_ca_client = new Fabric_CA_Client('http://localhost:7054', null , '', crypto_suite);

    // first check to see if the admin is already enrolled
    return fabric_client.getUserContext('admin', true);
}).then((user_from_store) => {
    if (user_from_store && user_from_store.isEnrolled()) {
        console.log('Successfully loaded admin from persistence');
        admin_user = user_from_store;
    } else {
        throw new Error('Failed to get admin.... run enrollAdmin.js');
    }

    // at this point we should have the admin user
    // first need to register the user with the CA server
    return fabric_ca_client.register({enrollmentID: 'vendor1', affiliation: 'org1.department1',role: 'client' ,  attrs: [{ na
}).then((secret) => {
    // next we need to enroll the user with CA server
    console.log('Successfully registered vendor1 - secret:'+ secret);

    return fabric_ca_client.enroll({enrollmentID: 'vendor1', enrollmentSecret: secret , attr_reqs: [{ name: "role" , optional
}).then((enrollment) => {
  console.log('Successfully enrolled member user "vendor1" ');
  return fabric_client.createUser(
     {username: 'vendor1',
     mspid: 'Org1MSP',
     cryptoContent: { privateKeyPEM: enrollment.key.toBytes(), signedCertPEM: enrollment.certificate }
     });
}).then((user) => {
     member_user = user;
```

Figure 2.27: User Enrollment NodeJS

The path of the Certificate Authority Server has been provided, so it can get its identity certificates. Afterwards, it is necessary to set the path for exporting from the path of the peers and orderers on which the request has to be sent:

```
module.exports = {

  invokeCreate: async function (request) {

    try {

      var fabric_client = new Fabric_Client();

      // setup the fabric network
      var channel = fabric_client.newChannel('mychannel');
      var peer = fabric_client.newPeer('grpc://localhost:9051');
      channel.addPeer(peer);
      var order = fabric_client.newOrderer('grpc://localhost:7050')
      channel.addOrderer(order);

      // load the base network profile and eventHub
      let event_hub = channel.newChannelEventHub(peer);
```

Figure 2.28: Export path

Once these configurations are made, it is necessary to create an API endpoint for the network which will be running on a port on which data can be sent and retrieved using this API to blockchain:

```
app.post('/api/addFarmer', async function (req, res) {

  var request = {
    chaincodeId: 'agri',
    fcn: 'addFarmer',
    args: [

      req.body.farmer_ID,
      req.body.username,
      req.body.password

    ]
  };
console.log(req.body);
  let response = await invoke.invokeCreate(request);
  if (response) {
    if(response.status == 200)
    res.status(response.status).send({ message: "The Expert with ID: "+req.body.farmer_ID+ " is
    else
    res.status(response.status).send({ message: response.message});
  }
});
```

Figure 2.29: API endpoint of Network

The Hyperledger Fabric network can be run on multiple peers by deploying both peers on different peers to ensure data integrity etc.

2.3 Testing

2.3.1 Testing for the Prediction of Nutrient deficiency

In Nutrient deficiency detection, here the researcher has tested some random images from the testing directory. If we input the image, it will give the output as which class that plant image belongs to. By increasing the number of datasets, we are able to increase the accurate rate of prediction in future. Below figures show the test outputs of sample prediction:

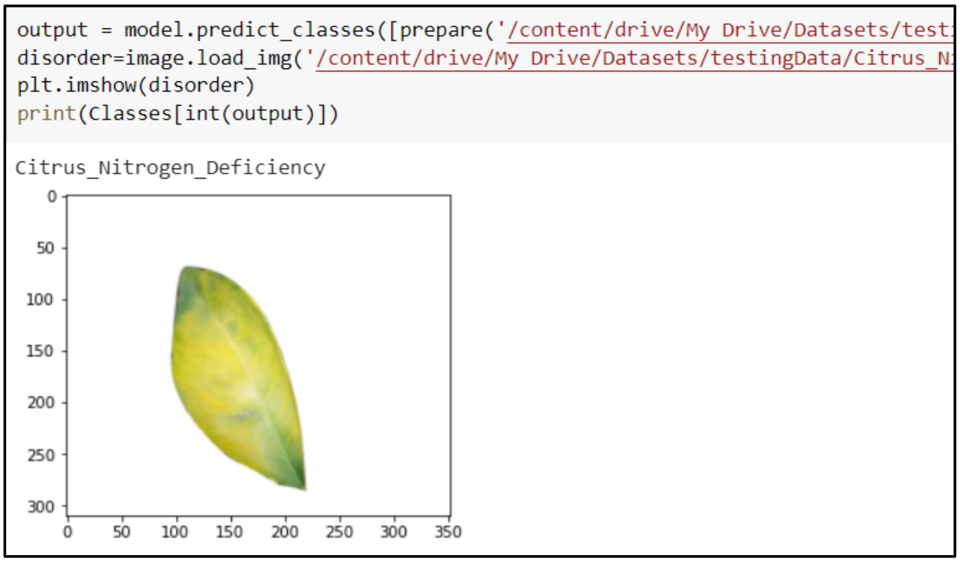


Figure 2.30: Testing a Citrus healthy image from the testing directory

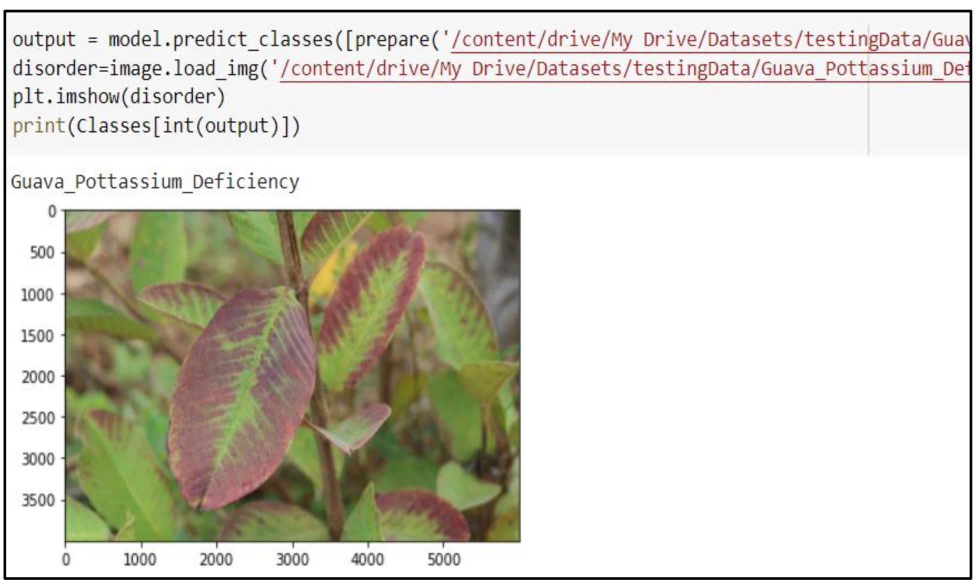


Figure 2.31: Testing a Guava Potassium deficiency image from the testing directory

2.3.2 Testing for the Degree of Nutrient deficiency

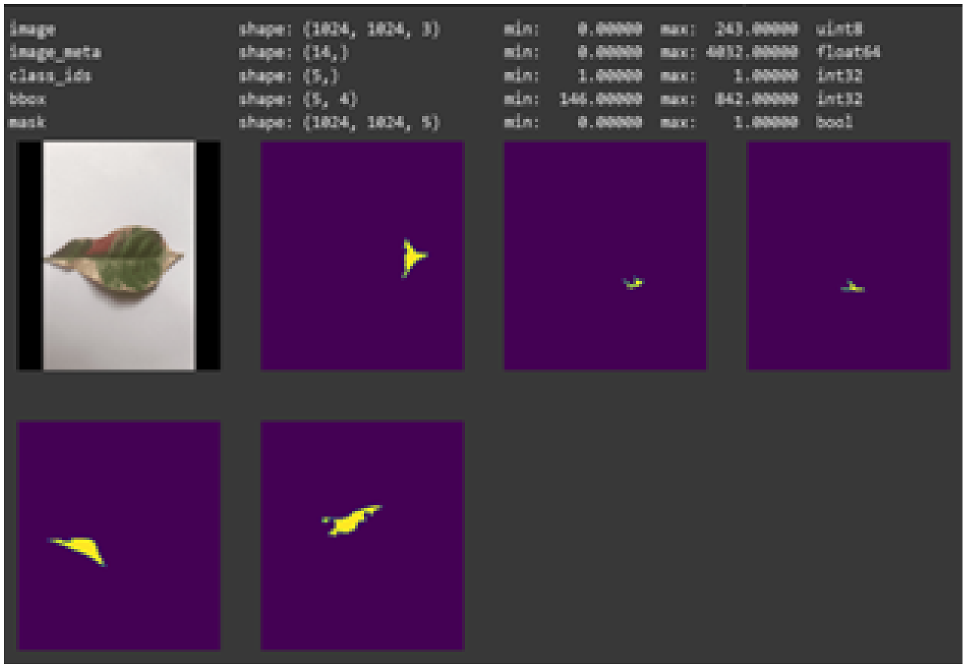


Figure 2.32: Masked Images of Leaf classified into 70% deficient class

In detecting the degree of the disorder, the output images were obtained with five areas of colour change masked as required. It is evident that the extent of disorder identification in plants can be carried out well using deep learning techniques. The masks work well on minor fragments and significantly large ones. One of the main concerns within this research component was whether minor colour variations would be identifiable in the leaf through a RCNN. The implementation shows that colour variation can be identified to a very satisfactory level in the leaf regardless of its visibility to the naked eye.

2.3.3 Testing for the Soil analysis using IoT

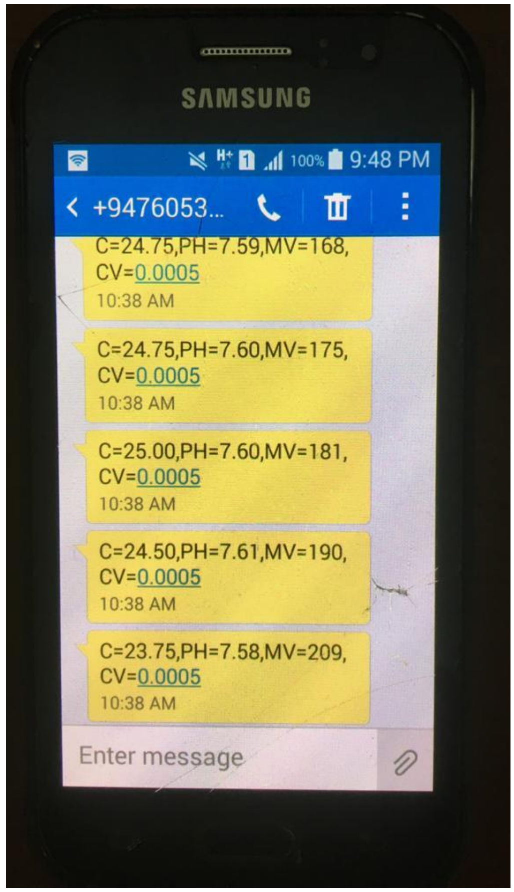


Figure 2.33: Mobile Message Notification

3. RESULTS & DISCUSSIONS

3.1 Results

3.1.1 Nutrient deficiency prediction results

By using the Augmented and preprocessed datasets, we have trained three CNN architecture models such as VGG16, ResNet50 and EfficientNetB0. As shown in the table 3.1, EfficientNetB0 has proved as effective technology with the 88.37% confidence level among those three models. According to the result, EfficientNetB0 was implemented for the nutrient deficiency prediction. Below figure shows the accuracy of prediction and confusion matrix.

Table 3.1: Comparison between Accuracy of CNN architectures

Model	Accuracy
EfficientB0	0.88
VGG-16	0.43
Resnet50	0.56

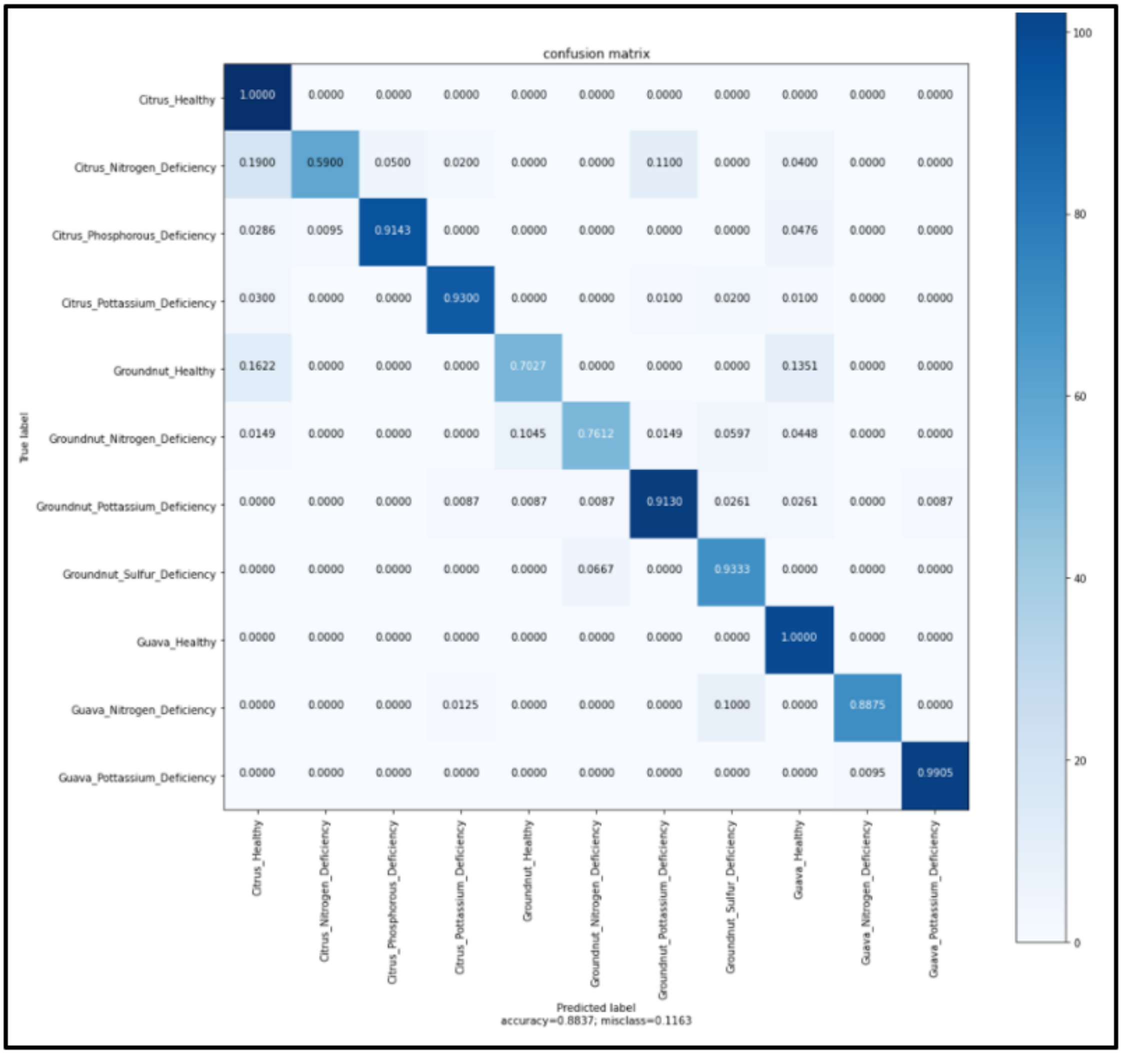


Figure 3.1: Overall accuracy using the EfficientNetBO

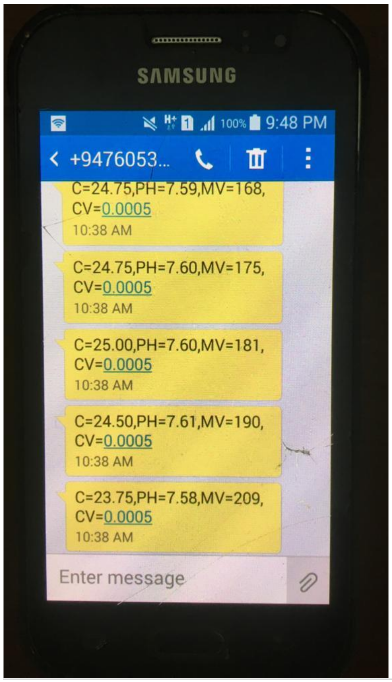
3.1.2 Soil analysis using IoT results

The sms will display pH, EC, Temperature & humidity levels of soil. All data goes to cloud to process the data from sensors in order to obtain N,P,K levels of soil. Processed data goes to subsystems to obtain other outcomes from the system. The results are given below.

```
Algorithm : LinearRegression for p
Train Data Count :  39
Test Data Count :  10
Accuracy : 0.8261193368642654
```

```
Algorithm : LinearRegression for n
Train Data Count :  39
Test Data Count :  10
Accuracy : 0.9778384757201466
```

```
Algorithm : LinearRegression for k
Train Data Count :  39
Test Data Count :  10
Accuracy : 0.9754462177731609
```



3.1.3 Secure and distributed platform – Blockchain

The results and outcomes of the blockchain solution have a societal impact as it would address a major issue faced by impoverished and ill-educated segments of the society.

The key impact of the blockchain network created was the lifting of a trust-driven and centralized nature in information management of fertilizer procurement. When such systems are trust-driven and reliant on human factors for the efficiency and reliability of the information retained, there is a conflict of interest with the most productive outcome.

By implementing a distributed and ledger-based blockchain network for the management of information shared amongst the stakeholders, a trust-free and decentralized platform where the source of information is accountable to all the stakeholders of the network is created. This would result in more efficient, auditable and reliable sharing of information.

Furthermore, a blockchain implementation for fertilizer procurement can enhance the penetration of Rural Advisory Services to impoverished farming communities and would initiate an ideal accessibility of information for rural communities.

3.2 Research Findings

The key issue identified when conducting the research was the lack of information with regards to sustainable and ‘smart’ farming communities in regions of the country away from major town centers. It is noteworthy that, during field visits conducted to agricultural research institutes, a lack of ready-made and accessible information was a major issue faced by the entire agriculture community in Sri Lanka. While researchers have the tools and the means to conduct efficient and meaningful research with regards to issues in crops and crop management, they lack an efficient mechanism to distribute this information.

Furthermore, while modern implementations are being adapted into the pipeline of agricultural research and development, most of the data and techniques used resonate a ‘generation gap’ as they have not been upgraded to the more modern approaches. As such, while information is available, it cannot be anticipated that any outcome would be as efficient as ones of an ICT based approach. Conclusively, while the governing and regulation bodies of Sri Lanka endorse a policy of ‘smart farming’ based on e-agriculture, such an approach is far-off from being integrated into the average farming and agriculture ecosystem. Any such mechanism is prevalent only in controlled field conditions.

Most farmers are not keen on adapting a technologically driven solution and continue to rely on heuristic approaches. Nutrient Deficiencies are identified mainly by a general observation of prevalent symptoms which often could be similar in the case of numerous deficiencies. As such, the administration of the wrong fertilizer could create a surplus of certain nutrients and concurrently a deficit of others. This leads to instability of soil conditions and is the major contributor to soil degradation in Sri Lankan cultivatable land.

3.3 Discussion

The requirement for sustainable agriculture practices, utilizing natural and artificial means of maintaining soil nutrition [9] is only evident. Initially, economically infeasible approaches [5] [7] were made, which are mostly exorbitant for the farming communities in developing regions such as Sub-Saharan Africa [6] and Sri Lanka [15]. This has also made such communities dependant on a ‘middle-man’ to cater for fertilizing needs which creates a bias and autocracy in such proceedings, eventually leading to these ‘middle-men’ capturing a margin of profit [4] due to the bias in the availability of information. Therefore, with the advancement of technology, agronomically-oriented technological research emerged as a contender for enhancing soil management practices and fertilization efficiency via effective interactions and communication [14]. The solution that has been structured utilizes technology to mitigate these identified issues and empower sustainable agricultural practices

Farmers face many difficulties in identifying the correct nutrient deficiencies and its degree based on symptoms via direct observation and existing experimental approaches are costly [6]. Farmers heuristically use fertilizers without knowing the disorder and its degree [7]. Administration of the incorrect fertilizer based on an erroneous judgement of deficiency could have detrimental effects [13]. This is where deep learning has been utilized to play a critical role. For the purposes of this research, Convolutional Neural Network (CNN) and Mask RCNN are used for the detection of the exact disorder and its degree with less cost through the hidden layers. Moreover, the current work done is to predominantly study the applicable technologies in identifying the disorders rather than utilizing an existing technique to identify the degree of the disorder and provide a practical solution. And mostly, past researchers have employed colour analysis to identify the nutrient disorder [5]. Here we have enhanced the approach to use edge detection, colour analysis and texture analysis which can be done automatically through CNN. Overall, with this amalgamation of techniques, a predicted result of higher accuracy can be obtained. Furthermore, due to the ongoing pandemic situation it has been challenging for us to collect enough datasets for training and testing purposes which has affected the accuracy of the model constructed. It is our ambition to enhance the accuracy of the model by utilizing extensive datasets to further increase the feasibility of the model.

In Sri Lanka, most farmers remain illiterate and impoverished. They operate in isolation, with little or no bargaining capacity and lack insight into high-quality agricultural practices that could improve their productivity, mostly depending on heuristic approaches [16]. A gap exists between the recommended dose and actual use of fertilizer. This is attributed to farmers most often being manipulated by vendors to use low-quality or inadequate fertilizer products at uneven prices [4]. M. Rivera et. al. [21] emphasizes how existing agriculture-driven information systems are institution-based and lack universal availability. Given this context, a solution has been proposed utilizing a permissioned and private blockchain platform (Hyperledger Fabric). The permissioned nature of the system disables the bias toward vendors as relevant information could be shared privately between farmers and experts involved. Such a universally available system interlinking key stakeholders in fertilizer procurement in a fair manner would enable better decision-making capabilities amongst farming communities.

4. STUDENT CONTRIBUTION

4.1 IT17110808 – Sukanya Manoharan

Implemented the Nutrient deficiency prediction component in the backend and frontend implemented for the mobile application using flutter.

4.2 IT15070418 – Kavindu Tharuka Ramasinghe

Implemented the IOT device for the soil analysis.

Implement a machine learning algorithm to predict the NPK level of soil.

4.3 IT17354516 - B. I. Sariffodeen

Implemented a Hyperledger Fabric based permissioned Blockchain Network as the platform for streamlined and decentralized fertilizer procurement.

5. CONCLUSION

This project managed to build a system where commercial fertilizer recommendations could be made, based on accurate identification of nutrient disorders. The deficient nutrient and level of deficiency were detected using a Machine Learning based approach, while streamlining the process of procurement was done using a Private and Permissioned Blockchain.

As future work, we recommend developing an IoT device to measure key nutrient values of soil with the help of sensor readings and machine learning algorithms. Also, since the limited access to datasets has influenced the accuracy of the model, we aspire to obtain extensive datasets to increase accuracy and enhance overall functionality of the system proposed.

The significance of this project is the potential it possesses to lift the bias toward vendors generated by information asymmetry evident in the agriculture industry. Accurate and reliable information is made accessible to farmers by this system and this information could be employed for overall better decision making.

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