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Detecting Crop Health using Machine Learning Techniques in Smart Agriculture System

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The crop diseases can't detected accurately by only analysing separate disease basis. Only with the help of making comprehensive analysis framework, users can get the predictions of most expected diseases. In this research, IOT and machine learning based technique capable of processing acquisition, analysis and detection of crop health information in the same platform is introduced. The proposed system supports distinguished services by monitoring crop and also managed its data, devices and models. This system also supports data sharing and communication with the help of IOT using unmanned aerial vehicle (UAV) and maintains high communication standards even in bad communication environment. Therefore, IOT and machine learning ensures the high accuracy of disease prediction in crop. The proposed integrated system is capable of detecting health of crop through analysis of multi-spectral images captured through the IOT associated UAV. The various machine learning is also applied to test the performance of our system and compared with the existing disease detection methods.

Keywords: Feature extraction, Image segmentation, Internet of things, Unmanned aerial vehicles

Introduction

The rapidly-increasing population of world has enlarged crop importunity for the survival of human on earth. The big challenge on us using limited resources is to fulfil food requirements according to the demand.[1] Various existing techniques are being used in agriculture field to increase the production to get through this challenge. The remote sensing technique through IOT sensors helps us to monitor states of crops at different levels. The IOT sensors are used for storing and processing of large information associated with the crop health. Various things are associated with plant disease like temperature, water level etc. Smart sensing[2,3] in agriculture gives the capability of farmer to analyse what is good for healthy crop, things are required where, in what amount and which duration of a time.[4] This wants gathering mammoth facts from various origins and from various plant fields such as nutrients in soil, existence of weeds and pests, weather conditions and percentage of chlorophyll in plants. The analysis of collected information produces some relevant recommendations to the farmer.[5] The monitoring in growth stage of plants to check for level of chlorophyll tells the amount of nutrients required. The combination of this information with soil characteristic along with the weather conditions where the plant situated. All these information are further required for the calculation of fertilizer dose required for plant in next coming days. The real-time delivery of information to farmers and ensuring that they follow these recommendations lead to increase the yields.[6]

The main component of smart sensing is WSN. The WSN is a collection of numerous nodes joined to monitor different metrics of good environment. The wireless nodes consist of sensors, micro-controller, transceiver and antenna. They communicate with the gateways for information transmission collected by smart sensors.[7] These sensors quantify different metrics and send metrics to controller, which again sends this metrics to portable device. Crop field has various requirements such as crop nature, water, weather conditions, and soil statistics. Crops have various stipulations such as distinct crops in same field and same crops in distinct fields.[8] The primary job of sensors is to monitor changing behaviour of parameters associated with the production of crops.

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Due to mammoth growth in WSN, the cost and size of sensors have significantly reduced. Due to this reason sensors have used in agriculture also.[9] The sensors which are helpful in agriculture field that monitor environmental metrics are given in Table 1.

The structure of WSN consists of different wireless nodes connected with sensors. Nodes in sensors are small in size are used for collecting information.[10] The nodes are of two types: one for collecting information called source and second for collecting information received from source node is called sink.[11] The computational strength of sink must be greater than source. The choosing of suitable wireless node is very difficult due to various constraints such as energy, power, memory, data rate, size and price.[12] All the wireless devices used so far, MICA2 is the most suitable device because it has so many expansion connectors to connect more sensors in the system.

Regardless of major advancements in IOT field, smart sensing in agriculture is limited to adopt only in developed countries. Due to shortage of equipment, smart sensing based methods to detect health of crop are uncommon in less undeveloped countries. Many countries having variations in climate and big arable lands enable them to plough various types of crops. Despite of availability of all these resources, they are unable to generate massive yields. They used traditional farming techniques for monitoring health of crop and yields prediction. The methods are purely based on farmer's experience and sense. Farmers regularly visit field to monitor crop, which is challenging and difficult in large land. The area is not measured accurately under healthy and unhealthy crop, which makes over shower of pesticide and insecticide, affects the diet of crops.

Keeping all above point in mind, our main goal is to give research and industry communities regarding communication sensors, devices and platforms used to analyse and monitor different sources of information in agriculture and environment implementations. The primary contribution of this work is to generate technology for smart sensing managed by IOT-based design to detect health of crop. The main objectives of this work are as follows:

(1) We proposed a new model for detection of healthy or unhealthy crop.

(2) Our model is the combination of IOT, UAV and machine learning which is able to monitor health of the crop.

(3) Our model is evaluated with the help of various machine learning techniques such as decision trees, linear regression, k-nearest neighbour, support vector machine, random forest and neural networks.

(4) The performance of our model is evaluated by the metrics like recall, precision and f-measure.

(5) The potential of our model has checked in multi-spectral images captured through the IOT associated UAV.

Table 1 — Agriculture field sensors

Sensors Name	Metrics Capture
ECH2O sensor for soil moisture	Temperature and moisture for soil, Conductivity
Field scout CM1000TM	Photosynthesis
Sensor for leaf wetness, LW100	Moisture, Temperature and Wetness for plant
MSO	Humidity, pressure and temperature of air, wind speed
TPS-2	CO_2, Moisture of plant

Related Works

Lots of applications with the help of Wireless Sensors Network (WSN) have been introduced since preceding decade to watch crop's health. Rad *et al.* introduced a cyber-physical based monitoring system for potato crop.[13] These types of system consist of hardware, software and some physical equipment combined to monitor changing states of world. The introduced system comprise of 3 layers. All the sensory data has been collected in first layer called physical layer. The data is sending to the cloud using second layer called network layer. The observed data is processed and analysed to take decisions are called decision layer.[14]

There are various challenges for researchers in IOT based models due to rapid growth in attached devices. Every node in the IOT network sends data to distant cloud, makes congestion in traffic, and major challenges in IOT network in IOT-based model are quiescence with less power demand, maximum utility from bandwidth and sporadic internet connectivity.[15] To overcome these problems, edge and fog computing helps us to reduce the computational load of cloud. Fog computing is used to preserve bandwidth and energy to maximize the standard of services for users. Baccarelli *et al.* proposed six layered energy-efficient structure of Fog of Everything.[16] The things processed under numerous spatially-distributed clusters called first layer. The second layer assist wireless channel for Communication using 'Fog to Thing' and 'Thing to Fog'. The interconnected fog nodes act as virtualised cluster in third layer. The fourth layer is used to connect between fog nodes using inter-fog backbone.[17] The fifth layer is used to provide every connected thing capability to enlarge its limited resources is called virtualization layer. The facility of virtual inter-clone system that allowed Peer to Peer communication is in last layer.[18]

Further, author presented a protocol stack for FOE tested by using V-FOE protocol and iFogsim toolkit simulation. The results were good enough to show the effectiveness, energy efficient, minimize delay and failure rate in proposed system.

The main consideration is kept while building any fog structure is energy efficiency. Naranjo *et al*. introduced a fog-supported wireless network based on energy-efficient protocol.[19] The author is also able to increase the life of network by equally spreading energy between nodes. The potential of introduced algorithm was compared the existing methods in MATLAB. The outcome analysis proved that proposed method was very efficient in energy with increase in life of network.[20]

Different communication protocol has been used in recent years due to lightning increase in the WSN and IOT devices. The specifications of each protocol depend on quantity of unoccupied channels,

bandwidth, data charge, price, battery life, and additional components.[21] The most popular used protocol in wireless network using IOT technology in agriculture is as follows:

Cellular

This technology is appropriate where application which requires higher data rate. It makes use of 3G, 4G and GSM communication capabilities giving high speed internet with high power consumptions.[22] It requires framework to be fixed and some cost of operation and backend staff for it and centralized authority system. It requires more battery backup, however it is good option in below ground wireless network, such as in agriculture applications and smart homes. Khelifa *et al*. introduced smart irrigation framework with various sensors for detecting soil moisture in ZigBee network.[23] The details collected from the field were sending to the cloud using 4G LTE cellular network.

ZigBee

This is a wireless protocol for communication popularly used in smart sensing in agriculture to look after healthier environmental conditions for crop.[24] It maintains the 802.15.4 wireless standard. It was created by ZigBee alliance for Personal Area Networks (PAN). It has more battery life, flexible network architecture, supports almost all topologies, with multi-hop transmission.[25] It can support large node and can be easily installed. It has less range, less data speed, less secure compare to wifi systems. It is popularly used in smart irrigation and smart greenhouses.[26] Chikankar *et al*. introduced a smart irrigation model based on ZigBee protocol. The model comprise of two types of nodes: actuator node and sensor node.[27] The sensor node is used to monitor soil's water level. The actuator node is used to take decisions according to soil's water level. ZigBee protocol is responsible for all communication.

BLE

It is renowned Bluetooth based smart technology, appropriate for agriculture and IOT. It is specially originate for short bandwidth, short range, and less latency in IOT.[28] The primary advantage of BLE on top of Bluetooth includes lesser time for setup, unlimited support and lesser power consumption for star topology nodes. It has substantially small range of 10 metres.[29] However, it can particularly able to give transmission among two physical devices, low security and mostly losses connections. Tanaka *et al*. introduced BLE based framework to collect the information from sensor.[30] The author has also used smart phone to collect the sensor's information with the help of BLE, where sensors are incorporated with plants.

RFID

RFID comprise of a transponder and a reader called RF tag. It has very less radio frequency. The RF tag is electronically programmed with different information that has reading properties.[31] Further, tag system is also categorised into active reader and passive reader tag. Passive reader tag is less powered while active reader tag requires more battery and high frequencies. The applications of IOT with RFID are healthcare, smart shopping, smart agriculture, and national security. Wasson *et al*. proposed an IOT based irrigation system using RFID.[32] The system comprise of sensors for soil temperature and soil moisture including water controlling device.[33] The readings were collected sent to the cloud with the help of RFID protocols.

Wi-Fi

It is very demanding protocol used for communication through wireless signal. It provides wireless LAN to connect different locations like offices, homes, and public places such as cafes, airports, hotels with high-rise speed. It supports IEEE 802.11n, 802.11g, 802.11b, 802.11a, 802.11. It is also generally applied in IoT-based systems including agriculture applications, i.e., greenhouse, crop health detection and smart irrigation. Liang *et al*. introduced a system to detect environmental variables in greenhouse like soil moisture, light intensity and temperature.[34] The sensors collected all information and then send it to cloud using wifi protocol. Usha *et al*. proposed another WiFi based system to detect the various parameters associated with environment.[35] The sensors collected data then data is send to cloud using wifi protocol.

Proposed Methodology

We have proposed a system for monitoring crop health using remote sensing and IOT. In the introduced system, health of crop is monitored using the collection of data from various IOT sensors. The design of proposed model is given in Fig. 1. Each sensor in the given wireless sensors network[36] is used to check the water level in the field. Every node is employed in the network in the star topology pattern. The master node collected all reading from other nodes and sends it to the server for processing further. The gateway node in the design acts as a primary node, which collects all data from secondary nodes using NRF protocol. After performing some processing, primary sends data to cloud with the help of GSM. The collected Multi-spectral image (MI) is converted into RGB using color matching function.[37] Our proposed method has five steps (see Fig. 2).

Step-1

Image acquisition using UAV based platforms, which is alternated method for airborne and satellite. This platform is also very cost effective and flexible. A UAV platform comprise of a navigation and communication system having various mounted sensors on it. There are two options in it either multirotor or fixed-wing. Fixed-wind having high fly time with respect to multirotor. We used fixed-wing in our experiment. It is very useful in agriculture field to monitor health of crops remotely. The multi-spectral images acquired by this type of devices are high in resolution, therefore, it is very difficult to extract more important information in contrast to satellite images. (see Fig. 3).

Step-2

Firstly, multi-spectral image is converted into RGB using colour matching function. To remove the noises in the RGB images, we use Gaussian smoothing. This is very popular method to reduce the noise in the RGB images. It is also very popular in computer

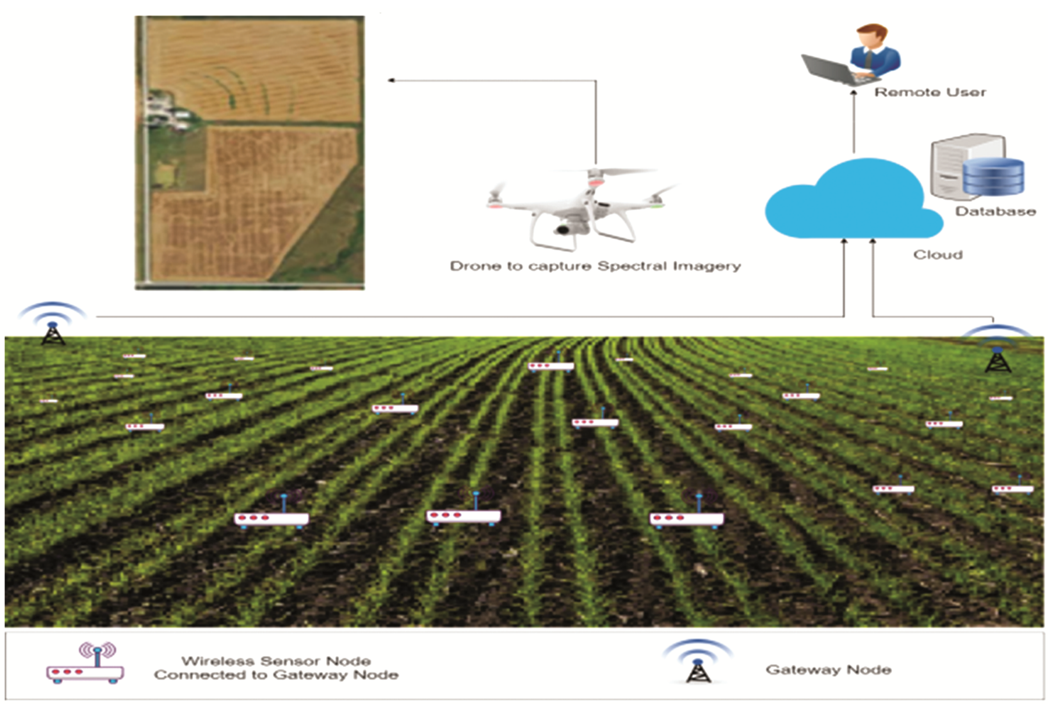

Fig. 1 — System Design

vision for the pre-processing of images for enhancement of images in different scales. The formula is given by:

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \quad \ldots (1)$$

Step-3

The RGB image after removal of noise is divided into multiple segments. The objective of segmentation in this step is to change and simplify the description of an image into thing which is easier and meaningful to analyse. It is used to locate boundaries objects in RGB images. It is method of allocating a class to each pixel of an image such that pixels from similar class share common properties. We used K-means clustering for the purpose of segmentation in our proposed system. It is an iterative method which is used to divide an image by *K* clusters. The algorithm is:

1. Choose centres of *K* cluster.
2. Allocate each image pixel to cluster having smallest length from the centre.
3. Re-evaluate centres of cluster by taking mean of all cluster pixels.

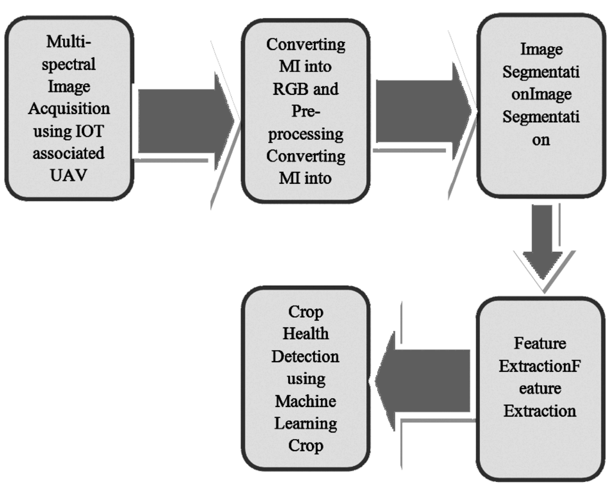

Fig. 2 — Block diagram of proposed methodology

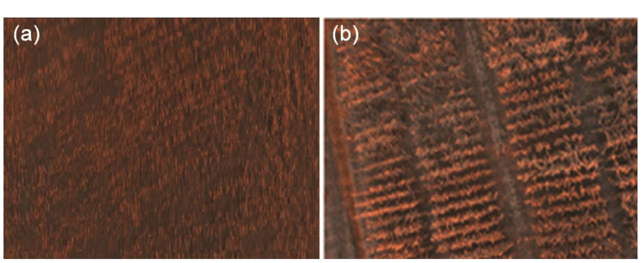

Fig. 3 — Spectral image of (a) Wheat Crop (b) Maize Crop

4. Redo steps 2 and 3 until no change in pixels of clusters.

Step-4

The most important step in our proposed model is feature extraction step. This step is responsible for the accuracy of machine learning methods. The principal component analysis (PCA) has been used for feature extraction. From the definition of PCA, we explain it into four steps:

1. Identify relationship between features using Covariance Matrix.
2. With the help of linear transformation of Covariance Matrix, we obtained eigen values and eigen vectors.
3. Transformation of our data into principal components using eigen vectors.
4. Lastly, we evaluate the significance of relationships using eigen vectors and kept the extracted principal components.

Step-5

After feature extraction step, detection of healthy crop using machine learning takes place. In this step, all the images coming from step 4 have to be partitioned into train and test set. We have follow n-cross validation rule. In this rule, all images have been partitioned into n sets. From n sets, n-1 sets are used to train the model and 1 set is used to test the model. The final result is the mean of all results.

Experiments and Results

The DJI-Phantom drone using Sentera spectral sensor is used to acquire mutli-spectral image (see Fig. 1). The drone contains its own camera to capture optical image, but spectral camera is built on drone to get spectral images. Different drone flights were performing to capture growing crop stages. We were focus only on grain filling and grain ripening stages. The collected information is transferred to the cloud for further processing. The optical image of harvesting stage of wheat was taken on 16 june 2020 (see Fig. 4(a)), while its corresponding multi-spectral

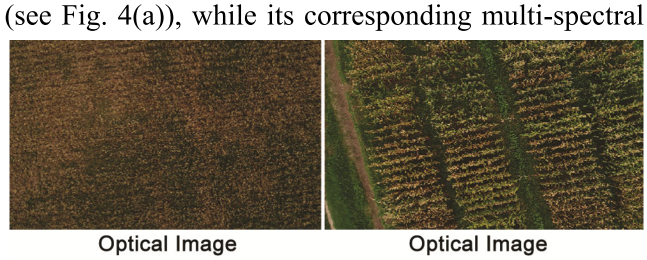

Fig. 4 — Optical image of (a) Wheat Crop (b) Maize Crop

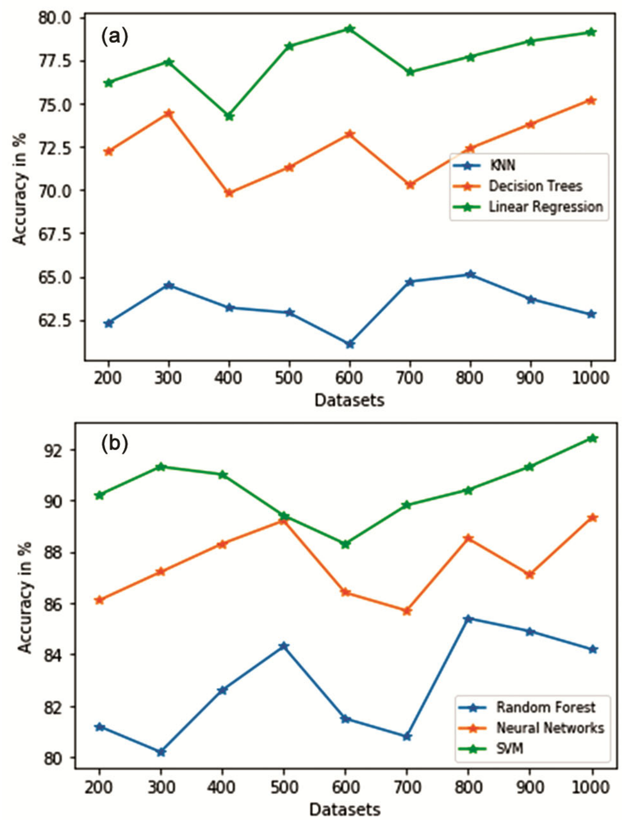

Fig. 5 — Comparison of machine learning methods: (a) KNN, Decision Tree, Linear Regression; (b) Random Forest, Neural Networks, SVM

image in Fig. 3(a). Further, these images are converted into RGB using color matching function. Wheat was in mature stage, therefore, there should be no green crop in the field. The less green region indicates the healthy wheat crop.

The same method was also applied to take optical and spectral image of maize crop. The optical image of harvesting stage of maize was taken on 10 July 2020 and presented in Fig. 4(b), while its corresponding multi-spectral image is presented in Fig. 3(b). Further, these images are converted into RGB using color matching function. The same method was applied to the maize crop. Maize was in mature stage, therefore, there should be no green crop in the field. The less green region indicates the healthy maize crop.

We apply a color matching function (CMF), converts visible spectrum of hyper-spectral information to the ABC color space and from ABC to the RGB color space. The method is standard, fast, deterministic, and produce more realistic image. The realistic is defines as a human perception processing under daylight illumination. The technique requires only HSI and its corresponding wavelengths.

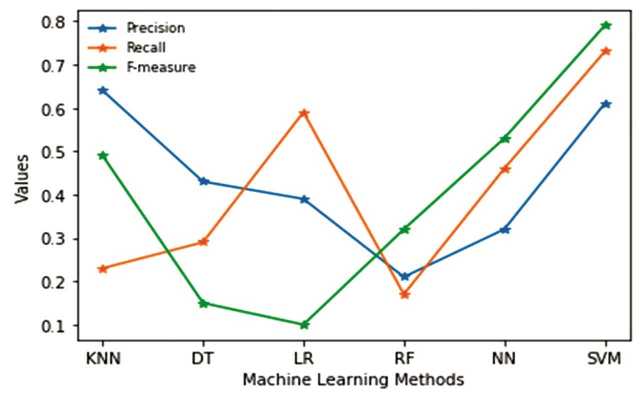

Fig. 6 — Comparison of Precision, Recall and F-measure for all machine learning methods

The proposed method is simulated in python 3.1.8 and runs in windows environment with configuration of I5 processor, 6 GB RAM. We perform a study to compare six machine learning methods such as decision trees, linear regression, k-nearest neighbour, support vector machine, random forest and neural networks in the above datasets using n-cross validation rule. This rule overcomes the problem of overfitting in the classification process of supervised learning.

The results showed the effectiveness of IOT and machine learning based detection of healthy crop. The support vector machine is best among all the machine learning methods in terms of accuracy in detection of crop health (see Fig. 5(a), 5(b)). Some more metrics are used to assess the performance of our proposed system (see Fig. 6). The reliability of our proposed method is checked with the dataset captured from the different sensors attached to the proposed system. However, accuracy of detecting healthy srop is still challenge for the researchers due to various requirements such as crop nature, weather conditions, soil statistics, and water are responsible for the healthy. The big challenges for researchers are to provide architecture, which is capable of fast data sharing, multiuser access and spectrum sharing. Also, able to preserve the global services of IOT like transparency and large data immutability is the important issue.

Conclusions and Future Works

The aim of this paper is to provide smart sensing in agriculture using IOT associated UAV and machine learning to detect the healthy crop in the field. We are also able to detect with good accuracy using various machine learning methods such as decision trees, linear regression, k-nearest neighbour, support vector machine, random forest and neural networks. It is also evaluated using several evaluation metrics like precision, recall and f-measure. Our objective is to provide support in smart sensing in agriculture platform to the research and industry communities on growth of present applications.

Since the main aim of the smart sensing in agriculture is to give excess yield by utilizing resources like fertilizers, pesticides, water, resources, prescription maps takes part a key role, which allows farmers to determine resources need for good health of crop at every growth stage. The majority of research and development in agriculture field is based on smart sensing to assemble image, which considers vegetation indices (VI) only like NDVI. The recommendation maps can't be easily generated by using only VIs; rather, various other metrics required to be examined like meteorological behaviour, soil properties, level of soil moisture etc.

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