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Smart Agricultural Decision Support Systems for Predicting Soil Nutrition Value Using IoT and Ridge Regression

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Abstract

Cost effective agricultural crop productivity is an everlasting demand, this predominant expedition has raised a global shift towards practicing smart agricultural methods to increase the productivity and the efficiency of the agricultural sector, using IoT. This research identified the benefits and the challenges in IoT adoption as an alternate for out-of-date agricultural practices. The proposed decision support system using IoT for Smart Soil Nutrition Prediction (SSNP) adopts IR sensors and implements diffuse reflectance infrared spectroscopy. Information is transferred using Arduino and Zigbee protocol. It has indicated precise outcomes in various studies giving a high repeatable, low cost and fast estimation of soil properties. The measure of light absorbed by a soil example is estimated, inside several particular wavebands over a scope of frequencies to yield an infrared range utilizing an IR sensor. Using the given values, the experimental analysis using the dataset and the nutrition values of the soil such as Ca, P, SOC, Sand and pH are predicted. This proposed IoT framework would enhance the farmer's knowledge regarding the type of crops they should grow to get maximum profit from their agricultural produce.

Keywords

Agriculture, Internet of Things (IoT), IoT in agriculture, IoT sensors, IR Sensor, Regression, Smart agriculture.

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Introduction

IoT, Data analytics and wireless systems support crop yield maximization that can automate day to day agricultural activities as well as offers real time monitoring and predictions for automated decision making.

Connected sensors possess various communication sensor connections, monitoring controls and so on to help farmers analyse their field and for a better operation. Using embedded wireless devices and other IOT systems can help measure moisture and nutrients in the soil and efficiently manage the energy usage. It is important to take note of such large scale solutions that are scalable for a better future in the agricultural industry. The benefits of including IoT in agriculture can be listed as follows.

1. **Community Farming:** IoT can be utilized so as to accommodate a common data storage where the farmers and agriculture specialists can connect and share information/data. Additionally through portable applications and the IoT facilities, the simplicity of communication can be expanded by means of free/paid services.
2. **Safety Control and Fraud Prevention:** As much as sufficient production is of concern, the safety and nutrition of the food supply is also important and needs to be noted.
3. **Wealth Creation and Distribution:** IoT deployment will produce new plans of action where the middle-men idea can be skipped and the farmers can be in direct relations with their clients prompting higher authentic benefits.
4. **Cost Reduction:** Since The capacity to realize when to apply pesticides with the assistance of IoT will diminish cost.
5. **Operational Efficiency:** Operational efficiency relates to farmers, government and non government agencies. The data collected using IoT can serve in making decisions on how one could prevent

the spread of diseases, avoid fire outbreaks, generate compensation schemes and allocate resources. With the help of data analytics, farmers can take timely decisions on farm processes and its management.

With our proposed solution, we aim to minimize losses and the cost of travel by providing farmers a clear understanding on the soil nutrition content using diffuse infrared spectroscopy. Using our smart solution combined with analytics, we aim to convey the farmer a clear idea on the values of Calcium, Phosphorus, Organic Content, pH and sand content present in the soil sample with the use of IR sensors.

Elijah et al. (2018) stated that the IoT ecosystem for agricultural domain contains four important components which are: the IoT devices, the technology used for communication, as well as Internet and data storage. Various applications could be viable such as monitoring, agriculture machinery, precision agriculture, tracking and tracing and greenhouse production. On studying further, the various issues found are to be under the broad categories of business, technical, and sectoral issues. The future trends they proposed on the basis of their study are: technological innovations, application scenarios and business and marketability.

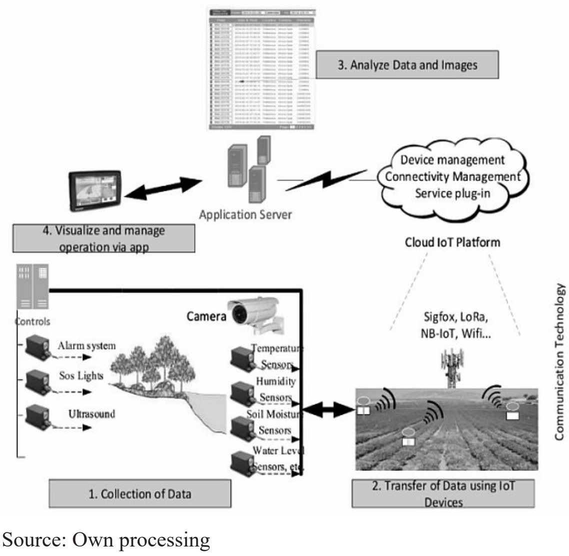

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Figure 1: Architecture of proposed SSNP model using data analytics and IOT.

They propose the usage of LPWA due to its low power consumption and long range communication. However, the infrastructure for LPWA is still being developed and it is not an open standard yet. For security, they use signcryption (data encryption + digital signature) to protect sensitive data. The disadvantage of signcryption is that it uses multiple machine cycles that increases the computational power usage. For communication, they use NB-IoT technologies to ensure the quality of service. However, NB-IoT offers low data rate and does not provide for voice transmission. Jat et al. (2019) mentioned certain considerations to be made while designing an IoT system: Hardware considerations, data acquisition, data processing and storage, connectivity, power source, physicality of the device, cost, security and software considerations. Various monitoring techniques can be used such as: detecting soil moisture, soil pH and nutrients, humidity, temperature, rain, sunshine and image monitoring to analyse the health of crops under various conditions. They then transfer the data using Zigbee or WiFi.

Using WiFi promotes mobility, productivity and deployment. However, certain disadvantages include comparatively weaker security, low range and speed. In case zigbee is used, the advantages would include flexible network structure, easy to implement along with long battery life and low power consumption. But there are major disadvantages considering the security and low transmission rates as compared to WiFi. Further after data storage and processing, the device can be automated and brought to use (Jat et al., 2019). Using a Raspberry Pi has its advantages such as low cost and easy to handle the light/ internal web traffic. But it cannot be used on X86 Operating systems.

Another method used by Salam and Shah (2019) is Precision farming. Through the utilization of different methodologies and technologies, alongside leveraging existing framework, by including progressed phenotyping and hereditary qualities, new strategies can be created so as to increase greatest yield and nourishment while preserving water assets. However, apart from lack of training, the other factors hindering the precision farming selection are: cost, quantifiable profit and absence of precision agribusiness big data analytics (Salam and Shah, 2019). The advancement of some test beds as well as stages are done so as to actualize any new precision horticulture advances for checking, planting, and reaping through farmer or the scholarly world commitment that will help in innovation. The information on different sorts of soil frameworks would significantly help in adding to the improvement of better underground sensing procedures. The major advantage of precision farming is that it enhances the agricultural produce by using water resources efficiently and also helps in preventing soil degradation. GPS trackers allow monitoring of fields and the method also reduces the effect of harmful environmental impact. However, the disadvantages include the cost and collection of data. Data collection and analysis is something that would take several years before one can implement this technique (Figure 2).

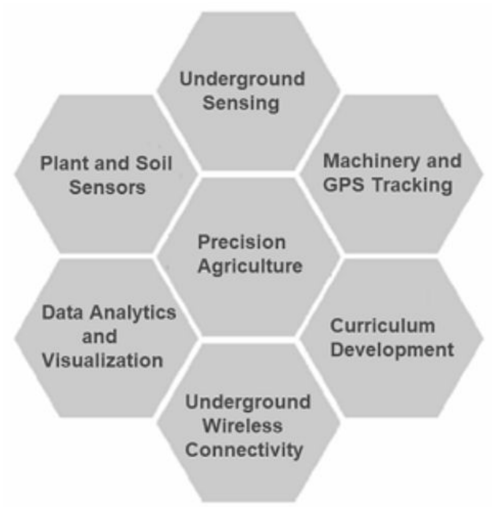

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Figure 2: Overview of precision agriculture.

The re-emerging recession worldwide, that has caused some flows along the developed as well as the developing economies (Lakhwani et al., 2019). The domain of agriculture needs to be not only competent but also irrepressible in order to ensure universal food security. Various applications have been stated such as sensor technology, RFID technology, Intelligent irrigation, radio transmission, precision seeding and spraying. The paper also states the various benefits in IOT that include: efficiency in input, cost reduction, profitability, sustainability, foot safety and environment protection.

The proposed model by Prathibha et al. (2017) suggests the below architecture that is portable, low power, battery-operated, secure and has a fast connection. They analyse environmental conditions variations that will affect the overall yield of the crop. Since plants require proper monitoring and support, they used sensors to keep a track on the conditions to ensure optimal growth. Sensors used include, temperature infrared thermopile sensor- TMP007 and humidity sensor- HDC1010. A camera is attached with a CC3200 camera booster pack via PCB using an MT9D111 camera sensor. It gives the data about the temperature, dampness in rural fields through a MMS to the farmer, on the off chance that it deviates off from the optimal range (Figure 3).

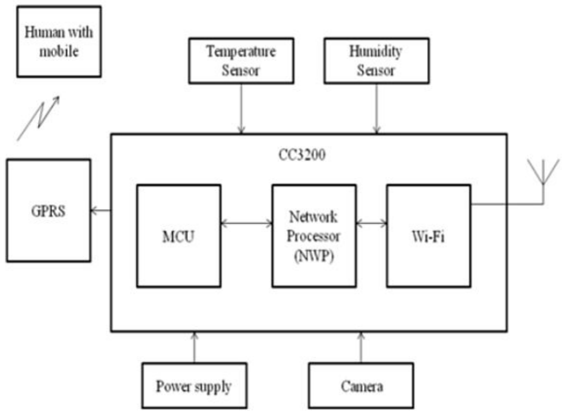

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Figure 3: Architecture diagram using Node MCU and sensors.

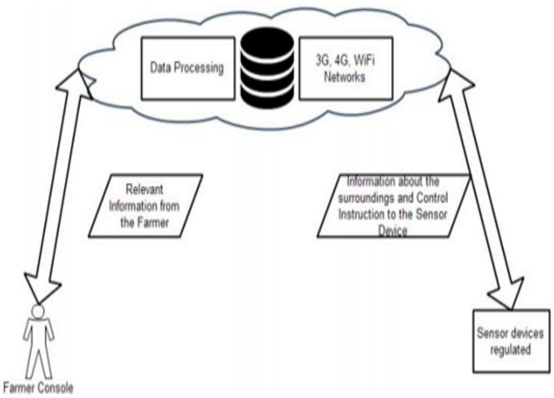
The above model uses Node MCU that may not be as powerful as Raspberry Pi but it is the best fit in the current problem statement since it's cheaper and one can exploit the inbuilt TCP/IP configuration along with the WiFi support without the explicit need to conduct heavy operations using multithreading.

Gayatri et al. (2015) have recommended another technique using various sensors and factors like principle of transduction, input parameter and the properties that it has to measure. Sensors such as DHT11 can predict both the temperature and humidity at the same instant. They make use of ZigBee sensor nodes to obtain natural parameters like temperature, humidity and illumination information which are transmitted to the remote monitoring centre.

The customizations that are carried out are non-localization of memory and the input data is directly transferred to the datacenter in the cloud for processing. The data centers help in processing the incoming data and then compare the values to the inbuilt threshold value. Then they further pass on this information to the farmer's console application.

Communication between the sensor nodes and the data centers is done by using CDMA, 3G and 2 G wireless broadband networks. 3G provides for efficient phone calls, emails or text but the performance significantly decreases when it comes to audio or video. Whereas 2G has a low rate of battery consumption and provides more data for an equivalent price.

Finally, in this method, water actuators will be made to water the plants immediately they sense that there is necessity for the plants to be watered (Figure 4).



Source: Gayatri et al. (2015)

Figure 4: Architecture diagram using sensors and 3G/2G networks.

Patil and Kale (2016) proposed a model for smart agriculture which can be used to develop a monitoring system which is real time for properties of soil like temperature, soil moisture, and soil pH as well as to implement some decision support advisory models for the pest and disease advance warning, Crop Disease identification using image analysis and SMS based alerts.

It comprises of sensing local agricultural parameters, identification of location of the sensor and data collection, transfer of data from crop fields for decision making, support, actuation and control based on the crop monitoring performed using the camera Module. The first layer (perception) consists of a Ubi-Sense mote which is a generic sensor board that has various sensors concerning Temperature and Relative Humidity, Light Intensity, Atmospheric Pressure and so on. Convenient wireless connection and fast access to equipment within a short-distance can be achieved using ZigBee technique that uses WINGZ (Wireless IP Network Gateway since Zigbee fits a small-size and a low-cost wireless network that lies between the WPAN and IP network. Zigbee is a flexible network structure that is easy to implement along with long battery life and low power consumption. But there are major disadvantages considering the security and low transmission rates as compared to WiFi. In the application layer, the framework can get and examine climate data from the web, remembering weather forecasts for the earlier days. The database then stores sensor data, streaming data, the geological data and various environmental reference values for notifying conditions into each database, and then creates an average statistical information by using the collected information. Thisis used to monitor crops and give alerts as and when required.

Zhao, Zhang, Feng and Li (2010) have proposed an "Agriculture greenhouse production environment measurement and control system" that uses IOT in agriculture. The basic temperature, dampness and soil signals are gathered constantly in the agriculture production process, which is sent utilizing wireless networks through the M2M (machine to machine) support stage. It is done in order to get some instantaneous information about the agricultural production environment by means of SMS, the World Wide Web, wireless application protocol (WAP) pattern, so that the terminal can use this information to guide the production. (Zhao et al., 2010) The WAP has various advantages such as real time communication of data, the multi platform functionality and the control of the appearance such as the layout and formatting for better user interface.

However, the disadvantages include cost, low speeds and low security provisions along with access to third party platforms. The estimation of these actual factors can be changed over into a low volt electric sign through a transmitter. This can be transmitted to the wireless communication terminal. The application interface shows customers information that include each greenhouse gas detection point, real-time data of air temperature and humidity, soil temperature, 24-hour, a week, or a month's curve and so on. Customers can set some alarm value, and this information can be conveyed to the manager's phone via SMS. This is done when the data is more than alarm value.

Mat et al. (2018) proposed a smart agriculture model using IOT, The Central Processing Unit (CPU) contains a microcontroller that interprets the input signals and executes control measures, in accordance with the programs stored in memory, and then further communicates the decisions they take as control signals to the output interface. The internal memory is used to perform the control measures and the programming tools are used to insert the required programs into memory.

Finally, GUI is a device that provides processed data onto the machine to the farmer and the farmers can control the equipment through GUI at the control centre. The most important part of the GUI is an alarm feature. Alarm is a digital state of NORMAL or ALARM. They tested this model on mushrooms and found that using their proposed model, the mushrooms and thicker and healthier with appropriate environmental conditions. Mat, et al. (2018) proposed an "A precision agriculture management system based on the Internet of Things and WebGIS that uses 3S, Internet of Things, network and communication techniques as its system support, to collect the data from various sources (Figure 5).

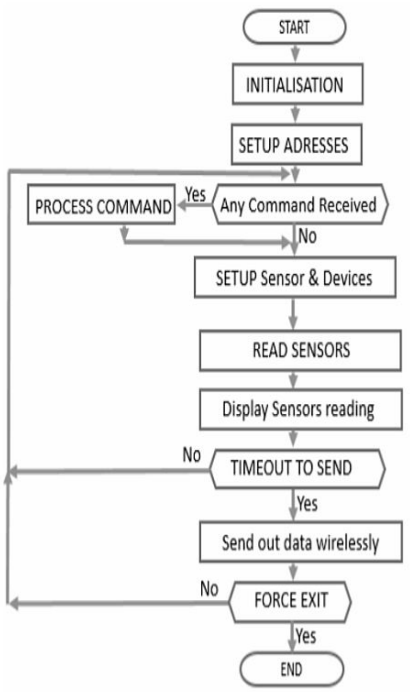


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Figure 5: Overview of proposed SSNP model process flow diagram.

It uses both IOT and WebGIS. WebGIS is easy to implement, flexible and has a low cost barrier. It supports real time spatial analysis and connects to multiple structured sources of data. The system firstly receives data in real time using RFID, sensor and a 2D code technique; then secondly it transfers data accurately in real time with the combination of tele- communications network and Internet; then finally it does smart processing that analyzes and processes the mass data and information to smart control things by using smart computing techniques such as cloud computing, fuzzy recognition. The staff uses the mobile client PAMS in order to post real-time data of the daily work done and other important updates on the growth of the plants. Then PAMS analyzes the data and gives suggestions to the staff about what to do at the next stage. This model has helped the farm monitor reduce a lot of time monitoring the staff worker and the plant growing information. Furthermore, due to the right planting methods, the plants grew better than before (Mat et al., 2018) (Figure 6).

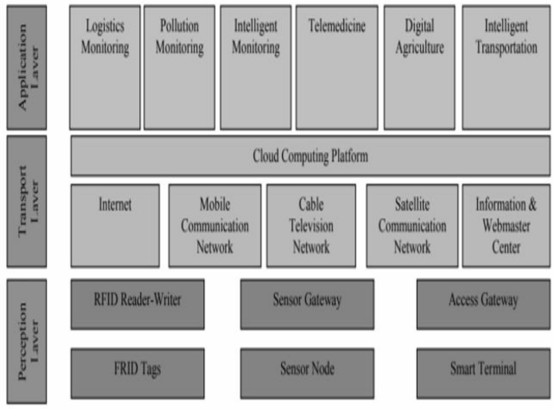

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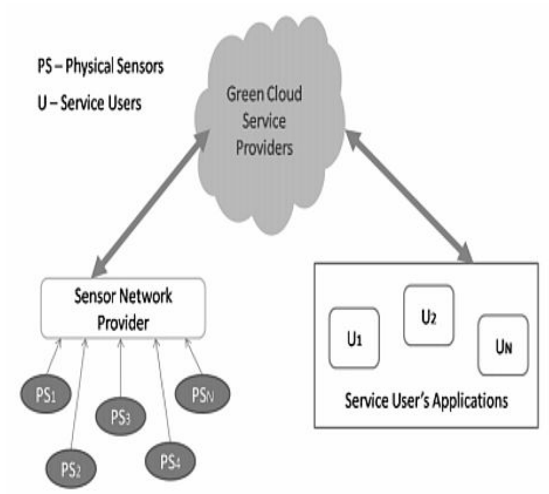
Figure 6. Architecture diagram of proposed model of PAMS using cloud computing.

Nandyala and Kim (2016) discussed the various technologies using green cloud computing and IoT. It also talks about the reduction in the consumption of energy when using Cloud Computing and IoT combination in agriculture .Additionally, this paper also presents a Green IoT Agriculture and Healthcare Application (GAHA) using a sensor-cloud integration model.

Sensor-cloud computing is considered to be one of the upcoming technologies to be used to effectively monitor agriculture. Sensor-Cloud is a new way for Cloud Computing which uses the sensors to gather data and communicate this gathered sensor data to a cloud infrastructure for analysis and effective handling of the collected data.

Sensor Cloud plays a vital role in provisioning the Sensors as a service platform while also satisfying multiple requirements. This service is provided by using virtual sensors in a cloud platform. It is also highly cost-effective as it does not require a lot of maintenance (Figure 7).



Source: Nandyala and Kim (2016)

Figure 7: GAHA Architecture.

Jaiganesh et al. (2017) outlined the uses of the Internet of Things combined with Cloud Computing in agriculture. It talks about using various kinds of sensors in order to track soil as well as the effective enabling technologies of IOT that can be used in order to optimize the farming process in order to get a better crop yield and help farmers.

Jain and Kumar (2020) used remote sensor properties to monitor the home conditions to decrease the overall costs of the agricultural process as well as to invigorate the productivity of growth normally. The proposed system suggests that the agriculture process is monitored by means of remote sensors. Precision Agriculture is clear on the boundaries of the product, geographically speaking. It makes use of a Wireless Sensor Network that needs an integrated unit of control. This WSN architecture is proposed because these sensors work very well considering the complexities of the unit controls. The sensors to be used for this collection of information must be functional, no lagging and legacy. Authentication will also be used to check credibility. There is a center area in these WSN which can include almost thousands of centers connected by means of sensors.

Centers constructed factoring in various constraints. These WSN can exhibit a simple star system and can be transformed to an advanced remote programming system.

Badhe et al. (2018) proposed systems of IOT use ZigBEE, GPS or GSM to transmit the information collected by means of soil monitoring. This method however, has been proven to not be very reliable and so a new method. This proposed method aims to conquer the problem of meandering by means of a sensor based application that is remote and checks the soil. This is to be used to measure the vital parameters of soil like temperature, moisture as well as light sensors. Information collected via these sensors is communicated to a Thing Speak Application which makes use of the popular WiFi protocol. An MCP3204 Analog to Digital converter is used so that the raspberry pi can be an interface.

In this proposed system, each sensor is to be connected to this MCP3204 unit separately. The information gathered is sent to the cloud application, where it will be processed using some tools. Based on the results of which we can make appropriate agricultural decisions which will have a positive effect on the crop yield. ThingSpeak is highly recommended for this process as it uses the HTTP and MQTT protocol to receive data from the sensors. Since this MQTT protocol is lightweight, it can be used with ease even in case of some problems. Raspberry Pi is used due to its low cost and ease of use, especially on a Linux server. It also allows for multiple sensors to be connected to it simultaneously (Figure 8).

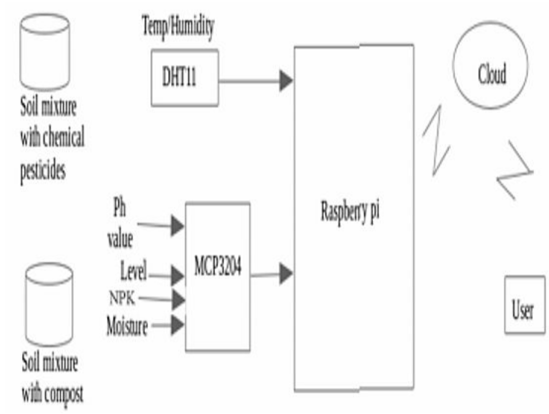


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Figure 8: Smart Soil Nutrition Prediction Model.

Surai et al. (2018) used sensor networking based on multi nodes connectivity while involving good communication with the end users. This way IOT helps with implementing the networking between two objects that are physically present.

This proposed SSNP - Smart Soil Nutrition Prediction system would initially collect information about the soil. The information collected such as moisture, decision, etc. must be communicated to the end user by means of a wireless connection, so that remote users can also participate. These types of sensor networks consist of multiple nodes.

Each of these individual nodes will sense the outside environment as well as perform computation and collect data. Also, Sensor networks must also be deployed in a scattered manner in this region. By means of these wireless sensor networks, one can incorporate global warming into the soil monitoring process. Based on decisions made, the farmers can take the appropriate measures to ensure a good harvest.

Balan and Tech (2017) described sensors on a board to reduce the decoupling effect and relay being a part of the aforementioned board while also integrating noise (Balan and Tech, 2017). This type of system is to be produced due to a heavy load consumption. Proposed system is an AVR based sensor node that is wireless.

It has the highlights of ceaseless checking of certain boundaries that are indicated, has a simple deployment procedure and increments the lifetime of the batteries utilized. The IOT used for this proposed system is established using an ESP8266 module which helps in data transmission from remote location in the farm to the user. Sensor node contains various kinds of sensors which help to monitor the values of the soil moisture content. Power of downpour, current consumed by the engine by which dry run conditions and over stacked state of the engine can be determined. It also provides accurate details about the consumption of motors. Since most farms are away from technology, it is difficult to calculate any motor fluctuations which can cause motor damage. The AVR controller is used due to its low power consumption as compared to any other microcontroller.

Suma et al. (2017) proposed system the use of many features like GPS based monitoring that is controlled remotely, sensing of temperature, sensing of moisture, scaring of intruders, security, leaf moisture as well as proper irrigation facilities. It makes use of a WSN for collecting important/relevant data about the key properties of soil needed for crops and various other environmental factors that play a key role in farming. Multiple sensors are deployed in different fields around the farm so as to get a good report of the usual area. The above mentioned parameters are controlled by means of a remote device or through internet services and the operations performed are done by interfacing the various sensors, a camera with a microcontroller as well as WiFi. The PIC microcontroller is used as it is convenient to use and programming it is easy. This method also makes use of an EEPROM which stores the data about transmitter codes and receives the data related to frequency. GSM module can act like a handphone, it can send as well as receive messages. At commands are used to send these messages. It has a reverse voltage based protection and operates in the voltage range of 900-1800 MHz. Soil moisture sensor works on the principle of an open and short circuit. For temperature an LM35 sensor is used with maximum output 5V. For every variation in temperature by 1 degree celsius its output increases by a quantity of 10 mV.

Rao and Sridhar (2018) proposed a raspberry pi based programmed irrigation system framework. This system will help to deliver modernization to the current farming system which will play a significant role in the development of crops especially in areas where the consumption of the resource water is low. This will speed us the process of farming and not to mention, significantly reduce the time spent by farmers on their fields. The management of the water system should be developed with a low complexity for circuits used. In the system proposed by them, the sensors will be placed in the field and give information about the amount of water required by the fields.

The above mentioned system makes use of two kinds of sensors: one to check the humidity and temperature of soil in the fields and another to measure the humidity and another to get the duration of daytime i.e, the time that the sun shines on the field. This system has an advantage because it uses the system of precision agriculture by integrating cloud computing to perform analysis to determine the amount of water to be used in order to ensure a good harvest. This method makes use of a Raspberry Pi microcontroller, which has a high speed. Pi3 works on a quad core 64-bit processing unit with Wifi and Bluetooth. RAM is 1GB.

Monitoring the external environmental factors is not the only thing important for automating the farming process. The system proposed by Vineela et al. (2018) to find a way to develop an automated system of agriculture using the relevant principles of IOT and hand this system to the farmers. Thing Speak will also be used to deploy this system so that it can be accessed remotely. Since this system will be developed as a low cost and efficient network of wireless sensors (Vineela et al., 2018). Raspberry Pi microcontroller is used in this proposed method as well. This method also incorporates a DHT 11 Sensor for temperature and humidity sensing. Output from this sensor is given directly to the data pin. The only disadvantage is, that a sensor can fresh data only in 2 second intervals. A relay is a switch that is operated electrically, it is essential to this setup as the circuit needs to be controlled by means of a low powered signal (Figure 9).

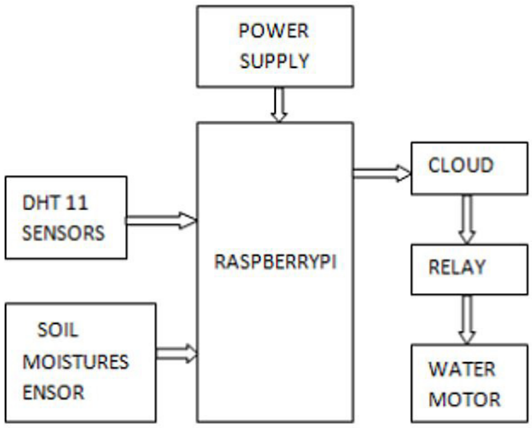

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Figure 9: Block diagram of the proposed system.

Channe et al. (2015) proposed a smart agriculture system, this has been developed using advanced technologies like: Cloud Computing, Big Data analysis, sophisticated sensors and Mobile Computing (Channe et al., 2015). The vendors and farmers must be registered on the cloud module through the mobile application. The data collected from this mobile application will be sent to the cloud for analysis. Since the data collected is of large volume, big data analysis will be done to get relevant inferences from collected data. Analysis will be done in order to make decisions for the farmer like, appropriate fertilizer and its quantity, best method of crop rotation, as well as demand forecasting to find out the in-demand crops in the relevant markets.

The sensor kit is a low cost kit that is also portable. This is an IOT enabled device that has been incorporated with a memory processing capability. A GPS sensor is also included in order to detect the location data. Soil attribute sensors are also included to detect the amount of nutrients present in the soil (pH, Nitrate, Potassium, Phosphorus sensors).

The total populace is anticipated to be about 9.7 billion in the year 2050, as thus there will be incredible demand for food. This issue coupled alongside the reducing common assets, the arable land and unpredictable climate conditions make food security a huge issue for most nations around the globe. The world is beginning to use IoT along with data analytics in order to address the high demand for food in the upcoming years (Turgut and Boloni, 2017).

Materials and methods

Problem description: The farmers in our country face continuous struggles in earning their daily bread. The issues listed are inaccessibility to good quality seeds, absence of present day advances and equipment, poor irrigation system, managing middlemen to begin with. Due to these, the farmers face severe losses and aren't paid in proportion to all the hard work they put in. With our proposed solution, we aim to minimize losses, prevent excessive labor work, save energy and the cost of travel by providing farmers a clear understanding on the soil nutrition content using diffuse reflectance infrared spectroscopy.

Smart Soil Nutrition Prediction model

The proposed framework utilized the proven Support Vector Regression and Tikhonov Regularization method as its core algorithms. A version of SVM used in regression was proposed by (Drucker et al., 1997) this method is known as the support-vector regression (SVR).

The model is produced by support vector classification (SVC). It totally relies upon the subset of training data, since the cost function so as to assemble the model doesn't consider the training focuses that lie past the edge. Also, the model created by SVR relies just upon the subset of training data. This is on the grounds that the cost function so as to assemble the model disregards training data that lies near the model forecast. Another version of SVM known as the least-squares support-vector machine (LS-SVM) was proposed by Suykens and Vandewalle (1999).

Tikhonov regularization, is known as ridge regression and is utilized to decrease the issue of multicollinearity that happens in linear regression. This is a typical event in models with enormous quantities of parameters (Kennedy, 2003). The method provides improved efficiency in problems that include parameter estimation in exchange for a tolerable amount of bias (Gruber and Marvin, 1998). Also, various machine learning models are widely used for weather monitoring in short term rainfall prediction (Sudha and Subbu, 2017). Also statistical models are applied (Sudha, 2017). Medical disease diagnosis, agro decision support and in various interdisciplinary domains IoT and machine learning methods are applied nowadays (Sudha and Valarmathi, 2014; 2016). As a recent trend hybrid machine learning models are applied in precipitation forecasting (Sudha and Valarmathi, 2015).

Process flow

We collect the data using multiple IR sensors to implement Diffuse Reflectance Infrared Spectroscopy. This is relayed using Arduino through the Zigbee protocol. The huge amount of collected data can be used to predict the values of soil nutrition for Calcium, Phosphorus, Organic Content, pH and Sand content. This will give an insight about the quality of the soil and the predicted crop yield for that area.

Experimental deployment

The proposed model will be a Level - 4 IoT System. A Level-4 IoT system is one which makes use of multiple nodes in order to perform local analysis. The information obtained from these sensors is stored. These subscribe and receive information that is collected in the cloud by means of the various IoT devices used. Level-4 IoT systems are characterized by their usability in solutions that require the use of multiple nodes and where the volume of data collected by these sensors is big.

Furthermore, the requirements of the solution are computationally intensive. The proposed solution consists of multiple nodes that monitor the soil at various areas.

Infrared sensing is utilized in a wide scope of uses including discovery, investigation: food safety, fire detection, fuel analysis, etc. Recently, they have been used for spectrometry and have facilitated as truly portable analyzers. An IR sensor could be active (emitter and detector) or passive (detector). The solution focuses on using passive IR sensors which will not have an influence over the samples or the environment around them.

Most IR sensors integrate with a microcontroller and in addition, a lens could be placed near the sensor that enables it to focus on some specific frequencies. Since all the soil samples transmit some type of radiation that normally lies in the infrared range and various materials retain particular frequencies of infrared energy, IR sensors will be used to analyse the components of the soil and identify the properties accordingly.

The advantages of utilizing the IR sensor for spectroscopy incorporate its capacity to catch an immense measure of information from the sample in detail that would help in deciding the sample structure and the fixation alongside the presence of added substances or contaminants.

Arduino the microcontroller used to support the IR sensor. The communication protocol used for this proposed system is the popular Zigbee protocol. Zigbee is a low range and low power IEEE 802.15.4 physical radio specification. It specializes in low power IoT devices, which is perfect for farmers as they can operate it using batteries. It works in permit-free groups including 868 MHz, 900 MHz and 2.4 GHz.. This protocol allows the IoT devices to communicate in many kinds of network topologies. It works especially well for a mesh topology as failure of one node does not result in failure of the entire network.

Results and discussion

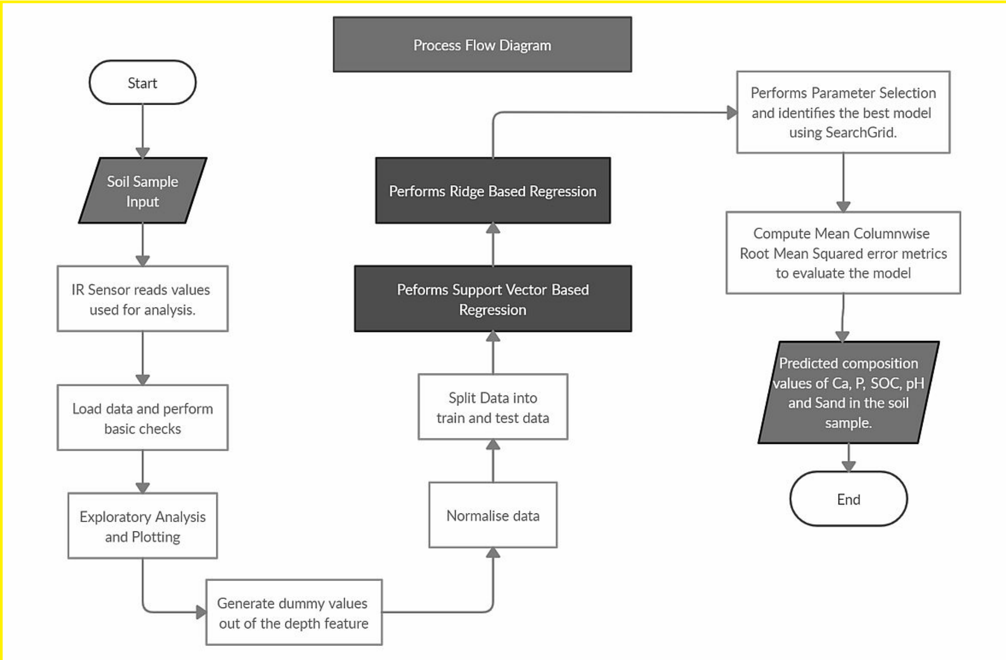
After data preprocessing and plotting to understand the values in the dataset, we apply the above mentioned algorithms in order to predict the values of the five contents mentioned before.

Intent of this research is to predict the mean column wise root mean squared error metric in order to evaluate the model that we are training. We use the grid search function on the training dataset and save the best model. Gridsearch is a thorough search over determined parameter esteems for an assessor. Important members of this function are fit and predict. GridSearchCV implements a "fit" and a "score" method.

This implementation also makes use of the parameters: "predict", "predict_proba", "decision_function", "transform" and "inverse_transform". These parameters are implemented in the estimator that has been used. These parameters of the estimator are then used to apply these methods. These are further optimized by means of a cross-validated grid-search over the parameter grid. We then shuffle the dataset and split it into training and testing data.

We then apply the algorithms: Regression based on SVM (SVR) and Ridge Regression. Model trained is saved using the pickle module which is the standard way of serializing objects in python. This activity is utilized to serialize the AI calculation and use it to make any new predictions.

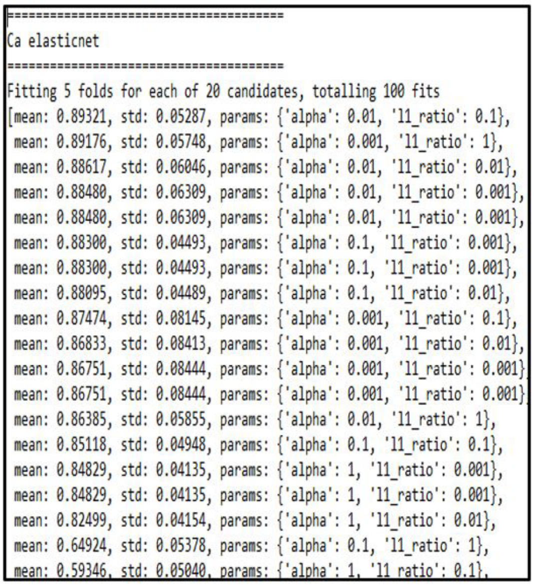
Models used as an input for search grid. Search grid generates all the possible combinations of the parameters. Then K-fold cross validation is performed on top of the training set with each of the previously generated combinations. It then returns the best model, which is then saved (Figure 10).



Source: Own processing

Figure 10: Smart soil nutrition prediction using IoT – experimental framework.

In the data frame considered, the number of features are actually higher than the number of entries. So proper algorithms must be implemented in order to handle the data as it is prone to overfitting. So we use simple regression models. We apply search grid to perform parameter selection.



```
========================================
Ca elasticnet
========================================
Fitting 5 folds for each of 20 candidates, totalling 100 fits
[mean: 0.89321, std: 0.05287, params: {'alpha': 0.01, 'l1_ratio': 0.1},
 mean: 0.89176, std: 0.05748, params: {'alpha': 0.001, 'l1_ratio': 1},
 mean: 0.88617, std: 0.06046, params: {'alpha': 0.01, 'l1_ratio': 0.01},
 mean: 0.88480, std: 0.06309, params: {'alpha': 0.01, 'l1_ratio': 0.001},
 mean: 0.88480, std: 0.06309, params: {'alpha': 0.01, 'l1_ratio': 0.001},
 mean: 0.88300, std: 0.04493, params: {'alpha': 0.1, 'l1_ratio': 0.001},
 mean: 0.88300, std: 0.04493, params: {'alpha': 0.1, 'l1_ratio': 0.001},
 mean: 0.88095, std: 0.04489, params: {'alpha': 0.1, 'l1_ratio': 0.01},
 mean: 0.87474, std: 0.08145, params: {'alpha': 0.001, 'l1_ratio': 0.1},
 mean: 0.86833, std: 0.08413, params: {'alpha': 0.001, 'l1_ratio': 0.01},
 mean: 0.86751, std: 0.08444, params: {'alpha': 0.001, 'l1_ratio': 0.001}
 mean: 0.86751, std: 0.08444, params: {'alpha': 0.001, 'l1_ratio': 0.001}
 mean: 0.86385, std: 0.05855, params: {'alpha': 0.01, 'l1_ratio': 1},
 mean: 0.85118, std: 0.04948, params: {'alpha': 0.1, 'l1_ratio': 0.1},
 mean: 0.84829, std: 0.04135, params: {'alpha': 1, 'l1_ratio': 0.001},
 mean: 0.84829, std: 0.04135, params: {'alpha': 1, 'l1_ratio': 0.001},
 mean: 0.82499, std: 0.04154, params: {'alpha': 1, 'l1_ratio': 0.01},
 mean: 0.64924, std: 0.05378, params: {'alpha': 0.1, 'l1_ratio': 1},
 mean: 0.59346, std: 0.05040, params: {'alpha': 1, 'l1_ratio': 0.1},
```

Source: Own processing

Figure 11: Log files of model training showing the target variables and their mean values.

Accordingly log files (Figure 11) are made for the other 4 parameters that are to be predicted as well. Based on the results of those log files we come to the conclusion that: For the values of Ca, P, Soil Organic Content and Sand, Support Vector Regression gives the highest accuracy whereas for pH value, Ridge Regression gives the highest accuracy.

On performing a test on the test set based on the parameters and algorithms mentioned above we get value of MCRMSE as 0.410190847722

MCRMSE or mean column wise root mean squared error is defined as:

$$\mathrm{MCRMSE} = \frac{1}{5}\sum_{j=1}^{5}\sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_{ij}-\hat{y}_{ij})^2}$$

where *y* and *y^* represent the actual and predicted values respectively.

Conclusion

This research focused on assessing the adoptability of various smart solutions using IoT in agriculture. This work explored the benefits of IoT and Data analytics and propose a model based on the same. The experimental results shown that Ridge Regression and Support Vector Regression attained maximum accuracy in predicting the soil nutrition value. On performing analysis on the data recorded by the IR sensor, the amount of Calcium, Phosphorus, Sand, pH and organic content in the soil sample were predicted. This would enable the farmer to understand the kind of crops to grow for maximum profit from the produce. It would enhance the operational efficiency and reduce the setup costs.

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