Smart Farming enabled by IoT and Spectral Imaging

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Abstract. Smart Farming System is an emerging concept which utilizes sensors in the field enabled through IoT to get live data from the farm. This paper aims at developing such a Smart Farming system using the highly advanced technology of Texas instruments microcontrollers, MSP430 and TIVA C Series TM4C1294. Along with IoT the system uses Multispectral Imaging in conjunction with Wireless Soil Embedded Sensor Networks. The goal of the system is to provide reliable live data which is obtained from the multiple sensor nodes placed throughout the farm, that use the sink nodes to transfer the data to the cloud. The farmer can access this data using the Blynk Mobile app and can thus take further calculated actions towards maintaining the farm and further monitor the soil/crop health to increase the ultimate yield from his farm.

Keywords: Smart Farming, Internet of Things, Multispectral Imaging, Data Acquisition, Image Processing.

1. Introduction
Development in India has been rapid over the years, both indigenously and globally and it’s not a surprise that agriculture is still a dominant part of the economy and the demographic. Directly or Indirectly 60-70% of India's population rely on agricultural development to make a living. The agricultural area occupies about 43% of the geographical area of our country [1]. Although India’s Agricultural production is among the highest in the world, its yield is not satisfactory. Primary reasons are, lack of soil and water management. Most farmlands get adequate rainfall only during the monsoon season which in itself is irregular. The overuse or underuse of fertilizers is another problem faced by farmers. Overuse of fertilizers causes runoff and erosion leading to soil infertility while underuse leads to lower yield. Apart from these, pest problems are also a major concern for crop yield. Farmers struggle to optimize the use of pesticides as they cannot determine areas with pest infestations. Hence, the aim is to solve these problems to help farmers, the backbone of Indian Economy, increase productivity which would in turn lead to a healthier economy.

Smart farming is a technique of farming which integrates IoT to help with the increase in yield. Smart farming helps with informing the farmers as to when to use appropriate fertilizers and other resources to increase the production. Since it is difficult for farmers to be present in the farm the whole day, this system overcomes that difficulty and helps farmers get all kinds of data from their farms even while not being present in their farms. There are a lot of difficulties faced by farmers these days,
including global warming, volatile weather conditions and the pressure of feeding such a large population, which makes smart farming a necessity.

2. Related work

Doshi et. al. [2], describes a device that monitors the farm and measures different parameters of the farm like temperature, humidity, UV, IR, soil moisture, soil nutrients and gives appropriate updates to the farmer, thus helping them make changes to the farm and increase the yield and help manage water and fertilizers. Nayyar et.al [3], proposes a Novel Smart IoT based Agricultural Stick that assists farmers by obtaining data regarding temperature and soil moisture, which enable them to get better yield. This gadget uses a concept of “Plug Sense”, so farmers can directly plug this stick into the soil and get the appropriate data. A system proposed by Sushanth et. al [4] uses IoT, WSN and cloud computing, where farmer can plan his agriculture schedule and works on the micro controller that gives the appropriate output to the actuators.

All of the above mentioned projects have a few similarities in that they all aim to solve the same problem faced by farmers and they all employ a module in the soil which gathers data and send it to the cloud where further data processing can be done. Our project is unique in that it employs an efficient method using multiple source nodes in the soil that can be spread throughout the farm and sink nodes are placed around the farm to gather data from the source nodes and send them to the cloud.

3. System Overview

Our project aims to be robust, cost-effective and also making sure it requires less maintenance. The whole project revolves around the use of Internet of Things (IoT) which enables storage of the farm data over the cloud which can later be used to perform data analytics and pattern recognition for future developments. Fig 1 shows the system overview. The sensor nodes acquire and transmit all the data that can be obtained from the soil. The Sink node takes these data and converts them to form IP packets that can be sent to the cloud. The Multispectral Image Module takes the spectral image and independently transmits it to the Cloud. The Cloud processes the data and sends it to the user. The user can view the status of the soil/crops through a mobile app [5].

3.1. Source/Sensor Node

Depending on the size of a farm, there will be a certain number of sensor nodes that will be placed in the farm, taking in the range of these modules. Dedicated modules are made for these which will be placed throughout the field, and the data from a set of source nodes will be sent to the sink node at different radio frequencies to distinguish between the different source nodes. The goal for the module design was to keep its energy consumption as low as possible, so as to increase its efficiency and also to prevent the constant removal of this module from the soil. The module is designed such that its battery will last for an entire crop season and can be replaced once the crop is harvested.

The sensor module is as depicted in fig. 2. The module consists of a Master Control Unit (MCU, MSP-EXP430F5529LP), which is an ultra-low powered microcontroller consisting of 2 sensors.
namely temperature and humidity sensor (HDC2080) & moisture sensor [6]. The modules have RF Transceivers (CC1150RGVT), to which the MCU sends data serially and this transceiver is connected to a dedicated antenna which is used to send the data from the module to the sink node, wirelessly. The entire module is placed in a robust and water proof container so that it remains safe when it is kept in the soil.

![Source/Sensor Node Layout](image)

The temperature sensor uses the I2C communication protocol in order to communicate with the microcontroller unit, which acts as the I2C master. The ‘Int’ pin on the sensor sends an interrupt to the microcontroller if the temperature goes above the set threshold. The interface diagram of the HDC2080 is as shown in Fig 3

![Temperature Sensor Interface with Source Node MCU](image)

The moisture sensor essentially uses an Operational Amplifier as a comparator in order to determine the moisture level in the soil. Current flows between the two moisture probes when there is more moisture in the soil which changes the potential difference between the probes. This circuit is made such that it gives us an analog voltage at the output of the Operational Amplifier. The microcontroller has a 10bit Analog to Digital converter, therefore the values range from 0 to 1023. The circuit can be tuned such that the values correspond to the particular moisture percentages. The circuit is as shown in Fig4.
Fig 4. Moisture Sensor Interface with Source Node MCU

The entire module is powered by lithium polymer cells whose nominal voltage is 3.7V. They are connected in series to achieve a voltage of 8.4V which is stepped down to 3.3V, using a TPS621351RGXR IC, the circuit for which was designed using the TI WEBENCH software [7].

3.2. Sink Node

The Sink Node as shown in fig 5 consists of the TIVA C Series TM4C1294 which has an integrated 10/100 Ethernet MAC+PHY which can be interfaced with a router to forward IP datagrams to the Cloud Server. This node also consists of a similar RF transceiver and antenna system that is present in the source node. Each sensor module has a different address so the incoming data can be differentiated easily.

The TM4C Master Control Unit (MCU) takes in data from the Source Nodes and forms an IP packet which connects to the TP Link Router via the Ethernet interface which then forwards the IP packets to the cloud server. It uses the LwIP TCP/IP protocol stacks and the embedded Ethernet is programmed to act as an HTTP client. The power supply to MCU is given through the compatible Battery Booster Pack from Texas Instruments.

Fig 5. Sink Node Layout

3.3. Spectral Imaging

In order to use visual data to obtain information about farmland we need the normalized difference vegetation index (NDVI). The normalized difference vegetation index requires both raw and infrared (IR) filtered images. In order to obtain raw image data, we used the Raspberry Pi Camera V2 module. An IR filter is used to get IR image data by coupling the filter along with the camera module. The camera module is integrated with a Raspberry Pi 4 which together constitute the spectral imaging module as shown in fig 6.
This module is placed either on an aerial platform like a drone or a stationary platform like a high pole that keeps collecting data at regular intervals which are determined by the type of crop and its characteristics. The data is directly sent to the cloud using the inbuilt WiFi feature in the spectral imaging module [8]. The image data obtained is then coincided with the actual map coordinates by the use of Image-to-map geometric rectification techniques after which the image is pre-processed before the spectral response is extracted from it. The processing involves subjecting the image appropriate smoothing filters for removing any outlier or erroneous portions of the data. The spectral response of the image is then extracted.

The spectral response describes the sensitivity of the sensor module to optical radiation of different wavelengths. The amount of different wavelengths in a particular area provides us with information regarding vegetation. The NDVI quantity is used here as a standard to estimate all the parameters we require. The processed data is then stored in the cloud along with data collected from the sensor node placed in the soil through the sink node. The data from both these sources are compared and processed according to the requirements of the crop and the soil parameters estimated from the data collected to arrive at information which is useful for the farmer. The farmer will now get information on the health of the crops, information about surplus and deficiency of nutrients and water and can therefore make informed decisions according to the intelligence provided by the system. This information is then either accessible to every farmer in the network or the company handling the operations of the network.

4. Internet of Things Interface

Internet of Things (IoT) where “Internet” stands for Global Communication network connecting multiple devices and enables information sharing and “Things” stands for multiple devices have different identities and have the ability to sense, actuate and measure data in the live environment [9] as seen in fig 7.
Fig 8 shows the Blynk App which collects the live data from through the sensor nodes. Blynk’s Cloud Server along with its IoT solution is used as the IoT interface for the Sink nodes and Multispectral imaging module. An android application was designed in its platform which allows the user to see the status of their crops/soil. It depicts the temperature and moisture levels as the graphs which helps to monitor the farm and its health remotely.

![Fig 8. Live data in Blynk App](image.png)

The application connects to the MCUs by means of an Authorization Token generated by the app. This Authorization is used by the MCU to send data to the cloud server. All this is done via the HTTP protocol stack on the MCU. The app setup for live data is as shown in Fig 8.

The NDVI variations is as shown in Fig 9 which is used to monitor the health of the plant. NDVI measures the leaf pigment color by the the ratio between red (~650nm) and near infrared (~850 nm) light reflected by the vegetation as given in (1).

$$\text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}}$$ (1)

NDVI index helps to understand vegetation dynamics and assess plant growth. Along with temperature, soil moisture, a comprehensive analysis of the plant health can be understood and targeted solutions can be sent to the farmer to help in effective management of the farm.

![Fig 9. NDVI formula with image capture](image.png)
Table 1 lists the result of assessing the plant health by analysing its image and calculating the corresponding NDVI value.

Table 1. Leaf Health Samples using NDVI

| Color image | IR image | NDVI | Health |
|-------------|----------|------|--------|
| ![Color image](image1) | ![IR image](image2) | 0.2 | Dried |
| ![Color image](image3) | ![IR image](image4) | 0.4 | Average |
| ![Color image](image5) | ![IR image](image6) | 0.6 | Healthy |

5. Conclusion

IoT based smart farming can prove to be very useful for farmers, as seen from the data obtained from multiple sessions of testing and prototyping for the different components involved. The data obtained can be used to develop an agricultural schedule and get live data based on the weather to maintain the farmland and increase the yield by keeping appropriate threshold values for the different parameters. The whole system is very efficient and produces pretty accurate data on the app, which we cross checked by measuring the corresponding parameters on the soil. The system was flexible, modular and with an added business model for the product got into the Semi-finals of Indian Innovation Challenge Design Contest 2019

**Impact of the solution:** The farmers’ efforts to analyses crop health and growth is immensely reduced. The farmers get the right estimate of water so that the crops are free from damage during bad weather and right fertilizer usage which strikes out the problems of consumption of harmful chemicals for consumers. Increased income for farmers allow them to flourish extensively with better crop growth replenishing stocks in case of drought. The storage of crop data over cloud allows estimation and prediction of crop growth by pattern recognition for future developments

References

1. Srivasthava, H.C. B.Vatsya, K.K.G.Menon. Plantation Crops, Opportunities and Constraints, Vol I and II, New Delhi: Oxford and IBH Publishing Co-Pvt., Ltd.
2. Jash Doshi, Tirthkumar Patel, Santosh kumar Bharti; “Smart Farming using IoT, a solution for optimally monitoring farming conditions”, 3rd International workshop on Recent advances on Internet of Things: Technology and Application Approaches (IoT-T&A 2019) November 4-7, 2019, Coimbra, Portugal.
3. Nayyar, Anand & Puri, Vikram, “Smart farming: IoT based smart sensors agriculture stick for live temperature and moisture monitoring using Arduino, cloud computing & solar technology”. The international conference on communication and computing (ICCCS-2016).

4. G. Sushanth and S. Sujatha, “IOT Based Smart Agriculture System”, 978-1-5386-3624-4/18/ IEEE 2018.

5. Nelson Sales, Orlando Remédios, Artur Arsenio; “Wireless Sensor and Actuator System for Smart Irrigation on the Cloud”, 978-1-5090-0366-2/15/ IEEE 2015.

6. B. Nath and S. Chaudhuri. “Application of Cloud Computing in Agricultural Sectors for Economic Development”. In Interplay of Economics, Politics and Society for Inclusive Growth - International Conference organized by RTC and GNHC, October 2012.

7. TI WEBENCH Power Designer, https://www.ti.com/design-resources/design-tools-simulation/webench-power-designer.html.

8. Christopher Lum, Madison Mackenzie, Charlie Shaw-Feather, Elaiza Luker, and Matthew Dunbabin, “Multispectral Imaging and Elevation Mapping from an Unmanned Aerial System for Precision Agriculture Applications”, Proceedings of the 13th International Conference on Precision Agriculture July 31– August 4, 2016.