IOT for Agriculture

Silicon Labs' Social Entrepreneurship Challenge

Team ID-3

ABSTRACT

This report gives a glimpse of the current state of IoT technology in the agriculture domain, the challenges faced by the farmers, and the solution implemented by us for the productivity of the crop. The total potential loss due to pests is about 50% in wheat and 80% in cotton production[6]. These losses in crops lead to a reduction in productivity. To overcome the challenges of climate change, the optimum requirement of pesticides and fertilizers, and low temperature during winter we implemented a sector-based design. Our device(Iota) gives updates to the farmer through the app about the selected crop that is sown in the field. These updates alert the farmer to take necessary measures.

PROBLEM STATEMENT IDENTIFICATION

Survey

We surveyed local villagers, healthcare experts in our health center, security experts on campus, customer service experts, business experts within our campus. For logistics, we see some problems related to business processes and customer services. In asset tracking, we see the existing solutions. After surveying, The important problem for local people that we found was in the domain of agriculture.

In agriculture, we brainstormed about the problems faced in cold storage and transportation of farm produce. We thought of a solution to measure the quality of produce in storage. Using image analysis we detect the patches and possible diseases in the item stored. The environmental conditions such as temperature, humidity, dust particles can be measured and controlled to have optimal storage. We thought of implementing the same solutions while transporting the farm produce because transportation also requires storage to some extent but after discussing with local farmers we found out that the important problem in agriculture is in production.

Introduction

Agriculture imparts direct correlation to social problems faced worldwide. Global Hunger Index (GHI) ranks India at 101 out of 116 countries [3]. Based on the projections done by Global Hunger Index the world will fail to achieve even low hunger by 2030. The estimates show that In 2014-16 27.8% of the Indian population suffered from moderate or severe food security which rose to 31.6% in 2017-19 [5].

As the need to improve agricultural productivity is increasing, the workforce in agriculture is decreasing in India (Figure 1).

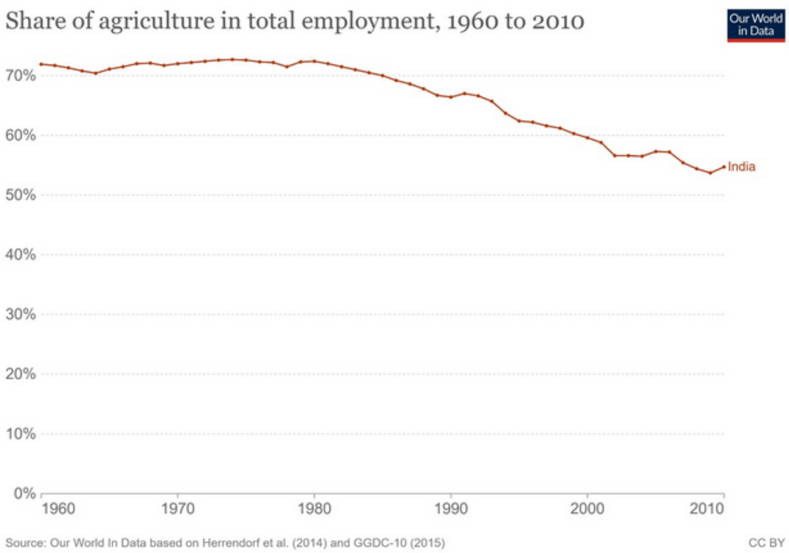


Figure 1 - Share of agriculture in the total employment of India from 1960 to 2010 [4]

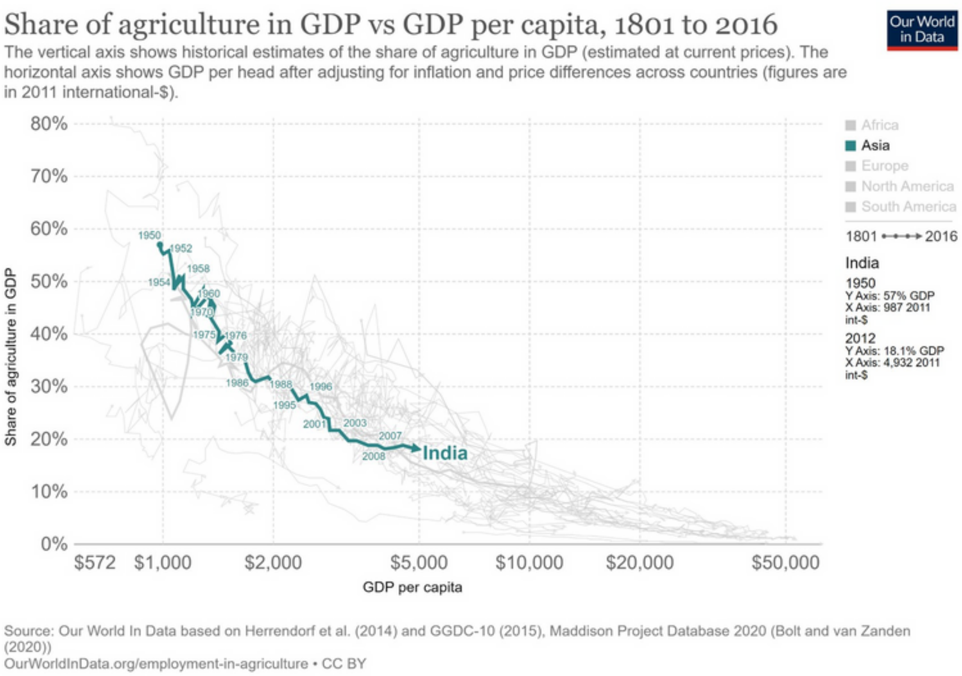


Figure 2 - Contribution of Agriculture in GDP for India [2]

India is on the second spot in farm outputs worldwide. Agriculture employment is more than 50% in the Indian workforce as per 2018 statistics. The contribution of agriculture to the country's GDP is 17-18% for the year 2018 [1]. As the workforce in the agriculture sector is decreasing and the pressure on the food requirements is increasing so there is a need for methods to improve the crop yield.

We felt that the problem of agriculture is very much related to the local people and will be helpful to a large population. Many of the farmers were not aware of available technological solutions. The climate changes drastically throughout India for example In the Himalayan region about 70 percent of the population relies on agriculture. The minimum temperature in the

Himalayan region is -5 degrees centigrade and the maximum is close to 40 degrees. This shows that the weather conditions change very drastically over a year.

Farmers can more efficiently produce more with less manpower and using fewer resources. These advancements in agriculture technology are important contributors to a more sustainable agriculture system that leads to continuous improvement in crop productivity. The health and well-being of millions of people will be improved.

Narrowing Down to the Problem

Following problems were highlighted by the farmers during the survey:

●**Lack of weather-based dynamic advisory**

For a particular crop, a particular temperature, water, and humidity are required which depends on the weather. Being aware of the weather and how it will affect the crop can help to take preventive measures. For example if we are aware of the precipitation we can adjust the irrigation in the field to fulfill the water requirement.

●**Frost damage**

During the winters, the roots of the plants burst due to low temperature, and also the enzymatic activity decreases in plants. To overcome this, the field is filled with water which has a high specific heat capacity and helps to maintain the temperature of the field.

●**Optimum requirement of pesticides and fertilizers**

Pesticides and fertilizers improve the productivity of crops up to many folds. Having an idea of the optimum amount of fertilizers and pesticides based on certain parameters of the soil prevents reduction in the yield and productivity of the crop and also could reduce the wastage of fertilizers and pesticides. Pesticides contribute majorly to the soil pollution and effective practices can help the problem reduce.

●**GPS tracking (self-monitoring)**

Geographical location of a farm can greatly affect the yield and thus, appropriate practices should be followed.GPS tracking is used for creating maps of the field and getting the location of our device for the safety of the device. Also, GPS will help to know the distance between two static devices. Furthermore, The data can be mapped with meteorological data to get weather-based predictions.

●**Heatmaps of the selected parameters**

Most farmers do not understand the requirements of the field at a particular location in the field. In case of bigger and dispersed farmlands, well visualization of the data is very needed to get an accurate idea about requirements and status of farmlands.

●**Handling Remote location**

The people in the remote location face the connectivity issue. The device should also handle the remote location and the user should not face any connectivity issues.

Description of the Problem Statement

A system that can help the farmers to automate cultivation. It shall get advice based on the change in weather conditions, get the optimum amount of pesticides and fertilizers required in the field, give the heatmaps of the selected parameters, self-monitored, overcome the effect of change in temperature during the winters, fit the budget of the farmer, easy usage for the farmer and feasible for remote locations without having connectivity issue.

DESIGN

There were a couple of designs that we thought of making, but those had a few limitations. To overcome those limitations we narrowed it down to one specific *sector-based design*. Initial designs were Drone and Rover based.

Shortlisted Designs

1.Drone Based Design

We brainstormed about using a drone. A drone camera will collect the images of all plants. The images will be then processed using machine learning algorithms. This indicates the presence of patches that signify disease. The drone also includes sensors that detect the humidity and temperature of the surrounding area of the crop. This will help us to get an idea about the weather. The drone also consists of a self spraying system that will spray the fertilizers and pesticides into the field based on the optimum requirement of the crop. This will improve the growth of the plants which will improve the yield.

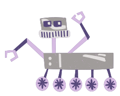
Limitations:

●**Usage Problems** - The farmers do not have sufficient knowledge about drone technology.

●**Cost** - The price of the drone will be around ₹ 45,000. Farmers can't purchase such high-cost products.

●**Energy Requirement** - The drone requires energy to move in addition to normal usage.

2.Rover Based Design



We thought of designing a rover that will go to the field and collect the information from different places. The rover includes a camera that will capture the images of all plants. The images will be then processed using machine learning algorithms. The purpose of this exercise is to detect patches in parts of plants. The patches signify the presence of diseases. The rover collects information on soil moisture, Nitrogen, Phosphorus, Potassium, Temperature, Humidity of the environment. In the end, this information will be compiled and a complete analysis of the whole field will be available to the farmer. After analyzing we will give the relevant alerts to the farmer about the necessary actions which need to be taken to have healthy soil which will eventually improve the yield of the crop.

Limitations:

●**Usage Problem** - On uneven terrain, the rover will not be able to work for a long period.

●**Maintenance** - The maintenance of the rover is also a headache.

●**Cost** - The price of the rover will be between 20,000-25,000 which is still a high amount for a farmer.

●**Energy Requirement** - The rover requires energy to move in addition to the normal usage. The energy usage can be reduced if we use a static system.

3.Sector Based Design

Due to the above shortcomings, we have designed a static solution covered in a weatherproof box. All our sensors will be inside this box. For detecting pH, temperature, Nitrogen, Potassium, and Phosphorus content in the soil we are using NPK-pH-T sensor RS-THNPKPH-N01-TR. It will collect data from soil and update the nutrition content in soil required in plants and according to the crop type app will tell the action required for it to detect the moisture content in soil DHT11. A soil moisture sensor is used to detect the moisture in farmland and an update in the form of an app notification will be received by the user. According to the requirement, irrigation on the field can be done. For communicating with the sensors, collection of data, updating of data and information we are using NodeMCU ESP822 which is a Wifi module for small farmlands. To cover large farm areas another solution is proposed which consists of a Lora module integrated with Arduino; it gives connectivity up to 10 km to get better range.

Features of Sector Based Design

After looking at the limitations of the drone and rover we thought of a static solution for the field. Any farmer lacks the technical knowledge to operate it manually. Hence, giving a fully automated solution will help the farmer. A thorough analysis of the field will be available if we use a sector-based solution. The cost of our solution is in the range of 8,000 to 10,000 which is less than the cost of the rover and drone and it is feasible for the farmer to purchase and use in the field. The maintenance of the module is also not difficult as in the case of drone and rover-based solutions.

Brief Description:

The aim is to collect various sensor data, process it, and utilize intelligent methods to help the farmers. This data has an impact on crop health and crop yield. The data is fed to a microcontroller (Arduino or nodeMCU as per our models). The controller is connected to a gateway. When using nodeMCU, it can be connected over TCP/IP to the gateway(which is a Raspberry Pi connected to the cloud). While using the long-range variant, We aim to establish a LoRaWAN. We are implementing a STAR topology because each device provides independent data. All the devices use a LoRa E5 module which supports LoRaWAN.

There is a LoRa Gateway module at the Server of the farm (Raspberry Pi). The Server can also be connected to motor peripherals such as Irrigation System to take automation one step ahead.

COMPONENTS OF FINAL MODULE WITH DISCRIPTION

- **Temperature and Humidity sensor DHT11:** It will measure the atmospheric temperature and humidity of the air. In case of high temperatures, certain plants shed their leaves to reduce the amount of water released. Farmlands can be covered with green sheets which will save the plants from burning. The rate of transpiration decreases as the relative humidity of the air surrounding the plant rises. This data will be updated in the app. **Cost: 95 rs**

- **NPK-pH-T sensor**: Nitrogen, phosphorus, potassium, pH, temperature, and humidity content of the soil is being measured using this sensor.

- Nitrogen is the main component of chlorophyll molecules. Low availability of phosphorus in the soil will lead to decreased root growth and lead to winter hardiness, and the presence of potassium increases disease resistance. All these data coming from the sensor will help the farmer to provide the required nutrients to the soil.
- The pH probe of the sensor measures the acidity and alkalinity of the soil. In the presence of acid in the soil, the growth of the root system deteriorates, which inhabits the supply of enough nutrients to plants. Phosphorus and zinc deficiency, as well as iron shortage and boron toxicity, are the end effects. When plants are injured by alkalinity, they have a harder time extracting important nutrients from the soil.
- The temperature probe will monitor the conditions whether the temperature is optimal for the growth of the plant or not. If not, then the app will suggest the solution so that these conditions will not harm the plant.
- The sensor will also measure the moisture content present in soil and update data in the app so that farmland can be watered according to the moisture requirement of plants.

The sensor will detect the presence of contents and in case of lack of it the solution will be updated in the app and the app will provide the solution for the same. **Cost:** 6760 Rs

●**LoRa module**: For communicating with sensors in large farmlands we are using the LoRa module with an Arduino which has a range of 10 km. It will help to place equipment in various farmlands at different positions and communicate with them to get data. **Cost:** 1099 Rs

●**NodeMCU**: For communication in small farmlands we are using NodeMCU which is a wifi module. All the data will be collected using this module. **Cost:** 289 Rs

●**GPS module**: We are using a GPS module so that in the case of large farmlands we can install the required amount of module setup at some particular distances till which the module can collect data. It will be mapped using device ID if any of the modules have electronic issues it will help to identify that particular module and we can solve the issue. **Cost:** 599 Rs

Total Cost Analysis: The given costs will be greatly reduced when mass manufacturing.

Prototype A(Long Range): 9583 Rs - Prototyping Cost

Prototype B(Short range): 8123 Rs- Prototyping Cost

Communication

The farms vary from very small regions to several hectares. Furthermore, the terrain can vary which can disturb line of sight. For example, In hills, the farms have a very long distance between them, and many times the devices have to be non-line (nlos) of sight. Furthermore, The communication devices are very power expensive and this factor has to be considered while prototyping. Also, in areas like hills internet connectivity cannot be ensured at all places; providing internet by use of routers can prove to be very expensive in extensive places. The following graph shows a comparison between various options available.

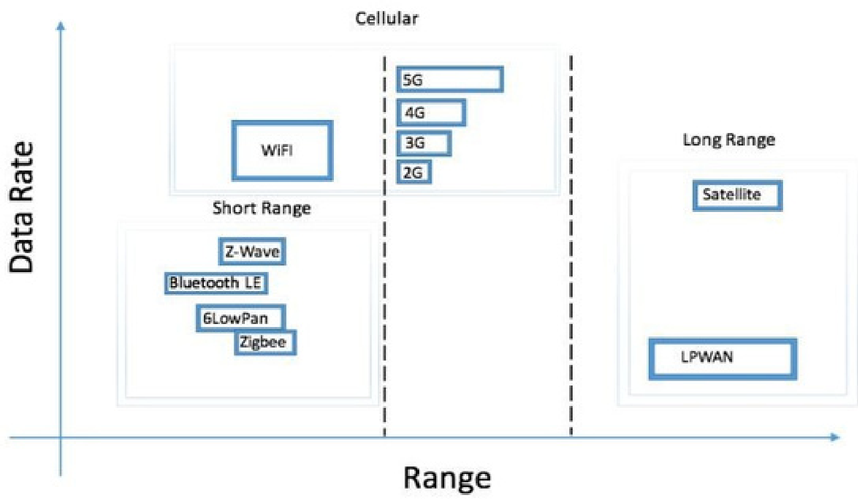


Figure [7]

While LoRa consumes less power and can communicate over long distances, the setup requires an Arduino and a LoRa module which is very costly. Therefore we have developed two prototypes: One is based on nodeMCU for small-range farm setups and the other uses the LoRa module for long-range farm setups.

Power

The factors we have considered for finalizing the power system are- Long operation of the device, Safety factors, and easy recharging. Upon various comparisons, we concluded that traditional 18650 Li-Ion cells are best since they are the best consumer-grade rechargeable batteries. They are easy to charge. Their chargers are also inexpensive. Most of the sensors are powered through a microcontroller only. These work on 5 volts. 7 in 1 NPK sensors work on 9V. An 11.1 V 18650 battery holder is used. This is stepped down to 9V and 5V using voltage regulator ICs. Duty Cycle will be optimized to conserve battery life. The Radio devices will not consume energy during the sleep period. The data can be transmitted around 1 time every minute. A 3 cell 18650 Li-ion charger is provided separately.

Data Collection:

The Temperature and Humidity Sensor (DHT11) is utilized to get the environment parameters. It utilizes a Digital pin. Standard Libraries provided by the Adafruit DHT series are used to get the data. The NPK sensor gives us soil moisture, Nitrogen,Phosphorous, Potassium, pH of the soil, and temperature of the soil. GPS data allows us to club data with meteorological reading.

Data Transmission:

The data is transmitted around 1 time every minute. A log file is maintained to monitor each entry. A buffer is maintained at the node which stores data till a flag from the cloud is sent which tells the node that a particular entry is received successfully. Every node is mapped to a specific data entry. We are using a SQL database. Live monitoring of this data is done at a cloud computer. Various triggers are set to interact with the Application Interface. The application interface is equipped with custom notifications. The motor peripherals are controlled by Application. Before performing any actions, the application confirms using proper authentication. The request is sent to the cloud which triggers the gateway (Raspberry Pi) which also controls the motor peripherals.

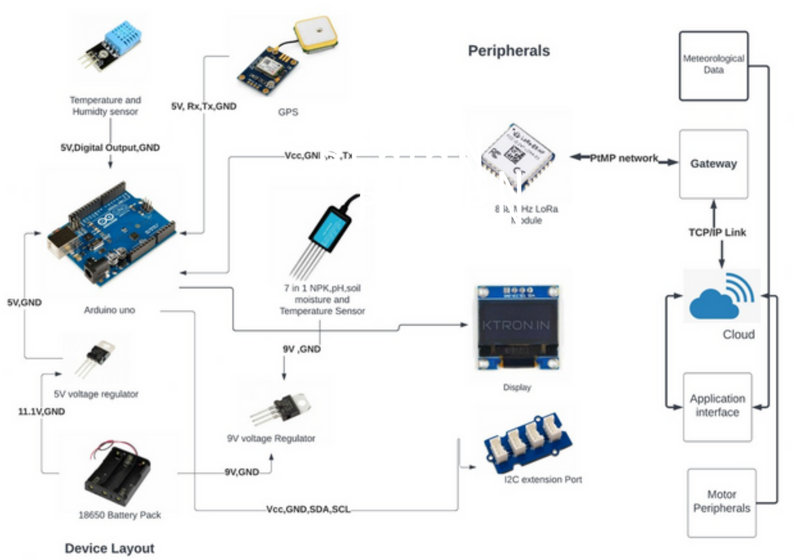
Data Analytics:

Cloud Computers use GPS data to get meteorological updates and notify users about any weather changes. Also, it analyzes the data for various time durations and predicts the ideal time for certain crop practices. It compares the needs to real-time data and calculates extra nutrients to be added. A shop/buy option is provided. The anti-frost feature works in very cold environments. It utilizes the temperature data and notifies if the weather is too severe. The optimum volume of water is also predicted which is very crucial for water-scarce regions. Heatmaps are generated using data analytics which helps in visualizing the parameter distribution across the farms and also across inter-farm deployments.

ELECTRICAL SCHEMATIC

Electrical Schematic

Long Range Prototype



Short Range Prototype

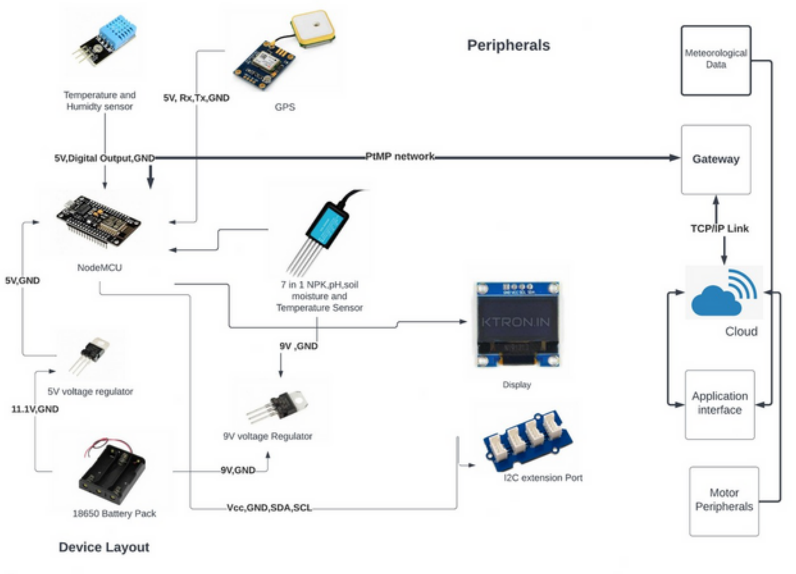


Figure 2 - The Schematic of electrical components

Block Diagram of the components

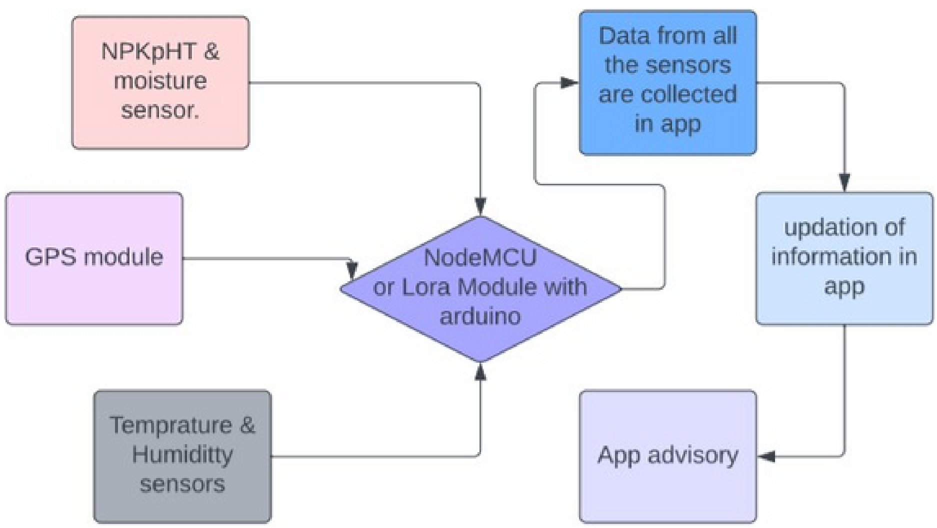
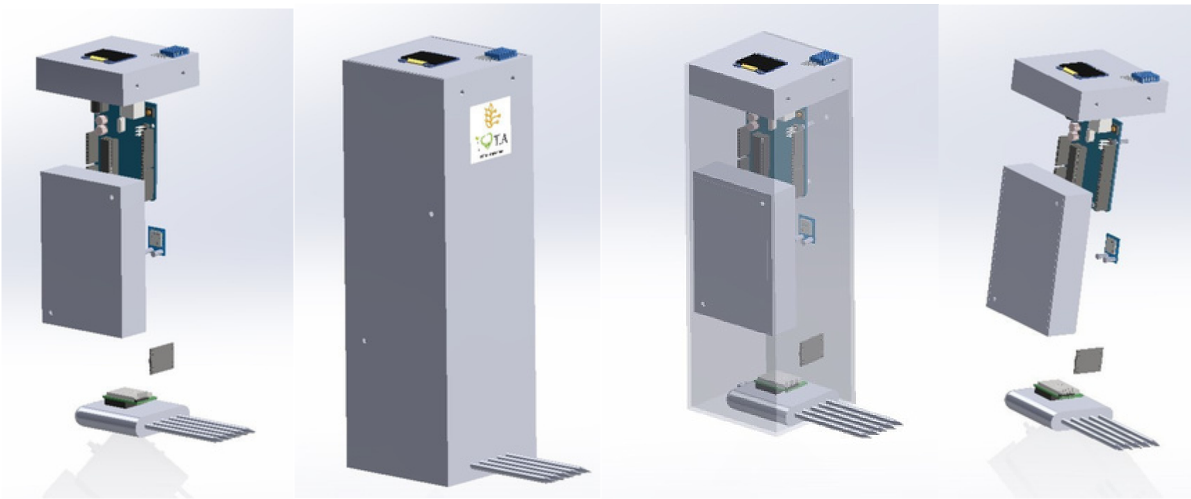


Figure 2 - Block Diagram of the components

CAD Model



This is the CAD Model of our Design that shall be implemented and installed in the fields. The height of the IOTA device is 250mm as the NPK-pH-T sensor needs to be buried around 150-200mm deep in the ground. The device will be buried in the ground to a depth of 150-200mm. The Casing is made of HDPE as it is durable and strong and is good for a long run. The holes in the casing are sealed and made waterproof using Silicone Sealant. The NPK-pH-T sensor, DHT11, Arduino, GPS Module, Display screen, battery case, LORA Module and all other modules are installed in the IOTA casing. The 5 long rods that are visible near the bottom are of NPK-pH-T sensor. On the top display and DHT11 are visible. For detailed design kindly refer to the attached folder with all the CAD files and also go through the readme file in the folder before going to the CAD Model.

IMPLEMENTATION (END TO END)

The IOTA Device Implementation

We will first get an idea of how big the farm is and according to the area of the farm, we will calculate the number of our iota devices that need to be installed there for optimal monitoring of the farmland. The data from all of these iota devices will be communicated to the server. From the server, the data will be made available on the mobile app. Monitoring and control: Users have to make an account in-app and connect to the module all the data of farmland like environmental temperature & humidity, soil temperature, nitrogen, phosphorus, potassium, and soil moisture this data will be stored in the cloud, and information of farmland will be updated in-app and if there is lack of any nutrient then the required supplement with measured amount according to the dimensions of farmland will be suggested. In case of less moisture in soil, the app will notify a user to irrigate its farmland.

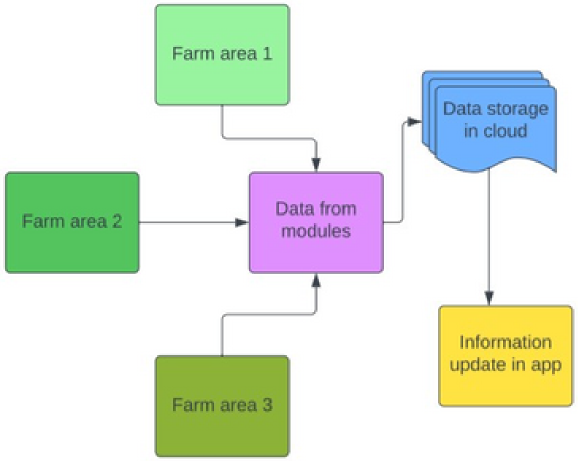


Figure 5: A diagram showing the usage of the proposed solution is case of a farmland which can be divided in three sectors

Advisory: If any advice regarding crop growth or precautions of plants from diseases users can get advice from different agriculture advisors. Also, meteorological data of their interest will be present which will advise them when to sow the crop and what and in which amount to add fertilizer for good growth of the crop.

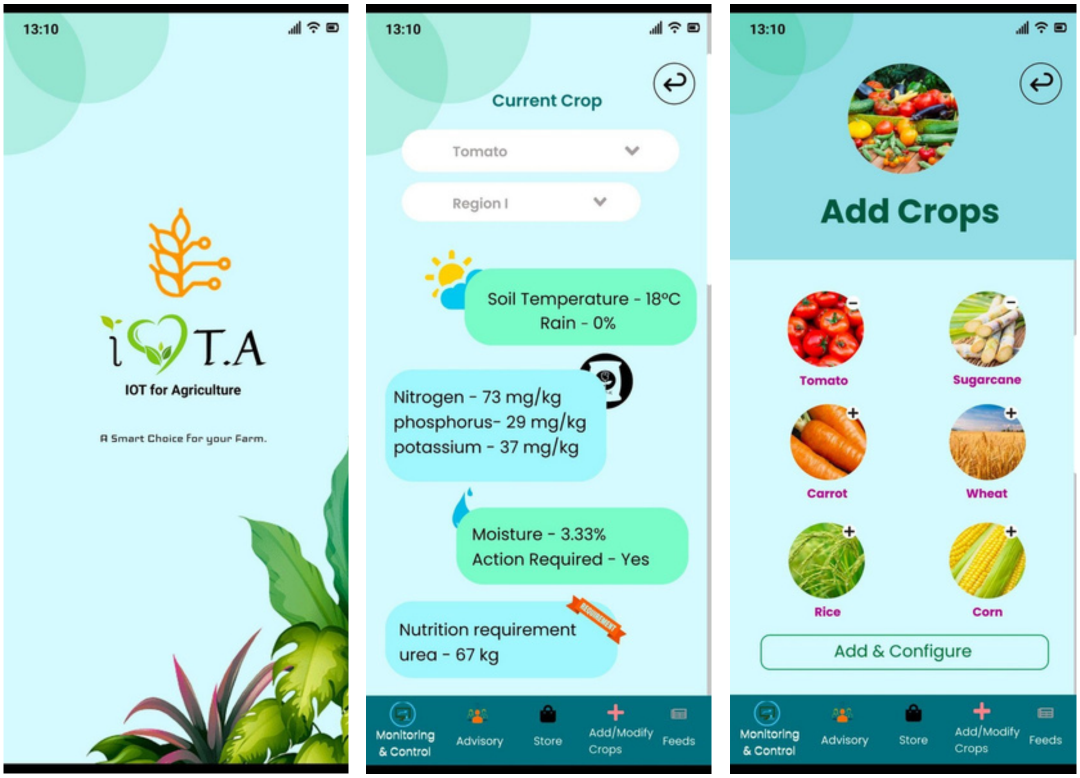
Store: The app will redirect the user to that particular store of fertilizers or farm equipment according to their requirement.

Add or modify crops: Users can also choose any crop of their interest and get all meteorological data of that crop. Also, when cultivating any crop, the crop can be selected at the beginning. The device can be reconfigured to any crop just with a screen touch.

Feeds: all updates regarding smart farming and new technologies having IoT solutions that will be helpful for farmland and their crops will be updated frequently.

WORKING OF APP

The name of our device and app is IOTA. The logo indicates the amalgamation of plant and IoT and the leaves above the IOTA symbol and heart shaped O made of leaves indicate the importance and love for agriculture. The detailed video is attached in the zip file.



DISCUSSION WITH FARMERS

After making the final design and prototype, we showcased the solution to the local farmers. We discussed the mobile application and implementation of the solution on their farmlands. We taught them how to use the mobile application, how the data will be collected, how the whole farm is connected and real-time data logging is possible. Farmers told us that they need this solution for some of the crops. After this, we updated the mobile application and added those crops advisories. Farmers seemed satisfied with the solution and appreciated the team's job.

FUTURE PLANS

The device comes with extra I2C ports which makes the device very dynamic and configurable. Extra attachments(peripherals) can be supplied with the device. The device can be reprogrammed using mobile phones therefore it doesn’t need any expert to get updates. The programming will be done through the app interface only. Agriculture is becoming a very technology-based domain. The device with its basic features can be extrapolated and modified to various agricultural practices like Drip irrigation, climate-controlled Agriculture, Horticulture, and much more. Not only this, the small-scale version can be used in home gardens connected to Home control devices like Alexa, etc to control home agriculture in a very smart way. Big chain companies can use this device across farms in various cities, various states, and even various countries utilizing the best of IoT.

WHAT'S DIFFERENT

Our product is scalable. Additional slots for additional sensors are available. This has been implemented because some crops require additional parameters to be monitored. The software is also scalable. This can be implemented in multiple farmers. If we update the sensors then we can update the software of the iota device through the application itself, we don't have to go to the device (Arduino) and update the software. Our product can also be implemented in home gardens and in controlled environment farms.

References

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