Department of Electronic & Telecommunication Engineering, University of Moratuwa, Sri Lanka.

Project Report

Farmer's Brain

Innovative farming based IOT Device

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EN 1190 Engineering Design Project

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Contents

1 Introduction and Functionality

Through our project we are mainly aiming to increase the efficiency in farming and make farming is easily done by anyone without any previous knowledge. In order to achieve it we are developing an IoT device which is capable of analysing the farming condition and make expert level suggestion by using predefined expert validated data. As this idea includes several measurements and devices as the first version, we are developing a device which is capable of analysing the soil nutrients and give suggestion for plantation that whether this soil is good for planting or what is need to add for plantation.

2 Background Research

Problem Description

Engaging in home or small-scale farming is often hindered by a lack of agricultural experience. Furthermore, medium and small-scale farming operations struggle with production efficiency due to limited access to affordable precision farming technologies. The excessive use of fertilizers compounds these challenges, increasing costs for farmers and introducing unwanted chemical content into food products. As a result, there is a pressing need for accessible solutions that address these issues, fostering sustainable and cost effective agricultural practices for individuals and small-scale farmers alike.

Solution

In order to address those issues according to our research we have decided to build a device. It's a compact device paired with an interactive web app designed to revolutionize farming. This device boasts advanced sensors and pre-programmed instructions to analyze soil conditions accurately. Using Bluetooth connectivity, it transmits data to the app, where it undergoes comparison with expert-validated agricultural data. Subsequently, tailored suggestions for optimal nutrient amendments are provided, specific to the plant being cultivated.

The app itself is a dynamic tool, continuously updated with insights from agricultural experts. This ensures users have access to the latest knowledge, empowering them to farm with the proficiency of seasoned experts. With its user-friendly interface, the app offers straightforward and practical advice, making farming accessible to everyone. Its interactivity fosters engagement, guiding users step-by-step toward successful cultivation. Ultimately, our goal is to fulfill the farming dreams of individuals, regardless of their prior experience, by equipping them with the tools and knowledge needed for successful and sustainable agricultural practices.

Validation

We had conducted a survey about that many individuals find it challenging to engage in home farming or small-scale farming due to their lack of experience in agriculture. Medium and small-scale farming operations still lack efficiency in production, because there no much affordable and efficient precision farming technologies to be able accessible by them. The excessive use of fertilizers imposes excessive costs on farmers and introduces unwanted chemical content into food products. It was conducted between agriculture-based peoples among that nearly 70% of people have accepted that the problem exists and worth solving with our solution.

3 Project Description

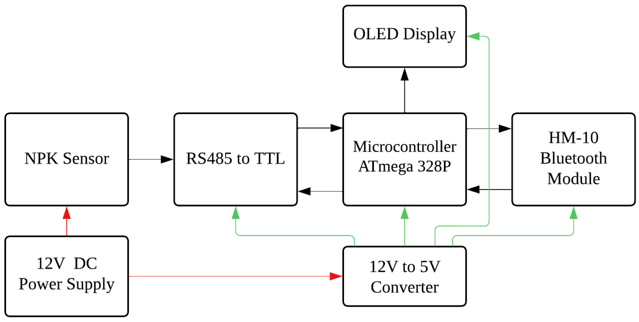

Figure 1: Device Architecture

3.1 Circuit Design

1. ATMega328p Micro Controller

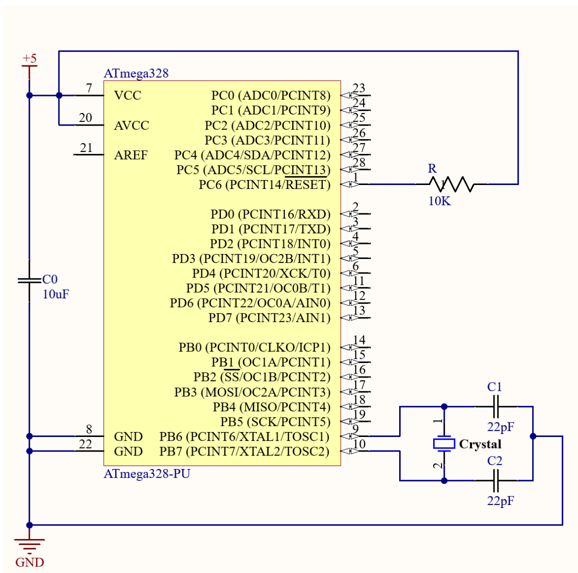

Figure 2: ATmega 328P

The ATmega328P is the 8-bit RISC heart of the Arduino Uno and Nano. It has advanced RISC architecture that allows it to achieve the most single clock cycle execution of 131 powerful instructions. It can commonly be found as a processor in Arduino boards. Due to its wide availability, low cost, and high performance with low power consumption, we are using it as the microcontroller in our device.

2. NPK Soil Sensor

The soil NPK sensor is suitable for detecting the content of nitrogen, phosphorus, and potassium in the soil and judges the fertility of the soil by detecting the conductivity transformation caused by different nitrogen, phosphorus, and potassium concentrations in the soil. Now several types of these sensors are available in the market. In our device, we are using the sensor (type RS485, V3) from manufacturer JXCT as it has good accuracy while low cost.

3. RS-485 to TTL Converter

RS-485 is a serial communication protocol that defines the physical layer and electrical interface for point-to-point communication between electrical devices. And this is the protocol used by the NPK sensor, but microcontrollers use TTL Serial Communication. To convert RS-485 to TTL, we are using this converter.

4. HM-10 Bluetooth Module

The HM-10 is a Bluetooth 4.0 module that includes Bluetooth Low Energy (BLE). It transmits over the 2.4 GHz ISM band, like traditional Bluetooth, but uses less power while still maintaining communication range. Due to its performance under low power and easy connectivity to modern devices, we are using this type of Bluetooth module. Here it's maintaining the communication between the device and web app.

5. OLED Display

A 0.96-inch OLED display is a small, monochrome display with a resolution of 128 x 64 pixels. It's also known as an organic light-emitting diode (OLED), which is a type of light emitting diode (LED) that uses organic molecules to produce light. OLED displays are thinner than LCD displays and have better brightness.

6. 12V to 5V DC-DC Converter

The 12V to 5V DC-DC converter is an essential component used to step down the voltage from 12V to a stable 5V output. This conversion is crucial when powering devices or modules that require 5V input but are connected to a 12V power source. These converters typically use switching technology, ensuring efficient power conversion with minimal heat generation. The consistent 5V output from this converter is used to power various components in the system, ensuring they operate within their specified voltage range without the risk of damage due to high voltage.

3.2 PCB Design

PCB Design

This device circuit has been designed using Altium Designer, which allows for an industry-standard PCB (Printed Circuit Board) design. In this section, we will explain some aspects of our PCB layout, such as the layout of the components used, trace width, and clearance for AC nets, and specific rules to make sure this device can be operated without any faults.

Component Placement and 3D Models

In the PCB design process, a huge amount of attention was given to the strategic placement of components to optimize, minimize noise, facilitate easy soldering, and make the smart plug as small as possible. We used Altium's new feature, the manufacturer part search section, to get the layout and 3D models for most of the components. It also ensured that the selected components are available in the market. Additionally, the Digikey website was used to obtain some footprints for some components. The 3D models allowed us to perform comprehensive mechanical checks, ensuring there was no interference with the enclosure or other components, thus making the assembling process easier.

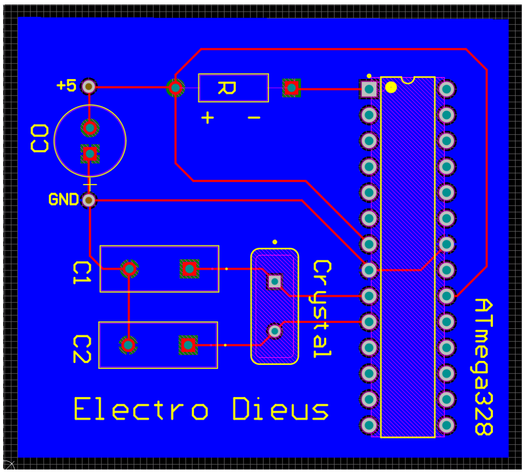

Figure 3: 2D Model

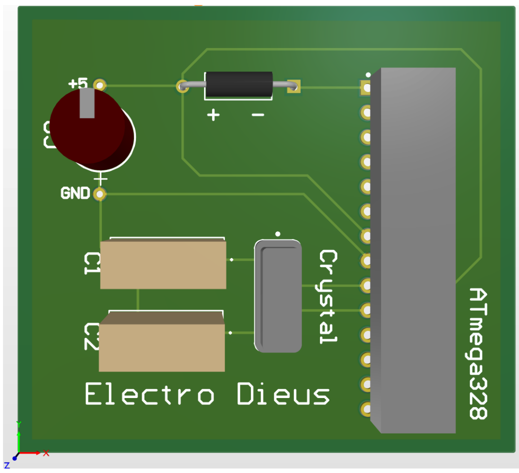

Figure 4: 3D Model

Trace width and Current Considerations

For the 5V DC traces on the PCB, we prioritized ensuring reliable power distribution while maintaining efficient use of space. To achieve this, we selected a trace width of 10 mils for the 5V DC lines. This width was chosen to balance the need for minimal resistive losses and voltage drop while optimizing the PCB layout. The 10 mils trace width is well-suited for carrying moderate current levels, ensuring stable performance without excessive heating. This approach helps maintain the integrity of the power supply across the board while maximizing the available space for other components and traces.

Issues with PCB design

We made a 2-layer PCB to mount many modules, but we really need a multi-layer PCB to handle everything properly. This is an issue because the 2-layer design doesn't provide enough space or routing options for all the connections we need.

Future Implementations

We have decided to mount the inbuilt modules directly onto the PCB, streamlining the design process and ensuring better integration of components. This approach minimizes the need for external wiring, leading to a more compact and reliable system. By embedding the modules within the PCB, you can also enhance the performance, as signal integrity is improved, and potential interference is reduced. This method facilitates easier assembly, maintenance, and potentially lowers the overall cost of production, making the design both efficient and cost-effective.

Manufacturability and JLCPCB Guidelines

Throughout the PCB design process, we remained aware of manufacturability requirements of the PCB. We referred to JLCPCB's manufacturing guidelines to ensure our design complied with their fabrication capabilities and processes. JLCPCB's rule file was import in to the "Rules" section of the Altium Designer and made necessary changes. This proactive approach enabled us to minimize manufacturing errors, reduce production time, and optimize costs.

3.3 Enclosure Design

Technology Used: 3D Printing

Material used: PLA Bioplastic

Issues with 3D Printing

When we were 3D printing the components, we encountered several issues related to dimensional accuracy and pin tolerances. One of the main problems was that the printed dimensions weren't as precise as we expected, causing faults where the pins didn't fit correctly into their slots or connectors. We realized that this could be due to various factors, such as errors in printer calibration, material shrinkage, or inaccuracies in the 3D model we used. Additionally, the tolerances we designed might not have accounted for the slight variations that naturally occur during printing. As a result, some pins were either too loose, leading to poor connections, or too tight, making assembly difficult or even causing damage to the components. This experience highlighted the importance of considering the printer's capabilities, the properties of the materials, and the need for precise tolerances right from the design phase.

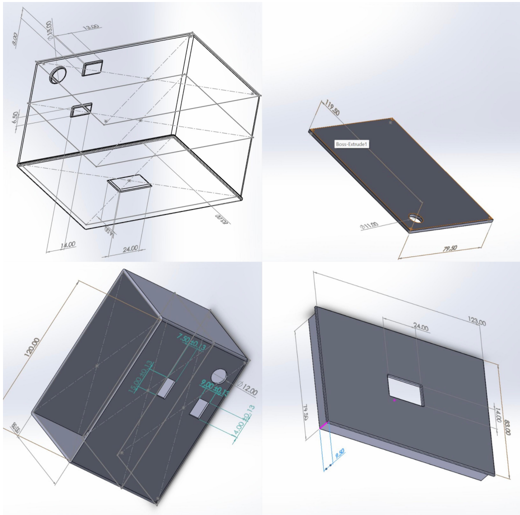

Figure 5: Enclosure of Control Unit

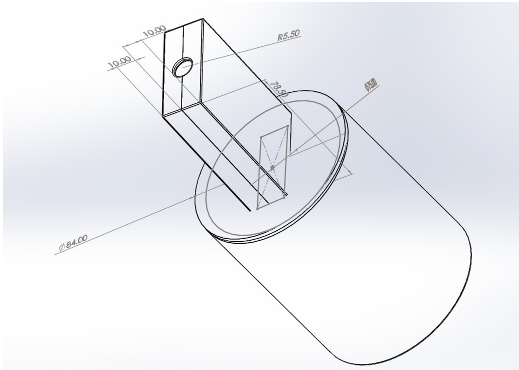

Figure 6: Enclosure of Sensor

3.4 Microcontroller Programming

The NPK sensor system's data acquisition and wireless communication are managed by the ATmega328P microcontroller, which we programmed using the Arduino IDE. This section provides an overview of the microcontroller programming process, emphasizing the utilization of libraries for sensor data handling, communication protocols, and the challenges encountered during development.

ATmega328P Development Process

The ATmega328P, a versatile microcontroller from the AVR family, served as the core of our system. We leveraged the Arduino IDE for programming, which offers a user-friendly environment and a wealth of libraries to facilitate the development process. These libraries allowed us to efficiently implement the sensor data acquisition, processing, and transmission functionalities.

Sensor Data Handling and Communication

The NPK sensor provides analog readings of soil nutrient levels, which are converted to digital values using the ATmega328P's built-in ADC (Analog-to-Digital Converter). The microcontroller processes this data and transmits it via RS485 communication. To bridge the gap between RS485 and the Bluetooth module, an RS485 to TTL converter was used. The processed data is then sent to the HM-10 Bluetooth module, which facilitates wireless communication with external devices.

Issues with Microcontroller Programming

During development, we encountered a challenge with the Bluetooth module's pairing process. If the system is already paired with a certain device, it does not allow re-pairing with a different device without a manual reset. To address this in future implementations, a code modification could be introduced to enable the reset functionality directly from the connected device, eliminating the need for manual intervention.

Future Implementation

To resolve the re-pairing issue, a code snippet could be added to allow the HM-10 Bluetooth module to reset its pairing information from the app itself. This improvement would streamline the process and enhance the user experience by removing the need for a manual reset when switching devices or networks.

3.5 Web App Architecture

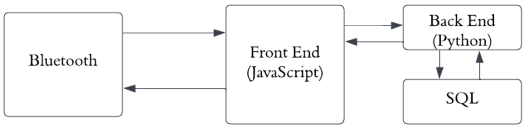

Figure 7: Website Design

Connectivity

Here we are using Bluetooth in the running device as our primary communication device.

Front End

In front end we are using JS as programming language to make our web app dynamic and we are using its web Bluetooth API to connect with our IOT device. By using JS, this app will connect with our device the using interactive buttons we can control the measuring process of the device after the measurements using Front End will send the data to backend using API call and finally show suggestion based on the result retrieved from backend.

Back End

We are using Python backend with popular Django Backend Frame Work as these are popular, we can host our web app from mostly any hosts and can easily implement advance function with latest libraries. Here we will process the API call made by front end and with the expert validated data stored in MySQL database we will make suggestion, reports and using JSON response we will send result back to front end.

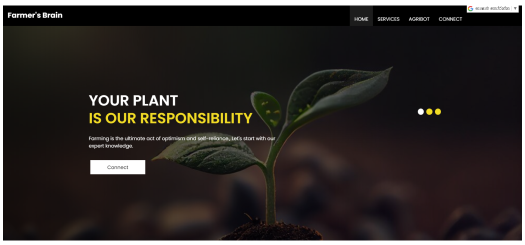

Figure 8: First Landing Page

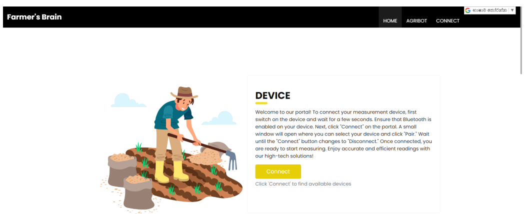

Figure 9: Device Pairing Page

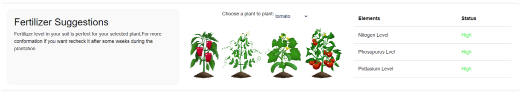

Figure 10: Suggestions

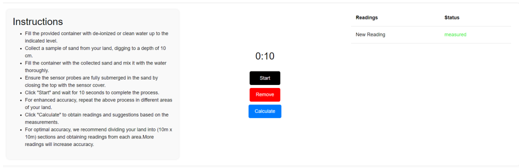

Figure 11: Instructions

4 Device Specification

4.1 Lifespan and Durability

The lifespan of the battery can be calculated using the formula:

$$\text{Lifespan (hours)} = \frac{\text{Battery Capacity (mAh)}}{\text{Current Draw (mA)}}$$

- Battery Capacity = 3500 mAh
- Current Draw = 13.8 mA

Substituting the values:

$$\text{Lifespan (hours)} = \frac{3500 \text{ mAh}}{13.8 \text{ mA}} \approx 253.62 \text{ hours}$$

Therefore, the expected lifespan of the battery under a continuous draw of 13.8mA is approximately 253.62 hours. By using 1 hr per day and considering other facts we can use this device upto 3 months without charging.It can transmit data upto 10 metres using bluetooth without interference.

4.2 Website Data Calculation

Crop : Tomato

Nitrogen Content Calculation (Urea)

Given data:

$$\begin{aligned} \text{Required urea} &= 65\,\text{kg/ha} \\ \text{Area} &= 1\,\text{ha} = 10^8\,\text{cm}^2 \\ \text{Depth} &= 30\,\text{cm} \\ \text{Soil density} &= 1.2\,\text{g/cm}^3 \\ \text{Urea nitrogen content} &= 46\% \end{aligned}$$

Soil volume:

$$V_{\text{soil}} = 10^8\,\text{cm}^2 \times 30\,\text{cm} = 3 \times 10^9\,\text{cm}^3$$

Soil mass:

$$m_{\text{soil}} = V_{\text{soil}} \times \text{density} = 3 \times 10^9\,\text{cm}^3 \times 1.2\,\text{g/cm}^3 = 3.6 \times 10^9\,\text{g}$$

Converting to kilograms:

$$m_{\text{soil}} = 3.6 \times 10^6\,\text{kg}$$

Nitrogen in urea:

$$m_{\text{N}} = 65\,\text{kg} \times 0.46 = 29.9\,\text{kg}$$

Nitrogen content in mg/kg:

$$\text{Nitrogen content} = \frac{29.9 \times 10^6\,\text{mg}}{3.6 \times 10^6\,\text{kg}} \approx 8.31\,\text{mg/kg}$$

Phosphorus Content Calculation (TSP)

Given data:

$$\text{Required TSP} = 305\,\text{kg/ha}$$
$$\text{TSP P}_2\text{O}_5\text{ content} = 45\%$$

Phosphorus content in TSP:

$$\text{Phosphorus content} = 325\,\text{kg} \times 0.45 \times \frac{62}{142} \approx 63.86\,\text{kg}$$

Phosphorus content in mg/kg:

$$\text{Phosphorus content} = \frac{63.86 \times 10^6\,\text{mg}}{3.6 \times 10^6\,\text{kg}} \approx 17.74\,\text{mg/kg}$$

Potassium Content Calculation (MOP)

Given data:

$$\text{Required MOP} = 65\,\text{kg/ha}$$
$$\text{MOP potassium content} = 60\%$$

Potassium content in MOP:

$$\text{Potassium content} = 65\,\text{kg} \times 0.60 = 39\,\text{kg}$$

Potassium content in mg/kg:

$$\text{Potassium content} = \frac{39 \times 10^6\,\text{mg}}{3.6 \times 10^6\,\text{kg}} \approx 10.83\,\text{mg/kg}$$

Using similar calculations as above, we can determine the nutrient requirements for nearly 10 other crops, focusing on the main nutrients like nitrogen, phosphorus, and potassium. Based on expert recommendations, each crop is categorized into low, medium, and high nutrient requirement levels. These levels are determined by analyzing the soil's nutrient content and comparing it with the specific needs of the crops. This approach helps ensure that the right amount of fertilizer is applied for optimal growth, minimizing waste and promoting sustainable farming practices.

5 Non-technical Issues

Since some components needed for our product, especially NPK, weren't available locally, we had to buy them from China. This led to extra costs due to shipping and taxes. However, when we order sensors in bulk, the price is lower, which helps offset some of these additional expenses.

6 Conclusion & Future Works

In the future, we aim to enhance the platform by expanding the database to include more detailed information on a wide variety of crops and introduce more sensors' input. This will allow the application to provide crop-specific recommendations based on soil nutrient data. Additionally, we plan to integrate a fully AI-powered Chat Bot that can offer real-time guidance, answer user queries, and provide personalized suggestions for optimal crop management. This Chat Bot will leverage the comprehensive crop database and advanced AI algorithms to deliver precise and context-aware advice, making the platform even more accessible and efficient for users.

7 Contribution of Group Members

Member	Contribution
Ahilakumaran T.	Mockups and Marketing resources,Solid works
Kishopan L.	Soldering, Assembling, Control Module programming
Kopithan M.	PCB Design, Simulation and Testing
Mugesram K.	Website design,Chat Bot Design

Table 1: Contribution

Appendix

1. Department of Agriculture SriLanka

2. NPK Sensor User Guide
3. ATmega328/P Microcontroller