Urban Farming: IoT Based Organic Plant Monitoring System

A project phase 1 report submitted to APJ Abdul Kalam Technological University in partial fulfilment of degree of

B.Tech.

in

Electronics and Communication Engineering

by

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KERALA

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

Certificate

*This is to certify that this report entitled "Urban Farming: IoT Based Organic Plant Monitoring System" is a bonafide record of the project presented by **Name, Reg No.RET19EC0** of seventh semester under our guidance towards the partial fulfilment of the requirements for the award of **Bachelor of Technology in Electronics & Communication Engineering** of the **APJ Abdul Kalam Technological University, Kerala** during the **academic year 2022-2023***

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RAJAGIRI SCHOOL OF ENGINEERING & TECHNOLOGY

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

Institute Vision

To evolve into a premier technological and research institution, moulding eminent professionals with creative minds, innovative ideas and sound practical skill, and to shape a future where technology works for the enrichment of mankind

Institute Mission

To impart state-of-the-art knowledge to individuals in various technological disciplines and to inculcate in them a high degree of social consciousness and human values, thereby enabling them to face the challenges of life with courage and conviction.

Department Vision

To evolve into a centre of excellence in electronics and communication engineering, moulding professionals having inquisitive,innovative and creative minds with sound practical skills who can strive for the betterment of mankind.

Department Mission

To impart state-of-the-art knowledge to students in Electronics and Communication Engineering and to inculcate in them a high degree of social consciousness and a sense of human values, thereby enabling them to face challenges with courage and conviction.

Program Educational Objectives (PEOs)

PEO 1: Graduates shall have sound knowledge of the fundamental and advanced concepts of electronics and communication engineering to analyze, design, develop and implement electronic systems or equipment.
PEO 2: Graduates shall apply their knowledge and skills in industrial, academic or research career with creativity, commitment and social consciousness
PEO 3: Graduates shall work in a team as a member or leader and adapt to the changes taking place in their field through sustained learning

Program Outcomes (POs)

Engineering Graduates will be able to:
PO 1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and Electronics and Communication Engi-

neering to the solution of complex engineering problems

PO 2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering.

PO 3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO 4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO 5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO 6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues relevant to the professional engineering practice.

PO 7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and nee for sustainable development.

PO 8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO 9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO 11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to ones own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO 12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes (PSOs)

PSO 1: Demonstrate their skills in designing, implementing and testing analogue and digital electronic circuits, including microprocessor systems, for signal processing, communication, networking, VLSI and embedded systems applications.

PSO 2: Apply their knowledge and skills to conduct experiments and develop applications using electronic design automation (EDA) tools.

PSO 3: Demonstrate a sense of professional ethics, recognize the importance of continued learning, and be able to carry out their professional and entrepreneurial responsibilities in electronics engineering field giving due consideration to environment sustainability.

Abstract

The recent seen intelligent technologies like the internet of things (IoT), facilitates different farming activities and provides flexible farm operations. Nowadays, farming has become feasible even in urban areas, especially building roofs, open gardens, and indoor agriculture. In this context, farm management and appropriate monitoring of farm parameters are now indispensable for productive farming in smart cities or rural areas. In this project, we are designing an IoT based Organic Plant Monitoring system in the context of urban farming that considers light, humidity, temperature, and soil moisture as necessary farming parameters. The proposed system decides whether the irrigation action should begin or stop depending on the farming land condition and provides the monitoring facility and remote control to the farm owner. An automatic sun protection blind is also activated corresponding to the data from light sensor. The system ascertains a feasible automatic plant monitoring system that provides advantages to the farming activities in future cities than other conventional methods.

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Chapter 1

Introduction

With population increasing in urban areas the nutritional requirements of this increasing population has to be met. People living in urban areas has very limited or no control over the supply and quality of food thus in this case organic urban farming or growing own food can be a possible solution to this problem.

Urban Agriculture contributes to enhance urban food security and nourishment of the poor class. Families that are involved in UA are exposed to better quality and variety of diet. They consume more herbs and greens than the others. Involvement in UA may also cause better mitigation of diseases as it has better nutritional and medicinal properties in homegrown medicinal plants, it causes more physical exercise, and people do not have to depend on gifts and food aid which may enhance their self-esteem. UA also increases the accessibility of fresh and affordable food for other urban consumers, as most of the food produced by urban farmers is bartered or sold locally.

With rapid worldwide population growth, there is scarcity of agricultural lands. It increases the demand for both more food and more land to grow food. But some entrepreneurs and farmers are beginning to find a solution to this problem, one of which can be found in the abandoned warehouses in our cities, in new buildings built on environmentally damaged lands, and even in used shipping containers from ocean transports. This solution is called vertical farming, which is an UA technology involving growing crops in controlled indoor environments, with precise light, nutrients, and temperatures. In vertical farming, growing plants are arranged in layers that may reach several stories high. This new farming technology is growing rapidly, and entrepreneurs in many cities are taking an interest in this innovative farming system .

An IoT based Organic plant monitoring system is thus developed to support people to effectively perform urban farming. The system is developed for vertical farming system which can be implemented in limited space.Different sensors are used to monitor the crop growth and sensor fusion is performed using the collected data. Automatic drip irrigation technique and shade release is installed within the system to take these actions when required. A camera is also installed for live surveillance of the plant growth development which helps the user for continuous monitoring. Alert messages and datas are displayed through the developed mobile application. This system is then converted into a kit which can be brought from the market by the user.

Chapter 2

Literature Survey

Agriculture sector has evolved with the emergence of the informa- tion and communication technology. Several attempts have been made to improve the crop productivity and minimize the loss by using the modern technology.

In [1], an IoT based Smart AgroTech system is proposed in the context of urban farming that considers humidity, temperature, and soil moisture as necessary farming parameters. The system's reliability is verified by determining the error percentage between actual data and observed data at different observations. The average error rate for humidity and soil moisture is below 3% and for temperature is below 1.5%.

In [2],a fuzzy based Decision Support System (DSS) to intelligently allocate water and fertilizer used in crop production based on the age of the plant and data collected from the soil and surrounding environment with the aid of a network of sensors is developed. An embedded hardware system consisting of a Cartesian robot has also been implemented to ensure effective application of the fuzzy derived decisions. Two Fuzzy Inference Systems (FIS) consisting of linear, non-linear Membership Functions and a 149-rule base for the PA system have been developed in MATLAB, implemented using Arduino microcontrollers and tested on spinach plants whereby results show that the linear FIS is able to achieve more accurate results in terms of the quality of yield realized and resource utilllisation.

The article in [3] highlights the potential of wireless sensors and IoT in agriculture, as well as the challenges expected to be faced when integrating this technology with the traditional farming practices. IoT devices and communication techniques associated with wireless sensors encountered in agriculture applications are analyzed in detail.

The paper given in [4] investigates the tools and equipment used in applications of wireless sensors in IoT agriculture, and the anticipated challenges faced when merging technology with conventional farming activities.

In [5], different input devices are synchronized by using a microcontroller system and each data, obtained from the sensors, are sent wirelessly by an (Internet of Things) IoT device to the cloud, by recording and monitoring from the graphical user interface on the web as a real-time environment to apply data mining algorithms thereafter. This study uses the regression trees to obtain the sensor data relations from 8 different data related to light, temperature, humidity, rain, soil moisture, atmospheric pressure, air quality, and dew point. Each sensor data has a different effect on the agricultural monitoring, however, reducing the number of sensors can reduce the cost of a system, by giving still accurate observations via sensor substitution proposed. Therefore, by using the regression trees, the classification of sensor data is inspected in this study. A test prototype of the hardware together with the software design is created for data monitoring and sensor fusion in different combinations. In the end, after fusion tests for all possible cases, outstanding results for each sensor substitution is presented.

Chapter 3

Methodology-phase 1

3.1 Problem Statement

To develop a self sustained real time system to monitor and support the growth of plants and to send the sensor data to a mobile app developed for observing the weather conditions.

3.2 Implementation

Data collection is the work of the sensors which is followed by the pre-processing. The sensor efficiency and sensitivity depend on the quality of the device and the physical environment (the external noises). The prototype is handled using the microcontroller-based development environment should be cleverly connected as many sensors concurrently run on the same platform. In a more application point of view, online monitoring assistant web tool, “ThingSpeak”, is used for real-time data. It provides a tunable graphical user interface especially for more graph-based scientific monitoring as it is ready to be used for the personal internet site, too. An App is developed with the help of MIT app developer tool to display the real time analysed physical quantities including graphs. It notifies the user when the parameters are not in the required range through text message. Sensor fusion is performed in order to do the most accurate decision making. Automated farming includes automatic drip irrigation and sunlight blocker(Blind) system. Here, an Led indicates the sensor fused outcome.

3.2.1 Block Diagram

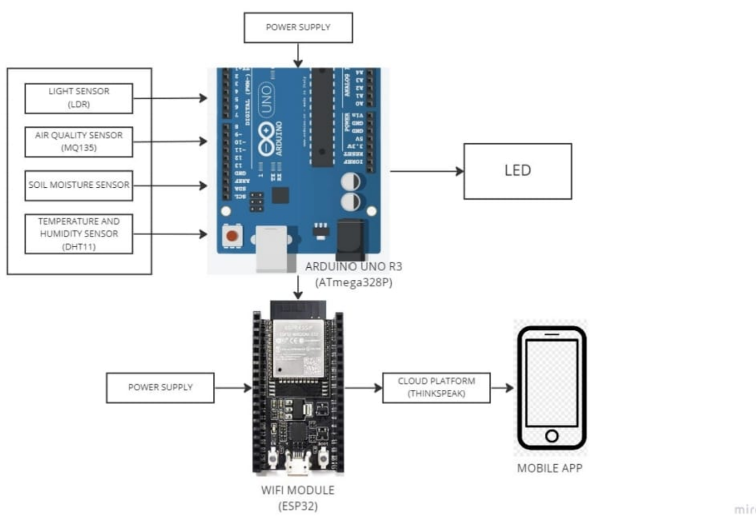

Figure 3.1: Phase 1 Block Diagram

3.2.2 Circuit Diagram

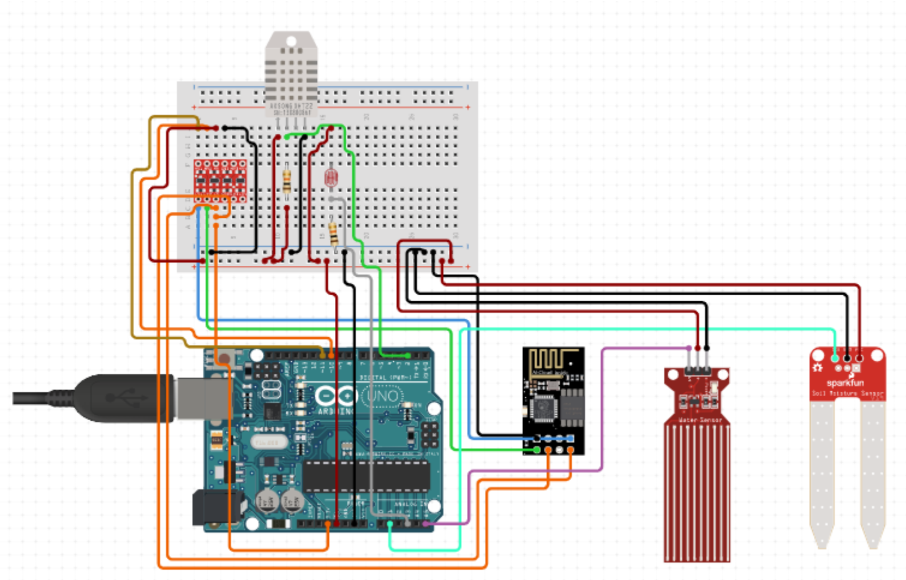

Figure 3.2: Circuit Diagram

3.2.3 Experimental Setup

The sensor data from various sensors (Light sensor,Temperature sensor,Soil moisture sensor and Humidity sensor)is collected using Arduino UNO. With the help of an IoT device ESP 32 the sensed data is uploaded onto the web environment for monitoring and further process. In that further step, the regression tree is constructed from the data of sensors by labeling the different sensor data on the leaves.This is to classify test data of a different sensor with the aid of sensor fusion on tree fitting.In the real monitoring stations, the data of the aforementioned sensors are captured via high sensitive devices that require a high amount of cost. However, for the data mining process on the decision of data regression, the prototype can be implemented easily in a cost- effective way. Less sensitive sensor data can be simultaneously compared with the data referenced from some weather monitoring internet sites to control the data correctness.Online monitoring assistant web tool, “ThingSpeak”, is used for real-time data.After obtaining the physical hardware and real-time monitoring environment, the analysis of the data, which is recorded with the comparison of reference values, is the key point scientifically analyzed.Sensor fusion is done to produce more reliable information with less uncertainty.A mobile application is created to update the user with the growing conditions in real time and to notify the user if certain actions are to be taken.

Chapter 4

Methodology-Final

4.1 Problem Statement

To develop a self sustained real time system to monitor and support the growth of plants and to send the sensor data to a mobile app developed for observing the weather conditions.

4.2 Block Diagram

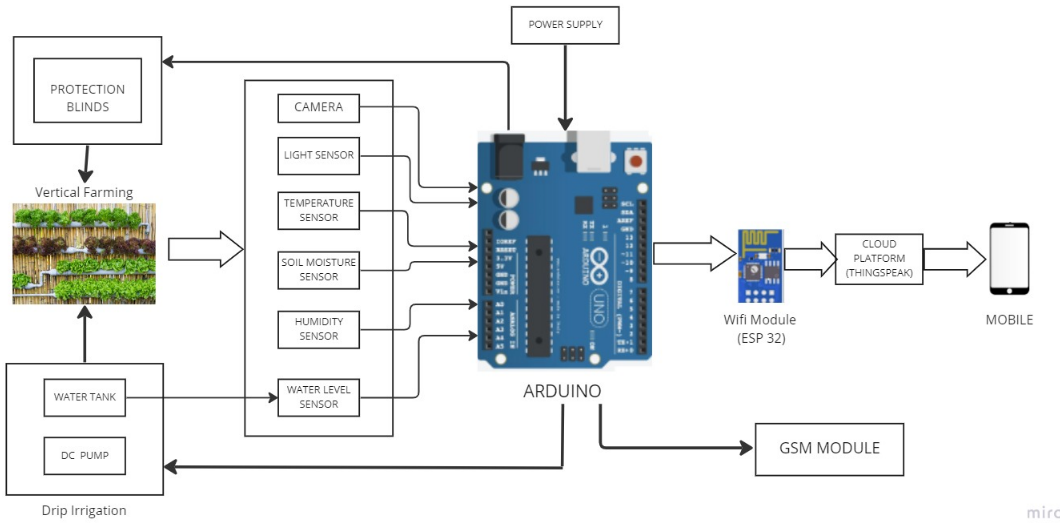

Figure 4.1: Final Block Diagram

4.3 Implementation

The sensors are interfaced with the micro-controller Arduino UNO. The Arduino Integrated Development Environment - or Arduino Software (IDE) - is used to connect to the Arduino hardware to upload programs and communicate.MIT App inventor is used to develop the mobile application that displays the real time values of the various environmental parameters.This app also displays if an automated action is initiated.

4.3.1 Circuit Diagram

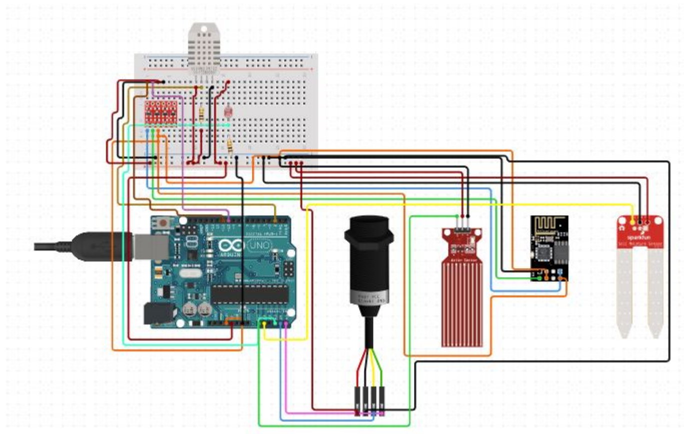

Figure 4.2: Final Circuit Diagram

4.3.2 Experimental Setup

The sensor data from various sensors (Light sensor,Temperature sensor,Soil moisture sensor and Humidity sensor)is collected using Arduino UNO.With the help of an IoT device ESP 32 the sensed data is uploaded onto the web environment for monitoring and further process. In that further step, the regression tree is constructed from the data of sensors by labeling the different sensor data on the leaves.This is to classify test data of a different sensor with the aid of sensor fusion on tree fitting.In the real monitoring stations, the data of the aforementioned sensors are captured via high sensitive devices that require a high amount of cost. However, for the data mining process on the decision of data regression, the prototype can be implemented easily in a cost- effective way. Less sensitive sensor data can be simultaneously compared with the data referenced from some weather monitoring internet sites to control the data correctness.Online monitoring assistant web tool, “ThingSpeak”, is used for real-time data.After obtaining the physical hardware and real-time monitoring environment, the analysis of the data, which is recorded with the comparison of reference values, is the key point scientifically analyzed.Sensor fusion is done to produce more reliable information with less uncertainty.A mobile application is created to update the user with the growing conditions in real time and to notify the user if certain actions are to be taken.System also has the feature of live surveillance.

Automation is also performed in this project.This includes the automatic irrigation system that takes action corresponding to the sensor fusion results from soil moisture,temperature and humidity sensors.The water level sensor monitors the water level in the tank and alerts the user if the level if low(if irrigation is not possible).Automated protection blinds are also released if the Sunlight is too bright to cause harm to the crop.The user is also informed if any of the environmental parameters exceeds the boundary set for normal conditions,through text message using GSM module.This is helpful if the user does not have access to Wi-Fi at the particular moment.

Chapter 5

Hardware and Software details

5.0.1 Hardware Details

Phase 1 of the project is implemented with the help of a set of hardware. They are as follows:

Arduino UNO R3

Arduino Uno R3 is one kind of ATmega328P based microcontroller board. It includes the whole thing required to hold up the microcontroller; just attach it to a PC with the help of a USB cable, and give the supply using AC-DC adapter or a battery to get started. This versatile microcontroller is equipped with the well-known ATmega328P and the ATMega 16U2 Processor.The Main Processor is a ATmega328P running at up tp 20 MHz. Most of its pins are connected to the external headers, however some are reserved for internal communication with the USB Bridge co-processor.The programming of an Arduino Uno R3 can be done using IDE software. The microcontroller on the board will come with pre-burned by a boot loader that permits to upload fresh code without using an exterior hardware programmer.

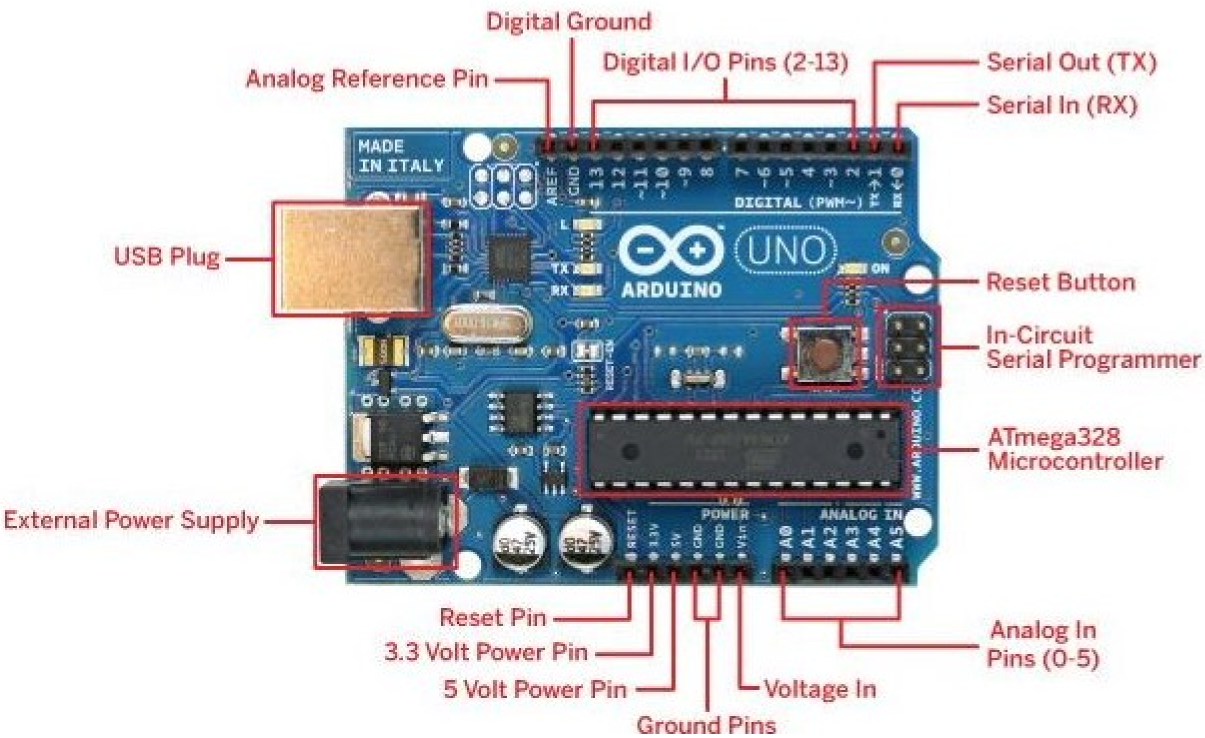

Figure 5.1: Arduino Uno Pin Diagram

Specifications

- ATMega328P Processor
- Memory

- AVR CPU at up to 16 MHz
- 32KB Flash
- 2KB SRAM
- 1KB EEPROM

- The Operating Voltage of the Arduino is 5V
- The i/p voltage (limit) is 6V to 20VPower On Reset (POR)
- Digital input and output pins-14
- Analog i/p pins are 6
- SRAM is 2KB
- The speed of the CLK is 16 MHz
- Peripherals
  - 2x 8-bit Timer/Counter with a dedicated period register and compare channels
  - 1x 16-bit Timer/Counter with a dedicated period register, input capture and compare channels
  - 1x USART with fractional baud rate generator and start-of-frame detection
  - Interrupt and wake-up on pin change

Node MCU ESP 32

With the NodeMCU-ESP32, comfortable prototyping is possible with simple programming via Luascript or the Arduino IDE and the breadboard-compatible design. This board has 2.4 GHz dual-mode Wifi and a BT wireless connection. In addition, a 512 KB SRAM and a 4MB flash memory are integrated into the microcontroller development board. The board has 21 pins for interface connection, including I2C, SPI, UART, DAC, and ADC.It is a successor to ESP8266 SoC and comes in both single-core and dual-core variations of the Tensilica's 32-bit Xtensa LX6 Microprocessor with integrated Wi-Fi and Bluetooth.It is integrated RF components like Power Amplifier, Low-Noise Receive Amplifier, Antenna Switch, Filters and RF Balun. This makes designing hardware around ESP32 very easy as very few external components is required.

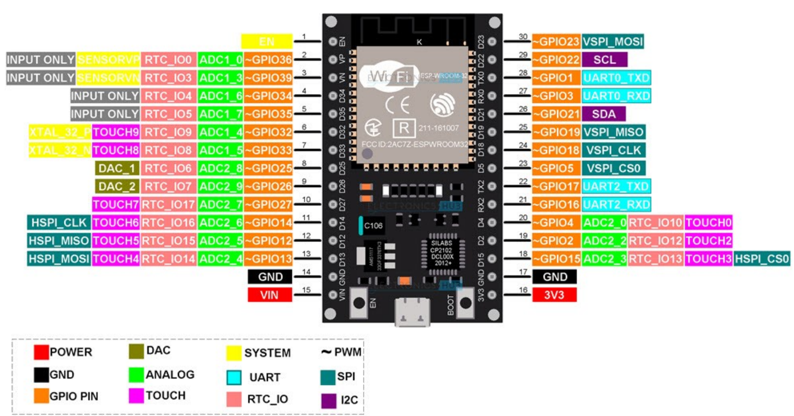

Figure 5.2: ESP32 Pin Diagram

Specifications

- Single or Dual-Core 32-bit LX6 Microprocessor with clock frequency up to 240 MHz.
- 520 KB of SRAM, 448 KB of ROM and 16 KB of RTC SRAM.
- Supports 802.11 b/g/n Wi-Fi connectivity with speeds up to 150 Mbps.
- Support for both Classic Bluetooth v4.2 and BLE specifications.
- 34 Programmable GPIOs.
- Serial Connectivity include 4 x SPI, 2 x I2C, 2 x I2S, 3 x UART.
- 1 Host controller for SD/SDIO/MMC and 1 Slave controller for SDIO/SPI.
- Motor PWM and up to 16-channels of LED PWM.
- Secure Boot and Flash Encryption.
- Cryptographic Hardware Acceleration for AES, Hash (SHA-2), RSA, ECC and RNG.

DHT11- Temperature and Humidity Sensor

The DHT-11 Digital Temperature And Humidity Sensor is a basic, ultra low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air and spits out a digital signal on the data pin (no analog input pins needed). This sensor can be easily interfaced with any micro-controller such as Arduino, Raspberry Pi to measure humidity and temperature instantaneously.

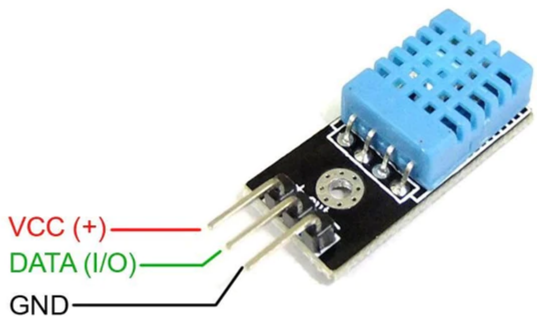

Figure 5.3: DHT11 Pinout Diagram

The humidity sensing capacitor has two electrodes with a moisture holding substrate as a dielectric between them. Change in the capacitance value occurs with the change in humidity levels. The IC measure, process this changed resistance values and change them into digital form. For measuring temperature this sensor uses a Negative Temperature coefficient thermistor, which causes a decrease in its resistance value with increase in temperature. To get larger resistance value even for the smallest change in temperature, this sensor is usually made up of semiconductor ceramics or polymers.DHT11 sensor has four pins- VCC, GND, Data Pin and a not connected pin. A pull-up resistor of 5k to 10k ohms is provided for communication between sensor and micro-controller.

LDR - Light Sensor

LDRs are tiny light-sensing devices also known as photoresistors. An LDR is a resistor whose resistance changes as the amount of light falling on it changes. The resistance of the LDR decreases with an increase in light intensity. This property allows us to use them for making light sensing circuits. For using an LDR, we always have to make a voltage divider circuit. When the value of resistance of LDR increases in comparison to the fixed resistance, the voltage across it also increases.

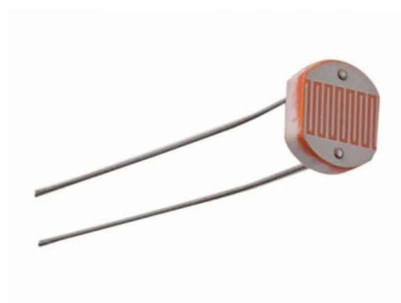

Figure 5.4: LDR Sensor

A photoresistor or light dependent resistor is an electronic component that is sensitive to light. When light falls upon it, then the resistance changes. Values of the resistance of the LDR may change over many orders of magnitude the value of the resistance falling as the level of light increases. It is not uncommon for the values of resistance of an LDR or photo-resistor to be several megohms in darkness and then to fall to a few hundred ohms in bright light. With such a wide variation in resistance, LDRs are easy to use and there are many LDR circuits available. The sensitivity of light dependent resistors or photoresistors also varies with the wavelength of the incident light.

Soil Moisture Sensor

Soil moisture sensors measure or estimate the amount of water in the soil. These sensors can be stationary or portables such as handheld probes. Stationary sensors are placed at the predetermined locations and depths in the field, whereas portable soil moisture probes can measure soil moisture at several locations. It gives a digital output of 5V when moisture level is high and 0V when the moisture level is low in the soil.

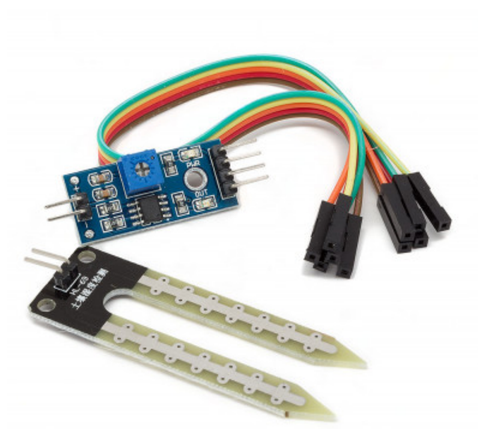

Figure 5.5: Soil Moisture Sensor

The sensor includes a potentiometer to set the desired moisture threshold. When the sensor measures more moisture than the set threshold, the digital output goes high and an LED indicates the output. When the moisture in the soil is less thatn the set threshold, the output remains low. The digital output can be connected to a micro controller to sense the moisture level. The sensor also outputs an analog output which can be connected to the ADC of a micro controller to get the exact moisture level in the soild.

5.0.2 Software Details

The software which we are using in our phase 1 project is Arduino IDE and MIT App Inventor. Detailed description about the software is given below.

Arduino IDE

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them.The ESP32 can be programmed using Arduino IDE. Before we can use the Arduino IDE with an ESP32 board we will need to add the ESP32 boards using the Arduino IDE Board Manager.

MIT App Inventor

An intuitive, visual programming environment that allows everyone to build fully functional apps for smartphones and tablets. Those new to MIT App Inventor can have a simple first app up and running in less than 30 minutes.Blocks-based tool facilitates the creation of complex, high-impact apps in significantly less time than traditional programming environments. The MIT App Inventor project seeks to democratize software development by empowering all people, especially young people, to move from technology consumption to technology creation.

Chapter 6

Results

Phase 1 of the project produced an output where the sensors have been integrated into the Arduino in which the data collection takes place. The collected data is then send into a cloud platform using a WiFi module here esp32. The data collected is then displayed in the Thingspeak platform where the data is seen as a graph. We then created an app using MIT App Inventor where all the obtained data is send in respective manner. Real time data monitoring of the selected field can be observed. Sensor fusion have been performed to obtain accurate results and it's output is used to decide whether to start drip irrigation which is indicated used led

Figure 6.1: Plots and Outputs

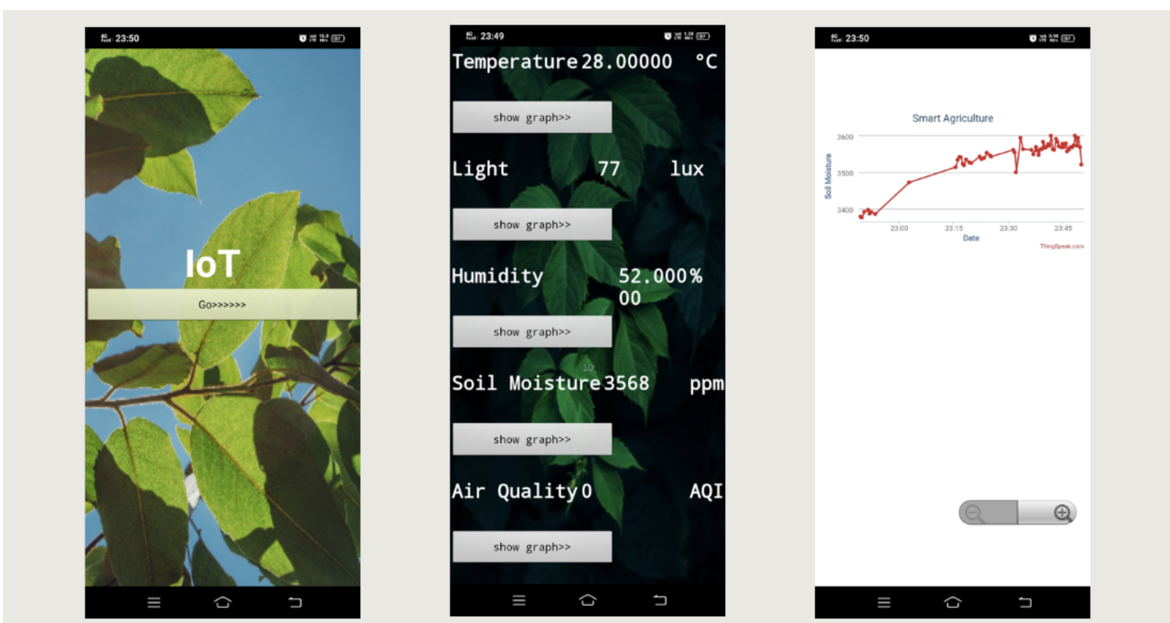

Figure 6.2: Outcome in App

Chapter 7

Conclusion & Future scope

In order to create a healthy habit among people, we have aimed at developing a marketable kit that can be used to grow vegetables within the small spaces of our houses. This idea has been thought of and we implemented the base work of what is then required to be converted to a product the basic set of sensors, real time monitoring and automation has been implemented with the selected hardware. Using a cloud platform to store all the collected data and using that information to perform sensor fusion that can produce accurate results.

The entire product can be developed as a self sustainable kit by introducing solar power supply and hence the manpower and man-hours that has to be spent in it can be reduced to minimum as just the planting of the seeds in the initial process is required as rest of the process will all be performed automatically, exceptional conditions has to be considered.

Chapter 8

Mapping CO and Project Objectives with PO-PSO

The mapping for different program outcomes, program educational objectives and program specific outcomes to the project work outcomes are shown in this chapter. **The course outcomes are as the following:**

CO 1	Be able to practice acquired knowledge within the selected area of technology for project development.
CO 2	Identify, discuss and justify the technical aspects and design aspects of the project with a systematic approach.
CO 3	Reproduce, improve and refine technical aspects for engineering projects.
CO 4	Work as a team in development of technical projects.
CO 5	Communicate and report effectively project related activities and findings.

Table 8.1: Course Outcomes.

Mapping:

The following tables shows the mapping for course outcome for PO, PEO and PSO.The mapping specifications are as follows, 1-Low, 2-Medium, 3-High

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
1	3	3	3	2	-	3
2	3	3	3	2	-	3
3	3	3	3	2	-	3
4	-	-	-	-	-	-
5	-	-	-	-	-	-

Table 8.2: Mapping of course outcome for PO1-PO6.

CO	PO 7	P0 8	PO 9	PO 10	PO 11	PO 12
1	-	-	-	-	-	2
2	-	-	-	-	3	2
3	-	-	-	-	3	2
4	-	3	-	3	3	2
5	-	3	3	3	-	2

Table 8.3: Mapping of course outcome for PO7-PO12.

CO	PSO 1	PSO 2	PSO 3
1	2	1	-
2	2	2	-
3	2	2	-
4	2	1	1
5	2	1	1

Table 8.4: Mapping of course outcome for PSO1-PSO3.

Mapping and justification of project objectives/outcomes with POs and PSOs: The table 9.5 shows the mapping of project objectives with POs and PSOs. Tables 9.6 and 9.7 shows the justification of project outcome mappings with POs and PSOs respectively.

Sl. No.	Project Objectives	POs	PSOs
1	Apply Engineering Knowledge	3	2
2	Self sustained farming	2	3
3	Healthy Society	2	3
4	Understand Modern day tools	3	2
5	Evaluate Credit and Synthesis sources	3	3

Table 8.5: Mapping of Project Objectives with POs & PSOs.

Project Outcomes	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	P0 8	PO 9	PO 10	PO 11	PO 12	Justification
Programming tool usage	1	3	2	2	1	3	1	2	2	3	1	2	Acquired skills in Arduino IDE
Applying Engineering Knowledge	2	2	3	1	3	2	1	1	2	3	1	2	Worked with Sensor fusion
Familiarized with cloud and app development	3	2	2	1	1	2	2	3	1	2	1	3	Thingspeak and MIT app inventor

Table 8.6: Justification for mapping of Project Outcomes with POs.

Project Outcomes	PSO1	PSO2	PSO3	Justification
Programming tool usage	2	2	3	Acquired skills in Arduino IDE
Applying Engineering Knowledge	1	3	3	Worked with Sensor fusion
Familiarized with cloud and app development	2	1	3	Thingspeak and MIT app inventor

Table 8.7: Justification for mapping of Project Outcomes with PSOs.

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Appendix A

Questions and Answers

1. What is the working frequency of Node MCU ESP32 ? Ans: ESP32 is a single 2.4 GHz Wi-Fi-and-Bluetooth combo chip designed with the TSMC low-power 40 nm technology.

2. How many ADC converters does Node MCU ESP32 have ? Ans: The ESP32 integrates two 12-bit SAR (Successive Approximation Register) ADCs, supporting a total of 18 measurement channels (analog enabled pins).

3. Why resistors are used while connecting LDR ? Ans: The basis of most of the LDR circuits is a potential divider, and then this can be used with various other circuit to process the voltage as required.A basic potential divider consists of two resistors in series where one end is typically connected to a fixed potential and the other to ground.

4. How many Sensors can be connected with Arduino ? Ans: A total of 7 sensors could be implemented on the Arduino UNO. When the sensor is connected correctly, a yellow LED will flash to indicate that the wire connections are correct.