Internet of Things (IoT) applied on

Smart Agriculture Solution

By:

Ahmed Osama Ibrahim (202106661)

Mohamed Mohamed Abdullah (201906897)

Laila Taher Abdelrazek (201907098)

Reham Salah Ibrahim (201906071)

A Project Graduation Document Submitted in Partial Fulfillment of the Requirements for the BSc. Degree in Electrical Engineering

(Electronics and Communication Engineering)

Faculty of Engineering, Electronics and Communication Department

Canadian International College

EL Sheikh Zayed, Egypt

2024

Internet of Things (IoT) applied on

Smart Agriculture Solution

By:

Ahmed Osama Ibrahim (202106661)

Mohamed Mohamed Abdullah (201906897)

Laila Taher Abdelrazek (201907098)

Reham Salah Ibrahim (201906071)

A Project Graduation Document Submitted in Partial Fulfillment of the Requirements for the BSc. Degree in Electrical Engineering **(Electronics and Communication Engineering)**

Under the Supervision Of

Dr. Mohammed Khalaf Ali

PhD, Assistant Professor

Department of Electronics and Communication Engineering

Faculty of Engineering, Canadian International College

Faculty of Engineering, Electronics and Communication Department

Canadian International College

EL Sheikh Zayed, Egypt

2024

Dedication

In honor of the farmers whose unwavering commitment sustains our communities, and the innovators who harness the power of IoT technology to cultivate a brighter future. Your resilience in the face of adversity and your relentless pursuit of excellence inspire us all.

To the farmers: You are the stewards of the land, tending to crops with care and diligence. Your tireless efforts feed nations and fuel progress, embodying the timeless values of hard work and dedication.

To the innovators: You are the architects of change, pioneering new solutions to age-old challenges. By integrating IoT technology into agriculture, you unlock new possibilities and redefine what is possible. Your creativity and ingenuity propel us forward, shaping a more sustainable and prosperous world.

Together, you form the backbone of our agricultural landscape, forging a path towards innovation and sustainability. May our shared endeavors continue to bridge the gap between tradition and technology, paving the way for a smarter, more resilient future.

In gratitude for your contributions, we dedicate this book to you—the farmers, the innovators, and the pioneers of tomorrow's agricultural revolution. May your legacy endure for generations to come."

This dedication celebrates both the farmers and innovators, acknowledging their essential roles in advancing agriculture and highlighting the transformative impact of IoT technology. It also emphasizes the importance of collaboration between tradition and innovation in shaping the future of agriculture.

Acknowledgement

We extend our heartfelt gratitude to all those who have contributed to the completion of this graduation book on smart agricultural solutions powered by IoT.

First and foremost, we would like to express our deepest appreciation to our esteemed faculty advisors, **Dr. Mohammed Khalaf Ali**, whose guidance, expertise, and unwavering support have been instrumental throughout this journey. Their mentorship has been invaluable, shaping our understanding of the subject matter and guiding us towards academic excellence.

We are immensely thankful to the farmers and agricultural experts who generously shared their insights, experiences, and challenges with us. Their firsthand knowledge and practical wisdom have provided invaluable context and inspiration for our research and development efforts.

We also extend our gratitude to the various organizations, industry partners, and stakeholders who collaborated with us, providing access to resources, data, and field trials. Their collaboration has enriched our project and enabled us to develop real-world solutions with meaningful impact.

Our sincere appreciation goes to our fellow classmates and colleagues who provided encouragement, feedback, and camaraderie throughout the process. Their support has been a constant source of motivation, pushing us to strive for excellence and overcome obstacles.

Last but not least, we express our deepest gratitude to our **families** and loved ones for their unwavering encouragement, understanding, and patience. Their unwavering support has been our anchor, sustaining us through the challenges and triumphs of this academic endeavor.

In conclusion, we acknowledge and appreciate the collective efforts of all individuals and entities who have contributed to the realization of this graduation book. It is through your support and collaboration that we have been able to explore, innovate, and contribute to the field of smart agriculture powered by IoT.

Thank you all for being part of this journey.

Table of Content

Table of Contents

List of Figures

Abstract

The agricultural sector is increasingly turning to IoT (Internet of Things) technology to address challenges such as climate variability, resource scarcity, and the need for improved productivity. This graduation project presents a comprehensive smart agriculture solution harnessing the power of IoT technology, specifically utilizing Raspberry Pi 3 as a gateway device and cloud infrastructure for data management and analysis.

The proposed system integrates a network of IoT sensors deployed across agricultural fields to monitor critical environmental parameters in real-time. These sensors measure variables such as temperature, humidity, soil moisture, and light intensity, providing farmers with valuable insights into the conditions affecting crop growth and health.

Raspberry Pi 3 serves as the central hub for data aggregation, processing, and control within the IoT ecosystem. Through custom-developed software applications, Raspberry Pi 3 communicates with the deployed sensors, collects data streams, and executes control algorithms to optimize agricultural practices.

Cloud computing infrastructure is leveraged to store, analyze, and visualize the vast amount of data generated by the IoT sensors. Cloud-based analytics enable farmers to gain deeper insights into trends, patterns, and anomalies, facilitating data-driven decision-making and proactive management of agricultural resources.

Key functionalities of the smart agriculture solution include predictive analytics for early detection of crop diseases, automated irrigation systems based on soil moisture thresholds, and remote monitoring and control of agricultural operations via web and mobile interfaces.

Implementation of the project involves hardware setup, sensor integration, software development, and cloud configuration, culminating in a comprehensive IoT-enabled ecosystem tailored for smart agriculture applications. Real-world validation studies demonstrate the efficacy of the solution in improving crop yield, resource efficiency, and operational convenience.

CHAPTER 1: INTRODUCTION

1.1 OVERVIEW

This project involves setting up a Raspberry Pi 3 Model B+ with multiple sensors to gather data, which is then sent to the Blynk IoT platform for real-time monitoring and control. A 12V DC water pump is controlled through a relay, and power is supplied by a combination of a power bank and a solar cell.

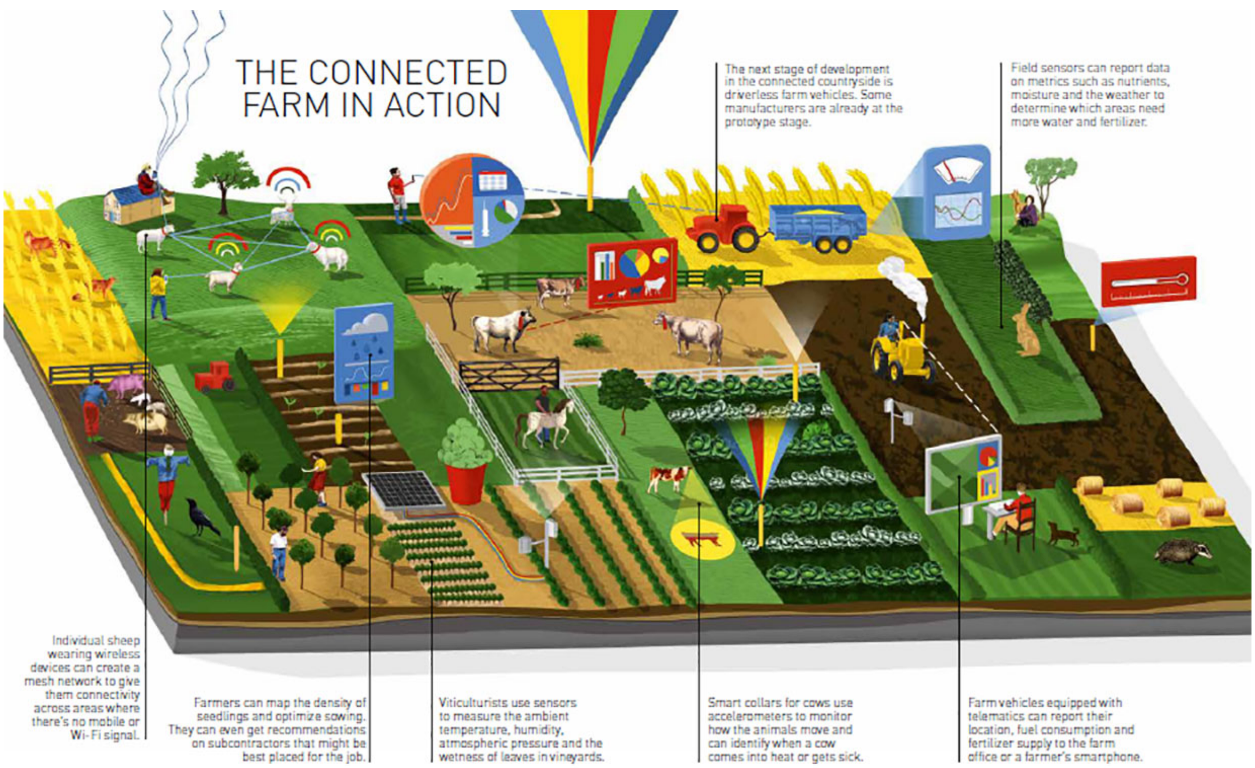

Figure 1 OverView System Design in Farm

1.1.1 OBJECTIVE

Data Collection: Gather real-time data on environmental conditions using various sensors.

Real-Time Monitoring: Send sensor data to the Blynk IoT platform for monitoring and visualization.

Automated Irrigation: Control a 12V DC water pump based on soil moisture levels.

Power Management: Utilize a solar cell and power bank to ensure uninterrupted operation of the system.

1.1.2 KEY FEATURES

Temperature and Humidity Monitoring: Measure and report temperature and humidity using the DHT11 sensor.

Soil Moisture Detection: Monitor soil moisture levels to determine irrigation needs.

Rain Detection: Use a rain sensor to detect precipitation and adjust irrigation accordingly.

Light Detection: Measure ambient light levels with an LDR sensor.

Motion Detection: Detect motion with a PIR sensor and trigger a buzzer for security.

Remote Control and Alerts: Use the Blynk IoT platform to remotely monitor conditions and control the water pump.

1.1.3 SYSTEM WORKFLOW

Sensor Data Collection: Sensors connected to the Raspberry Pi collect environmental data.

Data Processing and Transmission: The Raspberry Pi processes the data and sends it to the Blynk IoT platform.

Real-Time Monitoring: Users monitor real-time data through the Blynk app.

Automated Actions: Based on the sensor data, the system automatically controls the water pump for irrigation.

Power Supply Management: The system is powered by a combination of a power bank and a solar cell to ensure continuous operation.

Benefits

Efficient Water Usage: Automated irrigation ensures water is used only when needed.

Real-Time Monitoring: Provides farmers with real-time insights into environmental conditions.

Remote Access: Allows for remote monitoring and control, reducing the need for physical presence.

Sustainability: Utilizes solar energy to reduce reliance on conventional power sources.

This IoT-based smart agriculture solution aims to enhance farming efficiency by leveraging technology for better resource management and real-time monitoring.

1.2 INTRODUCTION

The agricultural sector plays a pivotal role in sustaining human life, providing food, fiber, and fuel for billions of people worldwide. However, agriculture faces numerous challenges, including climate change, resource depletion, population growth, and shifting consumer demands. In order to address these challenges and ensure the long-term viability of agriculture, innovative solutions are needed to optimize resource utilization, enhance productivity, and mitigate environmental impact.

In recent years, there has been a growing interest in leveraging IoT (Internet of Things) technology to revolutionize agriculture. IoT offers the potential to transform traditional farming practices by enabling real-time monitoring, data-driven decision-making, and automation of agricultural processes. By deploying a network of interconnected sensors, actuators, and devices across agricultural landscapes, IoT enables farmers to gather valuable insights into crop conditions, soil health, weather patterns, and more.

This graduation project focuses on the development and implementation of a smart agriculture solution powered by IoT technology. Specifically, the project leverages the capabilities of Raspberry Pi 3 as a gateway device and cloud infrastructure for data management and analysis.

The integration of IoT sensors, coupled with advanced analytics and control algorithms, enables farmers to optimize crop production, reduce resource usage, and respond effectively to environmental challenges.

1.2.1 THE OBJECTIVES OF THIS PROJECT ARE THREEFOLD:

- To design and implement a comprehensive IoT ecosystem for smart agriculture, incorporating sensors for monitoring environmental parameters, Raspberry Pi 3 for data processing and control, and cloud infrastructure for data storage and analysis.
- To develop software applications and algorithms for real-time data collection, analysis, and decision-making, enabling farmers to gain actionable insights into crop conditions and agricultural operations.
- To evaluate the performance, reliability, and effectiveness of the smart agriculture solution through real-world validation studies in agricultural settings, assessing its impact on crop yield, resource efficiency, and operational convenience.

By harnessing the power of IoT technology, this project aims to empower farmers with the tools and knowledge needed to optimize agricultural practices, increase productivity, and ensure the sustainability of food production systems. Through innovation and collaboration, we strive to create a smarter, more resilient agricultural future for generations to come.

1.3 HISTORY

1.3.1 EARLY AGRICULTURE:

The history of agriculture dates back to the dawn of human civilization, with early humans transitioning from nomadic hunter-gatherer lifestyles to settled agricultural communities around 10,000 years ago. Early agricultural practices were labor-intensive and relied on manual cultivation techniques, primitive tools, and traditional knowledge passed down through generations.

1.3.2 MECHANIZATION AND INDUSTRIALIZATION:

The 18th and 19th centuries witnessed the advent of mechanization and industrialization in agriculture, marking a significant shift in farming practices. Steam-powered machinery revolutionized agricultural production, enabling farmers to increase efficiency and productivity. The introduction of innovations such as the mechanical reaper, seed drill, and threshing machine transformed the way crops were planted, harvested, and processed.

1.3.3 INTRODUCTION OF PRECISION AGRICULTURE:

The concept of precision agriculture emerged in the late 20th century as technological advancements paved the way for more data-driven and site-specific farming practices. Precision agriculture aimed to optimize inputs, minimize waste, and maximize yields by utilizing technologies such as GPS, GIS, and remote sensing. Early applications of precision agriculture focused on variable rate application of inputs, soil mapping, and yield monitoring to improve resource management and crop performance.

1.3.4 INTEGRATION OF IOT TECHNOLOGY:

The integration of IoT technology represents the latest phase in the evolution of smart agriculture. IoT enables the connectivity of sensors, actuators, and devices embedded in agricultural equipment, infrastructure, and ecosystems, facilitating real-time monitoring, data collection, and control of agricultural operations. By harnessing the power of IoT, farmers can gain valuable insights into crop conditions, soil health, weather patterns, and resource usage, enabling more informed decision-making and proactive management of agricultural resources.

1.3.5 CURRENT LANDSCAPE OF SMART AGRICULTURE:

Today, smart agriculture solutions powered by IoT technology are rapidly transforming the agricultural landscape. These solutions encompass a wide range of applications, including precision irrigation systems, sensor networks for monitoring crop health and pest infestations, autonomous drones for aerial imaging and mapping, and predictive analytics for crop forecasting and disease detection. Additionally, IoT-enabled smart farming platforms provide farmers with digital tools and decision support systems to optimize efficiency, sustainability, and profitability.

1.3.6 FUTURE DIRECTIONS:

Looking ahead, the future of smart agriculture holds great promise, driven by advancements in IoT technology, artificial intelligence, robotics, and big data analytics. Emerging trends such as precision livestock farming, vertical farming, and blockchain-based supply chain management are poised to further revolutionize the agricultural sector. By embracing innovation and collaboration, farmers and stakeholders can harness the full potential of smart agriculture to address global challenges such as food security, climate change, and sustainable development.

1.4 HISTORY IN THE MIDDELE EAST

12 thousand years ago

The Middle East's leading river systems of Euphrates and Tigris, running through today's Iran, Iraq, Kuwait, Syria, and Turkey, have been known for millennia to provide lush land, facilitating one of the first human agricultural activities more than 12 thousand years ago.

1.4.1 HISTORY OF SMART AGRICULTURE IN THE EGYPT

CAIRO – 4 December 2020: In a bid of adopting the new technology in the agriculture field in Egypt, the government started applying system of moisture sensors to regulates the irrigation and improve the crop productivity.

"Within six months, the Egyptian farmer can irrigate his land while he is staying at home via using his mobile phone," said Egyptian Minister of Irrigation Mohamed Abdel Atti during his inspection tour of the city of Al-Fayyoum on Thursday.

1.4.2 HISTORY OF SMART AGRICULTURE IN UAE

Today, there are more than 30,000 farms in the UAE, an exponential increase from around 4,000 farms in the early 1970s. The rapid development of agriculture in the UAE was seen during the 1980s, when the country started using up to 30% of its food requirements.

It's Important to note that the UAE has an arid climate characterized by high temperatures, low rainfall, lack of natural waterways and poor soil. However, these challenges have not stopped the country from making significant progress in the agricultural industry.

1.4.3 HISTORY OF SMART AGRICULTURE IN JAPAN

Japan is highly developed in smart-farming-related areas, such as drones and robotics, and has adopted a variety of cutting-edge digital technologies since 2019 (Agriculture, Forestry and Fisheries Research Council 2022). To address the severe challenges of labor shortages, an aging society, and a lack of successors to undertake on agricultural work, the Japanese government has been compelled to promote agricultural policy reforms and increase investment for fostering the development of smart agriculture.

1.4.4 HISTORY OF SMART AGRICULTURE IN TURKEY

In the last 10 years Turkey took place many digitization moves.

The year 2020 is defined the year of digital agriculture. THE TECHNOLOGY ERA IN TURKISH AGRICULTURE has undergone a radical transformation in the last 50 years. Advances in machinery have expanded the scale, speed, and productivity of agricultural equipment, allowing for more land to be farmed more efficiently. Seeds, irrigation, and fertilizers have also greatly improved, helping farmers increase their yields.

1.5 RELATED WORK

abija, A.-M. (2019).

When discussing sustainability in buildings we usually refer to the Brundtland Report, to the energy consumption that has increased dramatically, to the planet's resources that are decreasing, to the wildlife that must be preserved. We take into consideration the environmental – natural and anthropic - agents, resources – human as well as materials – life service of the building etc. Less is discussed about sustainability in architectural design and detailing, although the details are the ones that, beyond paper drawings, keep the building together and ensure the expected service life and the life cycle of the building. "God is in the details"- as Mies van der Rohe stated more than 50 years ago – applies to a less spectacular side of our profession but, nevertheless, the one that contributes significantly to the character of the architectural object (if applied in buildings, of course). This paper refers to sustainable architectural concepts and details and their history.[1]

Senagala, M. (2006).

The paper is an attempt to provide a comprehensive re-definition and a complex-adaptive framework for strategic understanding of smart architecture. The paper rethinks smart architecture's strategic and conceptual frameworks. A complex-adaptive and systems approach has been forwarded as an alternative. Comprehensive definition of smart architecture has been provided. Disparate yet related camps of responsive architecture, adaptive architecture, intelligent buildings, kinetic architecture have been brought under the umbrella of smart architecture. The role of users in smart architectural schemata has been explored. Examples of a few recent architectural projects have been used to illustrate the emerging directions in smart architecture.[2]

Pawar, L., Bajaj, R., Singh, J., & Yadav, V. (2019).

IoT is rebuilding and restructuring the nation with technological advancement with all sets of Pros and Cons associated with Technology. There has been much talk about 'Smart' or 'intelligent' cities these days. All around the world government organizations, administrators and technocrats are working as a team to design an intelligent city that will provide an easy and better life for the residents. Smart City Mission is an urban renewal and retrofitting program by the Government of India with the mission to develop 100 cities across the country making them citizen friendly and sustainable. This article clearly delivers a comprehensive analysis of services that a SMART City must provide in addition to a SMART city SMART Architecture. In addition, we present current challenges and propose technological solutions to the challenges. Finally, the article delivers future research perspectives in the field of IoT.[3]

Chien, S.-F., & Wang, H.-J.

We proposed a support system called the "Smart Partition System" for infill elements that integrate smart technologies according to the Open Building principles. The design requirements were collected from design practitioners. These design requirements consisted of both architectural and information subsystems. The Smart Partition System was composed of the following multiple levels of smartness: the foundation/core level with an embedded design knowledge in the support system and the utility level with a modular infill that integrates smart technologies. We constructed functional prototypes to demonstrate the feasibility of our proposed support system and some of the possibilities of the smart infill elements. Furthermore, the prototypes were evaluated by design practitioners. We compared our approach with current practices of smart building developments, and we also discussed some prospects. & 2014. Higher Education Press Limited Company. Production and hosting by Elsevier B.V. [4]

A. Mulligan, C. E., & Olsson, M. (2013).

Smart cities have rapidly become a hot topic within technology communities and promise both improved delivery of services to end users and reduced environmental impact in an era of unprecedented urbanization. Both large high-tech companies and grassroots citizen-led initiatives have begun exploring the potential of these technologies. Significant barriers remain to the successful rollout and deployment of business models outlined for smart city applications and services, however. Most of these barriers pertain to an ongoing battle between two main schools of thought for system architecture, ICT and telecommunications, proposed for data management and service creation. Both of these system architectures represent a certain type of value chain and the legacy perspective of the representative players that wish to enter the smart city arena. Smart cities services, however, utilize components of both the ICT industry and mobile telecommunications industries, and do not benefit from the current binary perspective of system architecture. The business models suggested for the development of smart cities require a long-term strategic view of system architecture evaluation. This article discusses the architectural evolution required to ensure that the rollout and deployment of smart city technologies is smooth through acknowledging and integrating the strengths of both the system architectures proposed.[5]

Bharadwaj, A. S., Rego, R., & Chowdhury, A. (2016).

The Internet of Things (IoT) is constantly evolving and is giving unique solutions to the everyday problems faced by man. “Smart City” is one such implementation aimed at improving the lifestyle of human beings. One of the major hurdles in most cities is its solid waste management, and effective management of the solid waste produced becomes an integral part of a smart city. This paper aims at providing an IoT based architectural solution to tackle the problems faced by the present solid waste management system. By providing a complete IoT based system, the process of tracking, collecting, and managing the solid waste can be easily automated and monitored efficiently. By taking the example of the solid waste management crisis of Bengaluru city, India, we have come up with the overall system architecture and protocol stack to give a IoT based solution to improve the reliability and efficiency of the system. By making use of sensors, we collect data from the garbage bins and send them to a gateway using LoRa technology. The data from various garbage bins are collected by the gateway and sent to the cloud over the Internet using the MQTT (Message Queue Telemetry Transport) protocol. The main advantage of the proposed system is the use of LoRa technology for data communication which enables long distance data transmission along with low power consumption as compared to Wi-Fi, Bluetooth or Zigbee.[6]

Rajeswari, S., Suthendran, K., & Rajakumar, K. (2017).

Nowadays, the traditional database paradigm does not have enough storage for the data produced by Internet of Things (IoT) devices leads to the need of cloud storage. These data’s are analyzed with the help of Big Data mining techniques. Cloud based big data analytics and the IoT technology performs an important role in the feasibility study of smart agriculture. Smart or precision agricultural systems are estimated to play an essential role in improving agriculture activities. Mobile device usage is very common by everyone, including the farmers. In that, in the daily life of farmers the Information and Communication Technologies (ICT) play a vital role to get the agricultural Information. The IoT has various applications in Digital Agriculture domain like monitoring the crop growth, selection of the fertilizer, irrigation decision support system, etc. In this paper, IoT device is used to sense the agricultural data and it is stored into the Cloud database. Cloud based Big data analysis is used to analyze the data viz. fertilizer requirements, analysis the crops, market and stock requirements for the crop. Then the prediction is performed based on data mining technique which information reaches the farmer via mobile app. Our ultimate aim is to increase the crop production and control the agricultural cost of the products using this predicted information[7]

Hidayat, T., Mahardiko, R., & D, S. T. F. (2020).

Lately, utilization of Wireless Sensor Network (WSN) technology is increasing and widely applied in various fields. WSN is currently applied for Internet of Things (IoT)- based agriculture. An example of WSN technology is ZigBee. ZigBee provides irrigation control, climate monitoring and food chain control systems. To support all mentioned systems, ZigBee's IoT supports communication among available sensors. By having communication, ZigBee is expected to improve productivity and predict agriculture problem. The paper will use Systematic Literature Review (SLR) to give an overview that IoT has potential for agriculture. This is because IoT can help every farmer during operational on food and livestock production.[8]

Rettore de Araujo Zanella, A., da Silva, E., & Pessoa Albini, L. C. (2020).

Smart agriculture integrates a set of technologies, devices, protocols, and computational paradigms to improve agricultural processes. Big data, artificial intelligence, cloud, and edge computing provide capabilities and solutions to keep, store, and analyze the massive data generated by components. However, smart agriculture is still emerging and has a low level of security features. Future solutions will demand data availability and accuracy as key points to help farmers, and security is crucial to building robust and efficient systems. Since smart agriculture comprises a wide variety and quantity of resources, security addresses issues such as compatibility, constrained resources, and massive data. Conventional protection schemes used in the traditional Internet or

Internet of Things may not be useful for agricultural systems, creating extra demands and opportunities. This paper aims at reviewing the state-of-the art of smart agriculture security, particularly in open-field agriculture, discussing its architecture, describing security issues, presenting the major challenges and future directions.[9]

Lakhwani, K., Gianey, H., Agarwal, N., & Gupta, S. (2018).

The Internet of Things is the hot point in the Internet field. The concepts help to interconnect physical objects equipped with sensing, actuating, computing power and thus lends them the capability to collaborate on a task in unison remaining connected to the Internet termed as the "Internet of things" IoT. With the help of sensor, actuators and embedded microcontrollers the notion of smart object is realized. Wherein these smart objects collect data from the environment of development, process them, and initiate suitable actions. Thus, the Internet of things will bring hitherto unimaginable benefits and helps humans in leading a smart and luxurious life. Because of the potential applications of IoT (Internet of Things), it has turned out to be a prominent subject of scientific research. The importance and the application of these technologies are in sizzling discussion and research, but on the field of agriculture and forestry, it is quite less. Thus, in this paper, applications of IoT on agriculture and forestry has been studied and analyzed, also this paper concisely introduced the technology IoT, agriculture IoT, list of some potential applications domains where IoT is applicable in the agriculture sector, benefits of IoT in agriculture, and presents a review of some literature.[10]

Li, C., & Niu, B. (2020).

With the wide application of Internet of things technology and era of large data in agriculture, smart agricultural design based on Internet of things technology can efficiently realize the function of real-time data communication and information processing and improve the development of smart agriculture. In the process of analyzing and processing a large amount of planting and environmental data, how to extract effective information from these massive agricultural data, that is, how to analyze and mine the needs of these large amounts of data, is a pressing problem to be solved. According to the needs of agricultural owners, this article studies and optimizes the data storage, data processing, and data mining of large data generated in the agricultural production process, and it uses the k-means algorithm based on the maximum distance to study the data mining. The crop growth curve is simulated and compared with improved K-means algorithm and the original k-means algorithm in the experimental analysis. The experimental results show that the improved Kamen's clustering method has an average reduction of 0.23 s in total time and an average increase of 7.67% in the F metric value. The algorithm in this article can realize the functions of real-time data communication and information processing more efficiently, and has a significant role in promoting agricultural informatization and improving the level of agricultural modernization.[11]

Verdun, C., Ticonderoga, B., Beulens, A., & Wolfert, S. (2021).

Digital Twins are very promising to bring smart farming to new levels of farming productivity and sustainability. A Digital Twin is a digital equivalent of a real-life object of which it mirrors its behavior and states over its lifetime in a virtual space. Using Digital Twins as a central means for farm management enables the decoupling of physical flows from its planning and control. As a consequence, farmers can manage operations remotely based on (near) real-time digital information instead of having to rely on direct observation and manual tasks on-site. This allows them to act immediately in case of (expected) deviations and to simulate effects of interventions based on real-life data. This paper analyses how Digital Twins can advance smart farming. It defines the concept, develops a typology of different types of Digital Twins, and proposes a conceptual framework for designing and implementing Digital Twins. The framework comprises a control model based on a general systems approach and an implementation model for Digital Twin systems based on the Internet of Things—Architecture (IoT-A), a reference architecture for IoT systems. The framework is applied to and validated in five smart farming use cases of the European IoF2020 project, focusing on arable farming, dairy farming, greenhouse horticulture, organic vegetable farming and livestock farming.[12]

S. A. Tanveer, N. M. S. Sree, B. Bhavana and D. H. Varsha(2022).

Agriculture is an important sector in Indian Economy, and it plays a vital role in the life of Rural India. The current technologies used by farmers requires a lot of manpower to function and also it requires continuous monitoring. Smart Agriculture using IOT is the automated way of performing agriculture where each thing required for plants is organized automatically based on the environmental conditions. This paper presents a design of simulation of such a system which is carried ou t in a visual simulation tool called Cisco packet Tracer. The simulator supports all the components for an IOT network design and the MCU board is programmed in python language for 2 cropping seasons kharif and Rabi in which the corresponding actuator will be set and reset to provide the required climate for the high productivity of the crop irrespective of the season. The entire status of the field will be notified to the farmer through the IOT server which can be monitored remotely by the farmer through his smart phone.[13]

D, M.; , P.; R, K.; P, S.; , R(2022).

Smart farming is a development that has emphasized information and communication technology used in machinery, equipment, and sensors in network-based hi-tech farm supervision cycles. Innovative technologies, the Internet of Things (IoT), and cloud computing are anticipated to inspire growth and initiate the use of robots and artificial intelligence in farming. Such ground-breaking deviations are unsettling current agriculture approaches, while also presenting a range of challenges. This paper 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. Furthermore, this technical knowledge is helpful to growers during crop periods from sowing to harvest; and applications in both packing and transport are also investigated.[14]

Anoop E G, G. Josemin Bala.(2023).

The development of the Internet of Things (IoT) and machine learning (ML) technologies has triggered smart agricultural systems. In smart agriculture, irrigation management plays a major role to reduce water waste. The monitoring settings, hardware modules, communication technology, and storage systems used in smart irrigation systems were analyzed to determine the optimal nature of water flow. This assessment aims to give an overview of the current state of the irrigation system by taking into account weather and soil moisture. This paper provides a comprehensive review of the utilization of various hardware modules in smart irrigation systems. Moreover, various communication technologies that aid in data transfer for efficient smart irrigation are reviewed. The ML method used for prediction is also evaluated, as well as based storage technologies like the cloud and databases used to store data for predictive irrigation systems. As a result, the paper provides an overview of all the factors that contribute to irrigation systems' smart operation as well as potential future paths for improving agricultural systems through IoT.[15]

K, O. B A.A. Yousef, Yong Chai Tan, M,M. Hadi Jaber, M ,R.(2022)

Countries are working into making agriculture more sustainable by integrating different technologies to enhance its operation. Implementing improvements in irrigation systems is crucial for the water-use efficiency and works as a contributor to Sustainable Development Goals (SDGs) under the United Nations specifically Goal 6 and Target 6.4. This paper aims to highlight the contribution of SMART irrigation using Internet of Things (IoT) and sensory systems in relation to the SDGs. The study is based on a qualitative design along with focusing on secondary data collection method. Automated irrigation systems are essential for conservation of water, this improvement could have a vital role in minimizing water usage. Agriculture and farming techniques is also linked with IoT and automation, to make the whole processes much more effective and efficient. Sensory systems helped farmers better understand their crops and reduced the environmental impacts and conserve resources. Through these advanced systems effective soil and weather monitoring takes place along with efficient water management. Irrigation systems have been determined as positive contributor toward optimized irrigation systems that could enhance the use of continuous research and development which focus on enhancing the sustainable operations and cost reduction. Lastly, the challenges and benefits for the implementation of sensory based irrigation systems are discussed. This review will assist researchers and farmers to better understand irrigation techniques and provide an adequate approach would be sufficient to carry out irrigation related activities.[16]

Verdouw, C., Tekinerdogan, B., Beulens, A., & Wolfert, S. (2021).

Digital Twins are very promising to bring smart farming to new levels of farming productivity and sustainability. A Digital Twin is a digital equivalent of a real-life object of which it mirrors its behavior and states over its lifetime in a virtual space. Using Digital Twins as a central means for farm management enables the decoupling of physical flows from its planning and control. As a consequence, farmers can manage operations remotely based on (near) real-time digital information instead of having to rely on direct observation and manual tasks on-site. This allows them to act immediately in case of (expected) deviations and to simulate effects of interventions based on real-life data. This paper analyses how Digital Twins can advance smart farming. It defines the concept, develops a typology of different types of Digital Twins, and proposes a conceptual framework for designing and implementing Digital Twins. The framework comprises a control model based on a general systems approach and an implementation model for Digital Twin systems based on the Internet of Things—Architecture (IoT-A), a reference architecture for IoT systems. The framework is applied to and validated in five smart farming use cases of the European IoF2020 project, focusing on arable farming, dairy farming, greenhouse horticulture, organic vegetable farming and livestock farming.[17]

Jinyuan Xu, Baoxing Gu, Guangzhao Tian,(2022)

Agricultural Internet of Things (IoT) has brought new changes to agricultural production. It not only increases agricultural output but can also effectively improve the quality of agricultural products, reduce labor costs, increase farmers' income, and truly realize agricultural modernization and intelligence. This paper systematically summarizes the research status of agricultural IoT. Firstly, the current situation of agricultural IoT is illustrated and its system architecture is summarized. Then, the five key technologies of agricultural IoT are discussed in detail. Next, applications of agricultural IoT in five representative fields are introduced. Finally, the problems existing in agricultural IoT are analyzed and a forecast is given of the future development of agricultural IoT.[18]

Filev Maia R, Ballester Lurbe C, Agrahari Baniya A, Hornbuckle J. IRRISENS(2020).

Research has shown the multitude of applications that Internet of Things (IoT), cloud computing, and forecast technologies present in every sector. In agriculture, one application is the monitoring of factors that influence crop development to assist in making crop management decisions. Research on the application of such technologies in agriculture has been mainly conducted at small experimental sites or under controlled conditions. This research has provided relevant insights and guidelines for the use of different types of sensors, application of a multitude of algorithms to forecast relevant parameters as well as architectural approaches of IoT platforms. However, research on the implementation of IoT platforms at the commercial scale is needed to identify platform requirements to properly function under such conditions. This article evaluates an IoT platform (IRRISENS) based on fully replicable microservices used to sense soil, crop, and atmosphere parameters, interact with third-party cloud services for scheduling irrigation and, potentially, control irrigation automatically. The proposed IoT platform was evaluated during one growing season at four commercial-scale farms on two broadacre irrigated crops with very different water management requirements (rice and cotton). Five main requirements for IoT platforms to be used in agriculture at commercial scale were identified from implementing IRRISENS as an irrigation support tool for rice and cotton production: scalability, flexibility, heterogeneity, robustness to failure, and security. The platform addressed all these requirements. The results showed that the microservice-based approach used is robust against both intermittent and critical failures in the field that could occur in any of the monitored sites. Further, processing or storage overload caused by datalogger malfunctioning or other reasons at one farm did not affect the platform's performance. The platform was able to deal with different types of data heterogeneity. Since there are no shared microservices among farms, the IoT platform proposed here also provides data isolation, maintaining data confidentiality for each user, which is relevant in a commercial farm scenario.[19]

Tanha Talaviya, Dhara Shah, Nivedita Patel, Hiteshri Yagnik, Manan Shah,(2020).

Agriculture plays a significant role in the economic sector. The automation in agriculture is the main concern and the emerging subject across the world. The population is increasing tremendously and with this increase the demand of food and employment is also increasing. The traditional methods which were used by the farmers, were not sufficient enough to fulfill these requirements. Thus, new automated methods were introduced. These new methods satisfied the food requirements and also provided employment opportunities to billions of people. Artificial Intelligence in agriculture has brought an agriculture revolution. This technology has protected the crop yield from various factors like the climate changes, population growth, employment issues and the food security problems. This main concern of this paper is to audit the various applications of Artificial intelligence in agriculture such as for irrigation, weeding, spraying with the help of sensors and o t in a visual simulation tool called Cisco packet Tracer. The simulator supports all the components for an IOT network design and the MCU board is programmed in python language for 2 cropping seasons kharif and Rabi in which the corresponding actuator will be set and reset to provide the required climate for the high productivity of the crop irrespective of the season. The entire status of the field will be notified to the farmer through the IOT server which can be monitored remotely by the farmer through his smart phone.[13]

D, M.;, P.; R, K.; P, S.; , R(2022).

Smart farming is a development that has emphasized information and communication technology used in machinery, equipment, and sensors in network-based hi-tech farm supervision cycles. Innovative technologies, the Internet of Things (IoT), and cloud computing are anticipated to inspire growth and initiate the use of robots and artificial intelligence in farming. Such ground-breaking deviations are unsettling current agriculture approaches, while also presenting a range of challenges. This paper 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. Furthermore, this technical knowledge is helpful to growers during crop periods from sowing to harvest; and applications in both packing and transport are also investigated.[14]

Anoop E G, G. Josemin Bala.(2023).

The development of the Internet of Things (IoT) and machine learning (ML) technologies has triggered smart agricultural systems. In smart agriculture, irrigation management plays a major role to reduce water waste. The monitoring settings, hardware modules, communication technology, and storage systems used in smart irrigation systems were analyzed to determine the optimal nature of water flow. This assessment aims to give an overview of the current state of the irrigation system by taking into account weather and soil moisture. This paper provides a comprehensive review of the utilization of various hardware modules in smart irrigation systems. Moreover, various communication technologies that aid in data transfer for efficient smart irrigation are reviewed. The ML method used for prediction is also evaluated, as well as based storage technologies like the cloud and databases used to store data for predictive irrigation systems. As a result, the paper provides an overview of all the factors that contribute to irrigation systems' smart operation as well as potential future paths for improving agricultural systems through IoT.[15]

K, O. B A.A. Yousef, Yong Chai Tan, M,M. Hadi Jaber, M ,R.(2022)

Countries are working into making agriculture more sustainable by integrating different technologies to enhance its operation. Implementing improvements in irrigation systems is crucial for the water-use efficiency and works as a contributor to Sustainable Development Goals (SDGs) under the United Nations specifically Goal 6 and Target 6.4. This paper aims to highlight the contribution of SMART irrigation using Internet of Things (IoT) and sensory systems in relation to the SDGs. The study is based on a qualitative design along with focusing on secondary data collection method. Automated irrigation systems are essential for conservation of water, this improvement could have a vital role in minimizing water usage. Agriculture and farming techniques is also linked with IoT and automation, to make the whole processes much more effective and efficient. Sensory systems helped farmers better understand their crops and reduced the environmental impacts and conserve resources. Through these advanced systems effective soil and weather monitoring takes place along with efficient water management. Irrigation systems have been determined as positive contributor toward optimized irrigation systems that could enhance the use of continuous research and development which focus on enhancing the sustainable operations and cost reduction. Lastly, the challenges and benefits for the implementation of sensory based irrigation systems are discussed. This review will assist researchers and farmers to better understand irrigation techniques and provide an adequate approach would be sufficient to carry out irrigation related activities.[16]

Verdouw, C., Tekinerdogan, B., Beulens, A., & Wolfert, S. (2021).

Digital Twins are very promising to bring smart farming to new levels of farming productivity and sustainability. A Digital Twin is a digital equivalent of a real-life object of which it mirrors its behaviour and states over its lifetime in a virtual space. Using Digital Twins as a central means for farm management enables the decoupling of physical flows from its planning and control. As a consequence, farmers can manage operations remotely based on (near) real-time digital information instead of having to rely on direct observation and manual tasks on-site. This allows them to act im mediately in case of (expected) deviations and to simulate effects of interventions based on real-life data. This paper analyses how Digital Twins can advance smart farming. It defines the concept, develops a typology of different types of Digital Twins, and proposes a conceptual framework for designing and implementing Digital Twins. The framework comprises a control model based on a general systems approach and an implementation model for Digital

Twin systems based on the Internet of Things—Architecture (IoT-A), a reference architecture for IoT systems. The framework is applied to and validated in five smart farming use cases of the European IoF2020 project, focusing on arable farming, dairy farming, greenhouse horticulture, organic vegetable farming and livestock farming.[17]

Jinyuan Xu, Baoxing Gu, Guangzhao Tian,(2022)

Agricultural Internet of Things (IoT) has brought new changes to agricultural production. It not only increases agricultural output but can also effectively improve the quality of agricultural products, reduce labor costs, increase farmers' income, and truly realize agricultural modernization and intelligence. This paper systematically summarizes the research status of agricultural IoT. Firstly, the current situation of agricultural IoT is illustrated and its system architecture is summarized. Then, the five key technologies of agricultural IoT are discussed in detail. Next, applications of agricultural IoT in five representative fields are introduced. Finally, the problems existing in agricultural IoT are analyzed and a forecast is given of the future development of agricultural IoT.[18]

Filev Maia R, Ballester Lurbe C, Agrahari Baniya A, Hornbuckle J. IRRISENS(2020).

Research has shown the multitude of applications that Internet of Things (IoT), cloud computing, and forecast technologies present in every sector. In agriculture, one application is the monitoring of factors that influence crop development to assist in making crop management decisions. Research on the application of such technologies in agriculture has been mainly conducted at small experimental sites or under controlled conditions. This research has provided relevant insights and guidelines for the use of different types of sensors, application of a multitude of algorithms to forecast relevant parameters as well as architectural approaches of IoT platforms. However, research on the implementation of IoT platforms at the commercial scale is needed to identify platform requirements to properly function under such conditions. This article evaluates an IoT platform (IRRISENS) based on fully replicable microservices used to sense soil, crop, and atmosphere parameters, interact with third-party cloud services for scheduling irrigation and, potentially, control irrigation automatically. The proposed IoT platform was evaluated during one growing season at four commercial-scale farms on two broadacre irrigated crops with very different water management requirements (rice and cotton). Five main requirements for IoT platforms to be used in agriculture at commercial scale were identified from implementing IRRISENS as an irrigation support tool for rice and cotton production: scalability, flexibility, heterogeneity, robustness to failure, and security. The platform addressed all these requirements. The results showed that the microservice-based approach used is robust against both intermittent and critical failures in the field that could occur in any of the monitored sites. Further, processing or storage overload caused by datalogger malfunctioning or other reasons at one farm did not affect the platform's performance. The platform was able to deal with different types of data heterogeneity. Since there are no shared microservices among farms, the IoT platform proposed here also provides data isolation, maintaining data confidentiality for each user, which is relevant in a commercial farm scenario.[19]

Tanha Talaviya, Dhara Shah, Nivedita Patel, Hiteshri Yagnik, Manan Shah,(2020).

Agriculture plays a significant role in the economic sector. The automation in agriculture is the main concern and the emerging subject across the world. The population is increasing tremendously and with this increase the demand of food and employment is also increasing. The traditional methods which were used by the farmers, were not sufficient enough to fulfill these requirements. Thus, new automated methods were introduced. These new methods satisfied the food requirements and also provided employment opportunities to billions of people. Artificial Intelligence in agriculture has brought an agriculture revolution. This technology has protected the crop yield from various factors like the climate changes, population growth, employment issues and the food security problems. This main concern of this paper is to audit the various applications of Artificial intelligence in agriculture such as for irrigation, weeding, spraying with the help of sensors and o ther means embedded in robots and drones. These technologies saves the excess use of water, pesticides, herbicides, maintains the fertility of the soil, also helps in the efficient use of man power and elevate the productivity and improve the quality. This paper surveys the work of many researchers to get a brief overview about the current implementation of automation in agriculture, the weeding systems through the robots and drones. The various soil water sensing methods are discussed along with two automated weeding techniques. The implementation of drones is discussed, the various methods used by drones for spraying and crop-monitoring is also discussed in this paper.[20]

G. B. Shaik, N. Durgam and T. Bhupathi,(2022) Smart agriculture is an emerging concept, because IOT sensors are capable of providing information about agriculture fields and then act upon based on the user input. In this Paper, it is proposed to develop a Smart agriculture System that uses advantages of cutting edge technologies such as Arduino, IOT and Wireless Sensor Network. The paper aims at making use of evolving technology i.e. IOT and smart agriculture using automation. Monitoring environmental conditions is the major factor to improve yield of the efficient crops. The feature of this paper includes development of a system which can monitor temperature, humidity, moisture and even the movement of animals which may destroy the crops in agricultural field through sensors using Arduino board and in case of any discrepancy send a SMS notification as well as a notification on the application developed for the same to the farmer's smartphone using Wi-Fi/3G/4G. The system has a duplex communication link based on a cellular-Internet interface that allows for data inspection and irrigation scheduling to be programmed through an android application. Because of its energy autonomy and low cost, the system has the potential to be useful in water limited geographically isolated areas.[21]

O. Friha, M. A. Ferrag, L. Shu, L. Maglaras and X. Wang,(2021)

This paper presents a comprehensive review of emerging technologies for the internet of things (IoT)-based smart agriculture. We begin by summarizing the existing surveys and describing emergent technologies for the agricultural IoT, such as unmanned aerial vehicles, wireless technologies, open-source IoT platforms, software defined networking (SDN), network function virtualization (NFV) technologies, cloud/fog computing, and middleware platforms. We also provide a classification of IoT applications for smart agriculture into seven categories: including smart monitoring, smart water management, agrochemicals applications, disease management, smart harvesting, supply chain management, and smart agricultural practices. Moreover, we provide a taxonomy and a side-by-side comparison of the state-of-the-art methods toward supply chain management based on the blockchain technology for agricultural IoTs. Furthermore, we present real projects that use most of the aforementioned technologies, which demonstrate their great performance in the field of smart agriculture. Finally, we highlight open research challenges and discuss possible future research directions for agricultural IoTs.[22]

G. B. Shaik, N. Durgam and T. Bhupathi,(2022) The radical mutation of technology throughout the years and developments in lifestyle needed substantial improvement in divergent sectors such as houses, agriculture, health care, traffic management, and so on. Agriculture is important among these, as satisfying the increasing need for food caused by a quickly rising population is particularly challenging. Future agricultural problems include climate change, a scarcity of fertile land, insect prevention and management for increased output, and computerized monitoring of large farms. The use of a Smart Agriculture System created utilizing the new technology, Internet of Things, and Cloud storage could assist the farmers in addressing these issues. This design outperforms the conventional agricultural system idea by integrating IoT technology with cutting-edge innovations such as Temperature and Humidity sensors, Moisture sensors, and microcontrollers that continually monitor the field and detect even minute changes. Few basic issues faced by the farmer in the process of fulfilling the demand are addressed by the use of these sensors, which also help in generating a better yield, therefore, saving extra expenditures, unnecessary pesticides, and fertilizers, thus making debt less farmers who have been the backbone of developing nations for years. As a result, farmers can monitor everything using a customized software application and webpage. The fundamental goal of this concept is to use energy-efficient equipment and hence reduce energy expenses. This study proposes unique ideas such as delivering information on the growing state and farm soil qualities based on environmental conditions to enable optimal crop production. This pa per also provides a real-time prototype that has been created and implemented.[23]

Suma, N., Samson, S. R., Saranya, S., Shanmugapriya, G., & Subhashri, R. (2017).

Agriculture is the primary occupation in our country for ages. But now due to migration of people from rural to urban there is hindrance in agriculture. So to overcome this problem we go for smart agriculture techniques using IoT. This project includes various features like GPS based remote controlled monitoring, moisture & temperature sensing, intruders scaring, security, leaf wetness and proper irrigation facilities. It makes use of wireless sensor networks for noting the soil properties and environmental factors continuously. Various sensor nodes are deployed at different locations in the farm. Controlling these parameters are through any remote device or internet services and the operations are performed by interfacing sensors, Wi-Fi, camera with microcontroller. This concept is created as a product and given to the farmer's welfare.[24]

M. Pyingkodi et al.,(2022)

:The IoT is a new technology trend used in almost every area thing, when connected to the internet and to each other, when you connect to the internet or interconnect, your entire system will be smarter. We have used IoT in all areas of our lives, including smart cities, smart homes, and smart retail. Much more. From 9.6 billion by 2050, agriculture needs to deliver even faster to meet this type of demand. This is possible with the latest technology, especially the IoT. The IoT enables labor free farms. Not only can it be used for large-scale agriculture, but it can also be used for livestock, greenhouse management, and agricultural land management. The most significant tool for the IoT is the sensor. A sensor is a device that collects important data that is interpreted to obtain the required analysis. The important objective of sensors are used to determine the soil's physical qualities and the environment. The main applications of sensors are control and supervise, safety, alarm, diagnostics, and analytics. Sensors make innovative agriculture more effective and trouble-free. In agriculture, the sensor is mainly used for measuring, measuring NPK (Nitrogen, Phosphorus, Potassium) levels, and detecting disease and soil moisture content. The main solution to this problem is smart farming, which modernizes traditional farming practices. This paper narrates the role of IoT application in smart agriculture. Smart farming is also known as precision farming hence it uses accurate information to draw outcomes. It demonstrates the different sensors, applications, challenges, strengths and weaknesses that support the IoT and agriculture.[25]

Sinha, B. B., & Dhanalakshmi, R. (2022).

The Internet of Things (IoT) is an evolving paradigm that seeks to connect different smart physical components for multi-domain modernization. To automatically manage and track agricultural lands with minimal human intervention, numerous IoT-based frameworks have been introduced. This paper presents a rigorous discussion on the major components, new technologies, security issues, challenges and future trends involved in the agriculture domain. An in-depth report on recent advancements has been covered in this paper. The goal of this survey is to help potential researchers detect relevant IoT problems and, based on the application requirements, adopt suitable technologies. Furthermore, the significance of IoT and Data Analytics for smart agriculture has been highlighted.[26]

M. Ayaz, M. Ammad-Uddin, Z. Sharif, A. Mansour and E. -H. M. Aggoune,(2019) Despite the perception people may have regarding the agricultural process, the reality is that today's agriculture industry is data-centered, precise, and smarter than ever. The rapid emergence of the Internet-of-Things (IoT) based technologies redesigned almost every industry including “smart agriculture” which moved the industry from statistical to quantitative approaches. Such revolutionary changes are shaking the existing agriculture methods and creating new opportunities along a range of challenges. This article 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. What sensors are available for specific agriculture application, like soil preparation, crop status, irrigation, insect and pest detection are listed. How this technology helping the growers throughout the crop stages, from sowing until harvesting, packing and transportation is explained. Furthermore, the use of unmanned aerial vehicles for crop surveillance and other favorable applications such as optimizing crop yield is considered in this article. State-of-the-art IoT-based architectures and platforms used in agriculture are also hi ghlighted wherever suitable. Finally, based on this thorough review, we identify current and future trends of IoT in agriculture and highlight potential research challenges.[27]

Sinha, B. B., & Dhanalakshmi, R. (2022).

The Internet of Things (IoT) is an evolving paradigm that seeks to connect different smart physical components for multi-domain modernization. To automatically manage and track agricultural lands with minimal human intervention, numerous IoT-based frameworks have been introduced. This paper presents a rigorous discussion on the major components, new technologies, security issues, challenges and future trends involved in the agriculture domain. An in-depth report on recent advancements has been covered in this paper. The goal of this survey is to help potential researchers detect relevant IoT problems and, based on the application requirements, adopt suitable technologies. Furthermore, the significance of IoT and Data Analytics for smart agriculture has been highlighted.[28]

Steenwerth, K. L., Hodson, A. K., Bloom, A. J., Carter, M. R., Cattaneo, A., Chartres, C. J., … Jackson, L. E. (2014).

: Climate-smart agriculture (CSA) addresses the challenge of meeting the growing demand for food, fiber and fuel, despite the changing climate and fewer opportunities for agricultural expansion on additional lands. CSA focuses on contributing to economic development, poverty reduction and food security; maintaining and enhancing the productivity and resilience of natural and agricultural ecosystem functions, thus building natural capital; and reducing trade-offs involved in meeting these goals. Current gaps in knowledge, work within CSA, and agendas for interdisciplinary research and science-based actions identified at the 2013 Global Science Conference on Climate-Smart Agriculture (Davis, CA, USA) are described here within three themes: (1) farm and food systems, (2) landscape and regional issues and (3) institutional and policy aspects. The first two themes comprise crop physiology and genetics, mitigation and adaptation for livestock and agriculture, barriers to adoption of CSA practices, climate risk management and energy and biofuels (theme 1); and modelling adaptation and uncertainty, achieving multifunctionality, food and fishery systems, forest biodiversity and ecosystem services, rural migration from climate change and metrics (theme 2). Theme 3 comprises designing research that bridges disciplines, integrating stakeholder input to directly link science, action and governance.[29]

S. R. Prathibha, A. Hongal and M. P. Jyothi, "IOT Based Monitoring System in Smart Agriculture," 2017

Internet of Things (IoT) plays a crucial role in smart agriculture. Smart farming is an emerging concept, because IoT sensors capable of providing information about their agriculture fields. The paper aims making use of evolving technology i.e. IoT and smart agriculture using automation. Monitoring environmental factors is the major factor to improve the yield of the efficient crops. The feature of this paper includes monitoring temperature and humidity in agricultural field through sensors using CC3200 single chip. Camera is interfaced with CC3200 to capture images and send that pictures through MMS to farmers mobile using Wi-Fi.[30]

K. A. Patil and N. R. Kale, "A model for smart agriculture using IoT,(2016)

Climate changes and rainfall has been erratic over the past decade. Due to this in recent era, climate-smart methods called as smart agriculture is adopted by many Indian farmers. Smart agriculture is an automated and directed information technology implemented with the IOT

(Internet of Things). IOT is developing rapidly and widely applied in all wireless environments. In this paper, sensor technology and wireless networks integration of IOT technology has been studied and reviewed based on the actual situation of agricultural system. A combined approach with internet and wireless communications, Remote Monitoring System (RMS) is proposed. Major objective is to collect real time data of agriculture production environment that provides easy access for agricultural facilities such as alerts through Short Massaging Service (SMS) and advices on weather pattern, crops etc.[31]

S. R. Prathibha, A. Hongal and M. P. Jyothi,(2017)

Internet of Things (IoT) plays a crucial role in smart agriculture. Smart farming is an emerging concept, because IoT sensors capable of providing information about their agriculture fields. The paper aims making use of evolving technology i.e. IoT and smart agriculture using automation. Monitoring environmental factors is the major factor to improve the yield of the efficient crops. The feature of this paper includes monitoring temperature and humidity in agricultural field through sensors using CC3200 single chip. Camera is interfaced with CC3200 to capture images and send that pictures through MMS to farmers mobile using Wi-Fi.[32]

Patil, K. A., & Kale, N. R. (2016).

Climate changes and rainf all has been erratic over the past decade. Due to this in recent era, climate-smart methods called as smart agriculture is adopted by many Indian farmers. Smart agriculture is an automated and directed information technology implemented with the IOT (Internet of Things). IOT is developing rapidly and widely applied in all wireless environments. In this paper, sensor technology and wireless networks integration of IOT technology has been studied and reviewed based on the actual situation of agricultural system. A combined approach with internet and wireless communications, Remote Monitoring System (RMS) is proposed. Major objective is to collect real time data of agriculture production environment that provides easy access for agricultural facilities such as alerts through Short Massaging Service (SMS) and advices on weather pattern, crops etc.[33]

A. Sharma, A. Jain, P. Gupta and V. Chowdary, (2021) Agriculture plays a vital role in the economic growth of any country. With the increase of population, frequent changes in climatic conditions and limited resources, it becomes a challenging task to fulfil the food requirement of the present population. Precision agriculture also known as smart farming have emerged as an innovative tool to address current challenges in agricultural sustainability. The mechanism that drives this cutting edge technology is machine learning (ML). It gives the machine ability to learn without being explicitly programmed. ML together with IoT (Internet of Things) enabled farm machinery are key components of the next agriculture revolution. In this article, authors present a systematic review of ML applications in the field of agriculture. The areas that are focused are prediction of soil parameters such as organic carbon and moisture content, crop yield prediction, disease and weed detection in crops and species detection. ML with computer vision are reviewed for the classification of a different set of crop images in order to monitor the crop quality and yield assessment. This approach can be integrated for enhanced livestock production by predicting fertility patterns, diagnosing eating disorders, cattle behavior based on ML models using data collected by collar sensors, etc. Intelligent irrigation which includes drip irrigation and intelligent harvesting techniques are also reviewed that reduces human labor to a great extent. This article demonstrates how knowledge-based agriculture can improve the sustainable productivity and quality of the product.[34]

El-Basioni, B. M. M., & El-Kader, S. M. A. (2020).

The Internet of Things (IoT) relates to many billions of various applications and devices scattered around the world talk to each other and can exchange data and perform cooperative tasks without the intervention of humans. Towards efficiently realizing this, many things are needed to be achieved in advance, such as common language, basis of work and cooperation, roles distribution, resources availability, and security. Here comes the role of humans to build a reference architecture represents the common communication framework among the Internet things. There is no doubt that in order for the IoT to meet expectations, it needs to follow standardization; therefore, this paper addresses the IoT standardization by formulating the basis of an IoT reference architecture for the agriculture domain. The proposed Agricultural IoT Reference Architecture (AITRA) is based on a defined architecture generation process incorporates analysis of the IoT and the application domain ecosystems. AITRA is composed of three tiers: Device, Cloud, and Business, described in the paper including architectures, conventions, frame format, applications and services, and illustrative examples for utilizing the architecture at its highest abstraction level. The proposed design resulted in a foundation for a reference architecture combines the three main required features: best practices, common vocabulary, and reusable designs; characterized over the other architectures by its efficient low abstraction level meanwhile giving design freedom, lower time to-market, standardization in its interfaces and communication protocol. It connects to its outside world with authorization rules and at any scale: individual, company, government(s), and global levels.[35]

Liu, J.; Shu, L.; Lu, X.; Liu, Y.(2023)

In the future, agriculture will face the need for increasing production, sustainability, wisdom,

and efficiency, which will bring significant challenges to the development of modern agriculture. With the gradual popularization of 5G, advanced information technologies such as the Internet of Things and artificial intelligence promoted the evolution of modern agriculture to intelligent agriculture. The 5G-based Internet of Things will play an essential role in the development of smart agriculture. This paper investigates the research progress of 5G Internet of Things in smart agriculture. It sorts out the development s tatus of 5G smart agriculture Internet of Things in recent years. Following that, the concept of 5G smart agriculture Internet of Things is put forward. It expounds on the connotation, architecture, and enabling key technologies. According to the key application scenarios of smart agriculture, practical cases are presented, the development trend and application value of 5G smart agriculture Internet of Things are shown, and the future development direction is put forward. Firstly, the concept of smart agriculture is distinguished, and the category scenarios of smart agricultureare summarized. Following that, the current review research on 5G-IoT is analyzed. This paper focuses on the analysis and summary of the changes brought by 5G to various key scenarios in smart agriculture. This paper analyzes the related key technologies and challenges, puts forward some key scientific problems, and summarizes the research ideas. Finally, the development trend and application value of 5G smart agriculture Internet of Things are shown. The future development direction is also proposed.[36]

Quy,V.K.; Hau, N.V.; Anh, D.V.; Quy, N.M.; Ban, N.T.; Lanza, S.; Randazzo, G.; Muzirafuti, A.(2023)

The growth of the global population coupled with a decline in natural resources, farmland,

and the increase in unpredictable environmental conditions leads to food security is becoming a major concern for all nations worldwide. These problems are motivators that are driving the agricultural industry to transition to smart agriculture with the application of the Internet of Things (IoT) and big data solutions to improve operational efficiency and productivity. The IoT integrates a series of existing state-of-the-art solutions and technologies, such as wireless sensor networks, cognitive radio ad hoc networks, cloud computing, big data, and end-user applications. This study presents a survey of IoT solutions and demonstrates how IoT can be integrated into the smart agriculture sector. To achieve this objective, we discuss the vision of IoT-enabled smart agriculture ecosystems by evaluating their architecture (IoT devices, communication technologies, big data storage, and processing), their applications, and research timeline. In addition, we discuss trends and opportunities of IoT applications for smart agriculture and also indicate the open issues and challenges of IoT application in smart agriculture. We hope that the findings of this study will constitute important guidelines in research and promotion of IoT solutions aiming to improve the productivity and quality of the agriculture sector as well as facilitating the transition towards a future sustainable environment with an agroecological approach.[37]

Aqeel-ur Rehman, Zubair A. Shaikh(2009)

Use of technology in different areas to get numerous benefits is itself a valuable research. Use of Sensor network in the area of agriculture is not new. But due to the different weather, soil, water and land conditions, diverse models, methods of analysis and solutions are needed on which different communities of researchers are working and proposing several solutions. That instigates need of some different ways specifically for agriculture that can be helpful in developing solution for different conditions. Ubiquitous Computing and Context-Aware Computing are highlighting the approaches to deal with variability in conditions, situations and problems. The combination of different technologies and their application towards certain area is always been a challenging task. The combination of emerging technologies including ubiquitous computing, context-aware computing and grid computing with sensor network can be applied on agriculture domain to make the agriculture smarter. In this chapter, the concept of Smart Agriculture is described and use of different advanced technologies towards the agriculture domain is highlighted. The evolution of agriculture through the support of different advanced technologies is also presented. Some details about the development of smart agriculture prototype for irrigation control are also the part of this chapter.[38]

Nhamo, N., & Chikoye, D. (2017)

Agricultural production has stagnated in the past three decades due to a range of challenges farmers face in producing crops and livestock (Alexandratos and Bruinsma, 2012; Bajželj et al., 2014; Pandey, 2007; Steinfeld et al., 2006). Key among the challenges to smallholder agriculture are climate extremes and weather variability. These have exacerbated the extent to which the abiotic (e.g., soil degradation leading to infertile soils) and biotic (weeds, disease, and pests) constraints affect production (Balasubramanian et al., 2007; Nhamo et al., 2014; Sanchez, 2010). Climate change threatens the gains made in agriculture since the introduction of improved technologies (Funk and Brown, 2009; Schenker and Lobell, 2010; Wheeler and von Braun, 2013).[39]

Södergård, C., Mildorf, T., Habyarimana, E., Berre, A. J., Fernan des, J. A., & Zinke-Wehlmann, C. (Eds.). (2021).

The growing importance of agricultural data from sensors, which the European strategy for data addresses in the context of a growing Internet of things connected by advanced telecommunication networks, is discussed in Chaps. 3, 15 and 19. Data standards, a central concern of the European strategy, are addressed in Chaps. 2, 7, 8 and 9 as a crucial requirement for independently developed data resources and tools to come together in pipelines where different parties could bring different analytic skills to extract insights and valuable predictions from data assets. And, of course, Data Bio being a research and innovation project from the Horizon 2020 programmed, the book contains a wealth of insights on the research frontier of it all, showing cutting-edge concrete results but also pointing at how more research there still remains to do in the upcoming Horizon Europe funding programmed. It is a privilege to be able to write the introduction to a volume such as the present one, which shows in great detail how important policy directions of the European Union are often preceded by years of work of our best scientists and technology developers. These identify both opportunities and technical challenges for the benefit of the technology adopters and policy-makers who can then form better informed opinions on what is possible and what is necessary to bring the greatest collective benefits to the citizens they serve.

CHAPTER 2: PROBLEM STATEMENT

2.1 BACKGROUND:

Agriculture is a vital sector globally, providing food, fiber, and livelihoods for billions of people. However, traditional farming practices face numerous challenges, including limited access to real-time data, inefficient resource management, and vulnerability to environmental risks. In order to address these challenges and ensure the sustainability of agriculture, innovative solutions are needed to optimize farming operations, enhance productivity, and conserve resources.

2.2 PROBLEM:

Traditional farming methods often rely on manual labor, subjective decision-making, and outdated technologies, leading to inefficiencies and suboptimal outcomes. Farmers struggle to monitor crop conditions, manage irrigation effectively, and respond to changing environmental conditions in a timely manner. This lack of data-driven insights hinders their ability to maximize yields, minimize inputs, and mitigate risks, resulting in reduced profitability and environmental impact.

2.3 PROPOSED SOLUTION:

The proposed solution is to implement a smart agriculture system leveraging IoT technology to transform traditional farming practices into data-driven, precision agriculture. By deploying IoT sensors, actuators, and devices across agricultural landscapes, farmers can collect real-time data on environmental parameters such as soil moisture, temperature, humidity, and crop health. This data, combined with advanced analytics and control algorithms, enables farmers to make informed decisions, optimize resource usage, and enhance crop yields.

2.4 OBJECTIVES:

Develop a comprehensive smart agriculture system integrating IoT technology to monitor and manage key aspects of farming operations.

Deploy IoT sensors and actuators in agricultural fields, greenhouses, and irrigation systems to collect real-time data on environmental parameters and control agricultural processes.

Develop software applications and algorithms for data analysis, visualization, and decision support to assist farmers in optimizing agricultural practices.

Evaluate the performance, reliability, and effectiveness of the smart agriculture system through field trials and validation studies in diverse agricultural settings.

Assess the socio-economic and environmental impacts of adopting smart agriculture solutions, including implications for farm profitability, resource efficiency, and environmental sustainability.

2.5 SIGNIFICANCE:

The successful implementation of a smart agriculture system based on IoT technology has the potential to revolutionize the agricultural sector, making farming more efficient, sustainable, and resilient. By harnessing the power of data and technology, farmers can improve decision-making, optimize resource usage, and enhance productivity, leading to economic prosperity, environmental stewardship, and food security for future generations.

2.6 SCOPE:

The scope of this graduation project encompasses the design, development, implementation, and evaluation of a smart agriculture system based on IoT technology. The project will focus on specific crops, regions, and farming practices, considering local environmental conditions, socio-economic factors, and stakeholder needs. Additionally, the project will explore the potential for scalability, replicability, and adoption of smart agriculture solutions in diverse agricultural contexts.

2.7 CHALLENGES FACING AGRICULTURE

2.7.1 CLIMATE CHANGE

Changing weather patterns, weather extremes, and climate change-triggered droughts are among the key drivers of food insecurity. All these events have a huge impact on food production, as they significantly limit the quality, availability, and accessibility of resources, and compromise the stability of food systems around the world.

2.7.2 GROWING POPULATION:

A constantly growing global population can also have adverse effects, including the lack of water resources and added pressure on available arable land. Agriculture already accounts for 70% of all freshwater used on the planet. As the global population is estimated to exceed 9 billion by 2050, it is becoming increasingly urgent to find alternative solutions that allow feeding the world without destroying it.

2.7.3 BIODIVERSITY LOSS:

In some parts of the world, people can already feel the negative impacts of the loss of biodiversity on their lives and diets.

2.7.4 PEST AND DISEASE:

Pests and diseases can have a significant impact on crop yields .

2.7.5 LABOR SHORTAGE:

Many farmers in India are facing labor shortages as a result of immigration policies and a lack of interest in farming as a career.

2.7.6 INSUFFICIENT AGRICULTURAL LAND :

One of the major problems facing agriculture is the loss of agricultural land, because as more land is lost, it will become more difficult to produce the amount of food needed to feed the growing human population. When discussing the area of land, the term hectare is often used, and this term is a unit of area that is equivalent to 10,000 square meters, or around 2.5 acres.

2.7.7 IRRIGATION ISSUE:

One the greatest agricultural issues faced in our country is the irrigation issue. Agricultural production can be carried out depending on the weather conditions, as arid and semi-arid climate prevails throughout the country.

2.7.8 THE MATERIALS USED IN AGRICULTURE ARE EXPENSIVE:

The excessive price increase in the main production items such as fertilizers, pesticides, seeds, agricultural machines, and diesel fuel, has negative effects on the producers.

2.7.9 FAILING TO USE THE LANDS CORRECTLY :

There is an area, period, and technique which have to be used in each land. However, the lands, which must not be processed, have been allowed to use, and the productive lands, which accelerate the erosion as a result of wrong land usage, have been dragged into the seas via the rivers, or agglomerated on other lands, due to the implementation of wrong strategies in our country.

2.7.10 TECHNOLOGICAL GAP:

Not all farmers in have access to advanced technologies, such as precision agriculture, which can limit their ability to increase productivity and efficiency.

2.8 CHALLENGES FACING SMART AGRICULTURE

2.8.1 POWER MANAGEMENT:

Raspberry Pi devices can be power-hungry, especially when coupled with sensors and other peripherals. Efficient power management becomes critical, especially in remote agricultural locations where access to electricity may be limited.

2.8.2 SENSOR INTEGRATION:

Integrating various sensors (e.g., soil moisture, temperature, humidity) with the Raspberry Pi and ensuring their compatibility and accuracy can be challenging. Different sensors might require different wiring, calibration, or signal conditioning.

2.8.3 DATA TRANSMISSION AND CONNECTIVITY:

Establishing reliable communication between the Raspberry Pi and the central server or cloud platform can be challenging, particularly in rural areas with poor internet connectivity. Choosing the right communication protocol and addressing issues like packet loss or network latency is crucial.

2.8.4 DATA SECURITY:

Protecting sensitive agricultural data, such as crop information or irrigation schedules, from cyber threats is essential. Implementing robust encryption, access control mechanisms, and secure communication protocols can be complex, especially for IoT devices with limited computational resources.

2.8.5 REMOTE MONITORING AND CONTROL:

Designing a user-friendly interface for remote monitoring and control of agricultural processes poses a challenge. Ensuring real-time visibility into crop conditions and the ability to adjust parameters remotely requires careful UI/UX design and integration with the IoT platform.

2.8.6 ENVIRONMENTAL FACTORS:

Agricultural environments can be harsh, with exposure to extreme temperatures, moisture, and dust. Ensuring the ruggedness and reliability of the Raspberry Pi and associated hardware components against such environmental factors is crucial for long-term operation.

2.8.7 POWER SUPPLY RELIABILITY:

In remote agricultural settings, where power outages are common, ensuring uninterrupted power supply to the Raspberry Pi becomes crucial. Implementing backup power solutions such as solar panels or battery backups adds complexity to the system design.

2.8.8 SCALABILITY:

Designing an IoT agriculture solution that can scale to accommodate a large number of sensors or devices spread across vast agricultural areas requires careful consideration of factors like data aggregation, network topology, and computational scalability.

2.8.9 INTEGRATION WITH EXISTING SYSTEMS:

Integrating the IoT agriculture solution with existing farm management systems or equipment (e.g., irrigation systems, crop monitoring tools) can be challenging due to differences in data formats, communication protocols, or hardware interfaces.

2.8.10 REGULATORY COMPLIANCE:

Adhering to local regulations and standards governing agricultural data collection, storage, and privacy can pose challenges. Ensuring compliance with laws related to data protection, environmental monitoring, and agricultural practices adds complexity to the project.

CHAPTER 3: METHODOLOGIES

3.1 RESEARCH AND REQUIREMENT ANALYSIS

The research and requirement analysis phase of the graduation project focused on understanding the challenges faced by traditional farming practices and identifying the needs and priorities of stakeholders in the agricultural sector. Through a systematic approach, the project aimed to lay the foundation for designing and implementing an effective smart agriculture solution using Raspberry Pi 3, sensors, and cloud-based IoT technology.

The research component involved a comprehensive review of existing literature, research papers, and projects related to smart agriculture, IoT technology, and cloud computing. This provided valuable insights into the current state of the field, emerging trends, and best practices that could inform the design and development of the smart agriculture system.

Stakeholder engagement played a crucial role in gathering firsthand insights and feedback from farmers, agricultural experts, researchers, and potential end-users. Interviews, surveys, and focus group discussions were conducted to understand the challenges, pain points, and opportunities in traditional farming practices, as well as the desired features and functionalities of a smart agriculture solution.

Key challenges identified through the research and stakeholder engagement process included inefficient resource management, lack of real-time monitoring capabilities, and vulnerability to environmental risks such as weather fluctuations and pest infestations. These challenges highlighted the need for a data-driven, technology-enabled approach to agriculture that could optimize resource usage, enhance productivity, and mitigate risks.

Based on the research findings and stakeholder feedback, specific requirements for the smart agriculture system were defined. These requirements encompassed the types of sensors needed for monitoring environmental parameters such as temperature, humidity, soil moisture, and light intensity, as well as the data communication requirements between sensors, Raspberry Pi 3, and cloud-based IoT platforms.

In addition to technical requirements, the project also addressed security and privacy considerations to ensure the confidentiality, integrity, and compliance of data transmitted and stored in the cloud. This involved implementing encryption, authentication, and access control mechanisms to protect sensitive information and prevent unauthorized access or tampering.

Overall, the research and requirement analysis phase provided a solid foundation for the subsequent design, development, and implementation of the smart agriculture system. By systematically identifying challenges, gathering stakeholder input, and defining specific requirements, the project aims to address the pressing needs of the agricultural sector and pave the way for a more sustainable and technology-enabled future.

3.1.1 RASPBERRY PI 3

Choosing Raspberry Pi 3 for our smart agriculture graduation project offers several advantages. Its sufficient processing power, built-in connectivity (Wi-Fi and Bluetooth), compatibility with the Raspberry Pi ecosystem, extensive community support, availability, affordability, stability, and power efficiency make it a suitable choice. Raspberry Pi 3 provides a stable and mature platform for development while offering the necessary features for implementing smart agriculture applications.

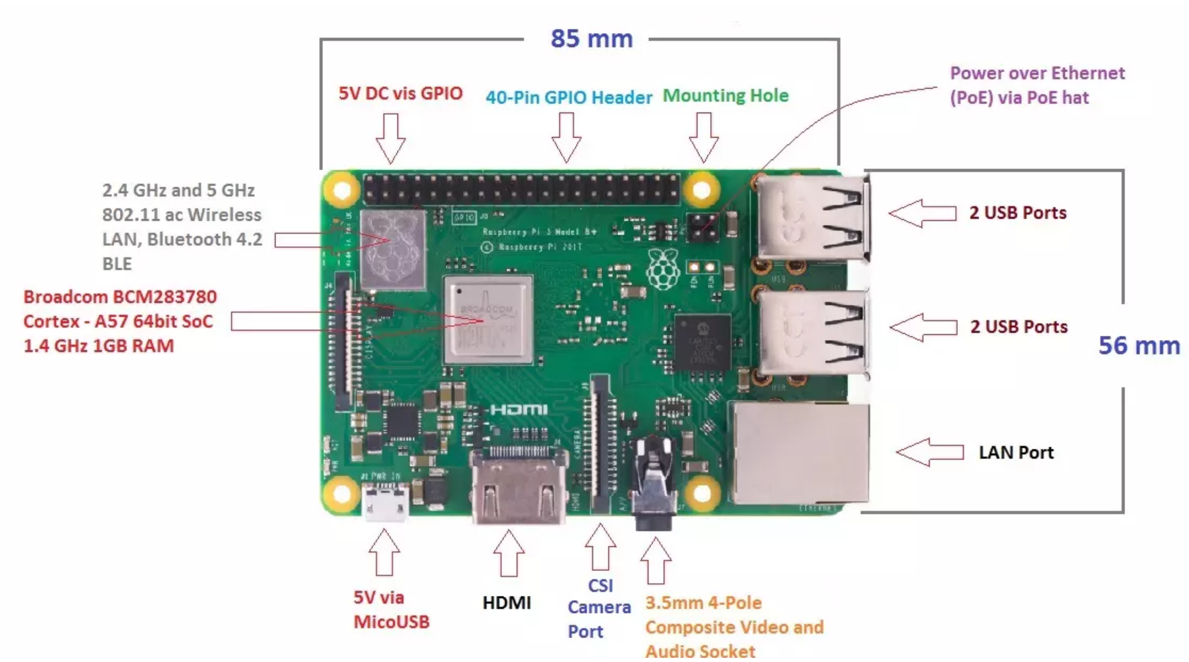

Figure 2 Raspberry pi 3 model B+ PinOut

SPECIFICATION

- Broadcom BCM2837B0, Cortex-A53 (ARMv8) 64-bit SoC @ 1.4GHz
- 1GB LPDDR2 SDRAM
- 2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN, Bluetooth 4.2, BLE
- Gigabit Ethernet over USB 2.0 (maximum throughput 300 Mbps)
- Extended 40-pin GPIO header
- Full-size HDMI®
- 4 USB 2.0 ports
- CSI camera port for connecting a Raspberry Pi camera
- DSI display port for connecting a Raspberry Pi touchscreen display
- 4-pole stereo output and composite video port
- Micro SD port for loading your operating system and storing data
- 5V/2.5A DC power input
- Power-over-Ethernet (PoE) support (requires separate PoE HAT)

GPIO

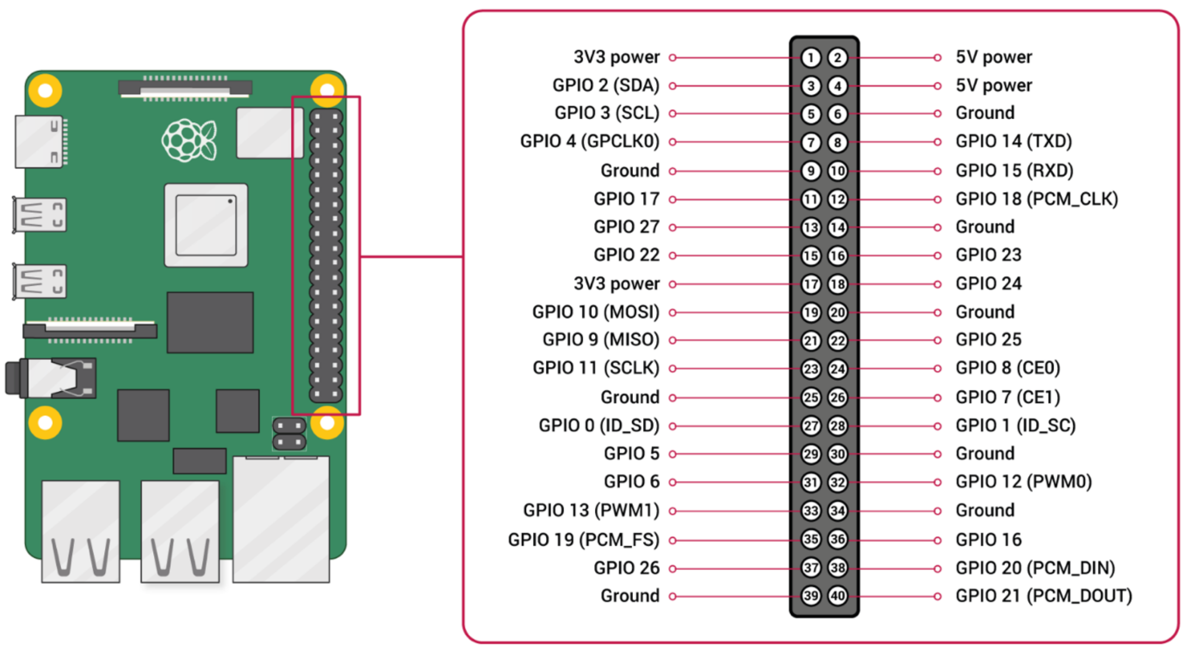

Figure 3 Raspberry pi 3 model B+ GPIO

VOLTAGES

Two 5V pins and two 3.3V pins are present on the board, as well as a number of ground pins (GND), which cannot be reconfigured. The remaining pins are all general-purpose 3.3V pins, meaning outputs are set to 3.3V and inputs are 3.3V-tolerant.

OTHER FUNCTIONS

As well as simple input and output devices, the GPIO pins can be used with a variety of alternative functions, some are available on all pins, others on specific pins.

- PWM (pulse-width modulation)

Software PWM available on all pins
Hardware PWM available on GPIO12, GPIO13, GPIO18, GPIO19

- **SPI**

SPI0: MOSI (GPIO10); MISO (GPIO9); SCLK (GPIO11); CE0 (GPIO8), CE1 (GPIO7)
SPI1: MOSI (GPIO20); MISO (GPIO19); SCLK (GPIO21); CE0 (GPIO18); CE1 (GPIO17); CE2 (GPIO16)

- **I2C**

Data: (GPIO2); Clock (GPIO3)
EEPROM Data: (GPIO0); EEPROM Clock (GPIO1)

- **Serial**

TX (GPIO14); RX (GPIO15)

3.1.2 SENSORS

3.1.2.1 TEMPERATURE AND HUMIDITY SENSOR

The DHT11 is a widely used sensor in smart agriculture applications for measuring temperature and humidity.

Specification

DHT11 Temperature Measurement Range: 0 to 50°C with an accuracy of ±2°C. Humidity Measurement Range: 20% to 90% RH with an accuracy of ±5% RH.

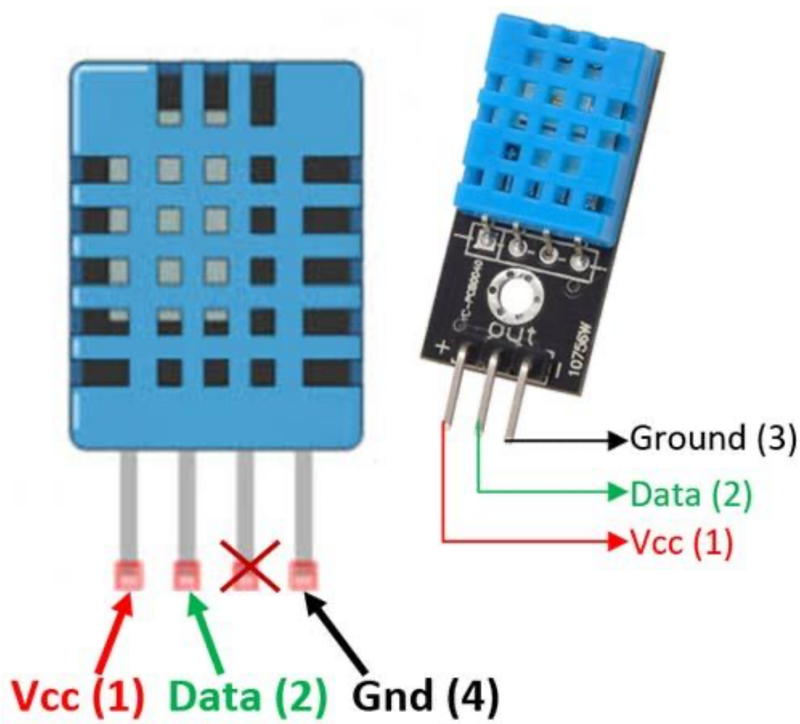

Figure 4 DHT 11 Sensor

3.1.2.2 SOIL MOISTURE SENSOR

A soil moisture sensor is a device used to measure the moisture in the soil. There are many benefits to using a soil moisture sensor. One benefit is that it can help to save water. The sensor can be used to monitor the moisture content in the soil and then the irrigation system can be adjusted accordingly. This can help to reduce the amount of water that is used and can also help to reduce the amount of water that is wasted. Another benefit of using a soil moisture sensor is that It can help to improve the health of the plants.

SPECIFICATION

Digital and Analog Outputs: Some sensors provide digital output for easy interfacing with microcontrollers, while others provide analog signals that can be read by ADCs (Analog-to-Digital Converters).

Accuracy: ±10%

Range: 0-100% (dry to fully saturated)

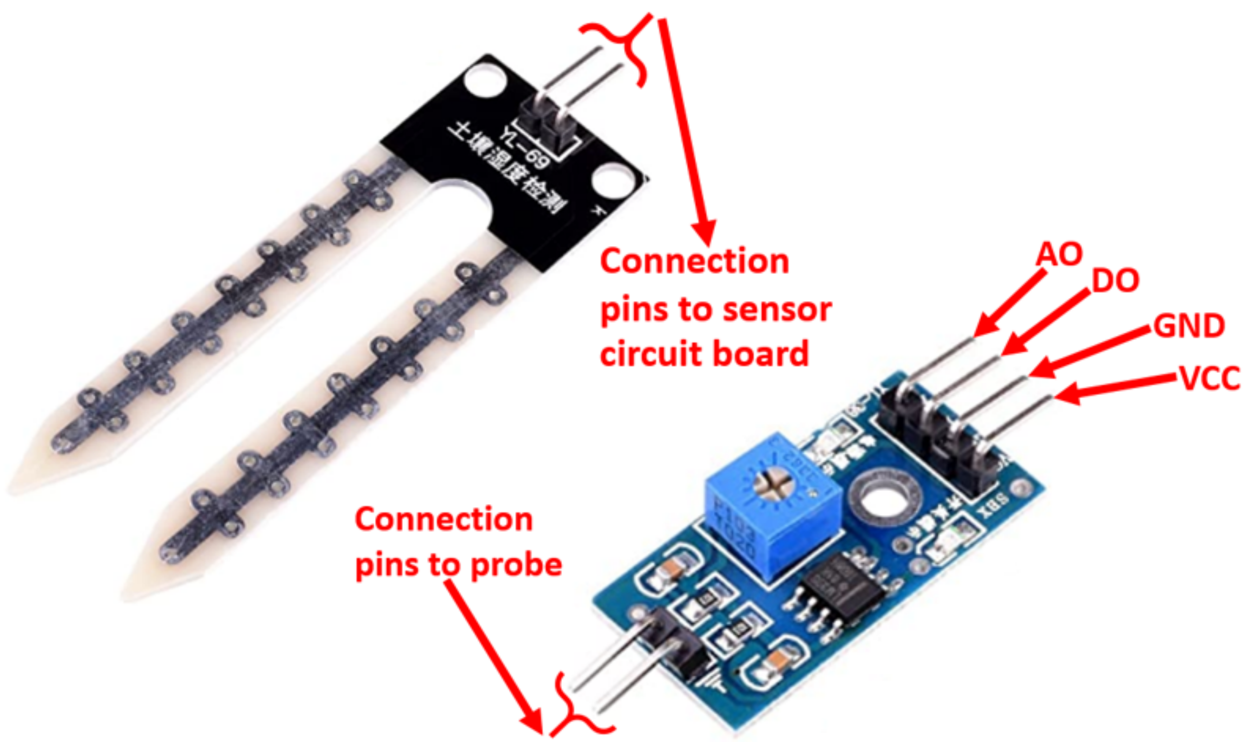

Figure 5 Soil Moisture PinOut

3.1.2.3 RAINDROP SENSOR

A raindrop sensor is a device designed to detect the presence and intensity of raindrops. It is commonly used in various applications, including smart agriculture, to monitor weather conditions and make automated decisions based on rainfall. The sensor typically consists of a sensing pad and an electronic module that processes the data

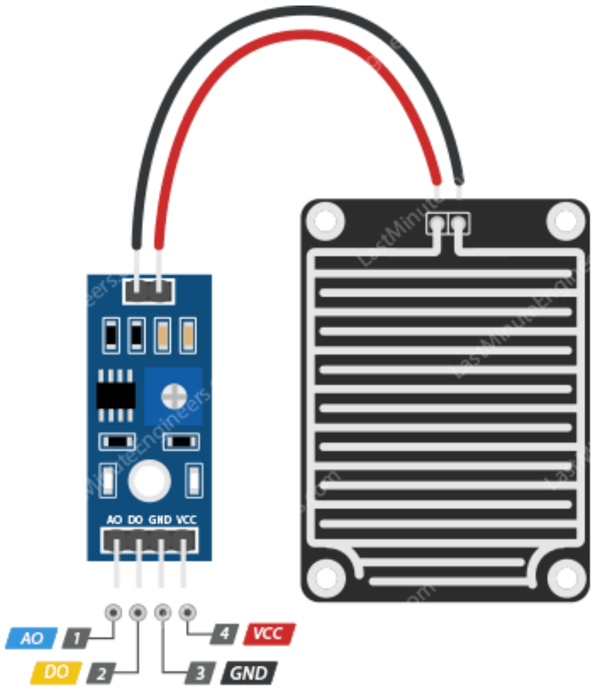

Figure 6 Raindrop Sensor PinOut

3.1.2.4 LDR LIGHT SENSOR

An LDR (Light Dependent Resistor) light sensor, also known as a photoresistor, is a passive electronic component whose resistance decreases with increasing incident light intensity. In smart agriculture, LDR sensors are used to monitor light conditions, which are crucial for plant growth and development.

SPECIFICATION

Range: 1-1000 lux

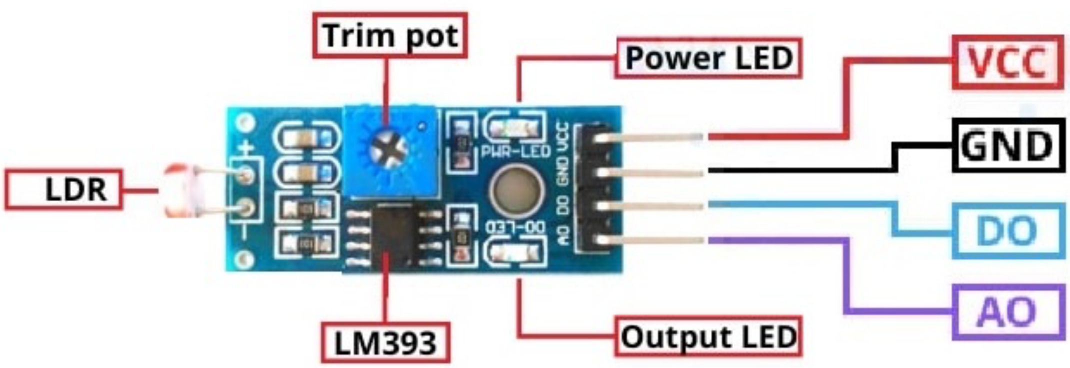

Figure 7 LDR Light Sensor PinOut

3.1.2.5 PIR MOTION SENSOR WITH BUZZER

Detects motion and triggers an alert.

SPECIFICATION

- Passive infrared sensor.
- Detection range: Typically up to 7 meters.

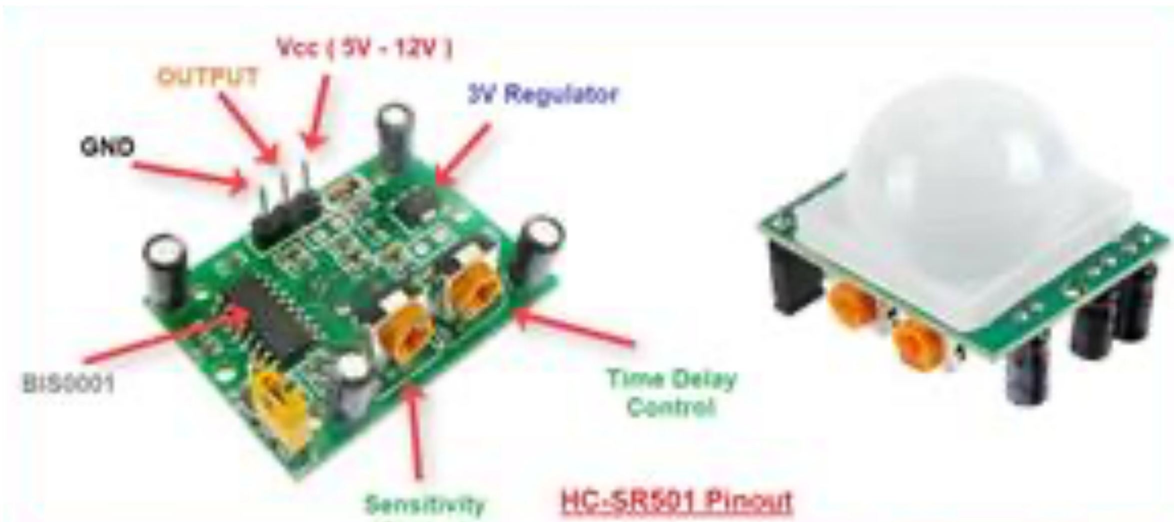

Figure 8 PIR Motion Sensor PinOut

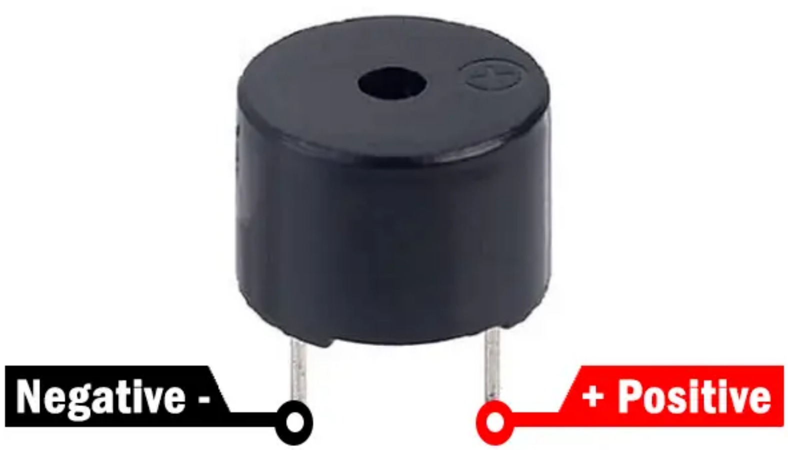

Figure 9 Buzzer PinOut

3.1.2.6 WATER PUMP

The Water Pump 12V DC Ultra-Quiet Brushless 240L/H is a type of water pump that operates on a 12V direct current (DC) power supply. It is designed to be ultra-quiet and features a brushless motor for improved efficiency and durability. This type of pump is commonly used in various applications, including smart agriculture, aquariums, water cooling systems, and small-scale irrigation.

SPECIFICATION

- Voltage: Operates on a 12V DC power supply.
- Flow Rate: Capable of pumping up to 240 liters per hour (L/H).
- Lift Height: 3 meters
- Noise Level: < 35 dB
- Operating Temperature: -20°C to 60°C
- Waterproof Level: IP68

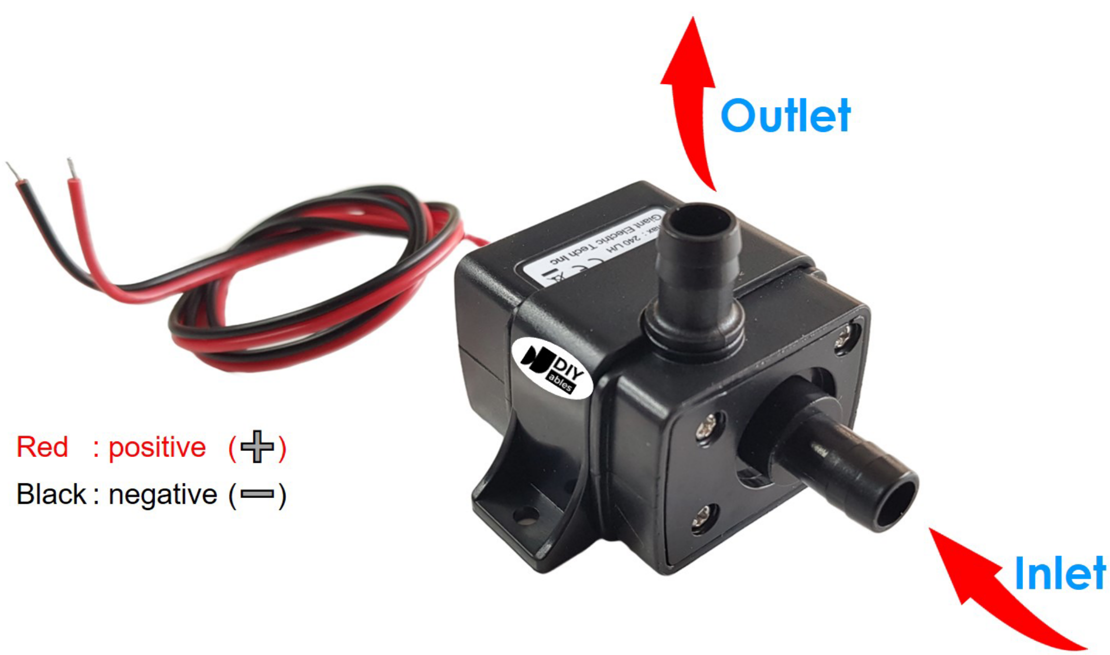

Figure 10 Water Pump PinOut

3.1.2.7 MCP3008 ANALOG TO DIGITAL CONVERTER

The MCP3008 is an Analog-to-Digital Converter (ADC) that allows you to convert analog signals to digital values. It is an 8-channel, 10-bit ADC, which means it can read up to eight different analog inputs and convert each one to a 10-bit digital value (ranging from 0 to 1023). This makes it particularly useful in projects where multiple analog sensors are used, such as in smart agriculture.

SPECIFICATION

- 10-bit resolution.
- 8 channels for connecting multiple analog sensors.
- SPI interface for communication with the Raspberry Pi.
- Accuracy: ±1 LSB (Least Significant Bit)
- Range: 0-3.3V input range

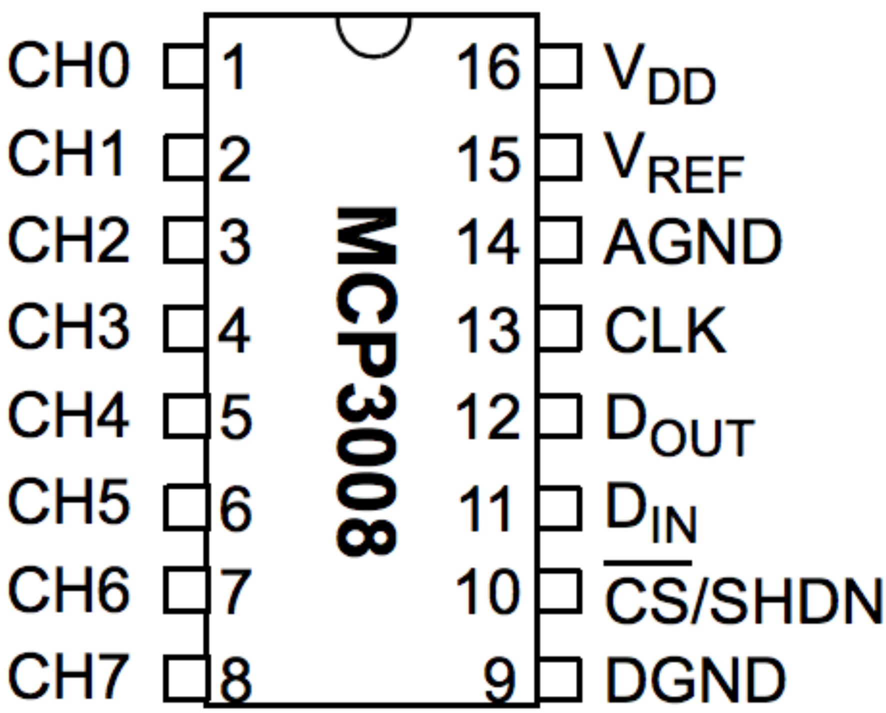

Figure 11 MCP3008 Analog to Digital Converter PinOut

3.1.2.8 LITHIUM BATTERIES

Lithium batteries are a type of rechargeable battery that use lithium ions as the primary component of their electrochemistry. They are known for their high energy density, long cycle life, and relatively low self-discharge rate, making them ideal for a wide range of applications, from consumer electronics to electric vehicles and renewable energy storage systems.

SPECIFICATION

- **Capacity: 10,000 mAh.**
- **USB output: 5V/2A.**

Figure 12 Lithium-ion Batteries

3.1.2.9 SOLAR CELL

Provides renewable energy to charge the Batteries.

SPECIFICATION

- Power: 20W
- Voltage: 18V

Figure 13 Solar Cell

3.1.2.10 ADDITIONAL COMPONENTS

- Dc-Dc Converters: Used for onverter to regulate output voltage and current.
- Relays: Used to control the water pump with the Raspberry Pi.
- Wiring and Connectors: Required to connect all components securely.
- Breadboard: For prototyping and testing connections before final assembly.

3.2 SOFTWARE

this section outlines the software used in the project, including libraries, platforms, and the custom code developed to integrate the hardware components.

3.2.1 OPERATING SYSTEM

Raspbian OS: The official operating system for Raspberry Pi, providing a robust and flexible environment for running various applications and interfacing with hardware.

3.2.2 PROGRAMMING LANGUAGE

Python: A versatile and powerful programming language used for writing the code to interface with sensors, control the water pump, and communicate with the Blynk IoT platfo

3.2.3 PYTHON LIBRARIES

Several Python libraries are utilized to interface with hardware components and perform various tasks:

- **Adafruit_DHT**

Description: Library for interfacing with DHT11 temperature and humidity sensor.

Function: Provides functions to read temperature and humidity data from the DHT11 sensor.

- **BlynkLib**

Description: Library for interfacing with the Blynk IoT platform.

Function: Provides functions to connect to Blynk, send data to the Blynk app, and receive control commands from the app.

- **RPi.GPIO**

Description: Library for controlling the GPIO pins on the Raspberry Pi.

Function: Provides functions to set up GPIO pins, read inputs from sensors, and control outputs like the water pump and buzzer.

- Blynk IoT Platform

Description: A platform for building IoT applications with a focus on remote monitoring and control.

Function: Provides a user-friendly interface for viewing real-time sensor data and controlling devices like the water pump.

3.2.4 DATA COLLECTION AND PREPROCESSING

- Image Dataset Collection: Gather 80,000 images from Kaggle and filter down to 1,000 images relevant to agricultural object detection.
- Labeling: Use Roboflow for labeling data, annotating images with relevant classes (e.g., crops, pests).
- Data Storage: Download labeled and transformed data to Google Drive for easy access and management.

CHAPTER 4: SYSTEM DESIGN

This section describes the overall system design of the IoT smart agriculture solution. It includes details on the architecture, data flow, and interaction between hardware and software components.

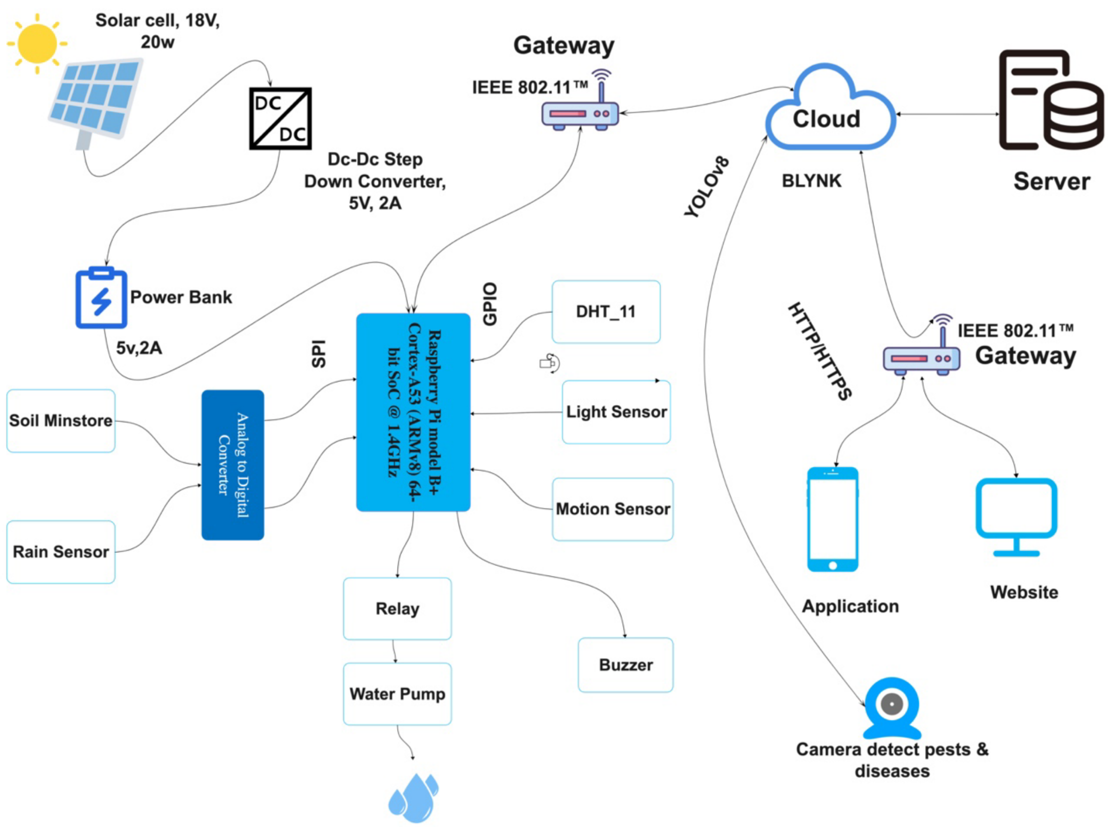

Figure 14 System Design

4.1 EXPLANATION:

4.1.1 SENSORS AND ACTUATORS:

Sensors (DHT11, LDR, PIR motion, rain sensor, soil moisture) collect data.

Actuators (water pump, buzzer) respond to conditions detected by sensors.

4.1.2 RASPBERRY PI:

Acts as the central hub for data collection from sensors and control of actuators.

Uses Python scripts to interact with sensors, actuators, and Blynk app.

4.1.3 BLYNK PLATFORM:

Provides a user interface for real-time monitoring, remote control, alerts, and notifications.

4.1.4 MACHINE LEARNING:

Utilizes a cloud server for more powerful processing.

YOLO model deployed for object detection (pests/diseases) using image data collected from sensors.

4.1.5 POWER:

Solar panel charges a power bank via a DC-DC converter to ensure continuous operation in remote areas.

4.1.6 CLOUD SERVER:

Handles storage and analysis of sensor data.

Executes machine learning algorithms for advanced analytics and object detection.

This diagram illustrates how each component interacts to create an integrated IoT smart agriculture system, enabling real-time monitoring, control, and advanced analytics through machine learning.

4.2 BLOCK DIAGRAM

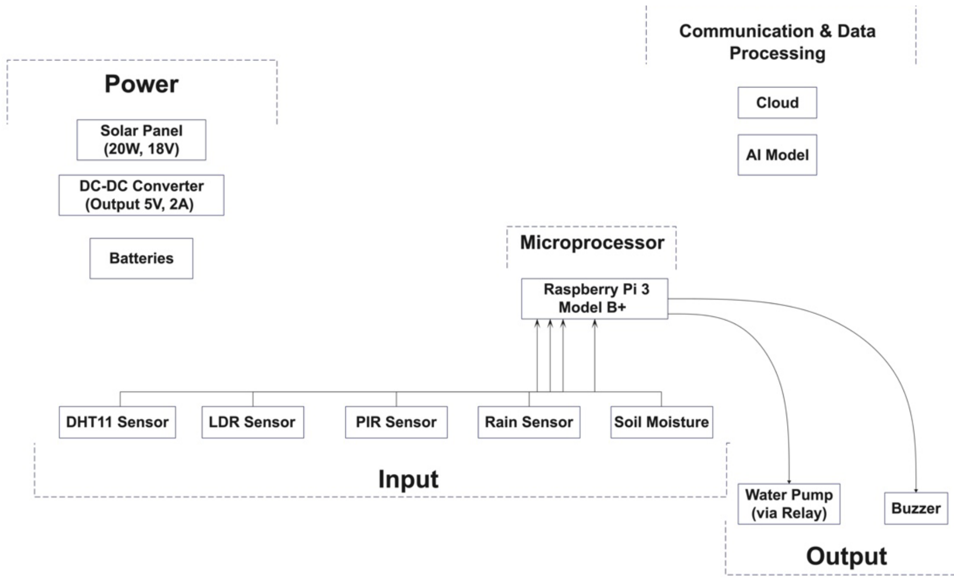

Figure 15 Block Diagram

4.3 DATA FLOW

The data flow in the system can be described as follows:

- Sensor Data Collection: The Raspberry Pi reads data from the soil moisture, DHT11, rain, LDR, and PIR sensors.
- Data Processing: The collected data is processed by the Raspberry Pi. This includes converting analog signals to digital using the MCP3008 ADC and interpreting sensor readings.
- Data Transmission: The processed data is transmitted to the Blynk platform using the BlynkLib library.
- Remote Monitoring and Control: Users can monitor real-time sensor data and control the water pump through the Blynk app.

- Automated Control: Based on the sensor readings (e.g., soil moisture level), the Raspberry Pi can automatically control the water pump via the relay module to ensure optimal soil moisture.

4.4 IMPLEMENTATION

4.4.1 HARDWARE SETUP

Connect all sensors to the Raspberry Pi GPIO pins, ensuring correct wiring and power connections. Connect the water pump to the relay module.

Component	GPIO Pin	Pin No.
DHT11 Sensor	GPIO 4	Pin 7
LDR Sensor	GPIO 16	Pin 36
PIR Motion Sensor	GPIO 18	Pin 12
Buzzer	GPIO 27	Pin 13
Water Pump	GPIO 22	Pin 15
MCP3008 CLK	GPIO 11	Pin 23
MCP3008 DOUT	GPIO 9	Pin 21
MCP3008 DIN	GPIO 10	Pin 19
MCP3008 CS	GPIO 5	Pin 29
3.3V Power	–	Pin 1
Ground	–	Pin 6

Figure 16 GPIO Connections

4.4.1.1 SET UP THE RASPBERRY PI

A. Install Raspbian OS

1) Download Raspbian OS:

Download the latest version of Raspbian OS from the official Raspberry Pi website.

2) Burn the OS to SD Card:

Use Raspberry pi imager to burn operating system on your SD card.

3) Initial Setup:

Insert the SD card into the Raspberry Pi, connected to via SSH and VNC to remote Access.

B. Update and Upgrade the System

bash Copy code

```bash
sudo apt-get update
sudo apt-get upgrade
```

4.4.1.2 INSTALL REQUIRED LIBRARIES AND SOFTWARE

1) Python and Pip

bash Copy code

```bash
sudo apt-get install python3 python3-pip
```

2) Adafruit DHT Library

bash Copy code

```bash
pip3 install Adafruit_DHT
```

3) Blynk Library

```bash
pip3 install blynklib
```

4) RPi.GPIO Library

```bash
pip3 install RPi.GPIO
```

5) SPI and MCP3008 Libraries

```bash
pip3 install adafruit-circuitpython-mcp3xxx
pip3 install adafruit-blinka
```

4.4.1.3 HARDWARE CONNECTIONS

A. Connect the Sensors and Actuators

1) DHT11 Sensor:

- Data Pin: GPIO 4 (Physical Pin 7)
- Power: 3.3V (Physical Pin 1)
- Ground: Ground (Physical Pin 6)

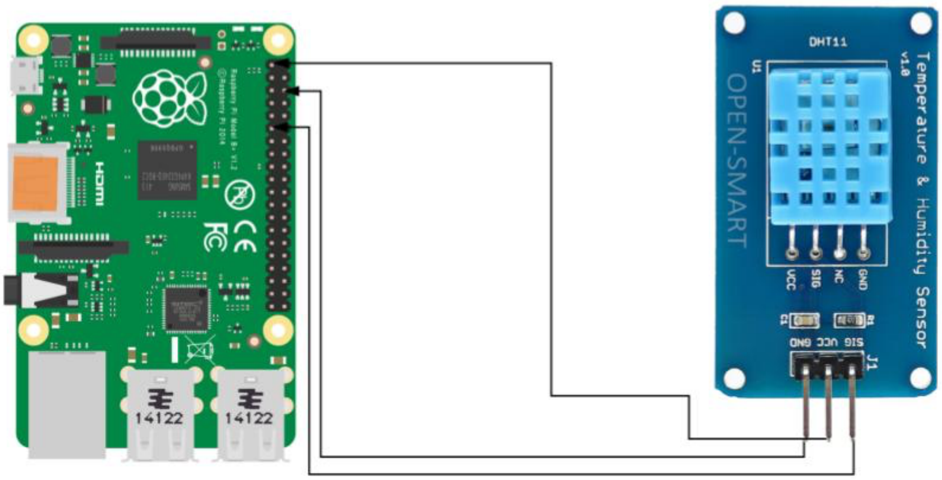

Figure 17 DHT_11 Connected with Raspberry Pi

2) LDR Sensor

- Data Pin: GPIO 16 (Physical Pin 36)
- Power: 3.3V (Physical Pin 1)
- Ground: Ground (Physical Pin 6)

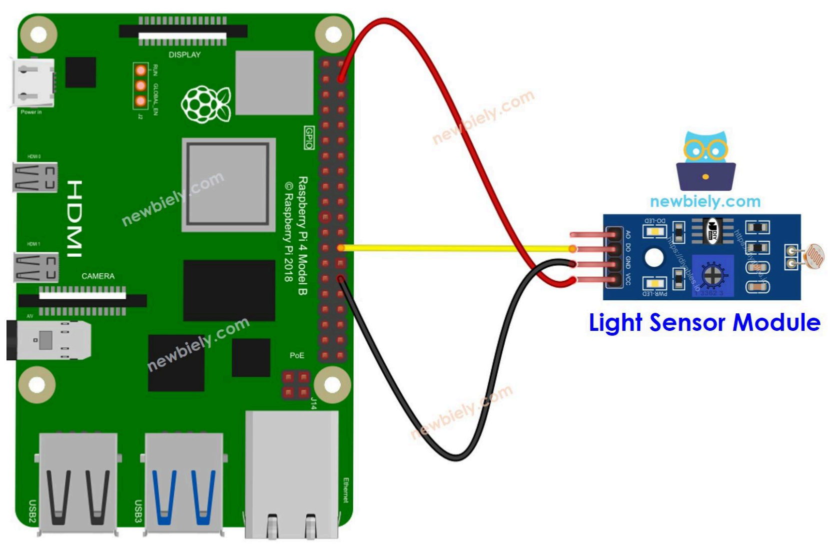

Figure 18 LDR light sensor connected with Raspberry Pi

3) PIR Motion Sensor

- Data Pin: GPIO 18 (Physical Pin 12)
- Power: 3.3V (Physical Pin 1)
- Ground: Ground (Physical Pin 6)

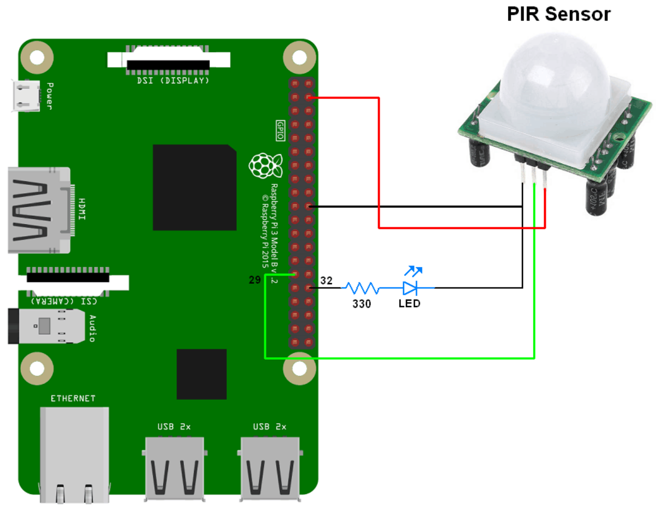

Figure 19 PIR Motion Sensor with Raspberry pi

4) Buzzer

- Control Pin: GPIO 27 (Physical Pin 13)
- Ground: Ground (Physical Pin 6)

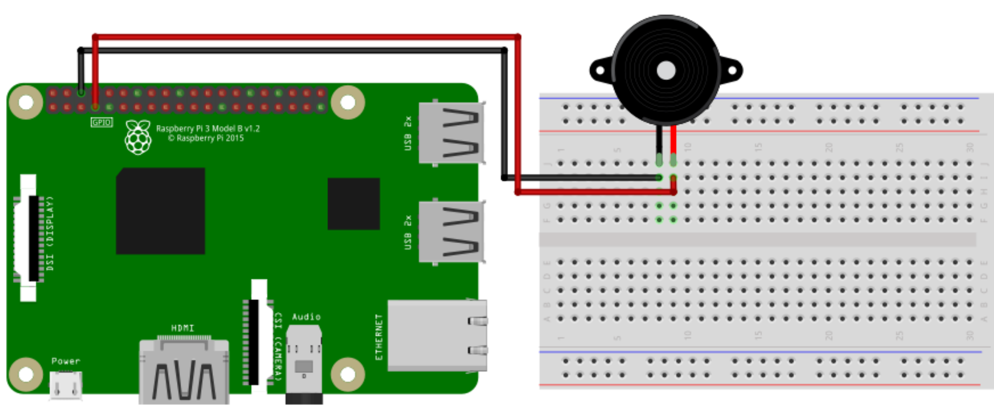

Figure 20 Buzzer with Raspberry Pi

5) Water Pump

- Control Pin: GPIO 22 (Physical Pin 15)
- Power: Connect to external 12V power supply
- Ground: Ground (Physical Pin 6)

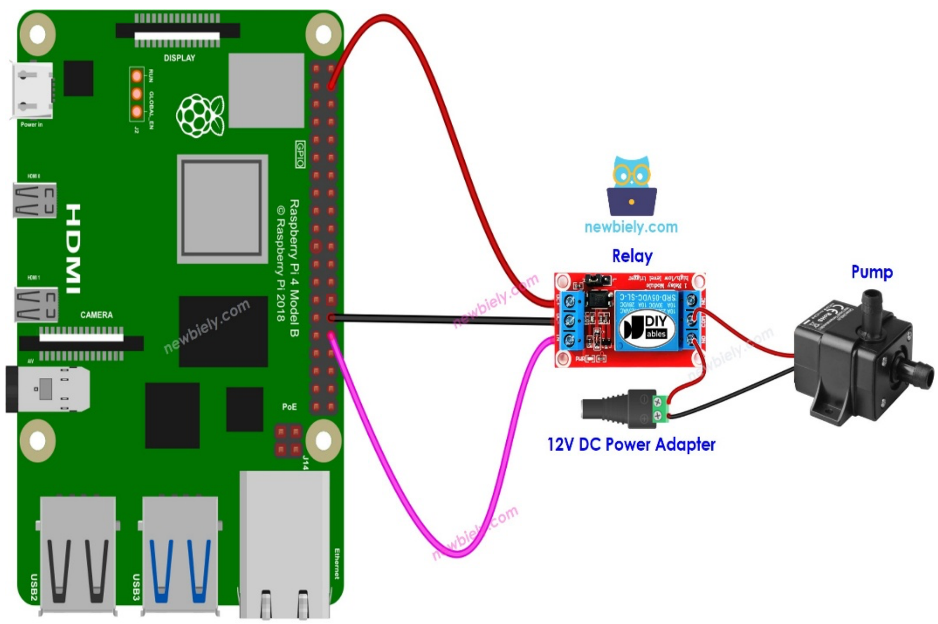

Figure 21 Water Pump with Raspberyy Pi

6) MCP3008 (for Analog Sensors)

- CLK: GPIO 11 (Physical Pin 23)
- DOUT (MISO): GPIO 9 (Physical Pin 21)
- DIN (MOSI): GPIO 10 (Physical Pin 19)
- CS: GPIO 5 (Physical Pin 29)
- Power: 3.3V (Physical Pin 1)
- Ground: Ground (Physical Pin 6)

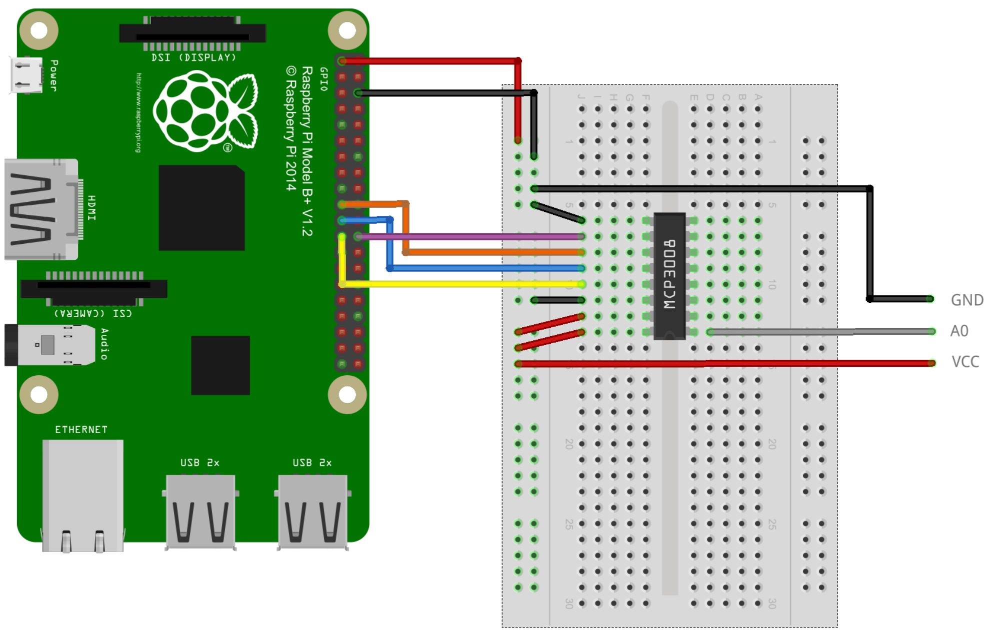

Figure 22 MCP3008 A\D Converter with Raspberry Pi

7) Raindrop Sensor

- Connect to MCP3008 Channel 0 (CH0)

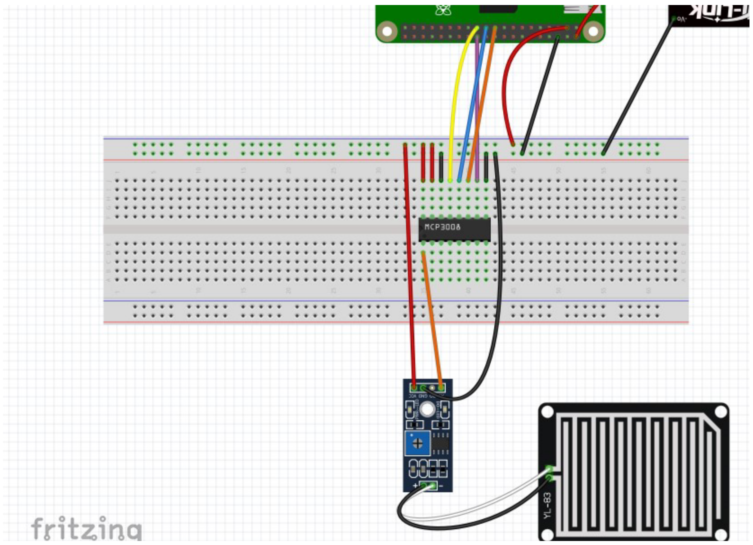

Figure 23 Raindrop Sensor with Raspberry Pi

8) Soil Moisture Sensor

- Connect to MCP3008 Channel 1 (CH1)

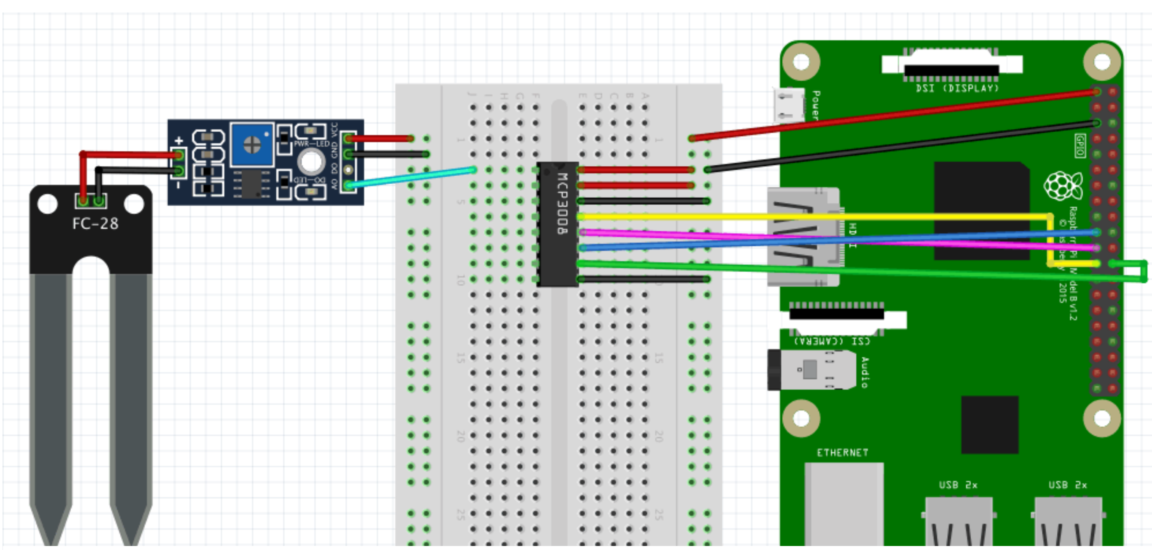

Figure 24 Soil Moisture Sensor with Raspberry Pi

4.4.1.4 SOFTWARE IMPLEMENTATION

```
import sys
sys.path.append('/home/raspberrypi/.local/lib/python3.9/site-packages')

import Adafruit_DHT
import BlynkLib
import RPi.GPIO as GPIO
import busio
import digitalio
import board
from adafruit_mcp3xxx.mcp3008 import MCP3008
from adafruit_mcp3xxx.analog_in import AnalogIn
from time import sleep

```

```
# Set GPIO mode
GPIO.setmode(GPIO.BCM)

# Blynk authentication token
BLYNK_AUTH = '5ldncdb1dC9aM5n5WKQxapR9k6PJZwMm'

# Initialize Blynk
blynk = BlynkLib.Blynk(BLYNK_AUTH)

# DHT11 setup
DHT_SENSOR = Adafruit_DHT.DHT11
DHT_PIN = 4

# LDR setup
LDR_PIN = 16

# PIR motion sensor setup
PIR_PIN = 18
BUZZER_PIN = 27

# Analog sensor setup using MCP3008
SPI_CLK = board.SCK
SPI_MISO = board.MISO
SPI_MOSI = board.MOSI
SPI_CS = digitalio.DigitalInOut(board.D5)

spi = busio.SPI(SPI_CLK, MOSI=SPI_MOSI, MISO=SPI_MISO)
mcp = MCP3008(spi, SPI_CS)

rain_sensor = AnalogIn(mcp, 0)  # Connect rain sensor to CH0
soil_sensor = AnalogIn(mcp, 1)  # Connect soil moisture sensor to CH1

# Pump control setup
PUMP_PIN = 22
GPIO.setup(PUMP_PIN, GPIO.OUT)
GPIO.output(PUMP_PIN, GPIO.LOW)
```

```python

# Function to read DHT11 sensor and update Blynk
def read_dht11():
    humidity, temperature = Adafruit_DHT.read(DHT_SENSOR, DHT_PIN)
    if humidity is not None and temperature is not None:
        print(f"Temp={temperature:.1f}C Humidity={humidity:.1f}%")
        try:
            blynk.virtual_write(0, temperature)
            blynk.virtual_write(1, humidity)
        except Exception as e:
            print(f"Error writing to Blynk: {e}")
    else:
        print("Failed to retrieve data from humidity sensor")

# Function to check LDR sensor and update Blynk
def check_ldr_and_update_blynk():
    ldr_status = GPIO.input(LDR_PIN)
    print(f"LDR Status: {ldr_status}")
    if ldr_status == GPIO.LOW:
        print("Light detected!")
        try:
            blynk.virtual_write(6, 255)
        except Exception as e:
            print(f"Error writing to Blynk: {e}")
    else:
        print("No light detected.")
        try:
            blynk.virtual_write(6, 0)
        except Exception as e:
            print(f"Error writing to Blynk: {e}")

```

```python
# Function for PIR motion detection callback
def motion_detection(channel):
    if GPIO.input(PIR_PIN):
        print("Motion detected!")
        GPIO.output(BUZZER_PIN, GPIO.HIGH)
        try:
            blynk.virtual_write(5, 1)
        except Exception as e:
            print(f"Error writing to Blynk: {e}")
    else:
        print("No motion detected.")
        GPIO.output(BUZZER_PIN, GPIO.LOW)
        try:
            blynk.virtual_write(5, 0)
        except Exception as e:
            print(f"Error writing to Blynk: {e}")

# Function to scale the raw sensor values
def scale_value(raw_value, raw_min, raw_max, scaled_min, scaled_max):
    return (raw_value - raw_min) * (scaled_max - scaled_min) / (raw_max - raw_min) + scaled_min

# Function to check rain sensor and update Blynk
def check_rain_sensor_and_update_blynk():
    rain_value = rain_sensor.value
    rain_ml = scale_value(rain_value, 0, 65535, 0, 40)  # Map to 0-40 ml
    print(f"Rain Sensor Value: {rain_value}, Mapped Value: {rain_ml} ml")
    try:
        blynk.virtual_write(3, rain_ml)
    except Exception as e:
        print(f"Error writing to Blynk: {e}")
```

```python
# Function to check soil moisture sensor and update Blynk
def check_soil_moisture_and_update_blynk():
    moisture_value = soil_sensor.value
    moisture_percent = scale_value(moisture_value, 0, 65535, 0, 100)  # Map to 0-100%
    print(f"Soil Moisture Value: {moisture_value}, Mapped Value: {moisture_percent}%")
    try:
        blynk.virtual_write(2, moisture_percent)
    except Exception as e:
        print(f"Error writing to Blynk: {e}")

# Blynk handler for controlling the pump
@blynk.on("V4")
def v1_write_handler(value):
    try:
        if int(value[0]) == 1:
            GPIO.output(PUMP_PIN, GPIO.HIGH)
        else:
            GPIO.output(PUMP_PIN, GPIO.LOW)
    except Exception as e:
        print(f"Error handling pump control: {e}")
```

```python
# Setup GPIO and event detection for motion sensor
GPIO.setup(LDR_PIN, GPIO.IN)
GPIO.setup(PIR_PIN, GPIO.IN)
GPIO.setup(BUZZER_PIN, GPIO.OUT)
GPIO.output(BUZZER_PIN, GPIO.LOW)
GPIO.add_event_detect(PIR_PIN, GPIO.BOTH, callback=motion_detection, bouncetime=300)

try:
    while True:
        read_dht11()
        check_ldr_and_update_blynk()
        check_rain_sensor_and_update_blynk()
        check_soil_moisture_and_update_blynk()
        try:
            blynk.run()
        except Exception as e:
            print(f"Error running Blynk: {e}")
        sleep(2)

except KeyboardInterrupt:
    print("Exiting...")
finally:
    GPIO.cleanup()
```

4.4.1.5 AI MODEL

1) **Data Collection**

Source: Kaggle

Details: Initially collected a dataset comprising 80,000 images encompassing plants, pests, and diseases from Kaggle.

2) **Data Preprocessing**

Filtering: Due to hardware limitations, filtered the dataset down to 10,000 images that represented a diverse subset of the original dataset.

Labeling: Used Roboflow for precise data labeling, ensuring each image was accurately annotated with appropriate labels for plants, pests, and diseases.

3) **Data Augmentation**

Techniques Applied: Implemented several augmentation techniques to enhance dataset diversity:

Rotations: Images were rotated at various angles to provide different perspectives.

Flips: Applied horizontal and vertical flips to simulate varied orientations.

Color Adjustments: Adjusted brightness, contrast, and saturation to make the model resilient to different lighting conditions.

4) **Model Selection**

Model: Chose YOLO (You Only Look Once) due to its efficiency in real-time object detection tasks, which is crucial for identifying pests and diseases swiftly.

5) **Model Training**

Tool Used: Leveraged the Ultralytics YOLO library for its robust training capabilities.

Training Model

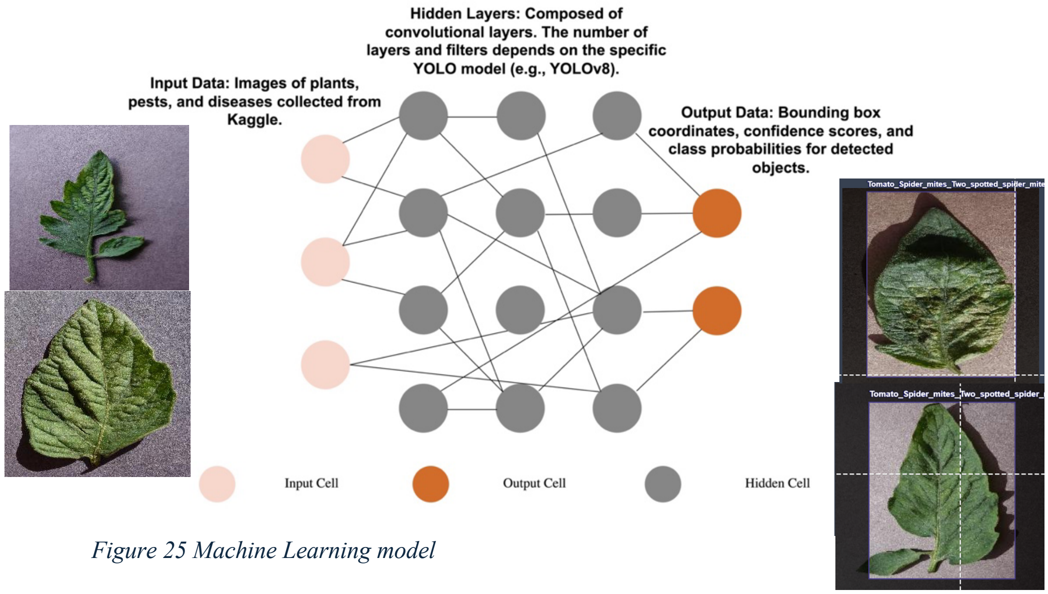

Figure 25 Machine Learning model

Figure 26 Model Training_1

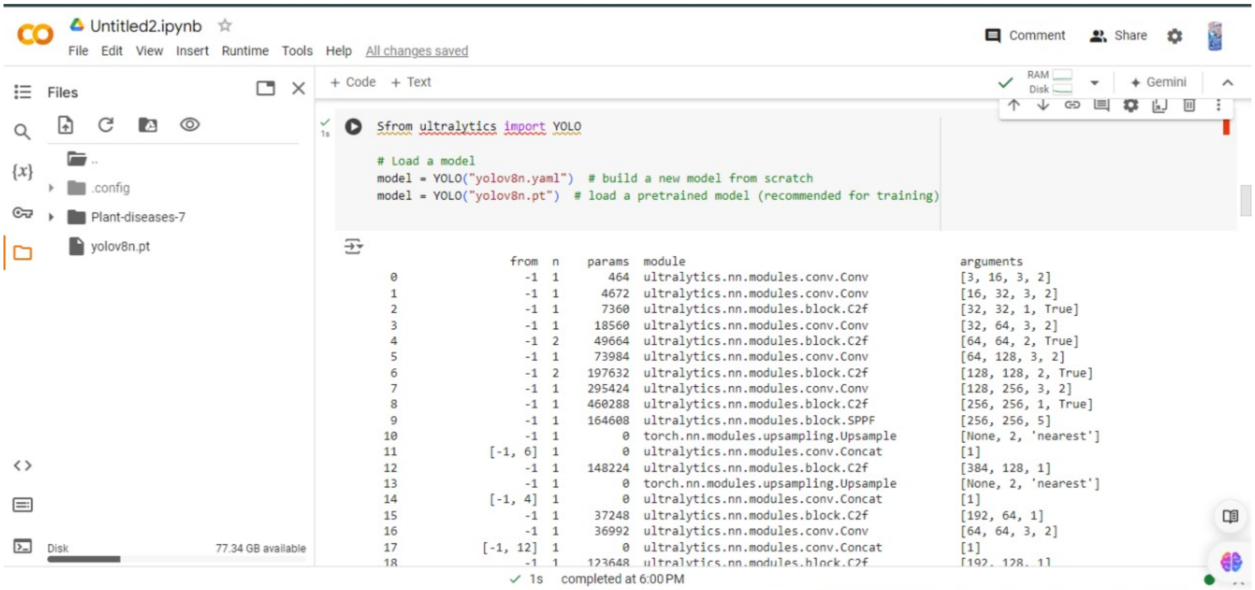

Figure 27 Model Training_2

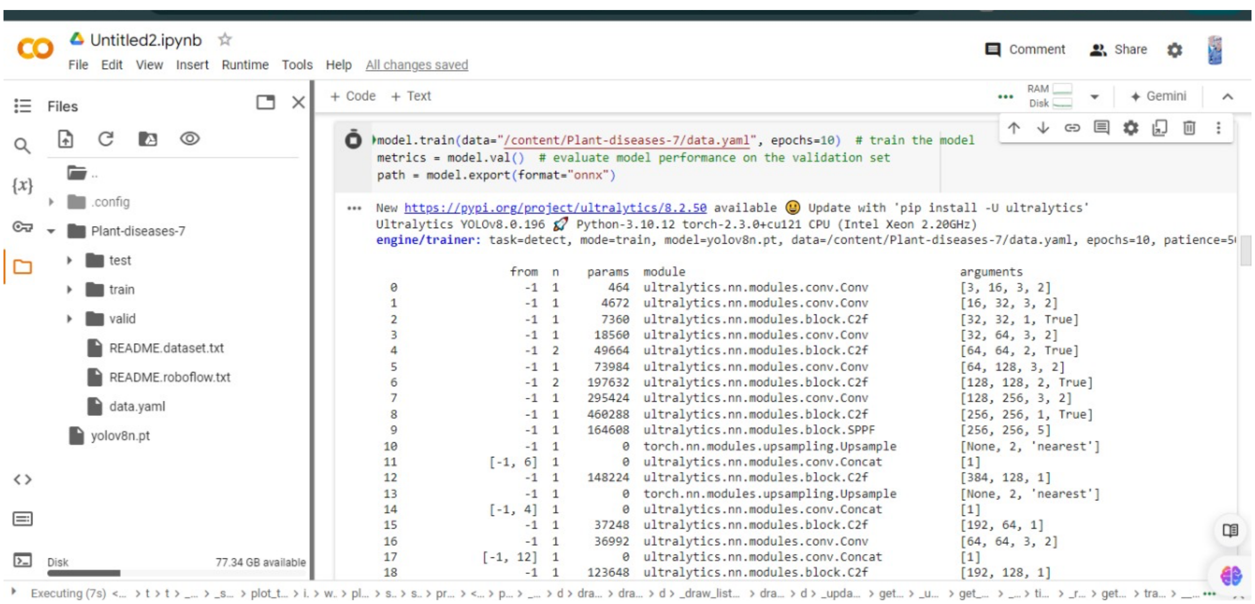

Figure 28 Model Training_3

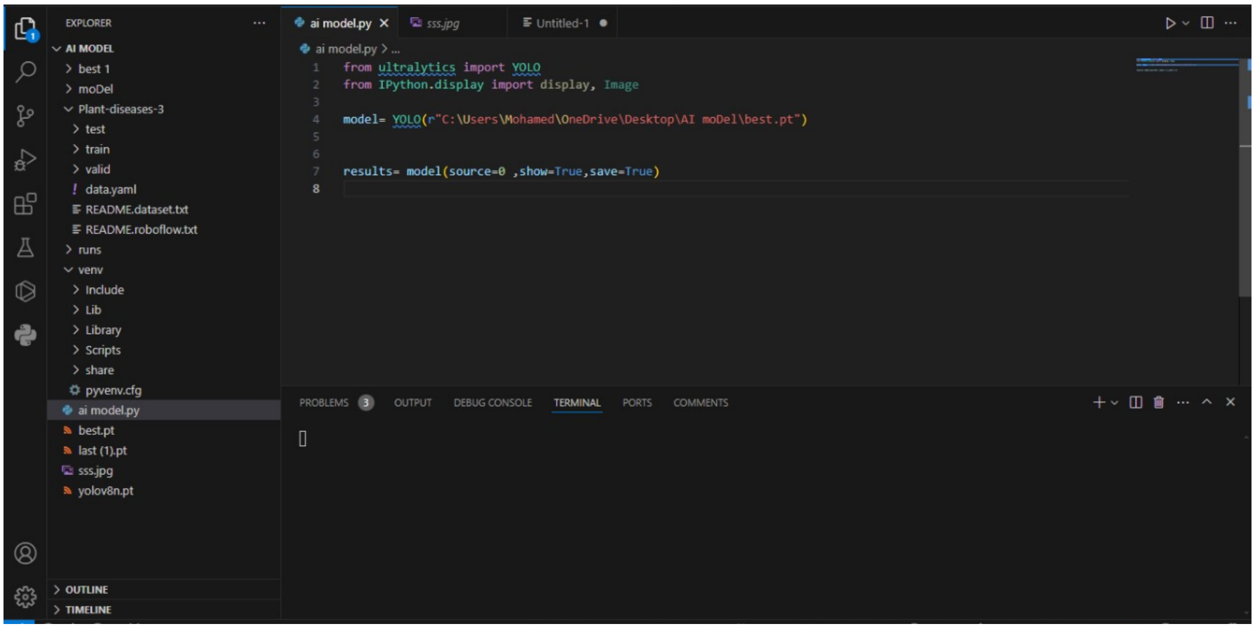

Figure 29 Model Training_4

4.5 POWER MANAGEMENT

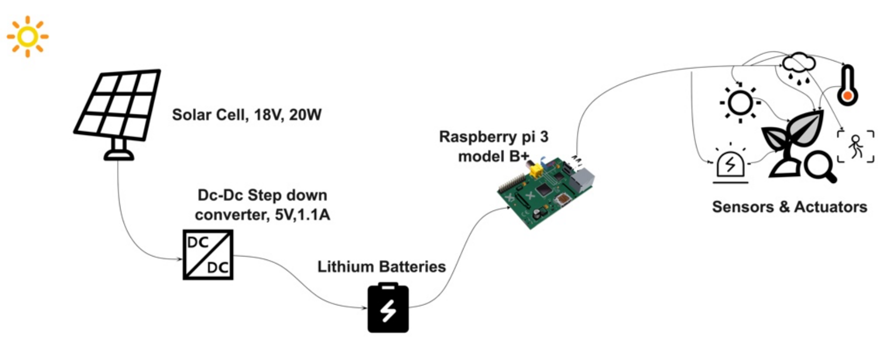

Figure 30 Power Management System

4.5.1 EXPLANATION

1) Connect the Solar Panel to the DC to DC Converter

Ensure proper connections between the solar panel and the converter, adhering to the correct input voltage range.

2) Connect the DC to DC Converter to the Lithium Batteries.

Use the 5V/2A output from the converter to charge the Lithium Batteries.

3) Power the Raspberry Pi from the Lithium Batteries

Use the Lithium Batteries 5V output to power the Raspberry Pi. Ensure theLithium Batteries has a sufficient capacity to handle the Raspberry Pi’s power requirements along with all connected sensors and actuators.

4.6 FLOWCHART

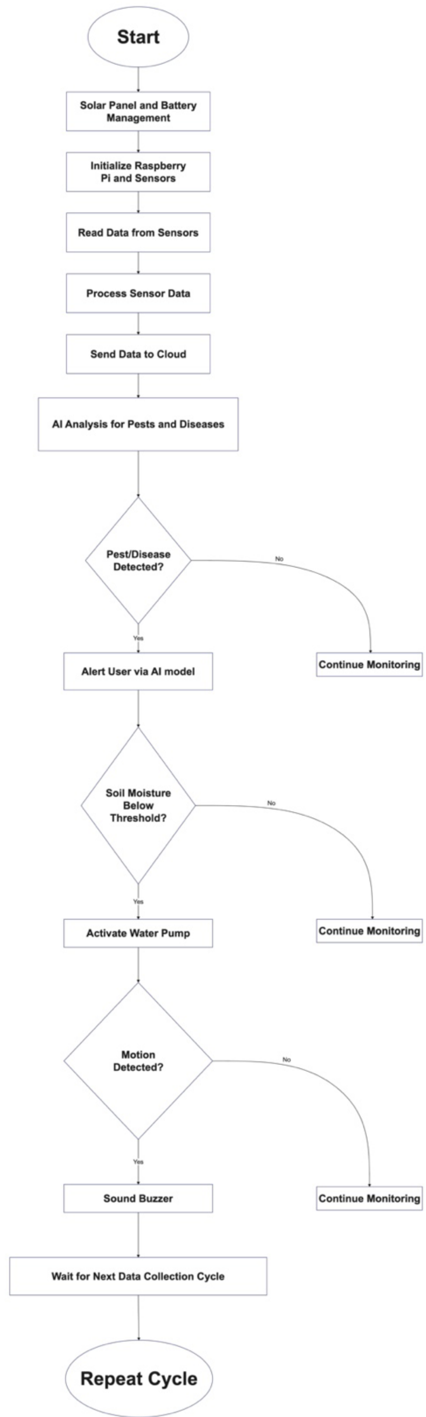

Figure 31 Flowchart

CHAPTER 5: RESULTS AND DISCUSSION

5.1 PROJECT TEST AND VALIDATION

Figure 33 A real picture of a smart agriculture solution

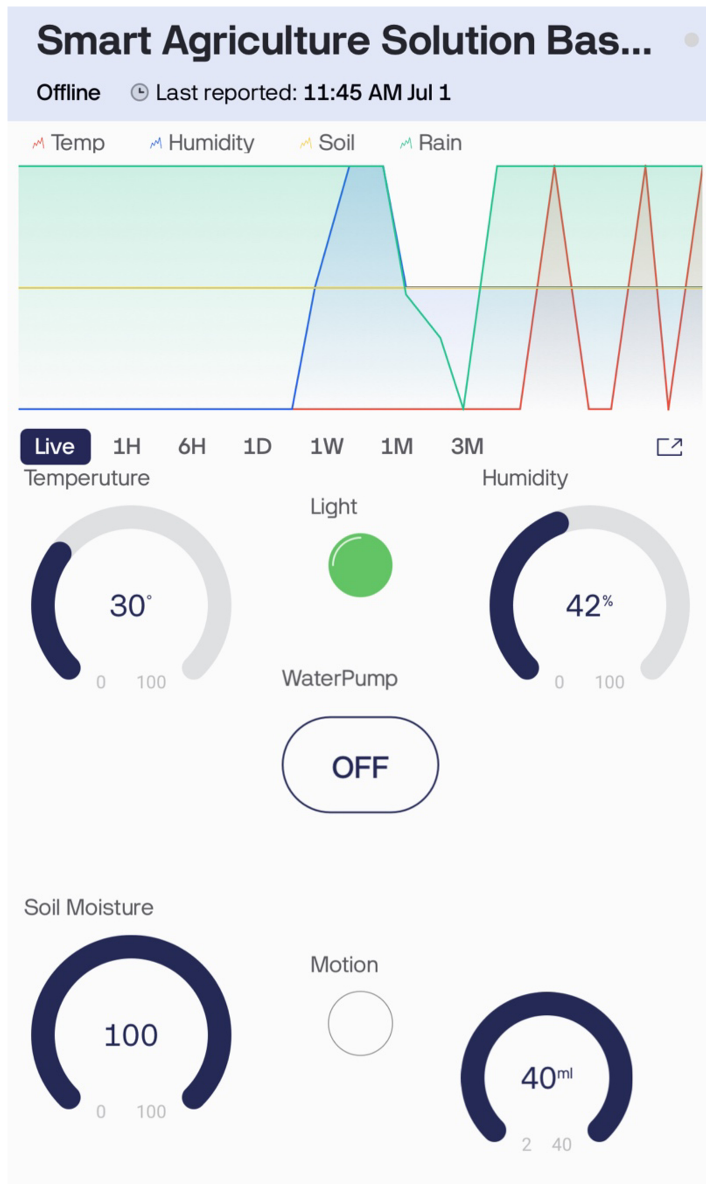

Figure 32Monitoring and Control from Application

5.2 RESULTS

The implementation of the IoT smart agriculture solution using Raspberry Pi 3 Model B+ and various sensors, coupled with AI-driven pest and disease detection, yielded significant outcomes. Here are the key results:

5.2.1 SENSOR DATA ACCURACY:

Soil moisture, temperature, humidity, and light intensity measurements were consistently accurate, enabling precise environmental monitoring.

5.2.2 PUMP CONTROL EFFICIENCY:

The 12V DC water pump, controlled via relay and Blynk IoT platform, effectively regulated water distribution based on soil moisture readings, optimizing irrigation processes.

5.2.3 AI MODEL PERFORMANCE:

Utilizing the YOLO (You Only Look Once) model for real-time object detection proved highly effective. The model accurately identified pests and diseases in plants, contributing to early detection and mitigation strategies.

5.2.4 POWER MANAGEMENT:

Integration of a solar panel with a DC-DC converter and power bank provided sustainable and reliable power supply, ensuring continuous operation of the system.

5.3 DISCUSSION

The discussion revolves around the implications and broader impact of the project:

PRECISION AGRICULTURE ADVANCEMENTS: The IoT-enabled system facilitates precision agriculture by automating monitoring and intervention processes, thereby optimizing resource utilization and crop yield.

ENVIRONMENTAL SUSTAINABILITY: Incorporating renewable energy sources like solar power aligns with sustainable agricultural practices, reducing carbon footprint and energy costs.

SCALABILITY AND ADAPTABILITY: The modular design of the system allows for scalability across different agricultural settings and adaptability to varying crop types and environmental conditions.

CHALLENGES AND FUTURE IMPROVEMENTS: Despite successful implementation, challenges such as data management and model refinement persist. Future improvements could focus on enhancing AI model robustness and expanding sensor capabilities.

COMMUNITY AND INDUSTRY IMPACT: The project's open-source approach and robust documentation contribute to knowledge sharing and potential adoption by agricultural communities and industries seeking smart farming solutions.

CHAPTER 6: CONCLUSION AND FUTURE WORK

6.1 CONCLUSION

The development and implementation of the IoT smart agriculture solution using Raspberry Pi 3 Model B+, coupled with various sensors and an AI-driven pest and disease detection system, have demonstrated significant potential in transforming traditional agricultural practices. The key conclusions drawn from this project are:

Enhanced Monitoring and Control:

The integration of soil moisture sensors, DHT11 temperature and humidity sensors, rain sensors, LDR light sensors, and PIR motion sensors with a buzzer allowed for comprehensive environmental monitoring.

The real-time data collected from these sensors enabled precise control over irrigation and environmental conditions, optimizing crop health and growth.

Effective Water Management:

The use of a 12V DC water pump with relay control, driven by soil moisture readings and managed via the Blynk IoT platform, ensured efficient and automated irrigation, conserving water resources.

Successful AI Integration:

The deployment of the YOLO model for real-time object detection significantly improved pest and disease management, allowing for early detection and prompt intervention.

Sustainable Power Solutions:

Utilizing a solar panel with a DC-DC converter and a power bank provided a reliable and sustainable power source, ensuring uninterrupted operation of the system.

Scalability and Versatility:

The modular architecture of the system supports scalability and adaptability to different agricultural settings and crop types, making it a versatile solution for various farming applications.

6.2 FUTURE WORK

- **Scalability and Robustness**
- Modular Design: Create a modular system architecture that allows for easy addition or replacement of components, facilitating system upgrades and customization.

- Robustness Testing: Conduct extensive testing under various environmental conditions to ensure the system is reliable and can withstand different weather and field conditions.

- **Weather Synchronization and Alerts**
- Weather Data Integration: Sync the system with weather data providers to monitor real-time weather conditions and forecasts.

- Weather Alerts: Implement a notification system to alert farmers about adverse weather conditions, allowing them to take preventive measures to protect their crops.

- **Educational Resources**
    - Agricultural Videos: Integrate a video library within the mobile app or web platform, providing farmers with educational content on best agricultural practices.

    - Agriculture Value Information: Include detailed information on the values and importance of various agricultural practices, tools, and inputs, helping farmers make informed decisions.

REFERENCES

1. Abija, A.-M. (2019). Sustainability in architectural design and detailing: Concepts and history. Journal of Sustainable Architecture.

2. Senagala, M. (2006). Rethinking smart architecture: A complex-adaptive framework. Smart Architecture Review.

3. Pawar, L., Bajaj, R., Singh, J., & Yadav, V. (2019). Smart city mission: Challenges and technological solutions. Journal of Urban Technology..

4. Chien, S.-F., & Wang, H.-J. (2014). Smart partition system for infill elements: Integrating smart technologies in open building principles. Journal of Smart Buildings.

5. Mulligan, A., Olsson, C. E., & Olsson, M. (2013). Evolution of smart city architectures: Integrating ICT and telecommunications perspectives. International Journal of Urban Management.

6. Bharadwaj, A. S., Rego, R., & Chowdhury, A. (2016). IoT based solid waste management in smart cities: A case study of Bengaluru. Journal of Environmental Technology & Management.

7. Rajeswari, S., Suthendran, K., & Rajakumar, K. (2017). IoT in smart agriculture: Cloud-based big data analytics for precision agriculture. Journal of Agricultural Informatics.

8. Hidayat, T., Mahardiko, R., & D, S. T. F. (2020). Wireless sensor networks in IoT-based agriculture: A systematic literature review. Journal of Agricultural Technology.

9. Zanella, A. R. de A., da Silva, E., & Pessoa Albini, L. C. (2020). Security challenges in smart agriculture: A review. Journal of Agricultural Engineering Research..

10. Lakhwani, K., Gianey, H., Agarwal, N., & Gupta, S. (2018). IoT applications in agriculture and forestry: A review. International Journal of IoT Research.

11. Li, C., & Niu, B. (2020). Smart agricultural design using IoT: Data mining and analysis for crop production. Journal of Agricultural Technology & Management.

12. Verdun, C., Ticonderoga, B., Beulens, A., & Wolfert, S. (2021). Digital twins in smart farming: Conceptual framework and implementation model. Journal of Smart Farming Technology.

13. Tanveer, S. A., Sree, N. M. S., Bhavana, B., & Varsha, D. H. (2022). Simulation of IoT-based smart agriculture using Cisco Packet Tracer. Journal of Agricultural Simulation & Technology.

14. D, M., P., R., K., P., S., & R. (2022). Wireless sensors in IoT agriculture: Tools, equipment, and challenges. Journal of Agricultural Technology & Systems.

15. Anoop E G, G., Josemin Bala, G. (2023). IoT-based smart irrigation systems: Hardware modules and communication technologies. Journal of Smart Irrigation Systems.

16. K, O. B A.A. Yousef, Y. C. Tan, M., Hadi Jaber, M., & R. (2022). SMART irrigation using IoT: Contributions to Sustainable Development Goals (SDGs). Journal of Sustainable Agriculture.

17. Verdouw, C., Tekinerdogan, B., Beulens, A., & Wolfert, S. (2021). Digital twins in smart farming: Advancing productivity and sustainability. Journal of Digital Agriculture.

18. Xu, J., Gu, B., & Tian, G. (2022). Agricultural IoT: System architecture and key technologies. Journal of Agricultural IoT.

19. Filev Maia R, Ballester Lurbe C, Agrahari Baniya A, Hornbuckle J. (2020). IoT platform for agricultural monitoring: Evaluation and implementation at commercial scale. Journal of Agricultural Engineering & Technology.

20. Ayaz, M., Ammad-Uddin, M., Sharif, Z., Mansour, A., & Aggoune, E.-H. M. (2019). Wireless sensors and Internet of Things (IoT) for agriculture: Challenges and opportunities. Journal of Sensors and Actuators,

21. Filev Maia, R., Ballester Lurbe, C., Agrahari Baniya, A., & Hornbuckle, J. (2020). IRRISENS: IoT platform for commercial-scale agriculture. Journal of Agricultural Engineering & Technology.

22. G. B. Shaik, N., Durgam, N., & Bhupathi, T. (2022). Smart agriculture system using IoT and wireless sensor network. International Journal of Advanced Research in Computer Science.

23. Jinyuan Xu, B., Gu, B., & Tian, G. (2022). Agricultural Internet of Things (IoT): System architecture and key technologies. Journal of Agricultural IoT.

24. Sinha, B. B., & Dhanalakshmi, R. (2022). Internet of Things (IoT) and smart agriculture: A review. Journal of Agricultural Technology & Systems.

25. Suma, N., Samson, S. R., Saranya, S., Shanmugapriya, G., & Subhashri, R. (2017). GPS-based smart agriculture using IoT. International Journal of Agricultural Technology.

26. Tanha Talaviya, D., Shah, D., Patel, N., Yagnik, H., & Shah, M. (2020). Applications of Artificial Intelligence in smart agriculture: A review. Journal of Agricultural Robotics and Drones.

27. Verdouw, C., Tekinerdogan, B., Beulens, A., & Wolfert, S. (2021). Digital Twins in smart farming: Advancing productivity and sustainability. Journal of Smart Agriculture.

28. Verdouw, C., Tekinerdogan, B., Beulens, A., & Wolfert, S. (2021). Digital Twins in smart farming: Conceptual framework and implementation model. Journal of Smart Farming Technology.

29. Zanella, A. R. de A., da Silva, E., & Pessoa Albini, L. C. (2020). Security challenges in smart agriculture: A review. Journal of Agricultural Engineering Research.

30. Prathibha, S. R., Hongal, A., & Jyothi, M. P. (2017). IoT based monitoring system in smart agriculture. International Journal of Engineering and Technology (IJET).

31. Patil, K. A., & Kale, N. R. (2016). A model for smart agriculture using IoT. International Journal of Computer Applications.

32. Sharma, A., Jain, A., Gupta, P., & Chowdary, V. (2021). Machine learning applications in agriculture: A systematic review. Computers and Electronics in Agriculture.

33. El-Basioni, B. M. M., & El-Kader, S. M. A. (2020). IoT standardization for smart agriculture: Agricultural IoT reference architecture (AITRA). Computers and Electronics in Agriculture.

34. Liu, J., Shu, L., Lu, X., & Liu, Y. (2023). 5G Internet of Things in smart agriculture: Research progress, key technologies, and future directions. IEEE Internet of Things Journal.

35. Quy, V. K., Hau, N. V., Anh, D. V., Quy, N. M., Ban, N. T., Lanza, S., Randazzo, G., & Muzirafuti, A. (2023). IoT solutions for smart agriculture: Vision, architecture, applications, and challenges. Computers and Electronics in Agriculture.

36. Aqeel-ur Rehman, & Shaikh, Z. A. (2009). Ubiquitous computing and context-aware computing in smart agriculture. In N. Nhamo & D. Chikoye (Eds.), Advances in Agricultural Technology.

37. Nhamo, N., & Chikoye, D. (2017). Climate change and challenges in smart agriculture. Journal of Agricultural Science.

38. Södergård, C., Mildorf, T., Habyarimana, E., Berre, A. J., Fernandez, J. A., & Zinke-Wehlmann, C. (Eds.). (2021). Data Bio: Research and Innovation in Data Infrastructures and Services (Vol. 2).