**HYDROBLEND: AN AUTOMATED NUTRIENT SOLUTION FORMULATOR FOR HYDROPONIC LETTUCE FARMING**

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**CHAPTER I**

**THE PROJECT AND ITS BACKGROUND**

**Introduction**

The significant growth of the human population certainly puts greater pressure on food security. Natural minerals, high-quality soil, and a longer production cycle are all necessary for traditional farming. Innovations in technology have led to the adoption of hydroponic farming techniques. Plants grown hydroponically grow faster and produce more without the need for soil. Mamata and Kavitha, (2023). The agricultural industry is now using more advanced technologies than before. They use various information and communication technologies, including the Internet of Things (IoT). The rapid adoption of modern technologies has impacted agriculture and other industries. Khan et. al (2021).

Hydroponic agriculture requires serious planning, preparation, and maintenance to produce crops; it goes beyond submerging plants in water and watching them grow. Careful consideration of several factors, including nutrient balance, water circulation, and environmental conditions, is required when using this method. Hydroponic farmers may improve plant growth and ideal crop yields without depending on the traditional soil-based farming method by utilizing advanced technologies and monitoring systems.

Lettuce cultivation is a crucial component of modern agriculture, as it is widely used in salads and other culinary uses. Successful lettuce cultivation requires a thorough understanding of the plant's growth needs. This includes selecting appropriate lettuce varieties, improving soil conditions, and deploying effective watering systems.

However, hydroponics is becoming a more common and innovative method of lettuce farming, replacing traditional soil with nutrient-rich water solutions. Hydroponic systems provide precise control over nutrient levels, pH balance, and water distribution, leading to faster growth rates and larger yields. This strategy conserves water while eliminating soil-borne illnesses, resulting in a cleaner and more controlled environment for lettuce plants. As we explore controlled environment agriculture, it appears promising, enabling year-round output, protection from bad weather conditions, and resource efficiency.

The technological advancements have greatly benefited hydroponic farmers by providing them with access to remotely create nutrient solutions and monitor status, such as the water level, pH status, and nutrient status inside the reservoir. Moreover, it also automates actions when environmental conditions change, such as low/high temperature, low water level, etc. This has made farming more efficient and productive. Tagle et al (2018).

Mr. Gerand and Mrs. Ann Peredo are the owners of HydroGreens Libmanan, which is located in Brgy. Puro-Batia, Libmanan, Camarines Sur. has been operational for two years. Their services extend across Libmanan, Naga, and Sipocot municipalities. They have served various establishments in the area, including Black Pepper Libmanan, Preciosa Insilada, Foodies Point, 8tea Trip Cafe, Espresso Libmanan, F&L Foods, Mang Dennis, Inkprinta Cafe, Mr. Wings Sipocot, Cbros, and Kap Onie Samgyup. Additionally, they cater to approximately 15 regular customers. HydroGreens specializes in hydroponic farming, employing the Kratky and Nutrient Film Technique (NFT) methods. Initially adopting the Kratky method, which requires no water pumps and sustains stagnant water for up to 2 days, they recently upgraded to the NFT System, utilizing pumps to circulate the nutrient solution through shallow channels, enhancing their farming capabilities.

The formulation of the nutrient solution has three phases: first, dissolving the water-soluble nutrients (Epsom Salt, Nutrient Hydro-NPK, Calcium Nitrate, and Iron) in water; second, combining the dissolved Epsom Salt and Nutrient Hydro (NPK) to create Nutrient A; and lastly, adding the formulations of nutrient solutions A, B (Calcium Nitrate), and Iron to the water, resulting in the final product of the nutrient solution to be supplied to hydroponic crops.

After the formulation, the solution's components, namely the pH and the nutrient levels or PPM, will be measured. Add a nutrient solution if the PPM level recorded on the TDS Meter is low. Conversely, if the PPM is high, water should be added to regulate and meet the standard PPM level of 880-1000 PPM. To assess acidity, the standard pH level should fall within the 5.5-6.0 pH range. If the pH level is high, one should add a pH-down solution. Conversely, if the pH level is low, a pH-Up solution needs to be added to adjust to the standard acidity of the solution.

The following are the main problems of the HydroGreens Libmanan: first, to create an accurate water-nutrient solution, Hydroponic systems rely on a precise balance of water and nutrient solutions to ensure optimal plant growth. Inaccuracies in formulating these solutions can lead to nutrient deficiencies or excesses, affecting the health and yield of hydroponic crops. Second, time conflict for monitoring crops and water levels, efficient hydroponic farming requires continuous monitoring of crop health and water levels. However, the time-consuming nature of these tasks can lead to conflicts, potentially resulting in delayed responses to issues—third, environmental conditions. Hydroponic systems are sensitive to environmental conditions, and variations can impact crop growth. Factors such as temperature and humidity must be carefully managed to maintain an optimal growing environment and the fluctuation of water solution content for hydroponic crops. Hydroponic crops rely on a stable and consistent nutrient solution. Fluctuations in solution content can lead to nutrient imbalances, affecting plant health and overall productivity.

To address the client's several challenges, the researchers have proposed a system that HydroGreens Libmanan can utilize to effectively resolve various issues, emphasizing creating water solutions for lettuce growth. This system offers an automated solution that formulates nutrients for lettuce farming. HydroBlend comes out for its use of Internet of Things (IoT) technologies and web applications to monitor and automate nutrient management procedures. HydroBlend's advanced technologies ensure a precise and efficient supply of nutrients for maximum lettuce growth in hydroponic systems. This improves the quality of lettuce produced and simplifies the entire cultivation process for HydroGreens Libmanan, making it easier to maintain and manage.

**Objectives**

The general objective of the study is to develop a device to Automate Nutrient Solution Formulator for Hydroponic Lettuce Farming; specifically, it aims to:

* 1. To design and develop an IOt-based automated formulation of

nutrient solution for lettuce.

* 1. To measure and monitor the formulated solution content using

sensors using a web application.

* 1. Remotely access temperature control for lamps and fans.
  2. Monitor hydroponic farm status, such as tank level, temperature, and

humidity.

**Scope and Delimitation**

The study covers the development of the automated system for HydroGreens Libmanan. This study aims to determine the effectiveness of IoT in the automation of formulating nutrient solutions for hydroponic lettuce with the integration of web applications for monitoring and remote access that ensure a precise and efficient supply for maximum growth in hydroponic systems.

The cover of this study is to automatically create actions when the sensors detect changes in the default setting of water tank level, temperature, and humidity. Additionally, it can monitor the sensor’s data in real-time and control remotely using the web application.

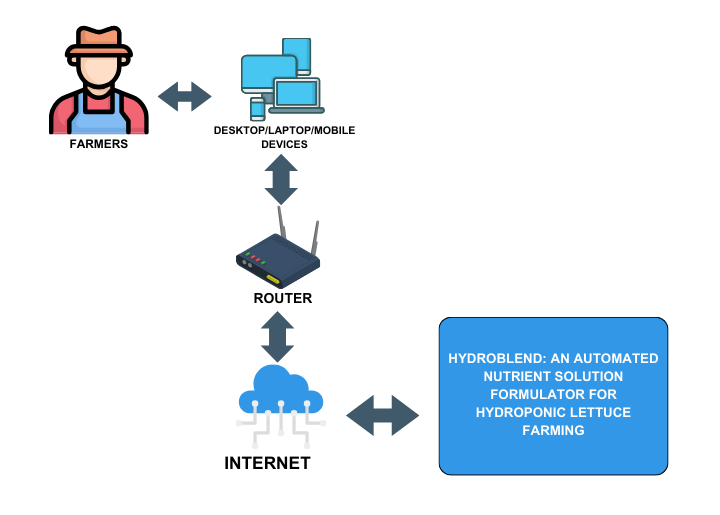
 This system exclusively focuses on hydroponic farming, specifically the Nutrient Film Technique (NFT) method, due to its utilization of a single water tank that can be monitored using sensors. In contrast, the Kratky method requires an individual water container per set. This study does not cover other agricultural practices. The initial phase of formulating the nutrient solution involves a manual process using powder-based nutrients. During this step, the powder is carefully mixed with water to ensure thorough dissolution of the nutrients before filling into the developed device container for formulation. Lastly, HydroGreens Libmanan farmers can utilize this system exclusively because the web application is designed to control and monitor the IoT devices within the hydroponic farm.

Figure 1.0

**Architectural Diagram of HydroBlend: Nutrient Solution Formulator for Hydroponic Lettuce Farming**

Figure 1.0 shows the architectural diagram of HydroBlend: Automated Nutrient Solution Formulator for Hydroponic Lettuce Farming. This diagram illustrates how a user's hardware device connects to the system. A farmer can use devices such as a mobile phone, desktop computer, laptop, or tablet to access the system. To have access to the system. To log in, the user's device must be connected to the internet and provide their authentication credentials. Using the router for internet connection allows farmers to access the system through a web browser application remotely. It enables them to monitor real-time data and receive alerts or notifications from any location with internet access. The Arduino acts as a microprocessor, controlling the sensors, pumps, fans, and lights. The NodeMCU connects the Arduino Uno to the router to facilitate remote access via a web application. Pumps are deployed to dispense the necessary liquids to create the nutrient mixture. A relay module connects these pumps for precise liquid dispensing and serves as a switch for temperature control. The DHT22 Sensor monitors the hydroponic farm's temperature and humidity, activating the fan or grow light when temperature changes are detected. The pH sensor measures the solution's acidity, and the Total Dissolved Solids (TDS) sensor measures the nutrient level of the solution.

**Significance of the Study**

The result of this study is expected to give great benefit to the following entities:

**Research Community.** Can benefit from the study by gaining insights into the automated nutrient formulation system in achieving sustainable agriculture practices.

**Agri-entrepreneur.** The developed device may be beneficial to Agri-entrepreneurs. The development of the device may help produce crops smoothly and maximize crop yield.

**Farm Owners.** Using the system will ensure that the farm will gain profit and attain sustainability. It helps them to engage in strategic, tactical, and operational planning.

**Consumers.** The developed device may be beneficial to customers engaged in hydroponic lettuce farming. By automating this process, consumers experience consistent and reliable fresh products because hydroponic farms can operate efficiently and produce goods to meet consumers' demands. This results in affordable prices and offers hydroponically cultivated goods to many consumers.

**Future Researchers.** This study will serve as valuable material for student researchers for their ongoing research and as a reference for other studies.

# Definition of Terms

Important terms used in this study were defined conceptually and operationally to provide a common framework of understanding for both researchers and readers.

**Arduino:** Open-source electronics platform based on easy-to-use hardware and software. It consists of a microcontroller board programmed to receive input from sensors, process data, and control various devices such as lights, motors, and other actuators. (Ismailov et al. 2022). In this study, Arduino acts as a microprocessor to send sensor commands to gather and process data. It enables automated actions to maintain and enhance the system's efficiency and effectiveness.

**Breadboard:** A breadboard (sometimes called a plug block) is used for building temporary circuits. It is helpful to designers because it allows for the easy removal and replacement of components. It is useful to the person who wants to build a circuit to demonstrate its action and reuse the components in another circuit. Bishop.(2001).In this study, the breadboard helps by letting researchers easily connect and test different electronic components, like sensors and controllers, for the hydroponic system. It's like a testing ground where they can try different setups before finalizing the design. So, the breadboard is a handy tool that helps ensure all the electronic components in the developed device work properly.

**Calcium Nitrate:** Calcium nitrate appears as white to light gray granular solid. It may be either the anhydrous compound or the tetrahydrate. Used in fertilizers, explosives, and pyrotechnics. National Center for Biotechnology Information (2024). In this study, It is a water-soluble nutrient used in hydroponic farming to provide essential calcium to plants, aiding their growth and development.

**DHT22 Sensor Module:** low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air and outputs a digital signal on the data pin. DHT22 Temperature and Humidity Sensor Module, (n.d) In this study, DHT22 sensors with Arduino to keep track of temperature and humidity in the hydroponic setup. This helps maintain the right conditions for plants to grow well by adjusting temperature and humidity as needed.

**Epsom Salt Solution:** Magnesium Sulfate is completely water soluble and specifically good for adding magnesium (10% Mg) and Sulfur (13% S) to plants. Magnesium sulfate and Epsom salt give the plants a dark green color and are great supplements for fruit plants. Epsom Salt – Philippines Aqua-Hydroponic Prime Ventures Corporation, (n.d.). This study uses a dissolved Epsom salt in hydroponic farming to provide magnesium sulfate to plants for optimal growth.

**ESP8266 NodeMCU**: The NodeMCU (Node Microcontroller Unit) is an open-source software and hardware development environment built around an inexpensive System-on-a-Chip (SoC) called the ESP8266. The ESP8266, designed and manufactured by Espressif Systems, contains the crucial elements of a computer: CPU, RAM, networking (Wi-Fi), and even a modern operating system and SDK. That makes it an excellent choice for Internet of Things (IoT) projects. John (2022). In this study, the Wi-Fi module allows remote monitoring and control of the hydroponic system, making it easier for operators to check data and adjust settings from afar. **Exhaust Fan:** It works by sucking hot or humid air out of a small, localized area, allowing fresh air to enter from elsewhere (perhaps a doorway or vent) to replace it. The warm air drawn out using an exhaust fan is pulled through a ducting system and expelled outside. (Exhaust Fans, n.d.). This study uses a hardware component to regulate temperature in hydroponic farming by activating when temperature changes are detected.

**Grow Light**: is a specialized lighting fixture designed to deliver the correct color or spectrum of light and the optimum light intensity for healthy and vigorous growth. **(**Torpey, 2024). In this study, it supplements natural light and ensures consistent and optimal lighting conditions for plant growth in the hydroponic system. This helps to promote photosynthesis, which is essential for healthy plant development, resulting in improved growth rates and higher lettuce yields.

**IoT (Internet of Things):** This is a network of physical devices. These devices can transfer data to one another without human intervention. (Schulze 2024). In this study, the sensors constantly check conditions like temperature and nutrient levels, helping create the perfect environment for lettuce growth in hydroponic systems. These sensors also trigger automatic adjustments when needed. With mobile access, users can easily monitor and manage the system over the Internet.

**Iron** is an essential micronutrient for almost all living organisms (Rout & Sahoo, 2015**)**. In this study, iron (Fe) is a metallic element with the atomic number 26 and the chemical symbol Fe. It is essential for plant growth and development, vital in photosynthesis, energy transfer, and enzyme activation. In crops like lettuce, iron aids in synthesizing chlorophyll, which is necessary for photosynthesis and overall plant vigor. Iron deficiency can result in leaf yellowing and stunted growth in lettuce plants.

**Jumper Wires:** Jumper wires are wires with a connector at both ends and are suitable for interconnecting components in a breadboard, prototype, or test circuit. They connect components without soldering. Jumper Wires – an Introduction, Applications, and Working Principles., (2022). This study connects sensors to the control unit, sensors, and electronic components, enabling real-time monitoring and adjustment of environmental conditions in the hydroponic system.

**LCD:** The liquid crystal display uses the property of light monitoring of liquid crystals, and they do not emit the light directly. It is a flat panel display or an electronic visual display. (LCD (Liquid Crystal Display) Introduction - Example Project, 2023). In this study, it is a screen technology used on devices like phones and TVs. LCD screens can show real-time sensor data, helping farmers monitor nutrient levels and temperature for better crop care.

**Nutrient Solution**: The nutrient solution acts as a fertilizer, providing plants with essential nitrogen (N), phosphorus (P), and potassium (K). These elements, represented by their symbols on the periodic table, make up the main components of the solution known as NPK. Plants have varying nutrient needs at different stages of growth, so these elements are mixed in different proportions accordingly. (NPK And Hydroponic Nutrient Solution - AGrowTronics - IIoT for Growing, 2021). In this study, it is essential for lettuce crop cultivation to provide the necessary nutrients for optimal plant growth in hydroponic systems.

**Nutrient Film Technique (NFT) Method:** The method by which water flow is circulated through growth tanks containing the roots of the plants. The plants absorb the nutrients through the roots, and because the stream is shallow and the roots are also suspended in the air, the roots can also absorb oxygen. (Adelmann 2023). This study delivers nutrients precisely to plant roots in hydroponic systems. This ensures that plants get the right amount of nutrients they need for healthy growth.

**Parts Per Million (PPM):** PPM means Parts Per Million, a unit of measurement used to indicate the concentration of particles in a solution. In hydroponics, PPM measures the concentration of dissolved nutrients in the water. The correct level is crucial for proper growth and yield (Livermore, 2022). This study helps by measuring the amount of nutrients in the water used for growing plants. This measurement ensures that the plants get the proper nutrients they need to grow well.

**PH:** Quantitative measure of the acidity or basicity of aqueous or other liquid solutions. (Britannica 2024). In this study, it is done by making sure the nutrient solution has the right acidity level for the plants to absorb nutrients properly.

**PH Sensor:** A scientific device accurately measures acidity and alkalinity in water and other liquid substances. (Wang, 2023). In this study, it is a device that measures the acidity of a solution, particularly in hydroponic farming, to ensure it falls within the optimal range of 5.5-6.0 pH for plant growth.

**PH Up Solution:** pH up solutions have strong bases that raise the pH level when added. Agrotonomy and Agrotonomy (2024). In this study, it is a substance used to adjust the acidity of a nutrient solution in hydroponic farming when the pH level is below the standard range of 5.5-6.0.

**PH Down Solution:** pH down solutions have powerful acids that decrease the pH level when added. Agrotonomy and Agrotonomy (2024). In this study, it is a substance added to reduce the acidity of a hydroponic nutrient solution when the pH level is higher than the standard range of 5.5-6.0 pH.

**Pump:** It is used to transport water from one location to another. To suck water in so that it can be expelled, a pump must be able to alter pressure within a system rapidly. What Is a Water Pump and How Is It Used? (n.d.). In this study, it is a device used to circulate the nutrient solution through channels or containers, enhancing plant growth and maximizing yields.

**Relay:** A Relay is a simple electromechanical switch. While we use normal switches to close or open a circuit manually, a Relay is also a switch that connects or disconnects two circuits. But instead of a manual operation, a relay uses an electrical signal to control an electromagnet, which connects or disconnects another circuit. (Prasad, 2022). This study helps by facilitating automated actions based on environmental data collected by sensors.

**Solenoid Valve:** A solenoid valve is an electromechanical device that controls the flow of a liquid or gas through a pipe or tubing system. It consists of a coil of wire called a solenoid, which, when energized, creates a magnetic field that opens or closes a valve mechanism, allowing or stopping fluid flow. What Is a Solenoid Valve: Your Comprehensive Guide, (n.d.). In this study, the 12V solenoid valve acts as a gatekeeper for the nutrient solution. It controls the flow of nutrients to the plants based on the information collected by sensors.

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**CHAPTER II**

**REVIEW OF RELATED LITERATURE AND STUDIES**

This chapter provides a comprehensive framework for our investigation, integrating relevant literature and references to facilitate the development of our proposed system. It includes reviews of existing research drawn from various scholarly sources, including journals, websites, and related publications.

**Hydroponic Lettuce Farming**

Lettuce (Lactuca sativa) is a well-known plant worldwide due to its use for salad, soup, and vegetable curries. This plant is cultivated worldwide and is one of the most consumed green leafy vegetables in raw form for its taste and nutritional value. Noumedem, J. A. K. et. al, (2017). Lettuce helps in proper digestion, supports liver health, reduces the risk of heart diseases and strokes, lowers cholesterol and cancer control, protects neurons, promotes sleep induction, manages anxiety, reduces inflammation, and supplies antioxidants. Cervantes, C. N. et al., (2017).

Lettuce farming can be optimized through various methods, such as vertical farming, traditional farming, and hydroponics. Vertical farming, as highlighted by Wiggins et al. (2020), is used primarily for leafy vegetables, such as lettuce, which are grown vertically arranged layers. This leads to a substantial increase in the number of plants per unit area. This innovative farming approach maximizes space efficiency and can significantly boost crop yields. Soil type also plays a crucial role in lettuce production, with studies indicating that lettuce is commonly grown in loam, clay-loam, and clay soils Moussa et al., (2021). Al alterations like biochar in soil have been shown to impact the availability of heavy metals in the soil and absorption by lettuce Kim et al., (2015).

Hydroponiccultivation is a soilless crop production technique wherein plants thrive in a nutrient-rich water solution. This method eliminates the need for soil and offers the advantage of water recycling. This offers a solution to combat climate change by reducing environmental damage and species extinction caused by intensive farming. It promotes rational water use, crucial in regions facing scarcity. Hydroponic crops are profitable, easier to control, and aid in fighting hunger and enhancing food safety, especially in developing countries. Iberdrola, (2021).

According to Rathnayake, K. T., and Sharmilan, T. (2023), various innovative techniques are used in hydroponics, and each technique has a different approach to plant growth. First, The Nutrient Film Technique (NFT) System. The nutrient-rich water is distributed over bare roots on a sloping channel. Any excess water flows back into the reservoir. This technique is commonly used to grow herbs and leafy greens. Second, Deep Water Culture (DWC) immerses plants in a nutrient solution where their roots float. This solution is oxygenated using an air diffuser system. Third, Ebb and flow, also known as flood and drain, involves submerging plants in trays or containers filled with growing media, with an overflow system efficiently draining water, which then returns to the reservoir. Fourth, Drip Irrigation delivers a slow, continuous drip of nutrient solution to each plant, ensuring moisture is maintained in perlite or coconut coir mediums. Fifth, Aeroponics suspends plant roots in the air and mists them with a nutrient solution. Lastly, Aquaponics combines fish and plants. Fish in a tank provides nutrients to plants without soil, creating a balanced farming system.

**IoT-Based Hydroponic System**

IoT technology has been increasingly integrated into agriculture, offering innovative solutions to enhance farming practices. Several studies have explored the application of IoT in agriculture, focusing on areas such as precision farming, smart farming, and greenhouse management. Farooq et al., (2022) emphasize IoT revolutionizes agriculture by providing smart solutions for precision farming, greenhouse management, and livestock monitoring. This indicates a shift towards more advanced agricultural approaches facilitated by IoT technology.

Moreover, Various IoT-based platforms have been developed to facilitate controlled agricultural practices, including in the field of hydroponics Farooq et al., (2020). Perwiratama et al., (2019) developed a smart system for hydroponic farming using IoT Technology. This system helps to automate tasks, reducing the need of human labor. For instance, controlling hydroponic nutrients makes it easier because the sensors can detect and collect data that will be sent to a microprocessor to create an automated action. Additionally, Iskandar et al. (2022), designed an IoT-based hydroponic nutrient automation system, which maintains plant quality and water nutrients with a 91.2% efficiency and enhances actuator functionality.

**Sensors Technology**

Hydroponic systems have undergone significant advancements with the integration of Internet of Things (IoT) technology. Researchers have focused on developing IoT-based monitoring and control systems for hydroponic plants to enable remote management of crucial parameters such as plant color, temperature, nutrient levels, and pH value of the water Untoro & Hidayah, (2022). Utilizing sensors like the DHT-22 sensor, PH-4502c, TDS sensor, and light intensity sensor, in conjunction with microcontrollers such as ESP8266 and Arduino Uno, facilitates efficient seeding maintenance and monitoring in hydroponic setups Setyowati et al., (2023); Ramsari and Hidayat, (2022). Moreover, integrating IoT technology in hydroponics assists in automating tasks like nutrient control, moisture monitoring, and pH level, thereby reducing the necessity for manual intervention. Novianty et al., (2023)

**Web-Based Monitoring**

Several studies have focused on developing IoT-based platforms for agricultural monitoring, such as Agri-Snaps by Anas et al., (2022) and LoRa-based systems for remote monitoring of large-scale farms Ahmed et al., (2022). These systems allow for continuous data collection from various IoT devices, including sensors, actuators, and drones, improving data-driven agricultural decisions. Mamata and Kavitha (2023) also developed a Remotely monitored Web-based Smart Hydroponics System for Crop Yield Prediction using IoT. This system uses sensors that collect data and send it to an ESP32 microprocessor. They created a web application for monitoring sensor data such as pH level, temperature and humidity, and nutrient level, as well as crop yield predictions, where farmers can enter the type of crop, the size of areas they want to grow, and the farm's location. Moreover, Gokul et al., (2021) developed an IoT-based smart hydroponic system that uses the Things Speak web application to operate actuators and monitor real-time sensor data stored in the Things Speak cloud.

**Synthesis of Related Literature and Studies**

HydroBlend: An Automated Nutrient Solution Formulator for Hydroponic Lettuce Farming This represents a significant advancement in the agricultural field. Using Internet of Things (IoT) technology, this system attempts to improve production and promote farming sustainability. Agriculture has embraced the widespread use of cutting-edge technologies in recent years, with the Internet of Things emerging as an important factor in this evolution. The synthesis of related literature and studies in this field emphasizes the growing focus and research efforts on IoT-based hydroponic lettuce farming systems.

Noumedem, J. A. K. et al. (2017) and Cervantes, C. N. et al. (2017) present an overview of Lettuce (Lactuca sativa), detailing its uses and positive impacts on health. Wiggins et al. (2020), Moussa et al. (2021), and Kim et al. (2015) highlight various methods to lettuce farming, encompassing traditional soil-based methods and the advantages of vertical farming. Iberdrola (2021) introduces hydroponic farming and its associated benefits, while Rathnayake, K. T., and Sharmilan, T. (2023) emphasizes the various techniques and procedures involved in hydroponic farming.

Farooq et al. (2022) discuss the application of Internet of Things (IoT) technology in agriculture, emphasizing its potential to improve farming operations across various fields. In a similar line, Farooq et al. (2020) emphasize several IoT-based platforms used in farming operations. Perwiratama et al. (2019) and Iskandar et al. (2022) describe the use of various sensors to monitor and collect data. When these parameters exceed predetermined limits, the sensors detect the change and send signals to the microcontroller, triggering the appropriate actions until the parameter returns to its optimal level.

According to Untoro and Hidayah (2022) identify the main parameters that should be monitored in hydroponic system. Setyowati et al. (2023), Ramsari and Hidayat (2022), and Novianty et al. (2023) emphasize the variety of sensors used to monitor temperature, humidity, nutrient level, pH level, and light intensity, assuring the best conditions for hydroponic farming.

However, Anas et al. (2022) and Ahmed et al. (2022) emphasize implementing IoT-based monitoring systems in agriculture, which collect data through multiple devices and platforms, allowing for better data-driven decision-making in farming practices. Similarly, Mamata and Kavitha (2023) and Gokul et al. (2021) point out the significance of an IoT-based hydroponic monitoring system with an integration of a web application for data collecting, crop production prediction based on user input and real-time monitoring from a range of sensors.

This synthesis will delve into existing literature and studies related to HydroBlend: A Web-Based Automated Nutrient Solution Formulation for Hydroponic Lettuce Farming. Our analysis will encompass the technological aspects, advantages, challenges, and the broader influence of these systems on contemporary agricultural practices. This comprehensive review aims to offer valuable perspectives on the present status of the discipline and its capacity to transform crop cultivation.

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**CHAPTER III**

**RESEARCH DESIGN AND METHODOLOGY**

The research design for studying soil nutrients monitoring for effective sweet potato production and this chapter presents the research design, research methodology, data gathering techniques, system architecture, and the software and hardware requirements.

**Research Design**

The researcher will use descriptive, experimental, and developmental methodologies to craft the intended system for this research project. The descriptive research design includes data collection, thorough observation, and understanding of the identified subjects. Using a Repeated Measures Design in experimental research enables researchers to evaluate the effectiveness of various procedures in formulating nutrient solutions for hydroponic lettuce while controlling for related factors. This design offers a robust approach to assess interventions on the quality of nutrient solutions. Collecting data from an automated nutrient solution formulator for hydroponic lettuce farming facilitates gathering the necessary information for the design system.

Furthermore, a developmental approach will be used in the research process. This entails developing, evaluating, and enhancing procedures to ensure the efficacy and reliability of the study.

**Research Methodology**

To develop this capstone project, the researchers used the Rapid Application Development (RAD) methodology, which is a concept introduced to the public by James Martin in 1991, who believed that it refers to a development life cycle designed for high-quality systems with faster development and lower costs than the traditional life cycle provided.

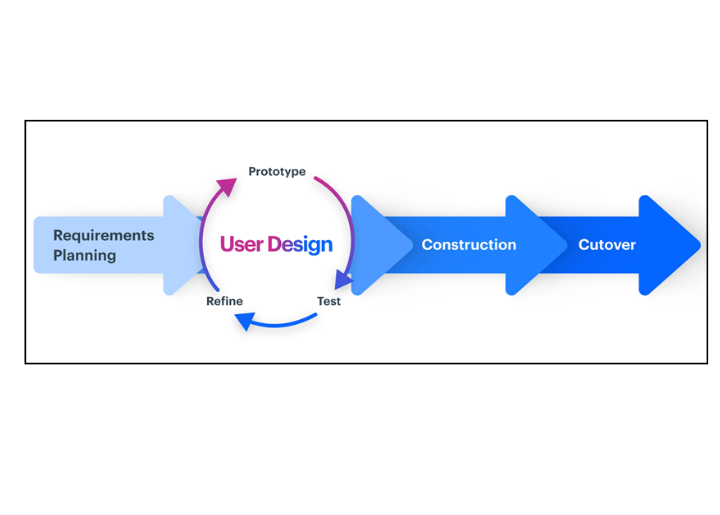
To develop this capstone project, the researchers adopted the Rapid Application Development (RAD) methodology, introduced by James Martin in 1991. Martin suggested that RAD offers a development lifecycle to deliver high-quality systems more rapidly and cost-effectively than traditional development approaches. Studies show that Rapid Application Development (RAD) provides a comprehensive method for designing systems in a shorter period, including a focus on prototype development. De Leon and Battung, (2021). This methodology is particularly useful in scenarios where there is a need for dynamic systems, limited development time and budget, quick access to up-to-date information, and a requirement for close interaction with end-users (Kosasi & Yuliani, 2015).

Figure 3.0

**Rapid Application Development**

**Phase 1: Requirements Planning**

In this phase, developers and clients engage in discussions to identify the project's objectives and expectations and address existing and potential challenges that must be resolved prior to and throughout the development process.

For this research, the researchers interviewed the clients. Unstructured and structured interviews with the owner of Hydroponic Lettuce Farm were done to gather important information and identify the problems that they encounter in Hydroponic Lettuce Farm due to its time-consuming nature and difficulties in manually formulating nutrient solutions.

In this study, the researchers carried out interviews with the clients. They have conducted unstructured and structured interviews with the owner of a Hydroponic Lettuce Farm to collect crucial information and identify the challenges faced in the hydroponic lettuce farming process, mainly the complex task of manually formulating nutrient solutions. After assessing the client’s issues, the researchers developed an automated nutrient solution formulator for hydroponic lettuce farming. This device is powered by an Arduino Uno and equipped with pumps. It is designed to blend nutrient solutions precisely by dispensing the exact volumes of each component into a tank. Additionally, it will utilize sensors to monitor nutrient and pH levels and manage environmental conditions like temperature and humidity.

|  |  |  |
| --- | --- | --- |
| **Software** | **Minimum** | **Recommended** |
| Browser | Any browser | |
| Internet Bandwith | 2-5 Mbps | 10Mbps and above |
| Operating System | Any operating system for mobile devices or desktop computers. | |

Table 3.1

**Software Requirements**

Table 1 shows the software requirements required for the system to perform properly and efficiently. These requirements were found by research and suggestions from developers using the same algorithm.

|  |  |  |
| --- | --- | --- |
| **Hardware** | **Minimum** | **Recommended** |
| Microcontroller | Arduino Uno R3 | Rasberry Pi |
| Wi-Fi Module | Wifi Module | NodeMCU ESP8266 |
| TDS Nutrient Sensor | Gravity Analog TDS Sensor | Atlas Scientific EZO Conductivity Circuit |
| pH Level Sensor | Gravity Analog pH Sensor | Atlas Scientific EZO pH Circuit |
| Temperature and Humidity Sensor | DHT11 | DHT22 AM2302 |
| Ultrasonic Sensor | HC-SR04 | JSN-SR04T |
| LCD | 20x2 LCD | Arduino 0.96 Inch OLED 128x64 I2C SSD 1306 LCD Screen |
| Relay | SainSmart 5V Relay Module | SunFounder 4-Channel Relay |
| 5v Water Pump | DC 3-5V Mini Submersible Water Pump | ZAOJIAO DC 3.5-9V Mini Submersible Water Pump. |
| 9v Exhaust Fan | DC 9V Mini Exhaust Fan | WINSINN 50mm Blower Fan |
| Strip UV Light | DC 5V UV LED Strip Light | UV LED Black Light |
| Solenoid Valve | DC 12V Electric Solenoid Valve | U.S. Solid 1/2" Brass Electric Solenoid Valve |
| Water Pump | DC 12V Submersible Water Pump | Homasy 400GPH Submersible Water Pump |
| Ultrasonic Turbine Washer | Fencia Ultrasonic Turbine Washer | |

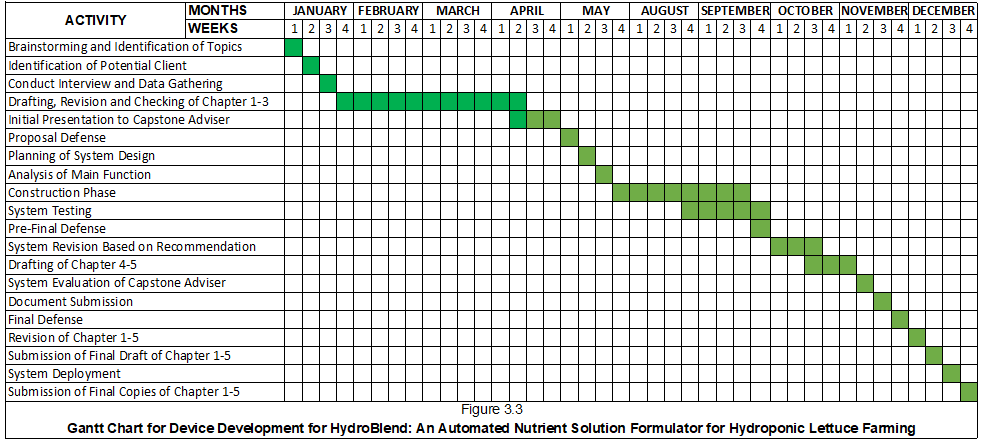
Table 3.2

**Hardware Requirements**

The preceding table shows the hardware components required for the development and operation of the system. Additionally, the researcher has compiled additional hardware specifications for creating a device intended to collect sensor data (refer to Table 3.2). This integrated hardware device includes an Arduino Uno, TDS nutrient sensor, pH level sensor, DHT22 Temperature and Humidity Sensor, and HC-SR04 Ultrasonic Distance Sensor, which are used to collect sensor data. The NodeMCU ESP8266 enables the transmission of sensor data to a web platform for remote monitoring, while a 20x2 LCD allows for on-site monitoring of current nutritional and environmental parameters. A relay controls the operation of exhaust fans, UV light strips control temperature, and amphibian-type pumps provide accurate nutrient solution dispensation. A solenoid valve controls the primary water source for formulation, a water pump enables irrigation for hydroponic lettuce crops, and ultrasonic turbine washer to mix thoroughly the formulated solution.

The hardware and software specifications outlined in Tables 3.1 and 3.2 were determined based on the specific requirements of the IoT-based project to ensure its proper functionality and alignment with its intended purpose. These specifications are essential for optimizing system performance, minimizing potential issues, and ensuring a smoother user experience with the application. The researchers will use both hardware and software requirements throughout the entire process of development and operation of the system.

Furthermore, the researchers created a Gantt Chart (shown in Figure 3.3) to act as a roadmap for tracking the project's progress. This application will serve as a basic project management tool, supporting the organizing and visualizing the whole project lifecycle. It will define multiple tasks, accomplishments, and connections, providing a clear timeframe for each project step. This visual representation will allow researchers to manage resources more effectively, identify potential challenges, and guarantee that projects move smoothly. The Gantt chart will act as a dynamic guide as the study progresses, allowing researchers to compare progress to the established schedule.



**Phase 2: Design**

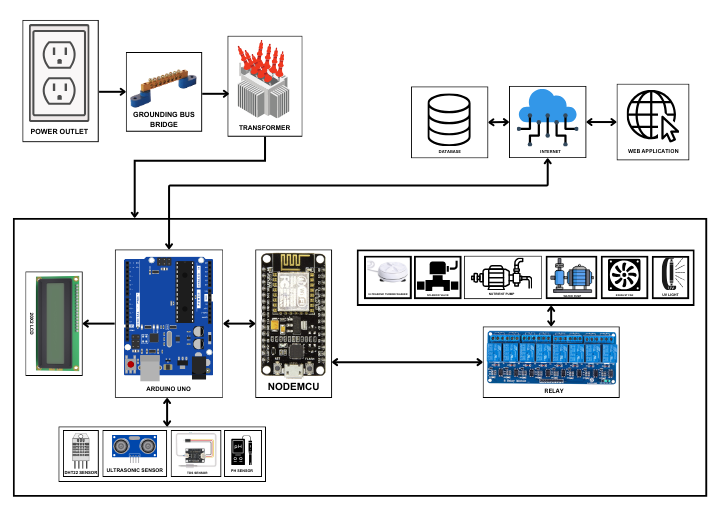
**** This phase contains the system architecture, outlining the components involved in the system development process. Following a thorough study of all gathered data, researchers will create a system architecture, block diagram, and data models to forward the project's development.

Figure 3.4

**Block Diagram of HydroBlend: An Automated Nutrient Solution Formulator for Hydroponic Lettuce Farming**

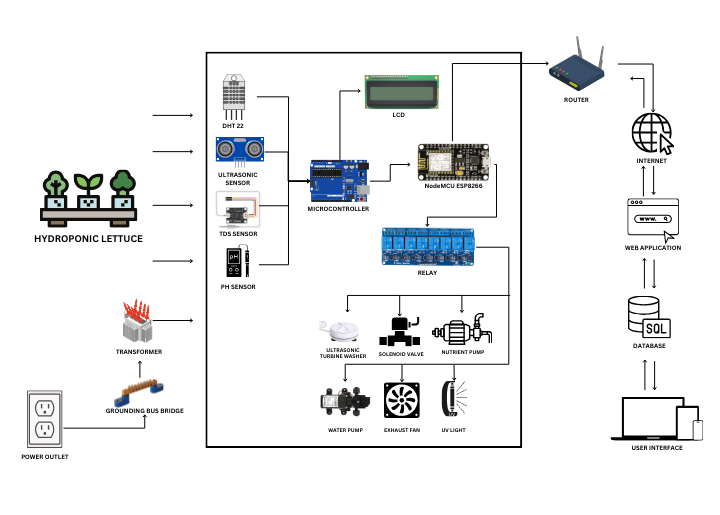
The sensor is a hardware device that can collect sensory input that is interpreted and transmitted to the base station using a variety of communication protocols. In this study, we employed a variety of sensors, including the DHT22 Temperature and Humidity Sensor, Ultrasonic Distance Sensor, TDS Sensor for nutrient levels, and pH Level Sensor for acidity level. These sensors collect nutritional content and environmental data to create decision-making and automation.

Figure 3.5

**System Architecture of HydroBlend: An Automated Nutrient Solution Formulator for Hydroponic Lettuce Farming**

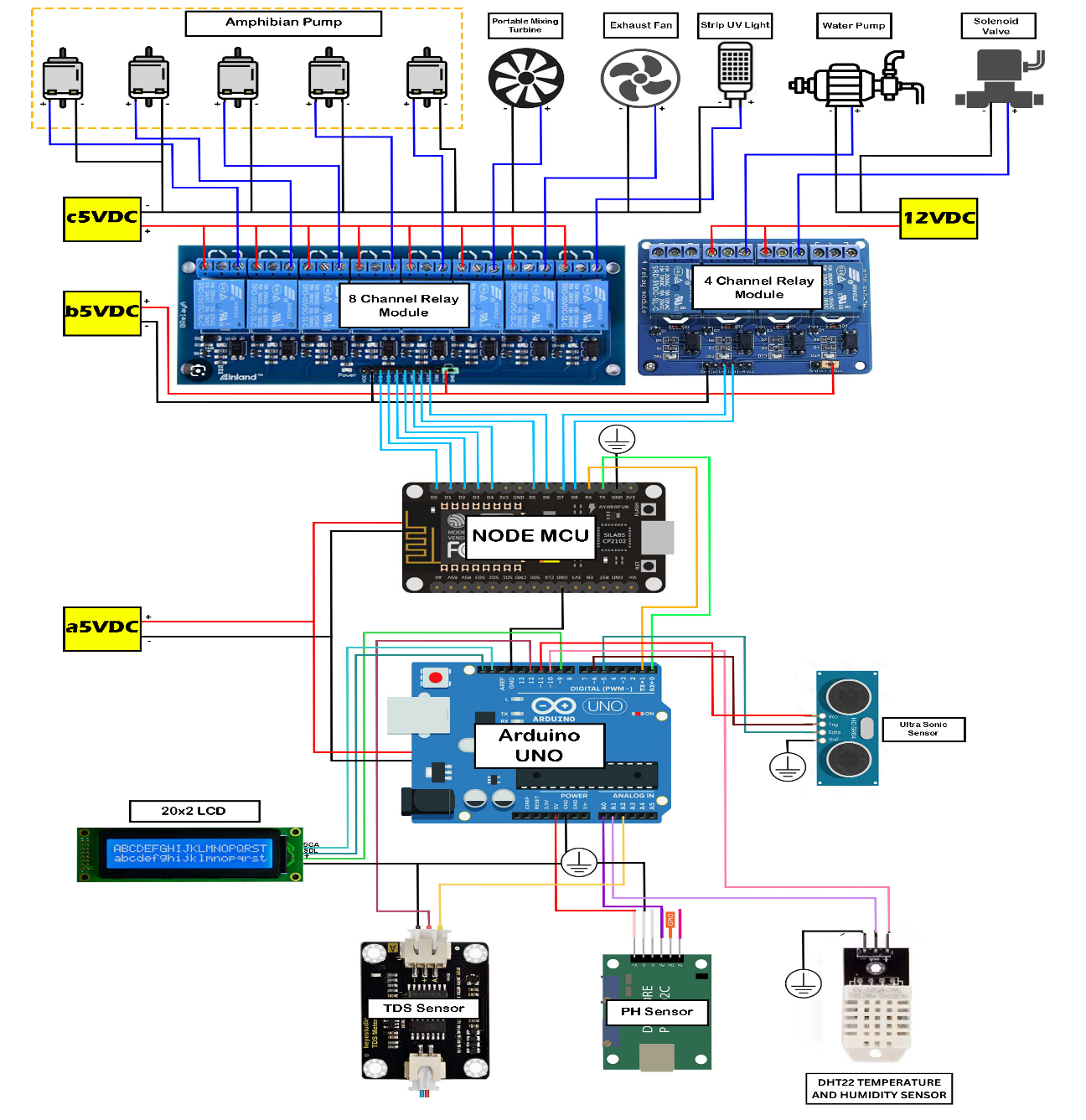
The diagram illustrates the collaborative operation of hardware components. The DHT22 gauges temperature and humidity within the hydroponic farm, the ultrasonic sensor measures nutrient volume in the water tank, the TDS sensor assesses nutrient levels, and the pH sensor determines the acidity of the nutrient solution. Data collected by these sensors is sent to the Arduino Uno microcontroller. The NodeMCU controls pumps, fans, and lights via relays and controls data transmission to the system. The LCD provides on-site data display for user monitoring, while a web application enables remote monitoring and configuring connected components for distant supervision. The main power source provides device functionality. The integration of IoT devices and software applications streamlines the formulation of nutrient solutions for hydroponic lettuce.

Figure 3.6

**Schematic Diagram of HydroBlend: An Automated Nutrient Solution Formulator for Hydroponic Lettuce Farming**

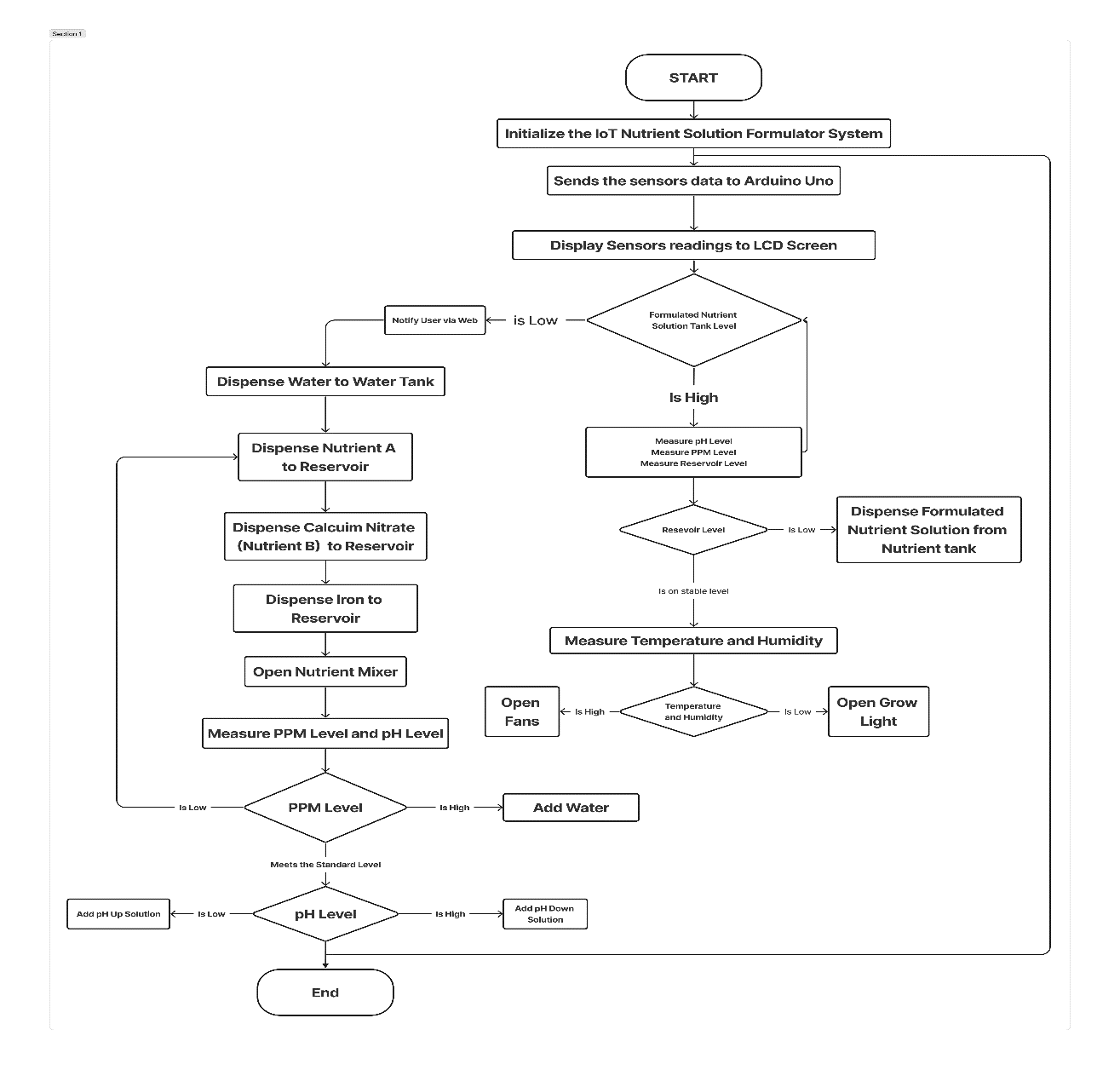
Figure 3.6 displays the schematic diagram of the automated nutrient solution formulator for hydroponic lettuce farming, depicting the interface of relays connected to various components such as the amphibian-type nutrient pump, exhaust fan, strip UV light, water pump, solenoid valve, and ultrasonic turbine washer. These relays are linked to the NodeMCU, which is connected to an Arduino Uno Microcontroller. Within the Arduino Uno connection are the LCD, TDS sensor, pH sensor, DHT22 temperature and humidity sensor, and ultrasonic sensor.

Figure 3.7

**Flowchart of HydroBlend: An Automated Nutrient Solution Formulator for Hydroponic Lettuce Farming**

Figure 3.7 shows that the system utilizes various sensors and automates the tasks involved in creating and maintaining a nutrient-rich environment for growing lettuce. The process starts with initializing the IoT Nutrient Solution Formulator System. This initializes the various sensors and control systems. Sensors send data to the Arduino Uno which controls the various actions based on the sensor readings. These readings are also displayed on LCD screens for on-site monitoring.

The system measures the reservoir level and if it is low, the system will send a command to dispense a formulated nutrient solution from a nutrient tank. If the reservoir level is sufficient, the system will check the environmental parameters such as temperature and humidity. Once the temperature and humidity exceed to desired level, the fan will turn on, and if it is low, the grow light will turn on.

The next process splits into two depending on the formulated nutrient tank level. If the formulated nutrient tank level is on sufficient volume, the system will measure its PPM and pH levels. In contrast, if the nutrient tank level reaches about 25% of the tank volume, it will measure its PPM and pH levels before the formulation process.

The formulation process starts by dispensing water to the formulated nutrient tank, next is the dispensing of concentrated nutrient solutions such as Epsom Salt and NPK (Nutrient A), Calcium Nitrate (Nutrient B), and Iron. Once all solutions are already in the tank, the ultrasonic turbine mixer will turned on to mix the solutions thoroughly. After the mixing process, sensors will measure again the pH level and the PPM level of the formulated nutrient solution. If the PPM level is high, the pump will dispense water, and if the PPM level is low, the nutrients A, B, and Iron will gradually re-dispense into the tank until the PPM reaches its standard level.

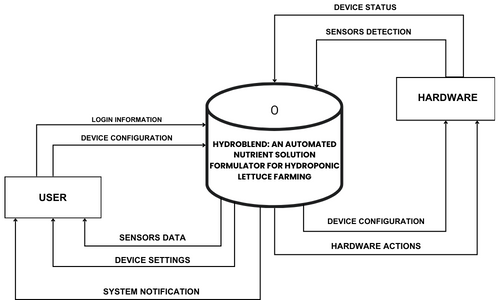
If the pH level is high, the pump will start dispensing the pH-down solution. In contrast, if the pH level of the formulated nutrient solution is low, the pump will dispense the pH-up solution until it reaches its standard level. Once all of those nutrient parameters are in a standard state, the system will continue to monitor the nutrient solutions including the environmental status inside of hydroponic farm.

Figure 3.8

**Context Diagram of HydroBlend: An Automated Nutrient Solution Formulator for Hydroponic Lettuce Farming**

Figure 3.8 depicts the interaction among the user, the system, and the hardware. HydroBlend operates through a well-organized structure. At its core lies Level 0 which receives inputs from both users and hardware components. Analyzing this data, Level 0 makes informed decisions, such as instructing devices to fix imbalances, like adjusting pH and PPM levels by adding necessary solutions.

The hardware of HydroBlend comprises sensors and devices responsible for physical tasks within the hydroponic system. Sensors detect important parameters like pH, PPM level, temperature, humidity, and tank levels relaying this information to Level 0 for processing. In response, devices under Level 0's control execute actions such as adjusting nutrient levels or regulating water flow to maintain optimal conditions.

Users engage with HydroBlend through a straightforward login system, gaining access to a user-friendly interface. Once logged in, users can customize settings, such as nutrient concentrations, and monitor vital parameters like pH and temperature in real time. This interaction empowers users to oversee the system's performance closely and make timely adjustments for optimal plant growth.

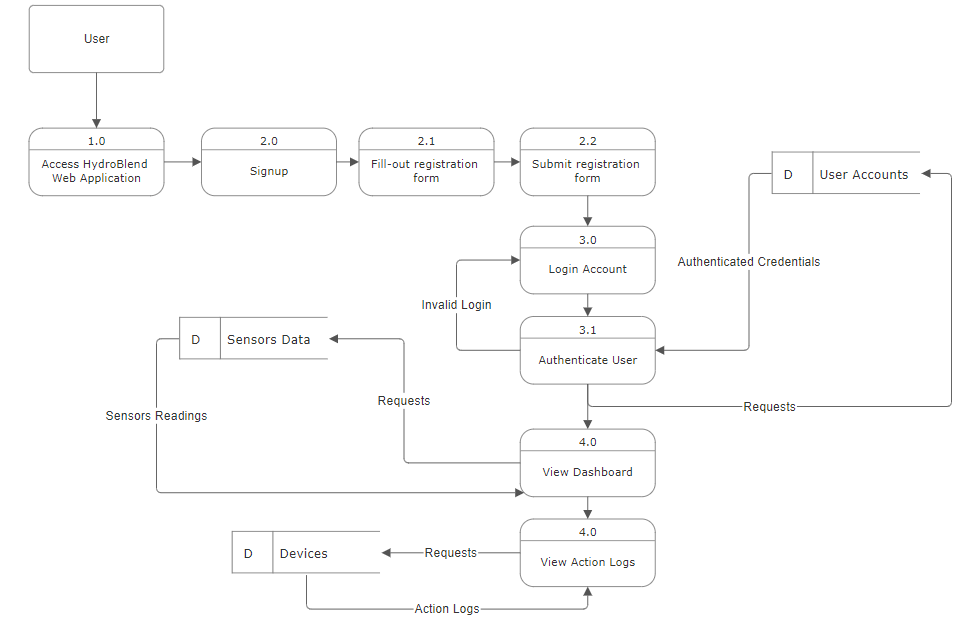


Figure 3.9

**Data Flow Diagram of HydroBlend: An Automated Nutrient Solution Formulator for Hydroponic Lettuce Farming**

The process starts with the user trying to access the HydroBlend web application. The user can then choose to either login to an existing account or create a new account. If the user chooses to log in, they need to provide their login credentials. The system will authenticate the provided login information. If the credentials are invalid, the user will return to the login page and will not proceed to the system dashboard, and if the user provides correct login information, the user will be granted to access the web application. The user can view the dashboard including the current state of the hydroponic farm, and the action logs of devices such as automation time in formulation, temperature control logs, and other actions.

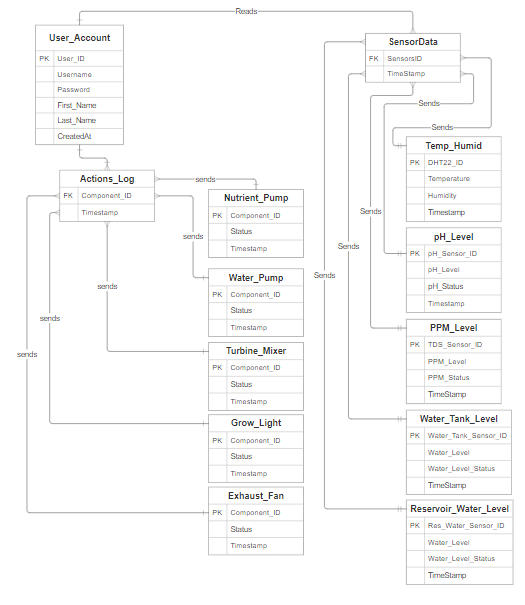


Figure 3.9

**Entity Relationship Diagram for HydroBlend: An Automated Nutrient Solution Formulator for Hydroponic Lettuce Farming**

**Phase 3: Construction**

During this stage, building an online research repository system began, followed by gradual refining and testing. This system was developed by thoroughly documenting client challenges and requirements. Throughout the Construction phase, developers methodically organized and structured the system's architecture and data flow model, creating a workable prototype for testing. This step makes it easier to identify and correct any mistakes, ensuring the system runs smoothly.

Furthermore, the researchers divided this phase into several sections: quick construction preparation, program and application development, unit coding, integration, and system testing. The researchers worked collaboratively to meet and surpass the client's expectations and standards.

**Phase 4: Cutover**

During this stage, building an online research repository system began, followed by gradual refining and testing. This system was developed by thoroughly documenting client challenges and requirements. Throughout the Construction phase, developers methodically organized and structured the system's architecture and data flow model, creating a workable prototype for testing. This step makes it easier to identify and correct any mistakes, ensuring the system runs smoothly.

Furthermore, the researchers divided this phase into several sections: quick construction preparation, program and application development, unit coding, integration, and system testing. The researchers worked collaboratively to meet and surpass the client's expectations and standards.

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