الجمهورية الديمقراطية الشعبية الجزائرية

وزارة التعليم العالي والبحث العلمي

جامعة الشهيد حمه لخضرالوادي

Faculty of Technology

Department of Electric engineering

Dissertation

ACADEMIC MASTER

Domain: Science and Technology

Division: Telecommunication

Specialty: wired and wireless telecommunication

Presented by:

- **Kherfi Ala Eddine**
- **Zabi Ala Eddine**

Entitled:

An automatic watering system for a smart greenhouse

Dissertation Submitted in Partial Fulfillment of the Requirements for the Master Degree

Publicly defended in: 04/06/2024

Board of Examiners:

Mr. Khatib mohammad najib	**MCB**	**Chairman**	**EL Oued University**
Mr. Ajgou riadh	**Prof**	**Examiner**	**EL Oued University**
Mrs. Boukaous Chahra	**MCA**	**Supervisor**	**Constantine 3 University**
Mr. Hima Abdelkader	**MCA**	**Supervisor**	**EL Oued University**

Academic Year: 2023/2024

Abstract:

Agriculture is one of the oldest and most important activities practiced by humans, and it still holds great significance for securing their food. However, achieving quality, saving time, and reducing effort require venturing into the digital world and employing technologies that contribute to this. In our project, we used Arduino as the mastermind to control and direct commands. Soil moisture levels are sensed using a moisture sensor, and they are managed by an Ultrasonic Humidifier. Temperature is controlled using a PTC Heating element, and ventilation system (door and fan) are regulated. The miniature controller ESP32 enables remote control via WiFi through an Android application. This work falls within the framework of designing and implementing a self-control platform and remote control in agricultural greenhouses. Through it, performance testing was conducted, and the project progressed successfully.

Keywords: agricultural houses, ESP32 controller, Arduino controller, smart irrigation system, Internet of Things.

ملخص :

تعتبر الزراعة من أقدم وأهم الأنشطة التي مارسها الإنسان، ولا تزال لها أهمية كبيرة لتأمين غذائه. إلا أن تحقيق الجودة وتوفير الوقت وتقليل الجهد يتطلب الدخول في العالم الرقمي وتوظيف التقنيات التي تساهم في ذلك .في مشروعنا، استخدمنا Arduino باعتباره العقل المدبر للتحكم وتوجيه الأوامر. يتم استشعار مستويات رطوبة التربة باستخدام مستشعر الرطوبة، ويتم إدارتها بواسطة جهاز ترطيب بالموجات فوق الصوتية .يتم التحكم في درجة الحرارة باستخدام عنصر التسخين PTC، كما يتم تنظيم نظام التهوية (الباب والمروحة). وتتيح وحدة التحكم المصغرة ESP32 التحكم عن بعد عبر WiFi من خلال تطبيق Android.يندرج هذا العمل في إطار تصميم وتنفيذ منصة التحكم الذاتي وعن بعد السيطرة في الدفيئات الزراعية. ومن خلالها تم إجراء اختبار الأداء، وتقدم المشروع بنجاح.

الكلمات المفتا حية : البيوت الزراعية , المتحكم ESP32 , المتحكم Arduino, نظام الري الذكي , انترنات الاشياء .

Résumé

L'agriculture est l'une des activités les plus anciennes et les plus importantes pratiquées par les humains, et elle revêt encore une grande importance pour assurer leur alimentation. Cependant, pour atteindre la qualité, gagner du temps et réduire les efforts, il faut s'aventurer dans le monde numérique et utiliser des technologies qui y contribuent. Dans notre projet, nous avons utilisé Arduino comme cerveau pour contrôler et diriger les commandes. Les niveaux d'humidité du sol sont détectés à l'aide d'un capteur d'humidité et ils sont gérés par un humidificateur à ultrasons. La température est contrôlée à l'aide d'un élément chauffant PTC et le système de ventilation (porte et ventilateur) est régulé. Le contrôleur miniature ESP32 permet la télécommande via WiFi via une application Android. Ce travail s'inscrit dans le cadre de la conception et de la mise en place d'une plateforme de maîtrise de soi et de contrôle à distance dans les serres agricoles. Grâce à elle, des tests de performance ont été menés et le projet a progressé avec succès.

Mots-clés : maisons agricoles, contrôleur ESP32, contrôleur Arduino, système d'irrigation intelligent, Internet des objets.

DEDICATION

We dedicate this humble work with heartfelt gratitude:

To our mothers, the sources of tenderness and love, for their unwavering support throughout our academic lives.

To our fathers, who have always supported us and done everything in their power to help us.

To our beloved brothers and sisters, whom we cherish dearly.

To our extended family.

To our esteemed teachers, from whom we learned the alphabet and how to pronounce words, and from whom we drew inspiration.

To our dear friends.

ACKNOWLEDGMENT

Praise be to Allah, who facilitated and aided us in completing this work and illuminated the path for us to perform it with all hope, God willing. We would like to express our heartfelt gratitude to our dear parents for their sacrifices, support, and encouragement throughout our study period. I extend my sincere thanks and appreciation to everyone who assisted me in preparing this master thesis, particularly my our supervisor Dr. Hima Abdelkader and the Dr.Boukaous chahra for their significant presence and wise advice. I also thank the members of the board of examiners who honored us by agreeing to evaluate and enrich this work.

Table of contents

Table of Figures

List of Tables

GENERAL INTRODUCTION

The development of hydraulic agricultural constitutes an essential factor in the intensification and increase of agricultural production. It is a strategic and innovative axis whose objective is to guarantee food security.

In Algeria, climate change, combined with the overexploitation of dams and boreholes, is favoring the depletion of water reserves. This, along with drought and soil salinization, has resulted in the expansion of arid and semi-arid regions, a more rapid degradation of plant cover and soil, and therefore, a progression of desertification. This induces an imbalance between the areas currently cultivated and the growing demand of the Algerian population. In addition, the evaporation and infiltration of water in poor soils rather than its use by the plant on a healthy substrate or growing medium, leads to a drop or reduction in the level of water resources implying a waste of rare, expensive and non-renewable water. This is why it is now more than urgent to resort to the adoption of new techniques which take into account scientific and technical parameters making it possible to make cultivated areas profitable, reduce their costs and increase their yields.

Having modern knowledge on water needs for crops with new irrigation techniques aimed at improving productivity and saving water. Currently we are able to accurately calculate the irrigation doses at the different stages of the crop by measuring the water needs of the plants according to their age, their stage, or even the expected yield, in order to limit the waste of irrigation water.

For this, it is necessary to know for each particular species, its water needs, the most favorable time for its irrigation, the optimum number of watering, their duration, the thickness of the water table, to be applied to such surface. and finally the depth to which the water must penetrate. Various practices can be implemented to use water efficiently in agriculture. This includes changing the irrigation schedule to closely monitor crop water needs, adopting more efficient techniques, using new irrigation systems or, smart irrigation.

The latter makes it possible to collect, share and exploit data collected via sensors in a connected object or loT (Internet of Thing) environment. Its objective is to record significant productivity gains and reduce invested costs. Connected smart farming objects, such as sensors and GPS geolocation for example, can concretely meet the needs of farmers. Connected weather stations make it possible to obtain a lot of information in real time, such as temperature and water level. humidity (hygrometry) or pressure atmospheric.

Proper soil irrigation and controlling water consumption are important issues for farmers to maximize profits and minimize expenses. They allow you to trigger automatic watering on the basis of predefined criteria (temperatures, changes in humidity levels, etc.), control the systems remote watering.

This theme presented in this master's thesis consists of setting up an intelligent watering system to manage modern agriculture more efficiently. This system will automatically water the plants according to their water needs, by measuring soil humidity using a hygrometer and controlling it remotely without any intervention. In addition, the system guarantees optimal monitoring of plant parameters (temperature and humidity) inside the agricultural greenhouse through the use of sensors. The measured data is then sent to a remote station for real-time display using a dashboard. The dissertation is composed of three chapters: After a general introduction, summarizing the theme and the objectives to be achieved.

The first chapter presents a state of the art on the internet of things, smart agriculture, smart greenhouses by detailing the environmental conditions such as temperature, humidity,….etc, and the presentation of different irrigation systems, explaining good water management in agriculture.

The second chapter will be devoted to the different hardware and software necessary for the creation of our system.

The design as well as the practical implementation of our project will be the subject of the third chapter.

This thesis master is closed by a general conclusion, which summarizes the different phases of our work by pointing out the beneficial points and some perspectives for improving the system in the future.

Chapter I:

Overview Of Smart Agriculture And Irrigation Systems

I.1. Introduction

This chapter will be devoted to a state of art on the internet of things, we then give an overview of smart agriculture, discussing their areas of application and the advantages. Afterwards we present in detail the intelligent greenhouses which are part of this modern agriculture, detailing the environmental conditions such as temperature, humidity, etc. the presentation of different irrigation systems, explaining good water management in agriculture will be the last element of this chapter .

I.2. Algerian agriculture

Since independence, Algeria, like other countries in the world, has been keen to strengthen the agricultural sector to keep pace with global transformations. This sector has witnessed multiple reform efforts, because of the economic, social, natural, political and technological challenges it faces. Accordingly, the Algerian government paid great attention to the agricultural sector, with the aim of developing it through the adoption of agricultural policies that include self-control and agricultural renewal programmers [1] .

The state endeavored with great effort to develop the agricultural sector, directing all material, moral and technical resources towards developing this sector. With the aim of achieving self-sufficiency and increasing its ability to export, however, the development policies and plans that were taken over the years were not successful, as they failed to meet the basic needs of citizens and increased Import rates, as shown in **Figure I. 1** [2].

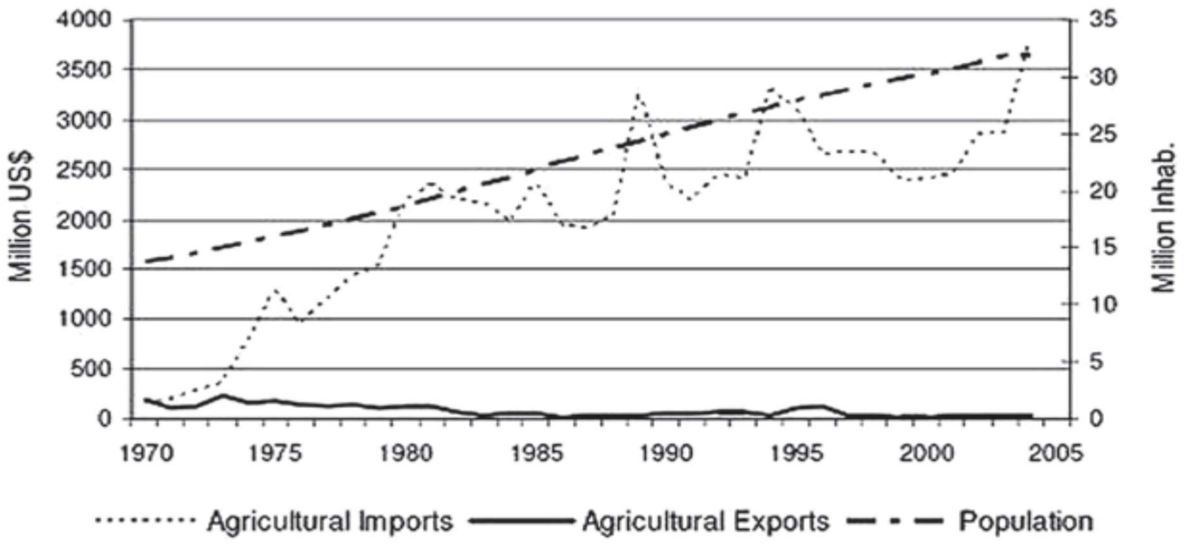

Figure I. 2 Trade in agricultural products (1970-2005) [2].

Keeping pace with global developments, Algeria has launched a group of new development plans and projects, with the aim of modernizing and developing the agricultural sector and making it more modern [3].

Relying on modern technology is a prominent solution in developing the industrial and agricultural sectors at the present time. Modern technology provides a solution to many of the challenges facing these sectors, especially the agricultural sector [1].

I.3. Internet of Things

British scientist Kevin Ashton introduced the term "Internet of Things" (IoT) in 1999 in the context of his research on Radio Frequency Identification (RFID) technology. Since the early 2000s, with the proliferation of smartphones and cloud storage systems, IoT has emerged as a technology that transforms ordinary objects into smart devices, allowing for remote control, monitoring of their status, and continuous communication.

Ibrahim and Shorb reference the definition of IoT provided in the Oxford Dictionary, which describes it as a progression of the traditional Internet, enabling objects to connect to communication networks and exchange data.

Internet of things can be described as a network consisting of interconnected computers, digital and mechanical devices, objects, and humans, each equipped with a unique identifier (UID) that facilitates data transmission across the network without direct human involvement or interaction. Sensors are instrumental in enabling this functionality [4].

I.3.1. Internet of Things concept

The Internet of Things, also referred to as the Internet of Everything (IoE), represents a communication network encompassing all internet-enabled devices capable of collecting, transmitting, and processing data from their environment. These devices utilize embedded sensors, processors, and communication mediums to facilitate this data exchange, often referred to as Machine-to-Machine (M2M) communication.

Building upon previous definitions, the Internet of Things can be understood as an evolutionary extension of the Internet, facilitating communication among network users and physical components, including digital devices, machinery, and objects in the surrounding environment. This communication relies on specialized sensors to transmit data through the network, where it is subsequently processed, leading to specific actions performed by the network's stakeholders [4].

I.3.2. Internet of Things features

The Internet of Things exhibits several key characteristics, including:

- **Interconnection:**

This involves linking devices, smart objects, and physical items within a single network to achieve specific goals and deliver services across various sectors. Flexible sensors facilitate this interconnectedness.

- **Availability:**

Data and information are accessible anytime, anywhere through compact devices such as smartphones, which can store vast amounts of data.

- **Sensor Integration:**

Sensors play a vital role in enabling interaction and communication among components within the IoT network.

- **Scalability:**

IoT technologies feature scalable communication protocols, allowing for seamless expansion and adaptation to accommodate a growing number of connected devices.

- **Component Homogeneity:**

IoT systems prioritize consistency and compatibility among their components, enabling seamless integration and scalability across different versions and manufacturers.

- **Interoperability:**

IoT devices and applications can seamlessly communicate and interact with one another, even if different companies manufacture them.

- **Thing Selection:**

This involves selecting the appropriate machine, device, or object for a given situation. Tags equipped with sensors and sensing materials can be attached to objects, enabling them to connect with other devices and systems as needed [4].

I.3.3. Application areas of the Internet of Things:

The Internet of Things offers many applications to its users in different fields; among these we can cite the following:

- **Agriculture**

Improving the efficiency of agricultural resource use and enhancing productivity and sustainability through the use of interconnected sensor networks and the Internet of Things in crop environment monitoring can yield positive developments. This includes improving the use of irrigation water, improving the use of agricultural materials, and organizing agricultural businesses more effectively. These technologies can also help combat agricultural damage and disasters, and improve the overall quality of the environment [5].

- **Smart cities**

The term “smart cities” is used to denote a cyber ecosystem, which provides advanced services that contribute to improving the use of the city’s physical infrastructure, such as road networks, electrical networks, and others. Thanks to these advanced services, the quality of life of citizens is effectively enhanced [5].

- **Health**

In the field of health, the Internet of Things is used to monitor patients' vital signs by creating personal networks and medical sensors. These devices monitor biological constants such as body temperature, blood pressure, and respiratory activity. This is intended to facilitate monitoring and delivery. Solutions, especially for people with limited mobility. In this context, their activities in their living environment are monitored using portable sensors such as accelerometers and gyroscopes, or using stationary sensors [5].

- **Smart gride**

A smart grid is defined as an electrical network consisting of a system of infrastructure, hardware and software solutions that enable two-way communication between all parts of the system and participants, and provides Power generation and distribution with an efficient electrical supply chain. As a result of the increasing demand for electricity, governments around the world have focused on adopting and integrating smart grid technology, through internet-connected sensing and actuation systems, to monitor electricity consumption, energy and its control. IoT offers smart grids multiple possibilities in applications, such as industry, solar energy, nuclear energy, vehicles, hospitals, and intelligent city control [6].

- **Home automation**

The range of technologies used in homes to achieve automation is called "home automation", and buildings equipped with IoT technologies are known as "smart buildings" or "smart homes". Advances in sensors, actuation technologies, and wireless sensor networks offer new possibilities to meet people's needs and improve their lives and the security of their homes, making smart homes increasingly popular. In smart homes, smart and automated services are provided to the user, where different sensors are deployed to automate daily tasks and maintain people's routine, in addition to using motion sensors to pioneer security. Enables home appliances to be controlled automatically remotely from anywhere via the Internet using smartphones. RFID technology is used to identify objects, and includes all technologies that use radio waves to automatically identify objects or people. The wireless sensor network includes a large number of nodes, which are tiny sensors that collect and transmit environmental data independently, allowing them to be linked to other devices in the network, such as a refrigerator equipped with an LCD screen that displays its contents, the ingredients that need to be purchased, and other information available via a smartphone application [6].

I.3.4. Importance of the Internet of Things in agriculture

The integration of the Internet of Things (IoT) is revolutionizing the agricultural sector, leading to the emergence of smart agriculture solutions. Around 100 new innovative applications have been developed to address the numerous challenges faced by farmers, aiming to enhance the quality, quantity, sustainability, and profitability of agricultural production.

Among the myriad advantages offered by IoT, its capacity to revolutionize traditional agricultural practices stands out. IoT sensors play a crucial role by providing farmers with real-time data on crop yields, rainfall patterns, pest outbreaks, and soil conditions. This data is invaluable for optimizing production processes and enables farmers to make informed decisions to improve agricultural techniques over time [7].

I.4. Smart farming

I.4.1. Definition of smart agriculture

Smart agriculture represents a revolution in traditional agricultural practices, aiming to reorient agricultural systems to effectively support food development. Its main objective is to increase agricultural productivity and income.

This approach integrates the use of Information and Communication Technologies (ICT), notably the Internet of Things (IoT) and the analysis of massive data (Big Data), to meet these challenges. It is based on electronic monitoring of crops, environment, soil, fertilization and irrigation conditions. The data collected can be analyzed to identify the crops best suited to the productivity goals of each farm around the world [8].

I.4.2. Areas of smart agriculture

- **Precision agriculture**

A management strategy that integrates temporal, spatial, agricultural, and climate data to inform decision-making, optimizing resource utilization for enhanced productivity and quality. This approach prioritizes profitability and sustainability in agricultural production, emphasizing the importance of adapting to variability while avoiding scientific theft [9].

- **Smart greenhouses**

The smart greenhouse, covering 22 m², efficiently cultivates safe fruits and vegetables in small spaces with minimal maintenance. Using a self-managed vertical aquaponic setup, it ensures produce quality and traceability. These greenhouses can be placed in unconventional locations like rooftops and degraded soils. Equipped with water and climate sensors, the system uses LPWAN IoT connectivity to send real-time data to the cloud. An AI processor analyzes this data, providing intelligent notifications and enhancing agronomic knowledge. It monitors water pH and alerts users to issues like algae development, offering corrective recommendations[10], the **Figure I. 3** is an exemple of a smart greenhouse.

Figure I. 4 smart greenhouses [6].

- **Monitoring of climatic conditions**

The most common and widely used agricultural applications are smart weather stations, which are vital tools in improving agricultural production whose function is to collect various environmental data directly in the field and then send it to the cloud for analysis. Using these readings, it is possible to draw a map of the current climatic conditions, choose appropriate crops, and take the necessary measures to improve their performance,Crops effectively and accurately [11].

- **Crop management**

Crop management technology is an important way to improve productivity and crop quality in precision agriculture and other types of agricultural products. This technology is similar to weather stations in the way it works, as they are installed in fields to collect agricultural data such as temperature, humidity measurement, leaf water potential, and overall crop health. By using these agricultural devices, farmers can monitor crop growth and detect any anomalies, helping them effectively and early prevent diseases or pests that may negatively affect their crops [11].

- **Monitoring livestock**

Internet of Things (IOT) technology is improving livestock resource management, from livestock and dairy tracking to poultry monitoring. Through the use of smart ear tags and biometric wearables, along with video cameras and environmental sensors, data is captured, In-depth information about animal care, nutrition and development, A pioneering step was taken by a farm in Paraguay where cattle trackers equipped with motion sensors were deployed, This allows livestock locations and behavior to be monitored to detect unwanted problems Natural diseases such as injuries, falls, or theft, in an effective and organized manner [12].

I.4.3. The benefits of smart agriculture

We can say that smart agriculture has several benefits and goals Important, most notably:

- Conservation and safeguarding of the environment via enhanced natural resource management.
- Adaptation strategies addressing the impacts of climate change.
- Mitigation efforts aimed at reducing greenhouse gas emissions.
- Alleviating hunger and poverty.
- Enhancing agricultural output and quality.
- Implementation of sustainable natural resource management practices.
- Enhancement of soil fertility and management techniques.
- Utilization of animal waste for the generation of biogas, a renewable energy source.
- Development of resilient fisheries and aquaculture systems to combat climate change, including storm-resistant enclosures and adaptable management approaches [13].

I.5. Smart greenhouses

The DG-12 Heating & Cooling Technology offers efficient climate control for greenhouses, managing humidity and temperature for both heating and nighttime cooling. It uses an external hot or cold water source and integrates dehumidification, optimizing energy usage. The unit, customizable to specific applications, can be centrally or peripherally placed, either floor-mounted or suspended. Featuring the SmartDG system for remote monitoring, it provides personalized assistance to growers. Adhering to GMP standards, the DG-12 is available in 50 Hz and 60 Hz versions for global compatibility [14] .

Figure I. 5 DG-12 Heating & Cooling [14].

I.5.1. Environmental conditions in greenhouses

The growth of plants in greenhouses involves certain special climatic conditions. In what follows, we present these conditions in a general way.

- **Light Requirement:** Vegetables typically require a minimum of 8 hours of daily light exposure to thrive. In regions with frequent cloud cover or shorter daylight hours, supplemental lighting may be necessary to ensure satisfactory growth, **Figure I. 6** show some technique to increases light**.**

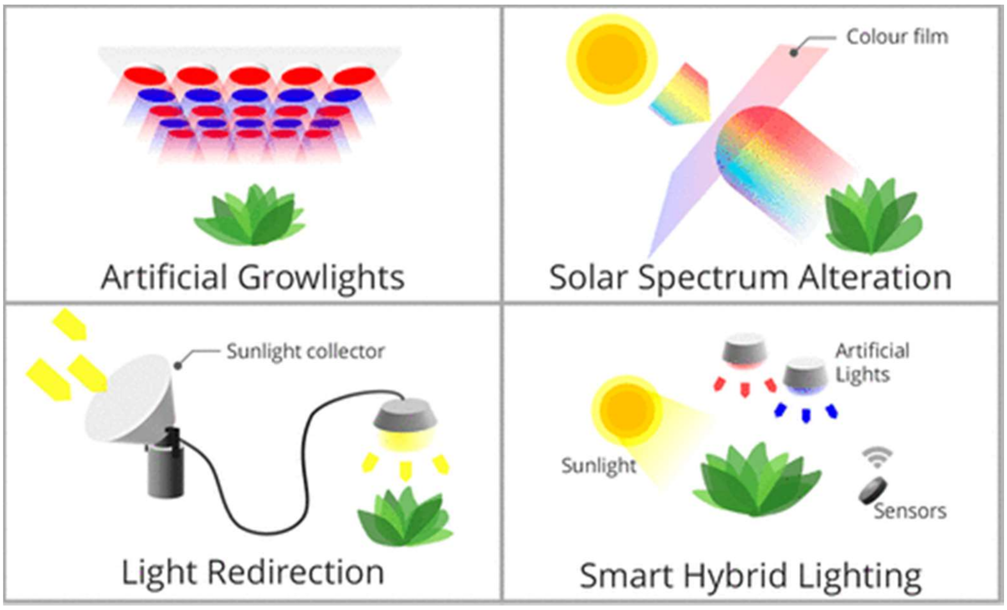

Figure I. 7 technique to increases light supplemental [15].

- **Carbon Dioxide Management:** CO2 generators are commonly employed in commercial greenhouses to optimize plant productivity[**Figure I. 8**]. However, the effectiveness of CO2 supplementation depends on it being the "limiting factor." This implies that unless all other growth variables such as light, fertilizer, temperature/humidity, and pH are adequately balanced, the benefits of increased CO2 levels may not be fully realized.

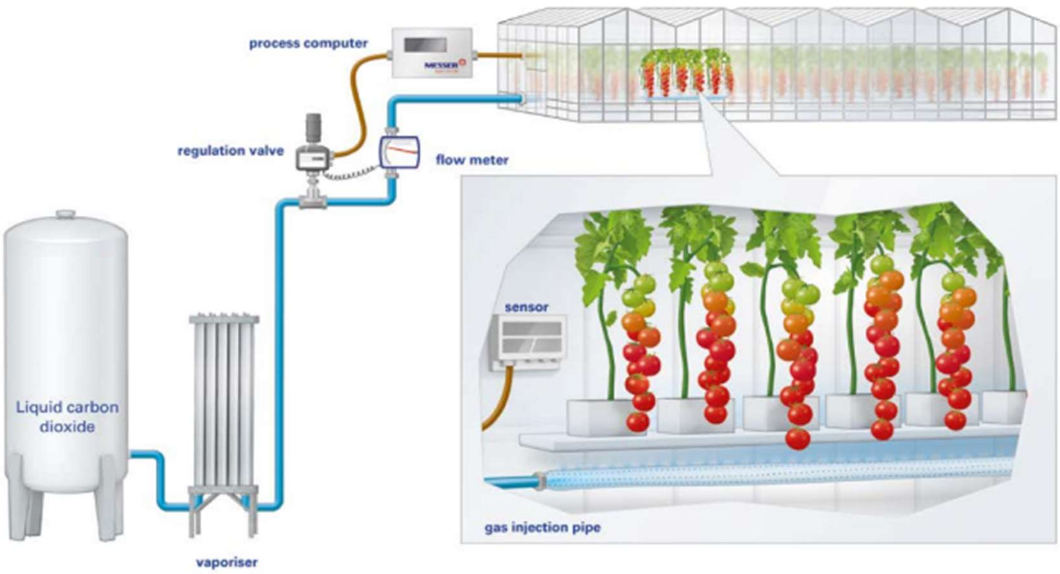

Figure I. 9 Carbon dioxide injection [16].

- **Air Circulation Importance:** Air movement plays a crucial role in plant growth by influencing energy transfer, transpiration, and CO_2 absorption. These factors, in turn, affect leaf size, stem growth, and overall plant performance. Enhanced air circulation within greenhouses can increase photosynthesis rates by up to 40% and boost wind speeds by 10 to 100 centimeters per second. **Figure I. 10** is an exemple of air fan used inside greenhouse.

Figure I. 11:Air circulation fan [17].

- **Humidity Control:** Both air and soil humidity levels significantly influence plant development. Maintaining appropriate humidity levels ensures optimal moisture uptake, facilitating nutrient absorption and overall plant health.
- **Temperature Regulation**: Proper temperature management is essential for creating favorable growing conditions. Monitoring and controlling the temperature of the air, soil, and water helps prevent stress on plants and promotes optimal growth rates.
- **Window Adjustment:** Properly managing greenhouse windows can help regulate temperature, humidity, and light levels. Adapting window openings based on environmental conditions ensures that plants receive the necessary resources for healthy growth.

These factors interact with each other synergistically, and their careful management is vital for creating an ideal growth environment and maximizing productivity in greenhouse cultivation.

I.5.2. Control of environmental conditions in greenhouses

- **Light control:**

Light control may concern surviving actions:

Enhancing Lighting: In regions with shorter winter days or limited sunlight, supplementary lighting becomes imperative. This can be achieved through additional electric lamps or by utilizing reflected sunlight. Reflected light, particularly significant in urban gardens, can amplify the available light sources, contributing to improved plant growth.

Diminishing Light Intensity: If the greenhouse is receiving excessive light, measures can be taken to reduce it. Adjustments such as shading or controlling the intensity of artificial lights can help create an optimal lighting environment for plant growth.

- **Carbon dioxide:**

Carbon dioxide regulation may include methods such as CO2 enrichment, which can be achieved through the use of CO2 generators or the dry ice method. It's important to note that the effectiveness of a CO2 system depends on CO2 being the "limiting factor." This implies that unless all other growth factors, such as light, fertilizer, temperature/humidity, and pH, are optimized, increasing CO2 levels will not yield significant benefits [18].

- **Air humidity:**

Humidity control can involve the following two actions:

Reduce high humidity: This can be achieved by ventilating the humid air to the outside. Whenever the outside temperature is warm enough, ventilation to the outside can reduce humidity.

Increase humidity: It is possible to increase humidity by simply watering the soil and using swamp cooler type air conditioners. Another method is to use a misting system to spray the mist into the air. This will help cool the greenhouse while adding humidity to the air.

- **Temperature:**

Temperature control may concern:

Cooling: Cooling can be achieved by several methods: by evaporation, by shade cloth and by air movement. The principle of evaporative cooling is simple. When exhaust fans expel air from one end of the greenhouse, they draw in humid air from the other end. The movement of humid air can lead to water evaporation and therefore heat absorption. Cooling can be carried out using an internal shade curtain, which can be drawn up on cloudy days and extended (manually or with small motors) on sunny days on demand.

Heating: The greenhouse can be heated by a small electrical system controlled by a thermostat. This system can deliver heat only when necessary. The greenhouse can also be heated using gas with central heating [18].

I.6. Presentation of the different irrigation systems

I.6.1. Interest in irrigation

Irrigation serves as an effective management tool to mitigate precipitation variability and is vital for global food security. Its utilization offers numerous advantages, including the expansion of cultivated land, particularly in arid regions. Moreover, it facilitates the cultivation of high-yield crop varieties through the application of necessary fertilizers, thereby enhancing the economic viability of these crops. Additionally, irrigation contributes to increased crop yields and, more broadly, to the intensification and stabilization of agricultural production by reducing dependence on climatic fluctuations.

I.6.2. Definition of irrigation

Artificial water provision and systematic distribution for agriculture and horticulture aim to increase production and enhance its quality. Various irrigation techniques exist, differing in how they distribute water obtained from the source across the terrain. Generally, the objective is to uniformly supply water to the entire area, ensuring each plant receives the necessary volume of water, neither too much nor too little.

I.6.3. Smart irrigation

Smart irrigation technologies mean using advanced methods to improve agricultural irrigation operations, with the aim of ensuring that the right amount of water is used at the right time and place. These technologies include the use of sensors, automatic control systems, and intelligent algorithms. Here is some information about smart irrigation:

- **Sensors:** used to collect data about soil condition such as humidity, temperature, and electrical conductivity, which...It enables crop water needs to be monitored.

- **Automated control systems:** used to regulate irrigation operations based on data collected from sensors, and can Programmed to operate irrigation operations accurately and efficiently.
- **Water saving:** Smart irrigation can improve water use efficiency by avoiding waste and adjusting the amount of water Automatically used according to actual crop needs.
- **Improving productivity**: by providing a smart, precise and programmed irrigation system that enhances the growth and development of crops by providing specific amounts of necessary water. This approach allows plants Making the most of available resources, which leads to improving agricultural productivity.
- **Cost Reduction:** By reducing unnecessary water waste and improving resource efficiency, a smart irrigation system can reduce costs associated with agricultural irrigation operations. Therefore, this includes Reduced water and energy costs, and contributes to reducing the overall costs of agricultural operations.
- **Remote monitoring**: Some smart irrigation systems allow remote monitoring and control, making it easier for farmers to monitor and manage irrigation operations from anywhere.

In short, smart irrigation represents a new and important aspect of agricultural irrigation, improving water use and enhancing agricultural productivity In a smart way [19].

I.6.4. The different irrigation system

Irrigation systems can be classified into three main categories: gravity irrigation, drip irrigation, and sprinkler irrigation. Drip irrigation and sprinkler irrigation are also referred to as pressurized irrigation [20].

- **Gravity irrigation**

Gravitational irrigation encompasses all irrigation techniques where water distribution to the plot occurs entirely in the open air through simple surface flow. Water distribution is ensured by the terrain's topography and the soil's hydraulic properties (runoff, infiltration, and capillarity). There are various modes of gravitational irrigation, and we will mention some of them [20].

- **Watering by runoff (by boards or by blocking)**

Consists of running a thin layer of water on a ground inclined by 0.2 to 3%, which will infiltrate vertically until this section of soil is humidified, the flow rate to be discharged depends on the slope, width and of the length of the board

Figure I. 12: Runoff watering [20].

- **Watering by submersion (or flooding)**

The principle consists of giving the soil a more or less thick layer of water, which is left to remain for necessary time for it to penetrate by infiltration to the useful depth, thus allowing the soil to reserves the water essential for crop development.

Figure I. 13 Flood watering [20].

- **Watering by infiltration (furrow)**

It is a method which consists of distributing water through channels or lines with a relatively low flow rate. large (5 to 10 l/s) compared to other processes. In this method, only part of the soil receives the water directly, the rest is moistened by lateral infiltration.

Figure I. 14: Infiltration watering [20].

- **Watering by bowl (or basin)**

The form of a sheet into a basin (which can be partitioned) constructed on a leveled surface (with a slope ranging from 0.1 to 1%). This is a traditional mountain technique that has been adapted to irrigated areas.Irrigation is achieved by dividing the field into several elementary basins (or plots) **[Figure I. 15]**, with an average size of 40 square meters each. Distribution channels (seguias), which in turn are fed by a main channel irrigate these basins. Water is divertethese channels by making a single breach in the headworks.

At the plot level, the water follows this route: Sprinkler-Seguia distribution, and finally, it arrives at the basins or irrigated areas in turn.

Figure I. 16: Watering by bowl [20].

- **Drip irrigation**

In drip irrigation **[Figure I. 17]**, water is delivered to the plant in low doses thus resulting in humidification of a fraction of the soil. This helps limit losses through evaporation and percolation. It also allows reduce the development of weeds. It also implements fixed equipment and light, and allows fustigation. In most cases, it requires automation through controllers associated with volumetric and/or hydraulic valves and solenoid valves. The installation consists of a water source, a pumping station, a head unit, main and secondary pipes, door ramps and ramps, and finally distributors [20].

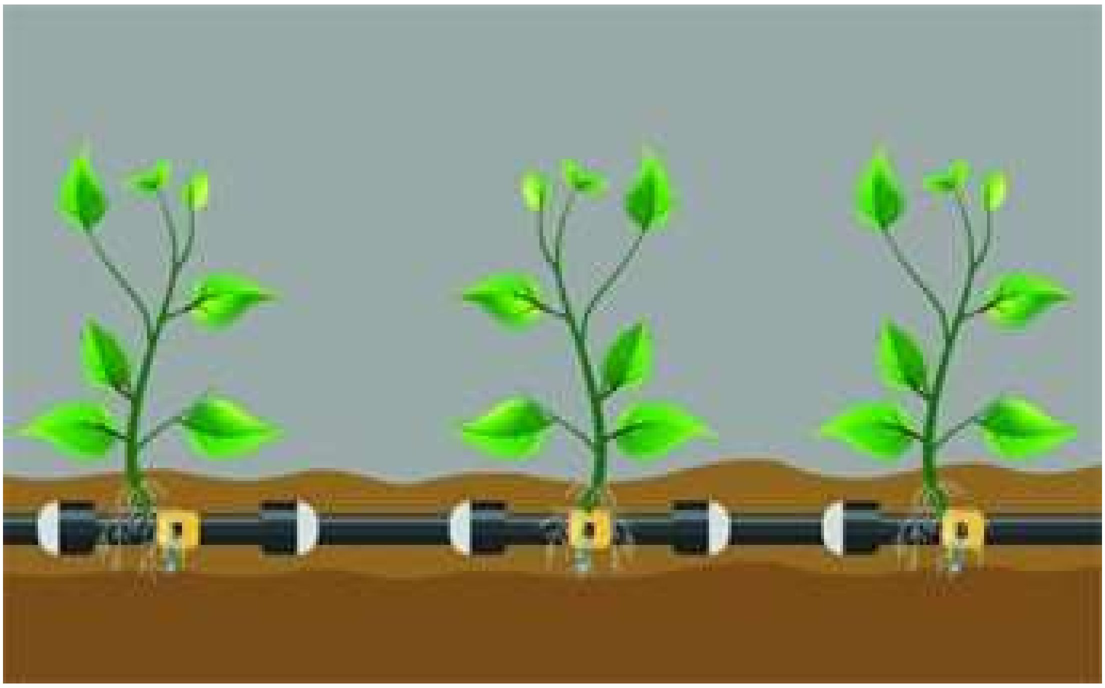

Figure I. 18: Drip irrigation [21].

I.7. Water management in agriculture

Agriculture consumes 70% of the world's fresh water, mostly due to poor irrigation systems and techniques. With climate change and population growth, there's an urgent need for improvement.

I.7.1. Improving irrigation systems is the key:

- Switching to bold irrigation (drip or spot irrigation), where water is distributed effectively around the plants.
- Reducing the use of surface irrigation and sprinkler irrigation, which lead to water waste and encourage saturation and salinization of the soil.
- Regulating deficient irrigation, which controls water deficit during periods of plant growth.
- Developing precision irrigation using sensors to measure soil moisture and data from meteorological stations, which...It allows farmers to make better decisions regarding irrigation.

I.7.2. Improving water-saving farming techniques:

- Diversify crops to include fruits and vegetables that require small amounts of water.
- Use drought-resistant plant varieties and crop production techniques.
- Promoting precision agriculture using new technologies that increase productivity and improve resilience with less water consumption [11].

I.8. Conclusion

In this chapter, we talked about the situation of agriculture in Algeria and some solutions to help develop this field

We talked about the Internet of Things (LOT), its applications, fields, relevance, and importance in developing agriculture and smart greenhouses. We also discussed the concept of irrigation, its types, and its importance in improving crops, along with ways to save water and make the best use of it.

We reiterate the importance of investing in developing and adopting smart technologies in agriculture, and the need to intensify efforts to promote the shift towards smarter and more sustainable agriculture.

CHAPTER II :

PROTOTYPE CONSTRUCTION

II.1. Introduction:

This chapter focuses on the detailed design and assembly of a working prototype, a critical step in realizing an automated greenhouse system. The objective of this chapter is to flesh out the conceptual framework of the system through meticulous design and assembly of the prototype.

Equipment selection is explained in each subsection of this chapter and emphasis is placed on its role in achieving the desired functionality of the prototype. This selection of equipment ranges from sensors and microcontrollers to actuators and power components.

Additionally, we emphasize the use of Proteus circuit simulation software, which facilitates extensive testing and validation before physical implementation, ensuring that the prototype conforms to design specifications and performs reliably. Reliable in real conditions.

II.2. PROTOTYPE DESIGN

Our prototype design **[Figure II. 1]** aimed for simplicity and functionality. We selected a large plastic container to simulate a greenhouse, offering a transparent view of internal processes. The container is insulating properties help maintain optimal levels for plant growth.

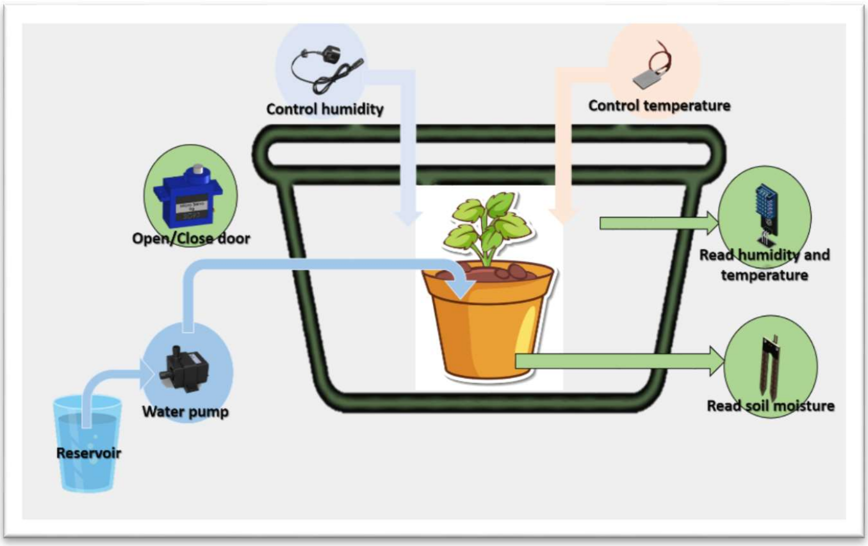

Figure II. 2: Prototype design.

II.3. Sensors

In our project, there is three main element, that we monitor continuously those element are the temperature and humidity inside the greenhouse and soil moisture.

II.3.1. Temperature and humidity sensor

When considering temperature and humidity sensors for our greenhouse monitoring system, we evaluated several options available in the market. These options included thermistors, thermocouples, and integrated sensors like the DHT series. While each type of sensor has its advantages and disadvantages, we ultimately chose the DHT11 sensor [**Figure II. 3**] for its simplicity, cost-effectiveness, and reliability. The DHT11 sensor is an integrated sensor that provides both temperature and humidity readings in a single package (Mouser Electronics, Inc), making it convenient for our application. Despite its lower accuracy compared to more advanced sensors, the DHT11 offers sufficient precision for our greenhouse monitoring needs while being budget-friendly, making it an ideal choice for our project.

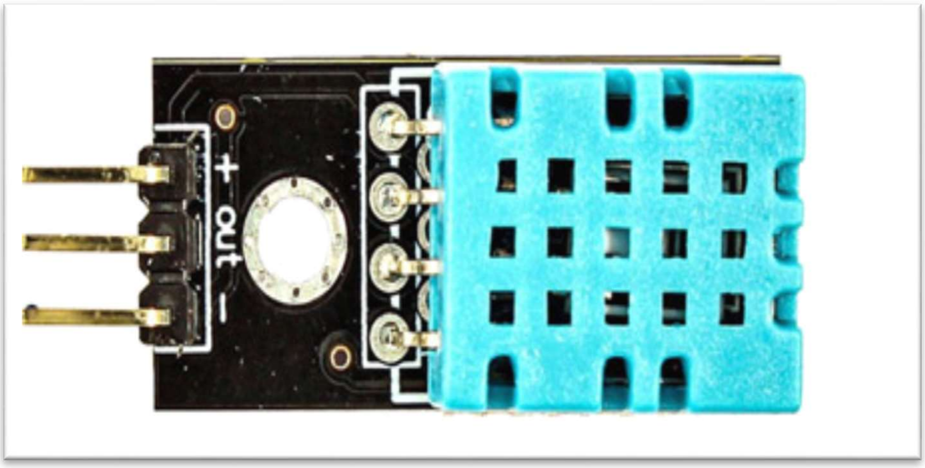

Figure II. 4: DHT11 sensor [22].

This sensor has three pins including two VCC and GND, used to supply the sensor with electricity and the other DATA connected to an analog pin of the Arduino board that collects the data measured [23].

- **CHARACTERISTICS :**

Supply voltage	5V
Supply current (running)	0.5mA typ. (2.5mA max.)
Supply current (stand-by)	100uA typ. (150uA max.)
Temperature range	0 / +50°C ±2°C
Humidity range	20-90%RH ±5%RH

Table 1: DHT 11 characteristics.

II.3.2.Soil moisture sensor

As part of our greenhouse automation project, the soil moisture sensor plays a vital role in maintaining optimal growing conditions for plants [**Figure II. 5**]. This sensor continuously monitors soil moisture levels, enabling precise irrigation management based on real-time data. By integrating this sensor into our prototype, we ensure that plants receive the appropriate amount of water, which promotes healthier growth and optimizes resource use [24].

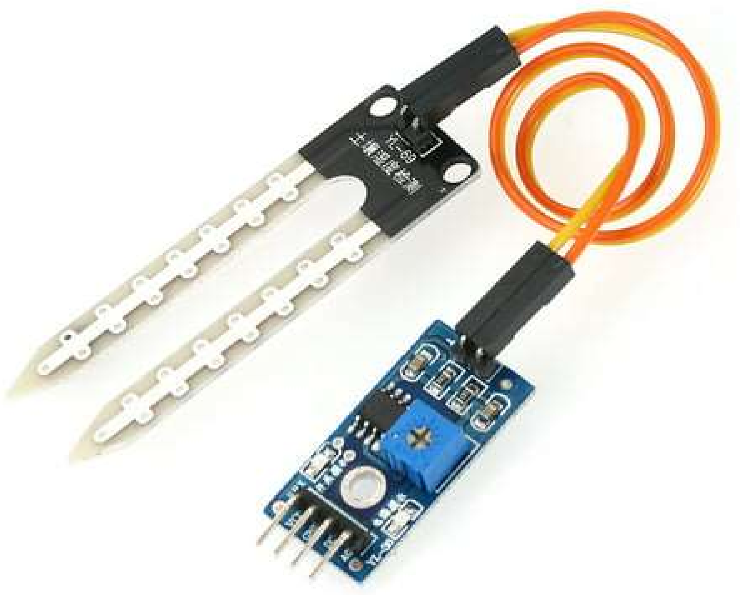

Figure II. 6: Resistive soil moisture sensor [25].

Two probes used in the moisture sensor to detect soil moisture, and their resistance varies with soil's moisture content. This resistance varies inversely with soil moisture:

- The more water in the soil, the better the conductivity and the lower the resistance.
- The less water in the soil, the lower the conductivity and thus the higher the resistance.

Features :

Operating Voltage:	**3.3V to 5V DC**
Operating Current	15mA
Output Digital	Adjustable trigger level from preset
Output Analog	0V to 5V.

Table 2: Sensor Features.

II.4. Actuators

After we discovered the element that need to be monitored and the sensor used for that, now we need to select suitable actuator to control those elements inside the greenhouse.

II.4.1.water pump

For the distribution of water with a certain pressure, we use the mini water pump. Submersible Elegant with a voltage of 12 V with a maximum flow rate of ten liters per minute (240 l/min).

Figure II. 7: Mini water pump.

Its compact size and efficient operation make it suitable for delivering water to plants with precision and reliability. By connecting the water pump to a water reservoir or supply system, this capability allows us to maintain optimal soil moisture levels for plant growth without the need for manual watering. Additionally, the low power consumption of the mini water pump ensures energy efficiency, making it an ideal choice for our greenhouse prototype. With the integration of the mini water pump into our system, we can achieve automated irrigation that promotes healthy plant growth while minimizing water wastage and manual labor [26].

II.4.2.Heater

In order to elevate the temperature inside the greenhouse, we used a 12v PTC heating element. The heater is built based on a ceramic PTC element. The heater regulates the temperature itself by simple correlation - as the temperature rises, its resistance also increases. The nominal temperature of the heater when supplied with 12V is 70C. This value is given for the environment at room temperature [27].

Figure II. 8: Heating element.

II.4.3.Humidifier

In our project, the mini ultrasonic humidifier serves a crucial role in maintaining optimal humidity levels within the simulated greenhouse environment. By introducing moisture into the air, it helps create a favorable atmosphere for plant growth, especially in regions with low natural humidity or during dry seasons. The compact size of the humidifier allows for easy integration into our prototype greenhouse setup, ensuring that plants receive the moisture they need for healthy development [28].

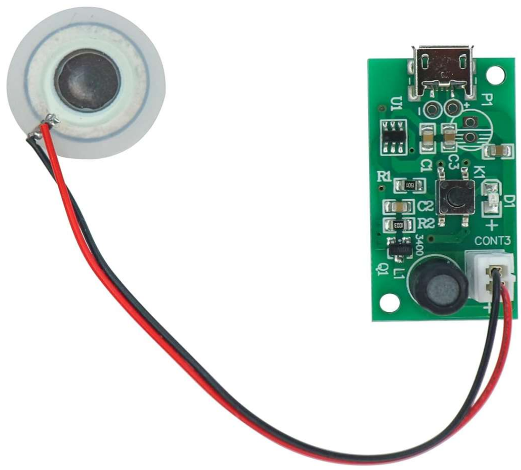

Figure II. 9: Ultrasonic Humidifier [28].

II.4.4.Servo-motor

The servomotor in our project serves the essential function of controlling the opening and closing of the greenhouse door. Its precise and controllable movement allows for accurate positioning of the door, ensuring efficient regulation of temperature and airflow within the greenhouse environment. By attaching the servomotor to the door mechanism, we can automate the process of opening and closing the door based on predefined conditions or user commands.

Figure II. 10 : servo motor G90 .

II.4.5.Air Circulation fan

In indoor environments like greenhouses, air movement becomes even more critical. Air mixers or fans are employed to maintain a uniform climate, preventing the buildup of hot air at the greenhouse's apex. This strategic airflow management not only reduces water condensation but also fosters transpiration and $CO2$ absorption by crops. By ensuring consistent air circulation, these systems optimize conditions for plant health and productivity, underscoring the significance of air movement in agricultural settings [29]., the following figure **Figure II. 11 and Figure II. 12** represent how the air fan function and the type of air fan used respectively.

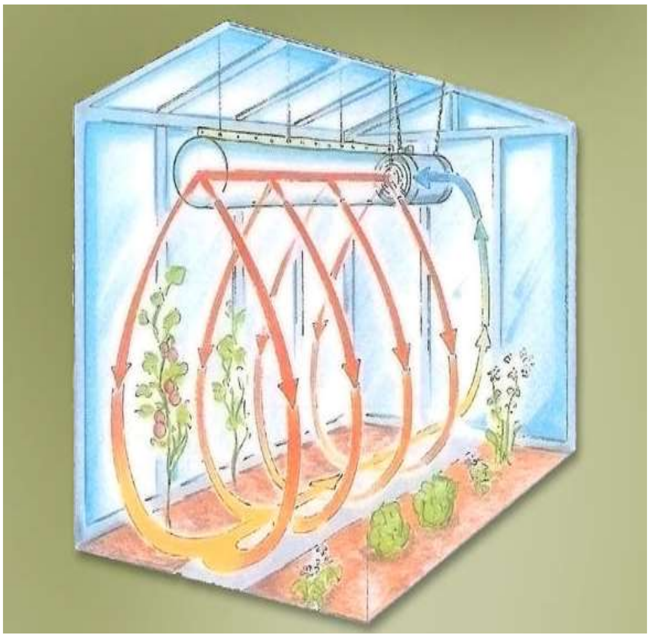

Figure II. 13: Principe function of air circulator fan [30].

Figure II. 14: Air circulation fan

II.5. Microcontroller

Now that we've discussed both sensors and actuator to be used to construct our prototype , it's time to look at the microcontroller that we going to use to collect the data from the sensors and control the actuator , and additionally display the data and state on user mobile's.

II.5.1.Arduino uno

The Arduino UNO is an open-source MCU board, The board is equipped with sets of digital and analog input/output (I/O) pins that can be interfaced to various expansion boards (shields), electronic module, sensors, etc... .

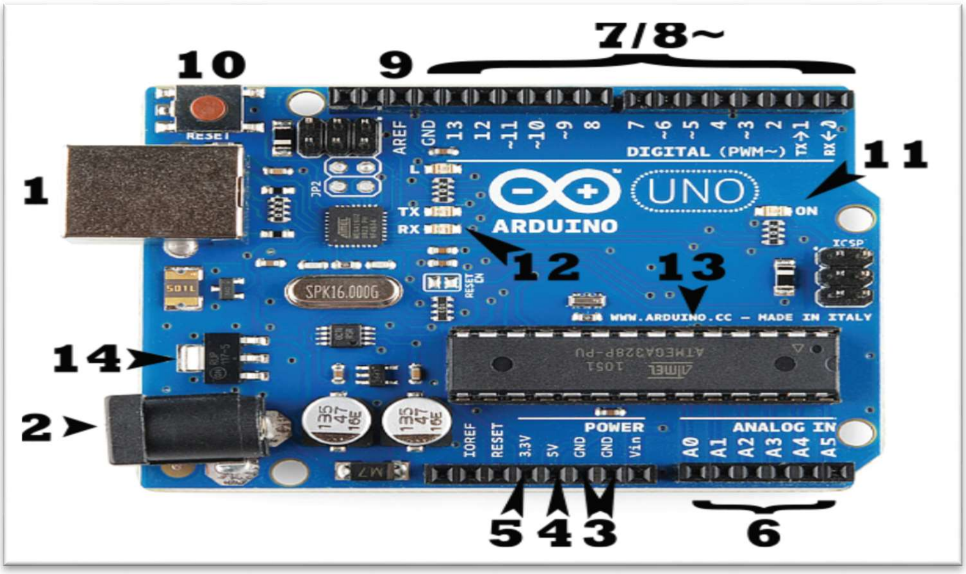

Figure II. 15: Ardunio uno board.

Every Arduino board needs a way to be connected to a power source. The Arduino UNO can be powered from a USB cable coming from a PC or a power supply (the power supply must be less than 20V otherwise it will destroy the board). **Figure II. 16** labeled all of the board components and I/O pins and the following table describe the role: [31]

PIN	Description
1	USB connection
2	barrel jack
3	GND
4	5V to supllies components
6	3.3V to supllies components
7.8	Digital I/O pins , Pulse-Width Modulation (PWM).
9	Analog Reference
10	Reset Button
11	Power LED Indicator
12	TX RX LEDs
14	IC Voltage Regulator

Table 3: Arduino Uno board PIN.

II.5.2.ESP32

The ESP32 baord [**Figure II. 17**] is a series of Espressif System (SoC) system-on-chip microcontrollers, it has integrated WI-FI and dual-mode Bluetooth, This microcontroller is a programmable circuit compatible with the ARDUINO environment. It accepts components offered for ARDUINO. The ESP32 unit is programmed with the ARDUINO IDE interface.

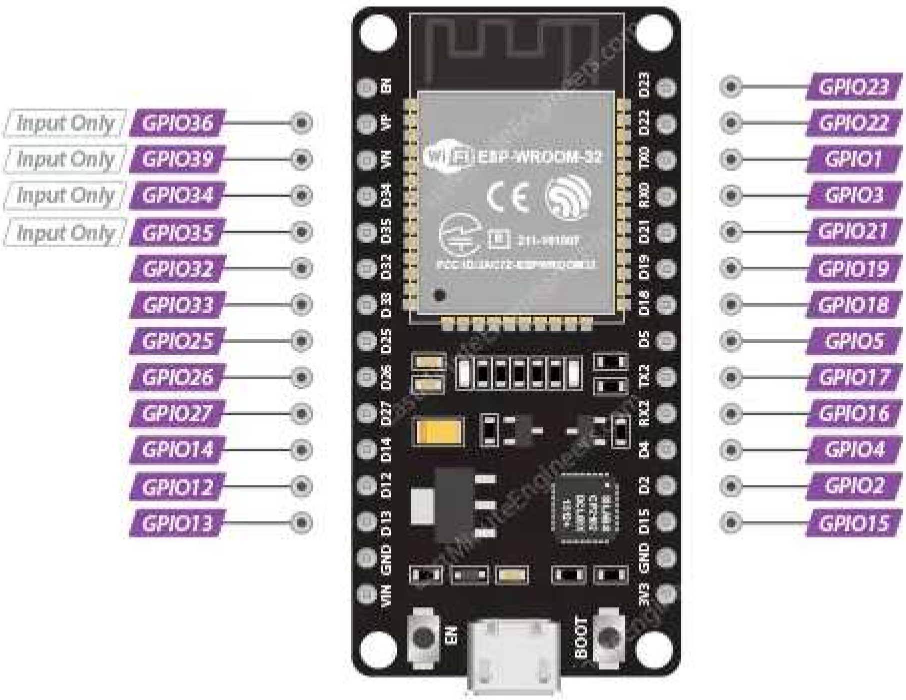

Figure II. 18 :ESP32 board pinout [32].

On the input and output side, the ESP32 uses GPIO (General Purpose Input/Output) ports which are the pins to serve either input or output depending on the uploaded program. The ESP32 offer many features, the following are the most important:

• **Networking:** The module's Wi-Fi Antenna and dual-core enables embedded devices to connect to routers and transmit data.

• **Data Processing:** Includes processing basic inputs from analog and digital sensors to far more complex calculations.

• **P2P Connectivity:** Creates direct communication between different ESPs.Web.

Server: Access pages written in HTML or development languages.

• **Security:** IEEE 802.11 standard security features supported, including WFA, WPA/WPA2 and WAPI. Moreover, ESP32 has a secure boot and flash encryption [33].

II.6. Arduino relay module

The Arduino board powered with a voltage of 5V while the actuator requires 12 V to operate. Therefor they cannot therefore be connected directly to Arduino, hence the use of a relay module [**Figure II. 19**].

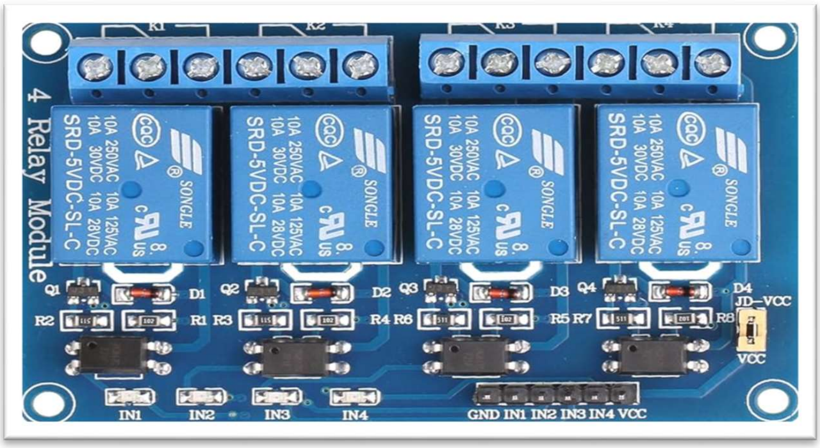

Figure II. 20: Arduino relay 4-channel module [34].

When using µC such as Arduino Uno board to control relay we looking for operating voltage of 5VDC as show in **Figure II. 21**.

Figure II. 22: Relay operating voltage.

II.7. Power supply

To operate our prototype effectively, we require two distinct sources of power. Firstly, we need power to drive the various actuators and components integrated into our system, ensuring their smooth operation. Secondly, we need power to supply the microcontroller, which serves as the brain of our prototype, orchestrating the control and monitoring processes. This dual power requirement ensures that our prototype functions optimally, with each component receiving the necessary power supply to carry out its designated tasks.

- **Actuator power supply:** requires a power supply capable to deliver 12V ,we chose to use Li-Po battery with 5000mAh battery capacity and 20-30C discharge capacity within one hour . the **Figure II. 23** show the battery we used .

Figure II. 24: Li-po battery.

- **µC power supply:** We opted for a power supply capable of providing a stable 5V output for extended periods to ensure uninterrupted operation, as both microcontrollers in our setup do not have stringent power requirements ,for that we chose to use power bank with 3300mAh battery capacity and 5V voltage output.

II.8. Simulation

In this section, we present the simulation model of our greenhouse automation system using the Proteus 8 software. The simulation allows us to assess the behavior of the system under various conditions and verify its functionality before deployment. Additionally, we provide detailed circuit diagrams to illustrate the connections and components used in our prototype.

II.8.1. Flowchart Representation

Before delving into the circuit diagrams, we present a flowchart [**Figure II. 25**] that outlines the operation of our greenhouse automation system. The flowchart provides a visual representation of the system's logic and helps in understanding the sequence of actions performed by the microcontroller to regulate environmental parameters.

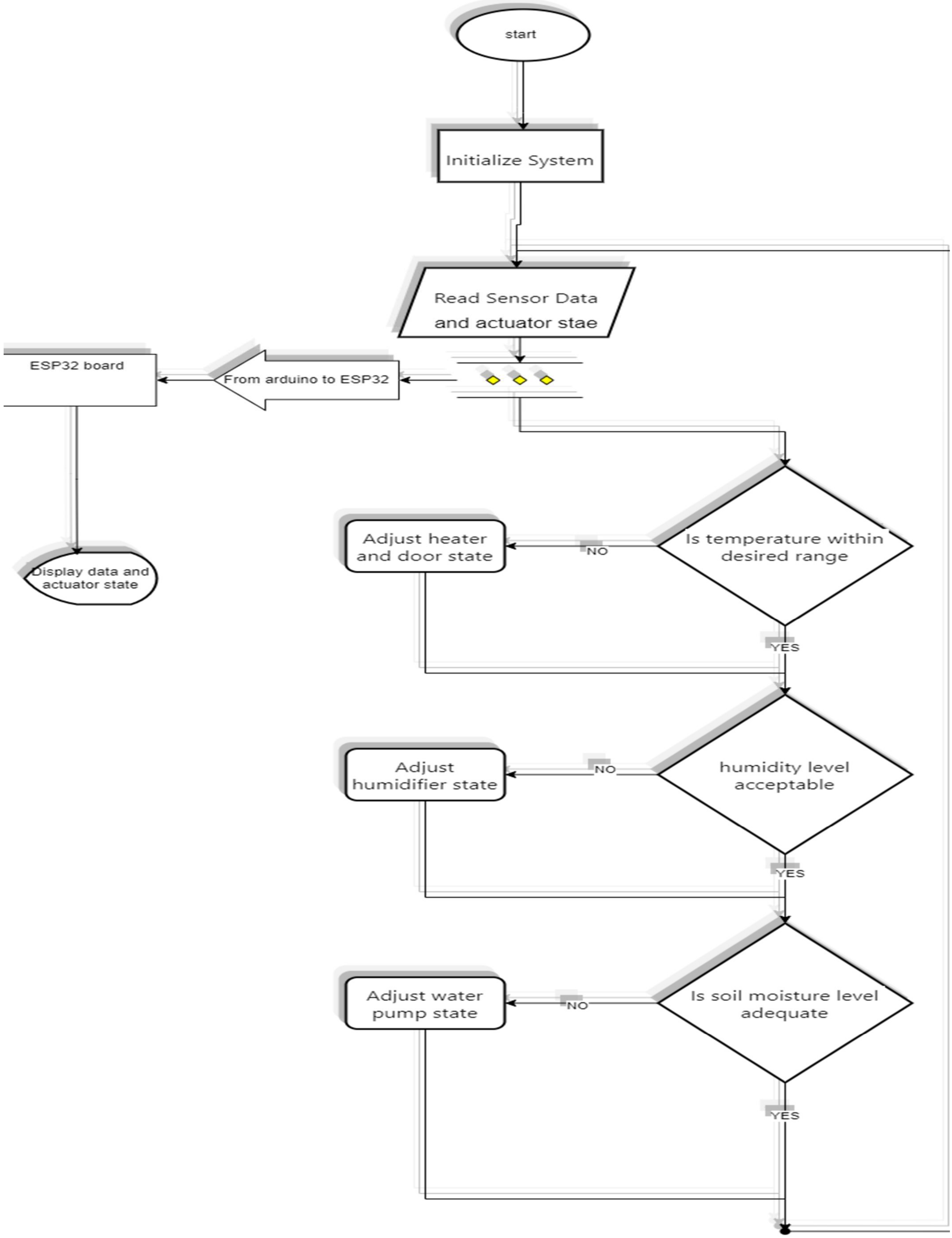

Figure II. 26: Flowchart Representation.

II.8.2.Circuit Diagram and Simulation

Following the flowchart, we provide comprehensive circuit diagrams depicting the connections between different sensors, actuators, and the microcontroller as show in **Figure II. 27**. These diagrams serve as a blueprint for constructing the physical prototype and are accompanied by simulations in Proteus 8 to validate the design and functionality of the system.

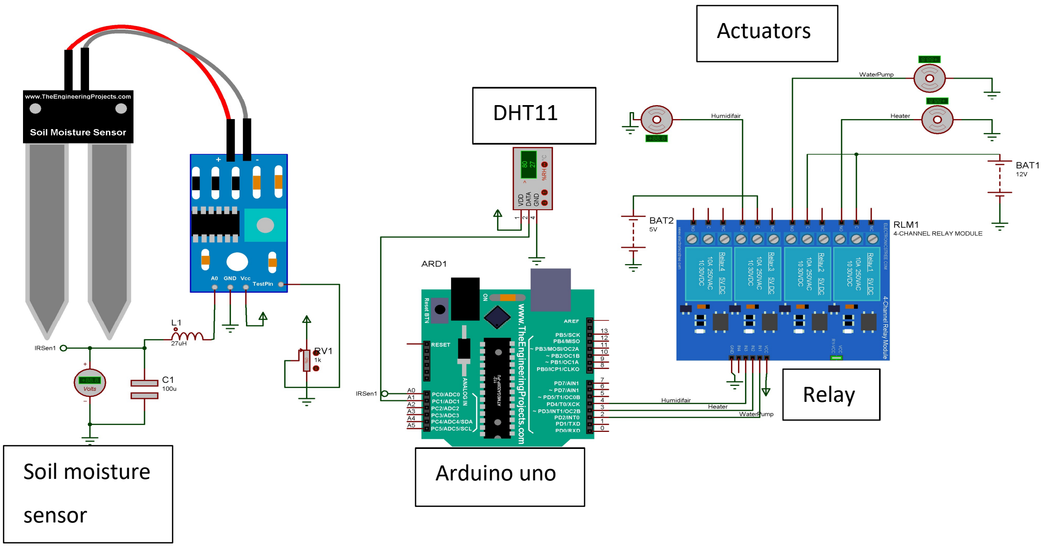

Figure II. 28: Proteus Circuit Diagram Simulation.

II.9. Conclusion

In this chapter, we outlined the construction of our prototype greenhouse automation system, emphasizing simplicity and functionality. We discussed the selection criteria for sensors, focusing on temperature, humidity, and soil moisture sensors. The DHT11 temperature and humidity sensor and soil moisture sensor.

Additionally, we introduced microcontrollers, power supplies, and actuators, including a mini ultrasonic humidifier, servo motor, and mini water pump, to regulate environmental conditions effectively. The utilization of power banks with a total capacity in addition to a LiPo battery for the actuators, underscores our commitment to reliability and longevity in operation. The integration of flowchart logic and detailed circuit diagrams with Proteus 8 simulations validates the robustness of our design.

Overall, the construction of our prototype lays the groundwork for the experimental study, highlighting the potential of our approach in creating a smart and sustainable agricultural environment.

CHAPTER III:

EXPERIMENTAL STUDY

III.1. Introduction

In this chapter, we delve into the practical implementation of our greenhouse automation system. We will explore the utilization of Arduino IDE as the primary software tool for coding our microcontrollers, providing insights into the programming logic behind our system. Additionally, we will discuss the integration of Arduino IoT Cloud, a powerful platform that enables real-time data visualization and remote monitoring of our greenhouse environment.

A crucial aspect of our discussion will be the wiring and coding procedures for interfacing with the various sensors and actuators employed in our prototype. We will provide detailed instructions on how to set up and configure each component, ensuring seamless communication and control within the system.

Furthermore, we will examine the outcomes of our experimental study and engage in a thorough discussion of the results. Additionally, we will outline potential future enhancements and innovations that could be implemented to further enhance the functionality and efficiency of our greenhouse automation system.

III.2. Arduino IDE

For the programming of the application, we used Arduino IDE which is an environment of Free development specially designed for Arduino board based projects. It is available in download for Windows, Mac and Linux. This editor allows us to write our code, compile it and upload it to the Arduino board. It also includes syntax highlighting features and allows us to spot errors [35].

Figure III. 1: Ardunio IDE software LOGO [36].

III.3. Arduino code

Now that we have introduced the Arduino IDE in the previous section, let's shift our focus to the practical aspect of interfacing each sensor with our microcontroller. We'll start by exploring how to wire and set up these sensors before delving into the coding aspect.

III.3.1. Soil moisture sensor

III.3.1.1. Interface sensor with Arduino uno

To interface this sensor with the Arduino board we have to connect it with 5V and GND pin for powering and a Analog Pin for data as show in **Figure III. 2** . The output of the soil moisture sensor changes in the range of ADC value from 0 to 1023.

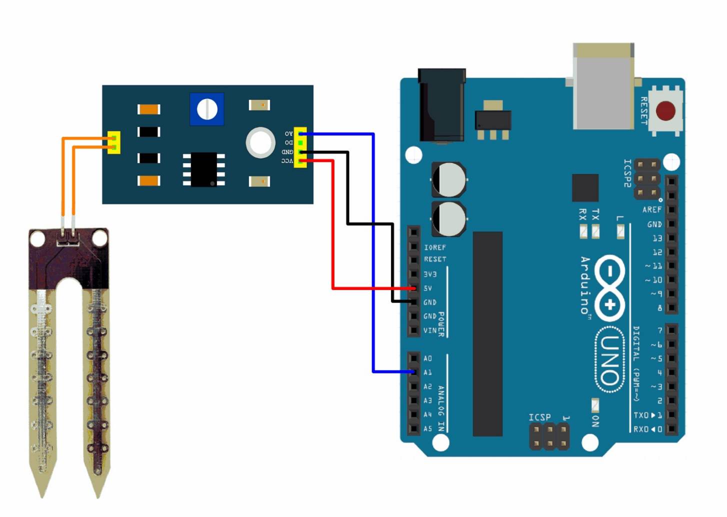

Figure III. 3: Wiring soil moisture sensor with Arduino board.

III.3.1.2. Soil moisture sensor Code

Before we can use this sensor properly, we have to calibrate it as each sensor have different reading in wet and dry condition that vary from sensor to another. To calibrate the sensor we have to get reading in completely dry condition and in wet condition, following code:

```
SoilMoistureCabliration §
// Sensor pins
#define sensorPin A0
int moisture ;
void setup() {
 Serial.begin(9600);
}

void loop() {
  //get the reading from the function below and print it
  Serial.print("Analog output: ");
  int moisture = analogRead(sensorPin);
  delay(1000);
}
```

Figure III. 4: Soil moisture sensor calibration Code.

In our test, the results was as following:

- Dry reading: 1003;
- Wet reading: 173;

Next; now, we have the calibration of our sensor; we use it to turn the reading into percentage, which will allow for precise control of moisture level:

```
// Variables for soil moisture
const int DryValue = 1003;// Constant for dry sensor
const int WetValue = 173;// Constant for wet sensor
int soilMoistureValue;
int soilMoisturePercent;

// soil moisture Sensor pins
#define sensorPower 7
#define sensorPin A0

void setup() {
  Serial.begin(9600);
  pinMode(sensorPower, OUTPUT);
  // Initially keep the sensor OFF
  digitalWrite(sensorPower, LOW);

}
```

```
void loop() {
  //get the reading from the function below and print it
  int moisture = readSensor();
  // Determine soil moisture percentage value
  soilMoisturePercent = map(moisture, DryValue, WetValue, 0, 100);
  // Keep values between 0 and 100
  soilMoisturePercent = constrain(soilMoisturePercent, 0, 100);
  // Print to serial monitor
  Serial.print("soilMoisturePercent: ");
  Serial.print(soilMoisturePercent);
  Serial.print("%  ");
  delay(1000);  // Take a reading every second for testing
}
//  This function returns the analog soil moisture measurement
int readSensor() {
  digitalWrite(sensorPower, HIGH);  // Turn the sensor ON
  delay(10);                  // Allow power to settle
  int val = analogRead(sensorPin);  // Read the analog value form sensor
  digitalWrite(sensorPower, LOW);   // Turn the sensor OFF
  return val;                 // Return analog moisture value
}
```

Figure III. 5: Code to turn reading soil moisture reading to percentage

Here we used "map" function to turn our reading into percentage following it with "constrain" function to keep all the reading between 0-100%.

Additionally, it is recommend that the sensor be turned on only when taking readings, constantly applying power to the sensor while buried in soil significantly accelerates the rate of corrosion causing shorter lifespan because they are constantly exposed to moisture [24]. One easy way to do this is to connect the sensor's power pin to a digital pin on an Arduino and set it to HIGH or LOW as needed.

III.3.2. DHT11 code

III.3.2.1. Interface DHT sensor with Arduino uno

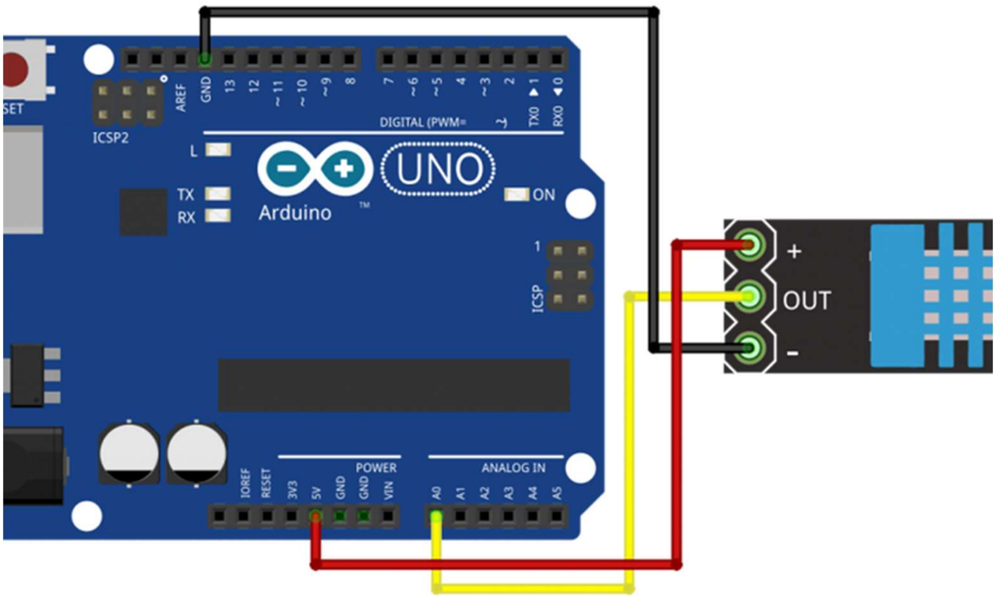

Figure III. 6: DHT11 wiring with Arduino board

Wiring the DHT11 to the Arduino board is simple. The wiring connections are represented in **Figure III. 7** :

- VCC pin of the DHT11 goes into +3v of the Arduino.
- DATA pin of the DHT11 goes into Analog Pin A0 of the UNO.
- GND Pin of the DHT11 goes into Ground Pin (GND) of the UNO.

III.3.2.2. DHT11 data read Code

The following code **[Figure III. 8]** demonstrates how to read data from the DHT11 sensor and display the current humidity and temperature values on the serial monitor, this code continuously reads data from the DHT11 sensor and prints the current humidity and temperature values to the serial monitor.

```
dht11 §
#include "dht.h"
#define dht_apin A0 // Analog Pin sensor is connected to

dht DHT;

void setup(){

  Serial.begin(9600);
  Serial.println("DHT11 Humidity & temperature Sensor\n\n");
}

void loop(){
    DHT.read11(dht_apin);
    Serial.print("Current humidity = ");
    Serial.print(DHT.humidity);
    Serial.print("%  ");
    Serial.print("temperature = ");
    Serial.print(DHT.temperature);
    Serial.println("C  ");
} |
```

Figure III. 9: Code to read from DHT11 sensor.

Let's break it down and explain each part:

- **Include Statement:**

#include "dht.h" This line includes the header file "dht.h", which contains the necessary declarations and definitions for using the DHT11 temperature and humidity sensor.

- **Constant Definition:**

#define dht_apin A0: This line defines a constant named dht_apin, which represents the analog pin to which the DHT11 sensor is connected. In this case, it's defined as A0, indicating analog pin 0.

- **Object Declaration:**

dht DHT;: This line declares an object named DHT of type dht, which is used to interact with the DHT11 sensor.

- **Setup Function:**

void setup() { ... }: This function is called once when the Arduino board starts up or is reset. It initializes serial communication with a baud rate of 9600 and prints a message indicating that the DHT11 sensor is being used for measuring humidity and temperature.

- **Loop Function:**

`void loop()` { ... }: This function is called repeatedly in a loop after the setup function completes.

`DHT.read11(dht_apin);`: This line reads data from the DHT11 sensor connected to the analog pin specified by dht_apin and stores the humidity and temperature values in the DHT object.

`Serial.print("Current humidity = ");`: This line starts printing the string "Current humidity = " to the serial monitor.

`Serial.print(DHT.humidity`);: This line prints the humidity value obtained from the DHT11 sensor to the serial monitor.

`Serial.print("% `");: This line prints the percentage symbol and two spaces to the serial monitor.

`Serial.print("temperature = `");: This line starts printing the string "temperature = " to the serial monitor.

`Serial.print(DHT.temperature);:` This line prints the temperature value obtained from the DHT11 sensor to the serial monitor.

`Serial.println("C `");: This line prints the unit "C" (for Celsius) followed by a newline character to the serial monitor, creating a new line in the output.

III.3.3. Irrigation control code

The following functions [**Figure III. 10**] work together to control the water pump based on the soil moisture level and provide an alert if the moisture level drops significantly while the pump is operating.

```
void controlWaterPump(int moisture) {
  if (pump == 0 && soilMoisturePercent < minMoisture) {
    digitalWrite(Waterpump, LOW);
    pump = 1;
  } else if (pump == 1 && soilMoisturePercent > maxMoisture) {
    pump = 0;
    digitalWrite(Waterpump, HIGH);
  }

}
void checkMoistureLevelAlert(int soilMoisturePercent) {
  // Check if soil moisture is significantly below min threshold while pump is ON
  if (pump == 1 && soilMoisturePercent < minMoisture - 10) {
    digitalWrite(redLedPin, HIGH);    // Activate red LED as an alert
    Serial.println("Alert: Soil moisture level is significantly low while pump is ON. Check pump and irrigation system.");     // Send serial notification
  } else {
    digitalWrite(redLedPin, LOW);
  }
}
```

Figure III. 11: Code to control water pump base on soil moisture level.

Control Water Pump Function:

This function is responsible for controlling the water pump based on the soil moisture level.

- Depending on the current state of the water pump (pumpState) and the soil moisture percentage, the function decides whether to turn the pump ON or OFF.
- If the pump is currently OFF and the soil moisture percentage falls below a minimum threshold (minMoisture), the pump is turned ON.
- Conversely, if the pump is ON and the soil moisture percentage exceeds a maximum threshold (maxMoisture), the pump is turned OFF.
- Finally, the state of the water pump is updated by writing to the Waterpump pin using digitalWrite.

Check Moisture Level Alert Function:

This function checks if the soil moisture level is significantly below a minimum threshold while the water pump is ON.

- If the pump is ON and the soil moisture percentage is below (minMoisture - 10), indicating a significant decrease in moisture level, it activates a red LED connected to redLedPin to alert the user.
- The alert message is also printed to the serial monitor to notify the user of the low soil moisture level while the pump is running.
- If the soil moisture level is within an acceptable range, the red LED is turned off.

III.3.4. Humidity controlling code

This code snippet [**Figure III. 12**] defines a function named **control Humidifier** that is responsible for controlling the operation of a humidifier based on the measured humidity level.

```
void controlHumidifier(float humidity) {
  static bool humidifierOn = false; // Track the state of the humidifier

  if (DHT.humidity < minHumidity ) {
    // If humidity is below minHumidity and the humidifier is not already on, turn on the humidifier
    digitalWrite(Humidifiar, LOW); // Turn on the humidifier
  } else if (DHT.humidity > maxHumidity) {
    // If humidity is at or above minHumidity and the humidifier is on, turn off the humidifier
    digitalWrite(Humidifiar, HIGH); // Turn off the humidifier
  }
}
```

Figure III. 13: Code to control humidifier base on humidity level.

Here's a breakdown of the code: void control Humidifier (float humidity):

This function takes a floating-point parameter humidity, representing the current humidity level. It uses a static boolean variable humidifierOn to track the state of the humidifier, ensuring that its state persists between function calls.

Humidifier Control Logic:

- If the current humidity level (humidity) is below a minimum threshold (minHumidity) and the humidifier is not already turned on (!humidifierOn), the humidifier is turned on by setting the Humidifiar pin to LOW using digitalWrite. The humidifierOn variable is then updated to indicate that the humidifier is now turned on.
- If the humidity level is at or above the minimum threshold (>= minHumidity) and the humidifier is currently turned on (humidifierOn), the humidifier is turned off by setting the Humidifiar pin to HIGH. Again, the humidifierOn variable is updated to reflect the change in state.

III.3.5. Temperature controlling code

This code snippet [**Figure III. 14**] defines a function named **control Heater** responsible for controlling a heater and a door based on the measured temperature.

```
void controlHeater(float temperature) {
  static bool doorClosed = false; // Track if the door is closed

  if (DHT.temperature < minTemperature && !doorClosed) {
    // If temperature is below minTemperature and the door is not closed, close the door
    digitalWrite(Heater, LOW);  // Turn on the heater
    servol.write(1);  // Close the door
    doorClosed = true; // Set the door state to closed
    door = 0;
  } else if (DHT.temperature >= minTemperature && temperature < maxTemperature) {
    // If temperature is within the ideal range, keep the door closed and turn off the heater
    digitalWrite(Heater, HIGH);  // Turn off the heater
    servol.write(1);  // Close the door
    doorClosed = true; // Set the door state to closed
    door = 0;
  } else if (DHT.temperature >= maxTemperature) {
    // If temperature is above maxTemperature, open the door and turn off the heater
    digitalWrite(Heater, HIGH);  // Turn off the heater
    servol.write(160);  // Open the door
    doorClosed = false; // Set the door state to open
    door = 1;
  }
}
```

Figure III. 15: Code to control heating element and door state base on temperature.

Void control Heater (float temperature):

This function takes a floating-point parameter temperature, representing the current temperature. It uses a static Boolean variable doorClosed to track whether the door is closed or not.

Heater and Door Control Logic:

- If the current temperature (temperature) is below a minimum threshold (minTemperature) and the door is not closed (!doorClosed), the heater is turned on by setting the Heater pin to LOW using digitalWrite, and the door is closed by adjusting a servo motor (servo1) to a specific position (presumably to close the door). The doorClosed variable is then updated to indicate that the door is now closed, and the doorState variable is set to "CLOSED" to reflect this state.
- If the temperature is within the ideal range (between minTemperature and maxTemperature), the door remains closed, and the heater is turned off by setting the Heater pin to HIGH. The door state and position remain unchanged.
- If the temperature exceeds the maximum threshold (maxTemperature), the heater is turned off, and the door is opened by adjusting the servo motor to a different position,

presumably to open the door. The doorClosed variable is updated to indicate that the door is now open, and the doorState variable is set to "OPEN".

III.3.6. Serial communication

This code [**Figure III. 16**] defines a function named **sendDataToESP32**, which converts sensor readings and actuator states into strings and sends them over UART (Universal Asynchronous Receiver-Transmitter) communication to an ESP32 device.

```
//converts the sensor readings and actuator states into strings and then sends them over UART
void sendDataToESP32(float temperature, float humidity, int moisture, ActuatorState pumpState, ActuatorState heaterState, ActuatorState humidifierState, String doorState) {
  // Convert float values to string
  String tempStr = String(temperature, 2);
  String humidStr = String(humidity, 2);

  // Convert int value to string
  String moistureStr = String(moisture);

  // Convert ActuatorState to string
  String pumpStr = (pumpState == ON) ? "ON" : "OFF";
  String heaterStr = (heaterState == ON) ? "ON" : "OFF";
  String humidifierStr = (humidifierState == ON) ? "ON" : "OFF";

  // Send data over UART
  Serial.print("Temperature: ");
  Serial.println(tempStr);
  Serial.print("Humidity: ");
  Serial.println(humidStr);
  Serial.print("Moisture: ");
  Serial.println(moistureStr);
  Serial.print("Pump State: ");
  Serial.println(pumpStr);
  Serial.print("Heater State: ");
  Serial.println(heaterStr);
  Serial.print("Humidifier State: ");
  Serial.println(humidifierStr);
  Serial.print("Door State: ");
  Serial.println(doorState);
}
```

Figure III. 17: Code to send Data from ardunio uno to ESP32 using UART

III.3.7. Arduino IoT cloud

The Arduino Cloud is a online platform that makes it easy for you to create, deploy and monitor IoT projects. This code is designed to interface with the Arduino IoT Cloud service, allowing communication between the ESP32 board and the cloud platform for remote monitoring. the code:

```
Untitled_mar23a §   arduino_secrets.h   thingProperties.h
#include "arduino_secrets.h"
#include "thingProperties.h"
#define RXp2 16
#define TXp2 17
void setup() {
  Serial.begin(9600, SERIAL_8N1, RXp2, TXp2);
  // This delay gives the chance to wait for a Serial Monitor without blocking if none is found
  delay(1500);
  initProperties();
  // Connect to Arduino IoT Cloud
  ArduinoCloud.begin(ArduinoIoTPreferredConnection);
  setDebugMessageLevel(2);
  ArduinoCloud.printDebugInfo();
}

void loop() {
  ArduinoCloud.update();
  if (Serial.available() > 0) { // Check if data is available to read
    // Read the incoming data until a comma is encountered
    float temperature = Serial.parseFloat();
    Serial.read(); // Consume the comma
    float humidity = Serial.parseFloat();
    Serial.read(); // Consume the comma
    int moisture = Serial.parseInt();
    Serial.read(); // Consume the comma
    String pumpState = Serial.readStringUntil(',');
    String heaterState = Serial.readStringUntil(',');
    String humidifierState = Serial.readStringUntil(',');
    String doorState = Serial.readStringUntil('\n');
    Serial.print("Received data: ");
    Serial.print("Temperature: ");
    Serial.print(temperature);
    Serial.print(", Humidity: ");
    Serial.print(humidity);
    Serial.print(", Moisture: ");
    Serial.print(moisture);
    Serial.print(", Pump State: ");
    Serial.print(pumpState);
    Serial.print(", Heater State: ");
    Serial.print(heaterState);
    Serial.print(", Humidifier State: ");
    Serial.print(humidifierState);
    Serial.print(", Door State: ");
    Serial.println(doorState);
  }
}
```

Figure III. 18: Arduino IoT cloud Code

- **Library Inclusions**:
    - **#include "arduino_secrets.h"**: This line includes a header file (**arduino_secrets.h**) that typically contains sensitive information such as WiFi

credentials and IoT Cloud authentication tokens. It is used to securely store this information without exposing it in the main code.

- **Setup Function**:
  - **Serial.begin(9600, SERIAL_8N1, RXp2, TXp2)**: Initializes the serial communication at a baud rate of 9600, using the specified RX (receive) and TX (transmit) pins (**RXp2** and **TXp2**).
  - **delay (1500)**: Adds a delay to allow time for the serial monitor to open before continuing.
  - **initProperties()**: Initializes the properties defined in the **thingProperties.h** file, which includes declaring variables and setting up communication channels for the IoT Cloud service.
  - **ArduinoCloud.begin(ArduinoIoTPreferredConnection)**: Initiates the connection to the Arduino IoT Cloud using the preferred connection method specified.
  - **setDebugMessageLevel(2)**: Sets the debug message level for monitoring and troubleshooting purposes.
  - **ArduinoCloud.printDebugInfo()**: Prints debug information to the serial monitor.
- **Loop Function**:
  - **void loop()**: This function continuously executes after the **setup()** function completes.
  - **ArduinoCloud.update()**: Checks for updates from the Arduino IoT Cloud service, such as incoming commands or updates to property values.
  - **if (Serial.available() > 0) { ... }**: Checks if there is data available to read from the serial port.
  - Within the conditional block, the code reads incoming data from the serial port, parses it, and assigns the values to variables representing temperature, humidity, moisture, and the states of various actuators (pump, heater, humidifier, and door).

- After reading the data, the code prints the received values to the serial monitor for verification.

The dashboard on the Arduino IoT Cloud platform provides a user-friendly interface to visualize real-time data from the greenhouse sensors and control the actuators remotely; here in **Figure III. 19** we see the live reading, graph for the data from the past hour up to past 15 days. And the actuator state.

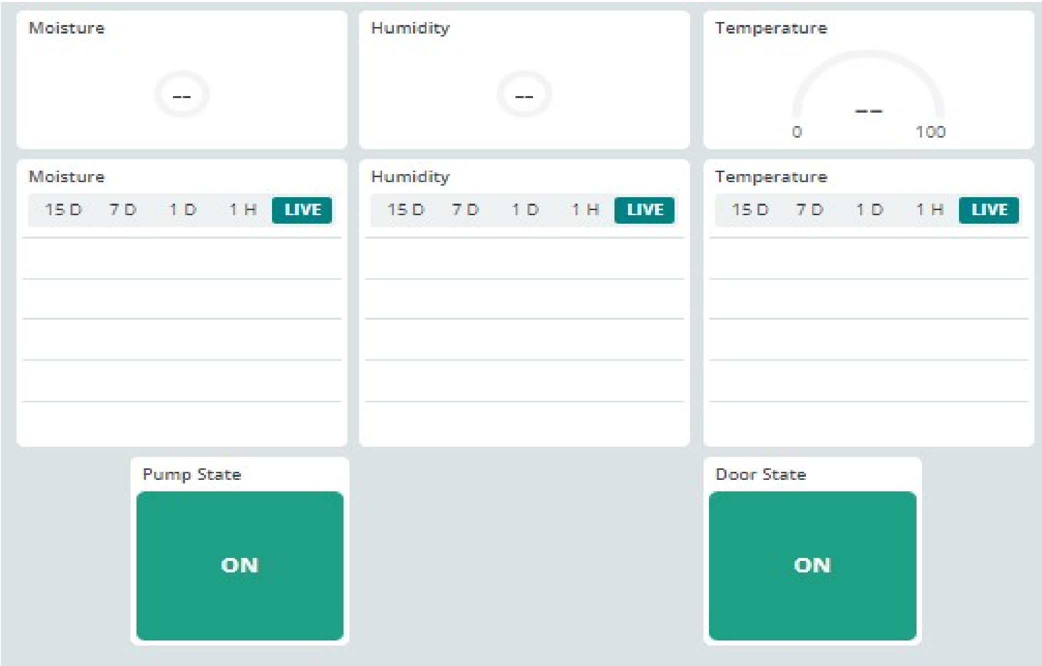

Figure III. 20: Arduino Iot cloud dashboard

III.4. EXPERIMENTAL RESULTS

In the experimental phase of our project, after running for long while we observed the successful performance of our prototype in regulating environmental conditions within the greenhouse simulation. Our expectations were met as we effectively controlled temperature, humidity, and moisture levels to remain within our predefined thresholds. The integration of the Arduino IoT Cloud provided real-time monitoring of these parameters, allowing us to track changes and make informed decisions.

However, it is important to note that while the Arduino IoT Cloud proved responsive and user-friendly, we encountered limitations in its free tier, particularly regarding the number of elements we could track simultaneously. This restriction restricted our ability to display the status of all actuators, limiting us to monitoring only five essential elements.

Overall, our experimental results demonstrate the feasibility and effectiveness of our prototype in creating a controlled greenhouse environment. We look forward to further refining our system and exploring additional functionalities in future iterations.

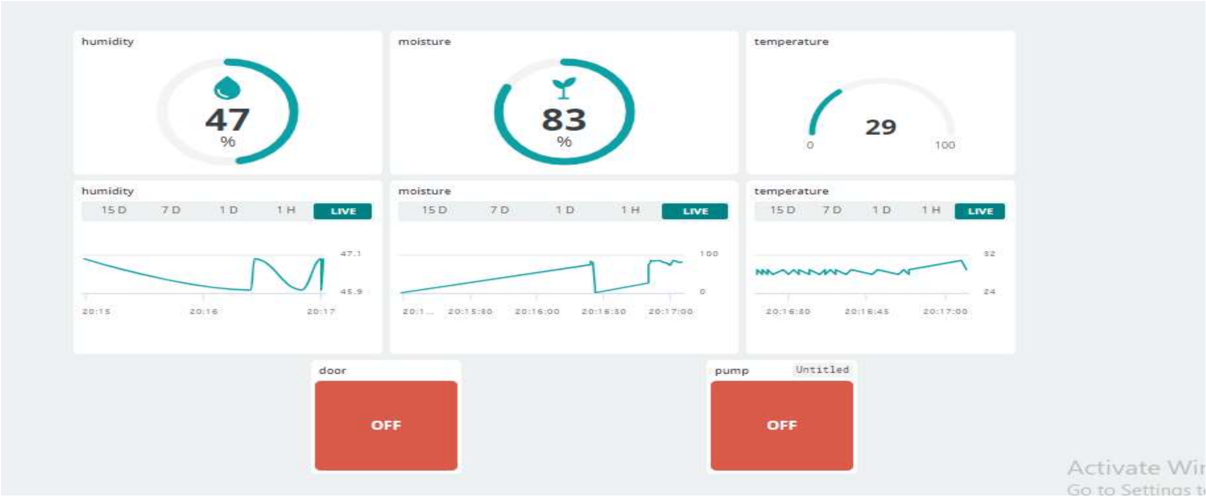

Figure III. 21: Live data monitoring.

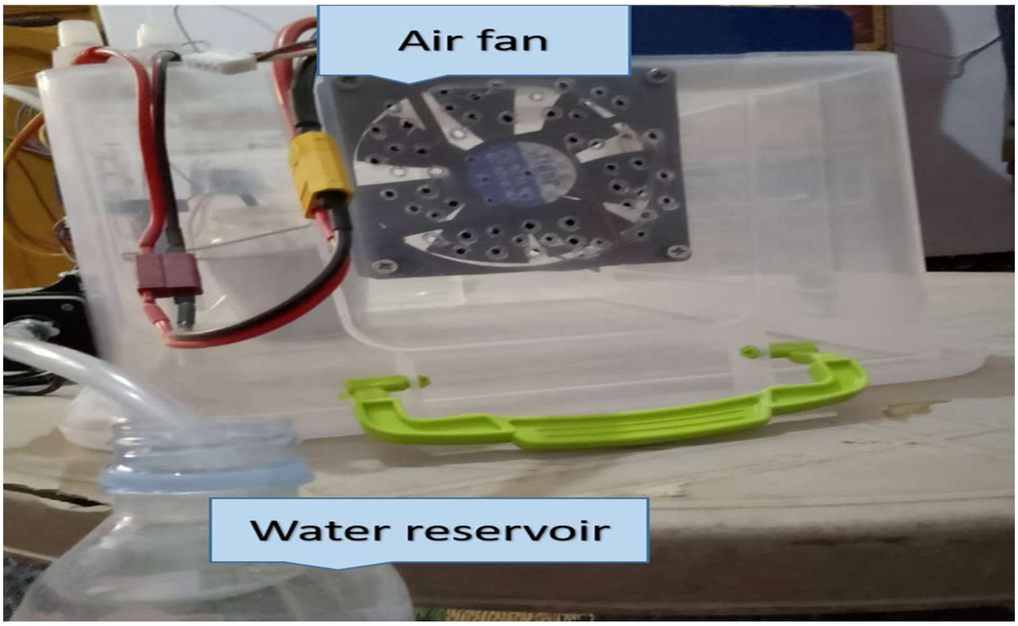

Figure III. 22 Prototype side view.

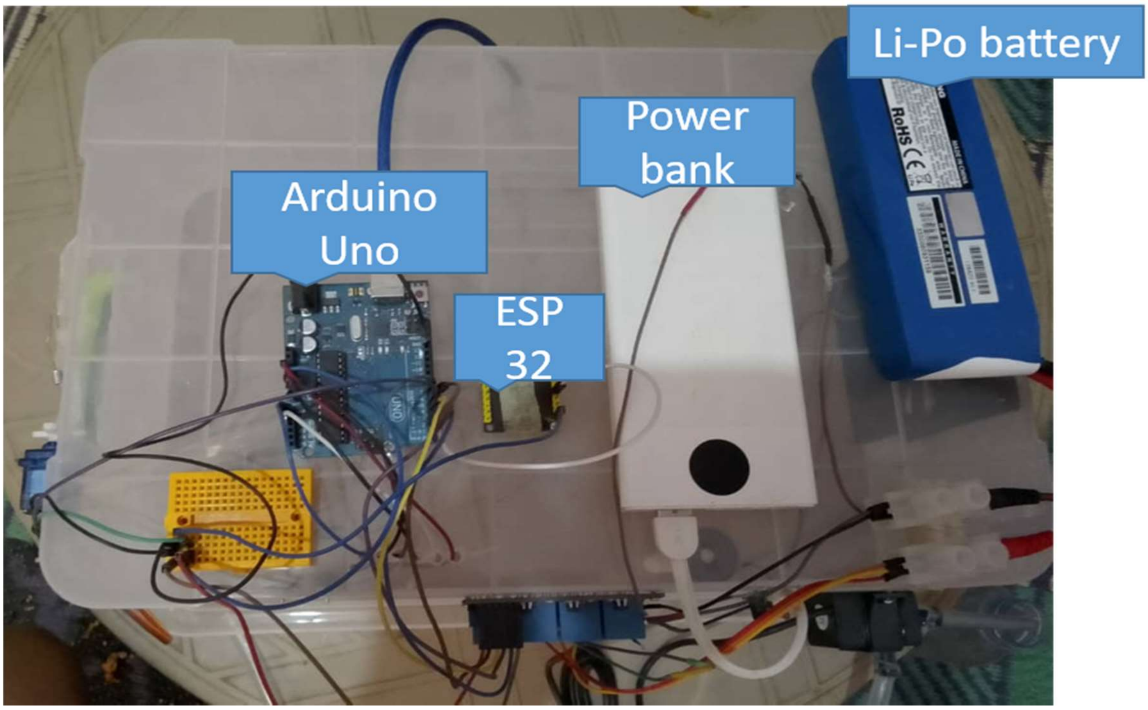

Figure III. 23: Prototype top view.

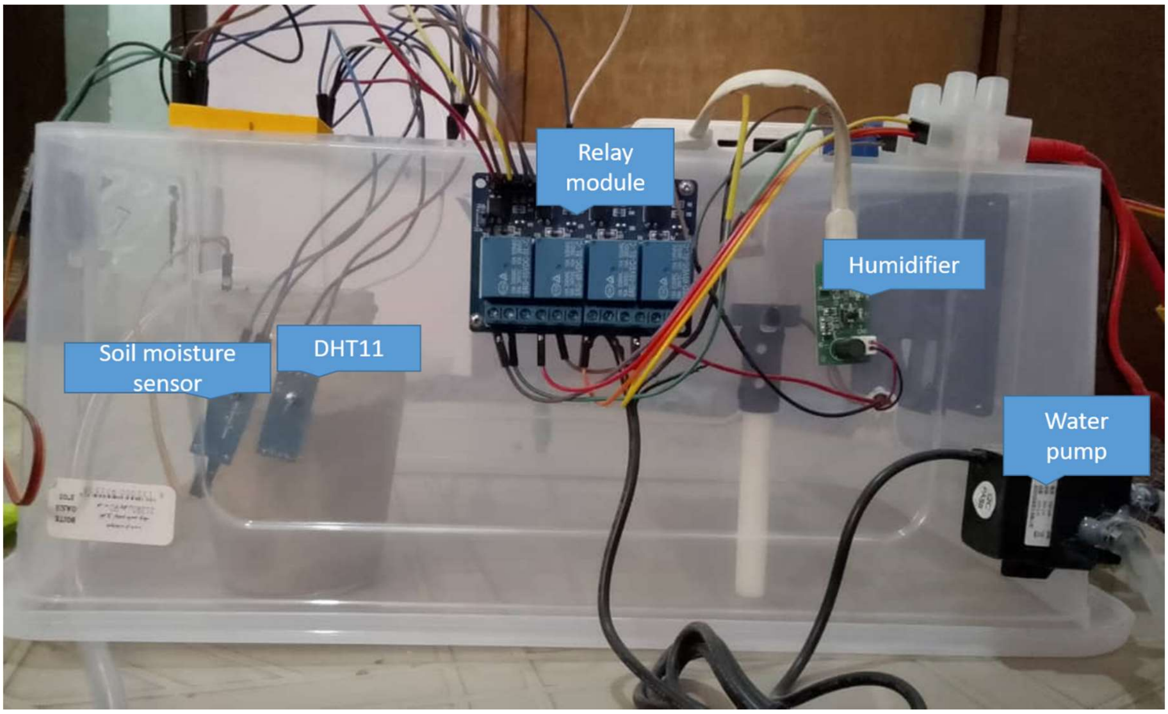

Figure III. 24: Prototype side view 2.

III.5. CONCLUSION

In this chapter, we started by introducing the Arduino IDE as the tool for programming our sensors and actuators. From there, we delved into the intricacies of coding, starting with sensor where we show how to interface each season with μC board and how to calibrate them if need.

Following the sensor setup, we explored the communication protocol UART employed to transfer data from the Arduino Uno board to the ESP32 board, facilitating data exchange between boards. Our exploration then led us to the Arduino IoT Cloud, where we displayed the dashboard designed to visualize and monitor environmental parameters in real-time.

Then we went to the experimental phase, where we put our prototype to the test, we obtained valuable insights into the performance and efficacy of our greenhouse system.

General Conclusion:

We have reached the end of the thesis master, in which our review of various aspects of agriculture, Internet of Things technology, and learning about different irrigation systems shows how technological development can transform the agricultural sector. Starting from understanding agriculture in Algeria and passing through the concepts of smart agriculture and its importance, in our work we developed a remote control and monitoring system for the smart irrigation system and focused on agricultural heaters, which have the ability to intelligently and automatically control climate management through the Internet of Things, where the farmer in turn can control by specifying Temperature, humidity, and real-time monitoring of indoor climate and climate parameters through a smartphone, through to model building and pilot experiments, we highlighted how Internet of Things (IoT) technology can be used in the irrigation system to improve agricultural productivity and enhance its sustainability.

The design of the model and the equipment used were presented. We first realized the irrigation system based on the Arduino board. According to the results obtained from scientific tests, using the Arduino card as an interface between the pump and the computer makes it possible to simplify and facilitate the control of our system, including the sensors and other smart controllers. and ESP32 actuators and guidance was provided on how to apply them effectively in areas such as water management and improving irrigation systems. By studying pilot trials and analyzing data, we have shown how these technologies can achieve positive results and improve agricultural performance.

Ultimately, this research combines theory and practical application to demonstrate how this smart system can be an essential part of the future of agriculture, enhancing sustainability and improving farmers' lives and crop quality

References:

[1] b. q. y. Fodad elias, "Master memory," *It is mandatory to turn to agricultural technology to increase the output of the agricultural sector in Algeria,* 2023.

[2] K. ・. M. LAOUBI, "The Challenge of Agriculture in Algeria: Are Policies Effective?," p. 5, 03 2012.

[3] B. A. R. Saidani Fawaz Kamal, "Master memory ," *Read about the extent to which the agricultural sector contributes to development And the development of the Algerian economy in the period 2010-2018 Case study (Tiaret state),* 2018.

[4] D. M. E. Al-Rashidi, "College of Education Journal ,University of Hail," *Requirements for employing Internet of Things technologies in the educational process from the point of view of faculty members,* 2022.

[5] M. A. A. Mr. BELHADJ Naceur, "Master memory," *Internet security Objects (IoT),* 2022.

[6] "Internet des Objet (Internet of Things," 2024. [Online]. Available: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.mcours.net%2Fcours%2Fpdf%2Fhassbg%2Fhassbgli822.pdf&psig=AOvVaw1Z0Ez0z2RwMU7ar4l2wVYc&ust=1715104989308000&source=images&cd=vfe&opi=89978449&ved=0CAUQn5wMahcKEwjgmNfI2_mFAxUAAAAAHQAAAAAQBA.

[7] A. CISSE, "Master memory," *Design and Implementation of an Intelligent Agricultural Management System based on the Internet of Things,* 18 02 2023.

[8] P. Jayaraman, "internet of things platform for smart farming: Experiences andlessons learnt," 2016.

[9] D. M. Elsayed, "Cairo University ,Faculty of Agriculture," *Precision agriculture managment,* 2020.

[10] "https://solarimpulse.com," 05 05 2024. [Online]. Available: https://solarimpulse.com/solutions-explorer/smart-greenhouse.

[11] "https://www.mutualia.fr," 05 05 2024. [Online]. Available: https://www.mutualia.fr/mutualia-mutuelle-sante-pour-entreprise-professionnel-et-particulier.

[12] 04 05 2024. [Online]. Available: https://www.mokosmart.com/.

[13] D. A. Haddada, "Faculty of Economic Sciences and Business Administration ,Smart agriculture," 12 2018.

[14] "dg-12-na-heating-cooling," 30 04 2024. [Online]. Available: https://drygair.com/dehumidifiers/dg-12-na-heating-cooling/.

[15] D. C. J. Neo, M. M. X. ong, Y. Y. Lee, E. J. Teo, Q. Ong, H. Tanoto, J. Xu, K. S. Ong and V. Suresh, "Shaping and Tuning Lighting Conditions in Controlled Environment Agriculture: A Review," 21 02 2022.

[16] "How CO2 can be consumed in a cultivation greenhouse," https://horti-generation.com, [Online]. Available: https://horti-generation.com/how-co2-can-be-consumed-in-a-cultivation-greenhouse/.

[17] "Air Circulation Fans," ABS, [Online]. Available: https://www.asbava.com/air-circulation-fans.htm.

[18] Z. Dafri, "Faculty of Mathematics, Computer Science and Material SciencesComputer Science department Master memory/Creation of a system based on the Internet of Things for the control of smart greenhouses," July 2019.

[19] "smart-irrigation," 29 04 2024. [Online]. Available: https://www.ais-agri.ma/smart-irrigation.

[20] C. T. KOUNDOUL, "End of studies dissertation For obtaining the Master's degree :Design of an automatic irrigation system," 07 07 2020.

[21] "https://earth.works," 06 05 2024. [Online]. Available: https://earth.works/drip-irrigation-the-good-the-bad-and-the-aesthetically-pleasing/.

[22] "https://www.researchgate.net," [Online]. Available: https://www.researchgate.net/figure/The-pin-diagram-of-DHT11-temperature-sensors_fig2_359068957.

[23] Transfer Multisort Elektronik, "DHT11 Humidity and Temperature," p. 2.

[24] "last minute engineers," [Online]. Available: https://lastminuteengineers.com/soil-moisture-sensor-arduino-tutorial/. [Accessed 02 04 2024].

[25] "https://forum.arduino.cc," [Online]. Available: https://forum.arduino.cc/t/question-about-soil-moisture-sensor/695425.

[26] "https://www.amazon.com/," LEDGLE, [Online]. Available: https://www.amazon.com/Mini-water-pump-Black-210L/dp/B085NQ5VVJ?th=1.

[27] "PTC Heating element 70C 12V," nettigo, [Online]. Available: https://nettigo.eu/products/ptc-heating-element-70c-12v.

[28] "Electronic Spices 5V DIY Ultrasonic Piezoelectric Humidifier Moisture Atomizing Chip Mist maker circuit board," ELECTRONIC SPICES, [Online]. Available: https://www.amazon.in/Electronic-Spices-Ultrasonic-Piezoelectric-Rechargeable/dp/B09SQ71RLS.

[29] P. v. Weel, "THE IMPORTANCE OF VERTICAL AIR MOVEMENT IN A GREENHOUSE," HINOVA, 16 04 2020. [Online]. Available: https://hinova.nl/en/the-importance-of-vertical-air-movement-in-a-greenhouse/. [Accessed 06 05 2024].

[30] "Air Circulation Tube," HT-BG-TUBE, [Online]. Available: https://www.greenhousemegastore.com/products/air-circulation-tube.

[31] Arduino uno board., "https://learn.sparkfun.com/tutorials/what-is-an-arduino.," [Online].

[32] "ESP32 Pinout Reference," esp32, [Online]. Available: https://lastminuteengineers.com/esp32-pinout-reference/.

[33] E. board., "https://www.tutorialspoint.com/arduino/arduino_," [Online].

[34] "4 module relay board," [Online]. Available: https://forum.arduino.cc/t/4-relay-module-no-second-grd-connection-for-relay-coils/672208.

[35] Arduino, "Arduino IDE 1 Basics," [Online]. Available: https://docs.arduino.cc/software/ide-v1/tutorials/arduino-ide-v1-basics/".

[36] [Online]. Available: www.arduino.com.

[37] B. H. Salhi Ammar, "Master's graduation note :Study and creation of an intelligent irrigation system," 15 September 2021.