الشعبية الديمقراطية الجزائرية الجمهورية
People's Democratic Republic of Algeria
وزارة التعليم العالي والبحث العلمي
Ministry of Higher Education and Scientific Research
جامعة غرداية
University of Ghardaia
كلية العلوم والتكنولوجيا
Faculty of Science and Technology
قسم الآلية والكهروميكانيك
Department of Automatics and Electromechanics

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Field: Science and Technology

Specialty: Automatics and Systems

Topic:

Design and development of an Arduino-based smart greenhouse

Candidate: **Achraf Mounir AGUIAR**

Defended publicly on: 22/06/2024

Before the jury composed of:

Naser HACENE	MCA	Ghardaia Univ.	President
Abdelouahab BENSEDDIK	MRA	URAER	Supervisor
Abdelmajid TIMMAOUI	Prof	Ghardaia Univ.	Examiner
Charaf Abdelkarim MOSBAH	MAA	Ghardaia Univ.	Examiner

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Dedication

“I would like to express my sincere gratitude to my late mother, who tirelessly supported me from my childhood until her death. Her encouragement and unwavering love served as a guiding light throughout my academic journey. I am also extremely grateful to my uncle, aunt and grandmother, who stepped in to offer me love, support and guidance after my mother’s death.” Their kindness and wisdom have been invaluable to me during difficult times, and I am forever grateful for their presence in my

Abstract:

Agriculture in semi-arid regions presents significant challenges due to harsh climatic conditions and scarce water resources. Our project aims to develop a smart greenhouse system using Arduino technology to achieve sustainable agriculture in these regions. This involves using advanced technologies to control the greenhouse's internal environment, including temperature, humidity, and soil moisture, to provide optimal conditions for crop growth and improve resource efficiency. We began the project with a comprehensive understanding of the concept and objectives of agricultural greenhouses and conducted in-depth research on the impact of climate inside greenhouses and how to improve it for the best agricultural outcomes. Choosing the Arduino unit as a main tool allowed us to program the system with high flexibility to meet our specific needs, along with using various sensors to transmit physical data to the Arduino unit, enabling precise monitoring of environmental parameters. The smart greenhouse system integrates data collection from sensors and analysis using the Arduino control unit, which issues necessary commands to control irrigation, ventilation, and lighting systems. This integration between data collection and automatic control helps improve crop productivity and reduce water consumption, enhancing the sustainability of the agricultural process in semi-arid regions.

Keywords: Sustainable agriculture; semi-arid regions; smart greenhouse; Arduino; microclimate control; resource efficiency; crop productivity.

Résumé :

L'agriculture dans les régions semi-arides présente des défis importants en raison des conditions climatiques difficiles et de la rareté des ressources en eau. Notre projet vise à développer un système de serre intelligente utilisant la technologie Arduino pour réaliser une agriculture durable dans ces régions. Cela implique l'utilisation de technologies avancées pour contrôler l'environnement interne de la serre, y compris la température, l'humidité et l'humidité du sol, afin de fournir des conditions optimales pour la croissance des cultures et d'améliorer l'efficacité des ressources. Nous avons commencé le projet par une compréhension approfondie du concept et des objectifs des serres agricoles et avons mené des recherches approfondies sur l'impact du climat à l'intérieur des serres et comment l'améliorer pour obtenir les meilleurs résultats agricoles. Le choix de l'unité Arduino comme outil principal nous a permis de programmer le système avec une grande flexibilité pour répondre à nos besoins spécifiques, en utilisant divers capteurs pour transmettre des données physiques à l'unité Arduino, permettant une surveillance précise des paramètres environnementaux. Le système de serre intelligente intègre la collecte de données des capteurs et leur analyse à l'aide de l'unité de contrôle Arduino, qui émet les commandes nécessaires pour contrôler les systèmes d'irrigation, de ventilation et d'éclairage. Cette intégration entre la collecte de données et le contrôle automatique contribue à améliorer la productivité des cultures et à réduire la consommation d'eau, renforçant ainsi la durabilité du processus agricole dans les régions semi-arides.

الملخص:

الزراعة في المناطق شبه القاحلة تمثل تحديًا كبيرًا نظرًا للظروف المناخية القاسية وندرة الموارد المائية. يهدف مشروعنا إلى إنشاء نظام دفيئة ذكي يعتمد على تقنية الأردوينو لتحقيق الزراعة المستدامة في هذه المناطق، ويتضمن استخدام تقنيات حديثة للتحكم في البيئة الداخلية للدفيئة بما في ذلك درجة الحرارة، الرطوبة، ورطوبة التربة، مما يوفر الظروف المثلى لنمو المحاصيل وتحسين كفاءة استخدام الموارد. بدأنا المشروع بفهم شامل لمفهوم الدفيئات الزراعية وأهدافها، وأجرينا بحوثًا معمقة حول تأثير المناخ داخل الدفيئات وكيفية تحسينه لتحقيق أفضل النتائج الزراعية. اختيار وحدة الأردوينو كأداة رئيسية أتاح لنا برمجة النظام بمرونة عالية لتلبية احتياجاتنا المحددة، مع استخدام أجهزة استشعار متنوعة لنقل البيانات الفيزيائية إلى وحدة الأردوينو، مما سمح بمراقبة دقيقة للمعلمات البيئية. يتضمن نظام الدفيئة الذكي تكاملًا بين جمع البيانات من أجهزة الاستشعار وتحليلها باستخدام وحدة التحكم الأردوينو، التي تقوم بإصدار الأوامر اللازمة للتحكم في أنظمة الري، التهوية، والإضاءة. هذا التكامل بين جمع البيانات والتحكم التلقائي يساهم في تحسين إنتاجية المحاصيل وتقليل استهلاك المياه، مما يعزز من استدامة العملية الزراعية في المناطق شبه القاحلة.

الكلمات المفتاحية: الزراعة المستدامة، المناطق شبه القاحلة، الدفيئة الذكية، الأردوينو، التحكم في البيئة الداخلية للدفيئة ، الري الذكي، استشعار الرطوبة، الزراعة الدقيقة.

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General Introduction

General Introduction:

Agriculture is the foundation of human civilization, providing the primary resources for food and essential materials. As such, the development of the agricultural sector is critical for the economic growth and stability of nations. Despite its importance, many farmers continue to use traditional farming methods that yield low productivity and face numerous challenges, including climate variability, water scarcity, and market competitiveness. To meet the demands of an ever-growing population and an increasingly competitive market, modern agriculture must evolve towards automation and smart farming solutions.

One promising approach to address these challenges is the development of smart greenhouses. These advanced systems leverage technology to create controlled environments that optimize conditions for crop growth, thus enhancing yield, reducing resource consumption, and ensuring sustainability.

Semi-arid regions, characterized by harsh climatic conditions and limited water resources, present significant challenges for conventional farming. In these areas, managing the microclimate within a greenhouse is essential to ensure the survival and growth of crops. To this end, our smart greenhouse system focuses on meticulously controlling several key parameters:

- ✓ ***Air temperature and humidity:*** These are vital for maintaining the physiological processes of plants. Proper regulation ensures that crops are not exposed to extreme temperatures or humidity levels, which can impede growth or cause stress.
- ✓ ***Soil moisture:*** Adequate soil moisture is crucial for plant health and nutrient uptake. By monitoring and adjusting soil moisture levels, the system ensures that plants receive the right amount of water, avoiding both drought stress and water logging.
- ✓ ***Lighting:*** Light is a fundamental requirement for photosynthesis. The smart greenhouse system provides optimal lighting conditions, using artificial lighting when natural light is insufficient, to ensure continuous and uniform growth.
- ✓ ***CO2 Concentration:*** CO2 is essential for photosynthesis. By controlling CO2 levels within the greenhouse, the system can enhance photosynthetic efficiency and boost plant growth.
- ✓ **Security:** Protecting crops from theft and vandalism is an important aspect of ensuring the economic viability of farming operations. An integrated security system helps safeguard agricultural investments.

General Introduction

Our project began with an in-depth understanding of the concept and objectives of greenhouses. We conducted extensive research on the impact of climate within greenhouses and explored ways to optimize these conditions for the best agricultural outcomes. A critical decision was selecting the Arduino platform as the core of our system, due to its flexibility and ease of programming.

The smart greenhouse prototype integrates various sensors to monitor environmental parameters and uses the Arduino control unit to process this data. Based on the sensor readings, the system automatically adjusts the irrigation, ventilation, and lighting systems to maintain optimal conditions. This real-time data collection and automatic control significantly improve crop productivity and resource efficiency, making agriculture more sustainable in semi-arid regions.

This master's thesis is divided into four chapters:

Chapter 1: We explore the definitions and challenges faced in agriculture, provide a general overview of greenhouses, their conditions, and various types.

Chapter 2: This chapter reviews the components and software used in our design, detailing their characteristics and performance, and explains why these components were chosen..

Chapter 3: Focuses on assembling the structure and organizational equipment of the greenhouse, presenting the overall system performance through a functional organizational chart, and detailing the operation and initial testing of the system.

Chapter 4: Describes the practical implementation of our model, initial operational tests, and the results obtained.

By incorporating advanced technology into greenhouse management, our project aims to revolutionize farming practices in semi-arid regions. The smart greenhouse not only enhances crop productivity but also ensures sustainable use of resources, providing a viable solution to the challenges faced by modern agriculture.

Chapter I:General information on agricultural greenhouses

I.1 . *Introduction*

Water scarcity and climate change are among the biggest challenges facing agriculture in dry lands. Harsh conditions make it difficult to create the right conditions for plant growth and efficient, sustainable agriculture. Smart farms using Arduino technology enable sustainable agriculture in these areas by enabling better monitoring and control of the park environment. This technology can help improve water use, reduce waste and provide better plant growth in dry areas.

This chapter is dedicated to the state-of-the-art in presenting greenhouses and their various types, as well as the equipment and tools that allow us to control and manage climatic parameters.

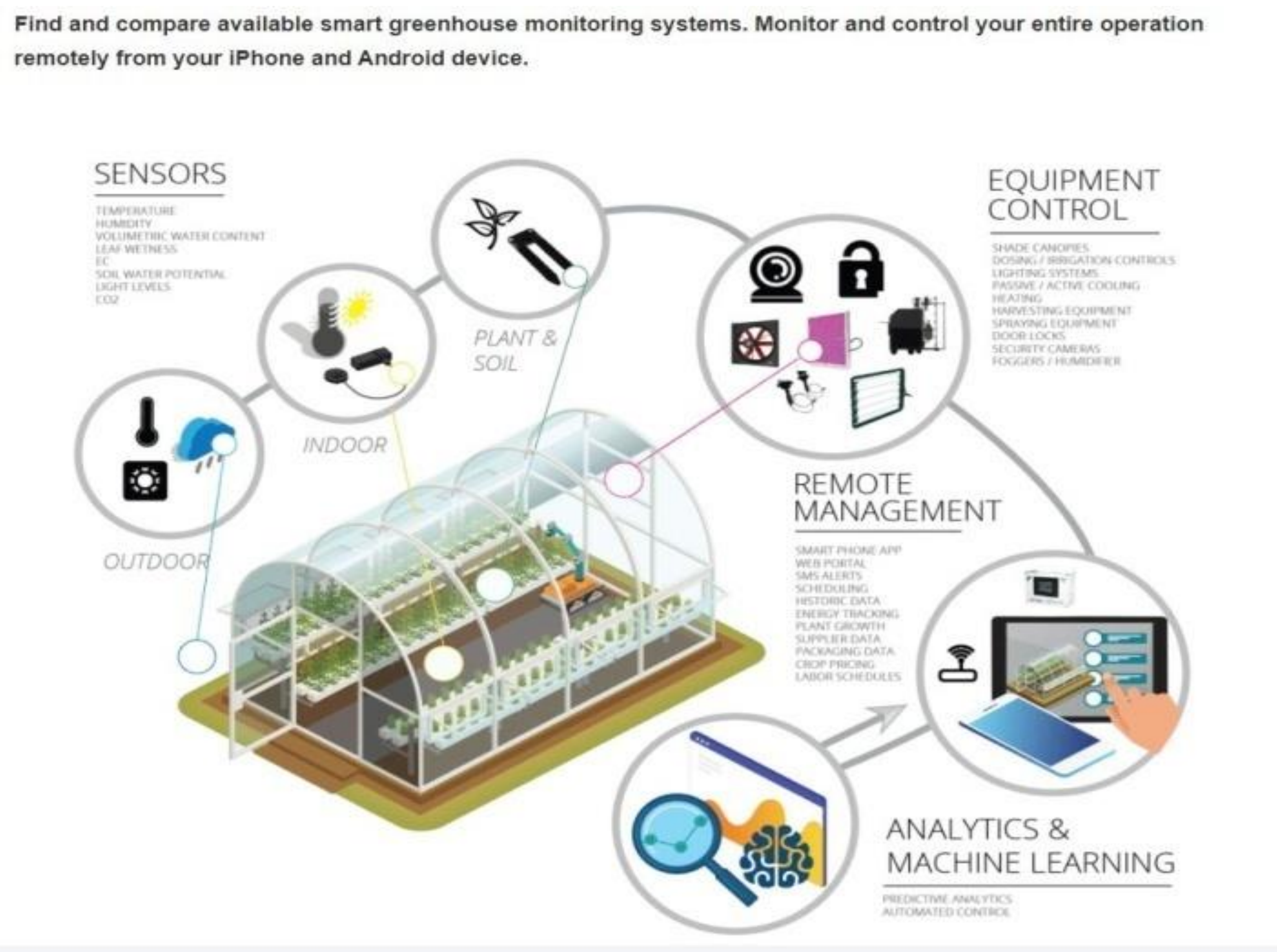


Figure I.1: Smart greenhouse [1]

I.2 *The main causes and challenges facing agriculture in semi-arid areas [2]:*

In semi-arid areas, agriculture faces several significant challenges due to the harsh climatic conditions and limited water availability. Some of the main causes and challenges include [2]:

- ✓ Water Scarcity: Semi-arid regions typically experience limited rainfall and drought conditions, leading to water scarcity for agricultural purposes.
- ✓ High Evaporation Rates: The high temperatures prevalent in semi-arid areas result in increased evaporation rates, further exacerbating water scarcity and affecting soil moisture levels.
- ✓ Poor Soil Quality: Semi-arid soils often lack organic matter and nutrients, making them less fertile and suitable for crop cultivation.
- ✓ Extreme Temperatures: Wide temperature fluctuations, including high daytime temperatures and low nighttime temperatures, pose challenges for crop growth and development.
- ✓ Pest and Disease Pressure: Semi-arid conditions can create favorable environments for pests and diseases, impacting crop health and yield.
- ✓ Land Degradation: Overgrazing, deforestation, and improper land management practices contribute to soil erosion and land degradation, reducing the suitability of land for agriculture.
- ✓ Limited Crop Diversity: The harsh environmental conditions limit the range of crops that can be successfully cultivated in semi-arid areas, reducing agricultural diversity and resilience.

I.3 *The definitions:*

I. 3. 1 agricultural greenhouses:

Agricultural farms are simple, enclosed or partially open structures, usually made of glass or plastic, supported by metal or wood. Its main purpose is to cultivate plants or protect them from sunlight. Over time, it became the center of industrial facility production, where attempts were made to adapt to the fast-paced environment of the factory. Climate change aims to increase productivity and quality by adapting crops [3].

Figure I.3.1: Greenhouse agriculture to reduce water consumption[4].

I.4 *Advantages of Production in Greenhouses:*

Production in greenhouses offers several advantages including [5]:

- ✓ The long growing season makes year-round cultivation possible.
- ✓ Protect crops against extreme weather conditions, insects and diseases.
- ✓ Better control of environmental factors such as temperature, humidity and light intensity leads to increased product quality and efficiency.

I.5 *Description of the Greenhouse and its Microclimate:*

A greenhouse is a transparent structure typically made of glass or plastic, supported by a metal or wooden frame. Its microclimate is characterized by controlled temperature, humidity, and light levels, creating optimal conditions for plant growth. The greenhouse microclimate is influenced by factors such as ventilation, heating, and shading systems[6].

I. 5. 1 Multi-span Greenhouses:

Multi-span greenhouses are larger structures composed of multiple connected bays or spans, often with a gutter system between each span. These greenhouses offer increased production space and versatility compared to single-span structures, allowing for the cultivation of a wider range of crops and more efficient space utilization.

Figure I.5.1: Multi-span Greenhouses [7].

I. 5. 2 Tunnel Greenhouses:

Tunnel greenhouses, also known as hoop houses or poly tunnels, are low-cost, simple structures consisting of arched hoops covered with polyethylene plastic. They are typically used for seasonal crop production, providing protection from weather elements while allowing for ventilation and sunlight penetration.

Figure I.5.2: *Tunnel Greenhouses[8].*

I.6 *Covering Materials:*

Greenhouse covering materials play a crucial role in regulating the greenhouse microclimate by controlling light transmission, heat retention, and insulation. Common materials include glass, polycarbonate, and polyethylene films, each with its own advantages and disadvantages in terms of cost, durability, and light diffusion[9].

I. 6. 1 Glass:

Glass is used in greenhouse coverings to provide a transparent barrier that allows sunlight to penetrate while offering protection from external environmental factors. Glass is known for its durability and transparency, allowing for the transmission of a significant amount of light to the plants.

I. 6. 2 Plastic Materials:

Plastic materials include polyethylene, polycarbonate, polyvinyl chloride, polyamide, and others, which are widely used in greenhouse coverings due to their lightweight nature, low cost, and ability to provide good thermal insulation.

I.7 *Microclimate of greenhouse:*

Greenhouses provide a unique microclimate environment, playing an essential role in the growth and development of crops. This microclimate is shaped by a multitude of factors, including temperature, humidity, light, ventilation, and carbon dioxide (CO2) level. These elements are of paramount importance as they directly influence crucial biological processes such as photosynthesis, plant transpiration, seed germination, and even pollination[11].

I. 7. 1 Temperature:

Temperature plays a crucial role in the growth and development of crops, as well as in various physiological processes, both low and high temperatures can negatively impact plant growth and productivity ,at low temperatures, essential life processes may stop, ice can form within plant tissues, and cells may be damaged by ice crystals. Conversely, high temperatures can lead to enzyme inactivity and the cessation of vital processes ,Controlled temperature in greenhouses directly influences growth, development, nutrient uptake, disease resistance, and pest activity. For instance, air temperature affects leaf expansion, with higher temperatures promoting more rapid expansion and growth.To optimize photosynthesis and growth, plants are typically grown in cooler temperatures at night to minimize respiration rates and warmer temperatures during the day to enhance photosynthesis. The temperature differential between day and night is typically 3°C to 6°C on cloudy days and 8°C on clear days. Blackman's law emphasizes that the rate of processes like photosynthesis is limited by the factor in least supply. For photosynthesis, factors such as temperature, light, and CO2 availability play critical roles. Understanding these factors helps optimize temperature management for crop production .In summary, proper temperature management is essential for maximizing crop productivity. Understanding the temperature requirements and constraints of specific crops is crucial for effective cultivation[12].

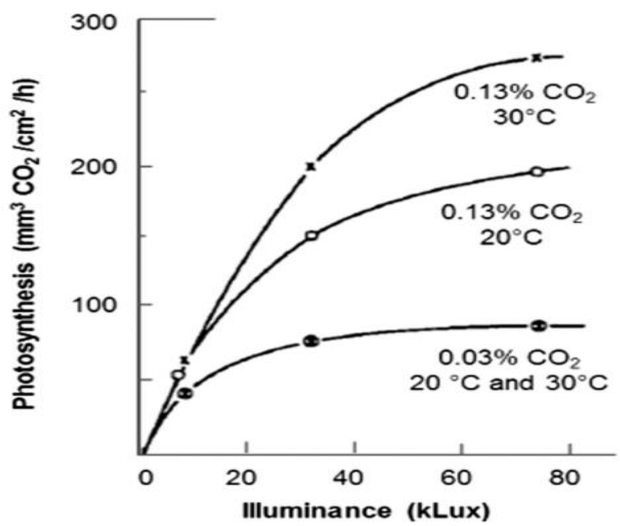


Figure I.7.1: Effects of CO_2, Light and Temperature on Photosynthesis in Cucumber [10]

Photosynthesis is an obvious example of this phenomenon. It depends on various factors such as temperature, light intensity, carbon dioxide concentration and other environmental conditions. Blackman's law describes the interaction of several factors on photosynthesis and can be illustrated by ***Figure I.7.1.***

In the bottom curve of the figure, the photosynthesis rate plateaus at around 40 Klux light intensity, regardless of whether the temperature is maintained at 20 °C or 30 °C. At this point, a CO2 level of 300 ppm (parts per million) (equivalent to a CO2 concentration of 0.03%) becomes the limiting factor for further increases in photosynthesis. This suggests that carbon dioxide concentration affects the overall rate of photosynthesis, even when other factors such as temperature and light intensity are optimal.

Furthermore, maintaining a constant temperature of 20°C while increasing carbon dioxide levels resulted in changes in photosynthesis rates, highlighting the interplay of environmental factors in influencing plant physiological processes.

Optimum Temperature Range (◦C)		
Crop	*Day*	*Night*
Tomato	21–27	13–16
Pepper	23–27	16–18
Cucumber	20–25	16–18
Eggplant	22–27	17–22

Table [1]: shows some temperature requirements for different cultures.

Optimum range:

Factors	***Growth Range***	***Optimum Range***
Air temperature	Germination to seedling stage	24–26 ◦C
Sunny daytime	Seedling to termination	24–27 ◦C
Cloudy daytime	Seedling to termination	22–24 ◦C
Night air temperature	Seedling to termination	18–20 ◦C
Root temperature	Germination to early growth	24–27 ◦C
Vegetation to termination20–24 ◦C		
Relative humidity Germination to earlygrowth75–88%		
Seedling stage 70–80%		
Vegetation totermination60–80%		
pH nutrient solution Germination to earlygrowth5.5–6.5		
Electrical and conductivity of thenutrient solution ermination to earlygrowth1.8–2.0 ds m☐1		
Sunny day Seedling to termination 1.5–2.0 dSm☐1		
Cloudy day Seedling to termination 2.5–4.0 ds m☐1		

Table(2): Optimum range[12].

I. 7. 2 Humidity:

Relative humidity inside greenhouses affects various processes, including temperature regulation, transpiration rates, tissue growth, pollen viability for fertilization, and the development of diseases and pests. It is determined by both water content (absolute humidity) and temperature, with these properties being closely linked through psychometric laws. Temperature and relative humidity have an inverse relationship, with high temperatures decreasing relative humidity and low temperatures increasing it. While the interactions of moist air in plant environments are complex, allowing relative humidity to vary within established plant canopies generally has few negative effects. Low relative humidity leads to reduced plant growth due to stomata closure, while high relative humidity can reduce transpiration, limit calcium uptake, induce physiological disorders, and promote fungal diseases and insect infestations. Each species has an ideal humidity level for optimal growth, as indicated in Table (2)[11].

Crop	*Optimum Relative Humidity Range (%)*
Tomato	60–80
Pepper	50–60
Eggplant	50–60
Cucumber	70–90

Table(3): Relative Humidity Requirements for Different Crop Species[11].

I. 7. 3 Light intensity:

The rate of growth in a closed plant canopy is intricately linked to the process of photosynthesis and the absorption of Photo synthetically Active Radiation (PAR). Light saturation occurs at relatively high light levels, where the efficiency of plant processes in utilizing incident radiation diminishes. Greenhouses typically transmit less than half of the solar radiation incident on their exterior surfaces, reducing the likelihood of light saturation compared to outdoor conditions. Prior to reaching light saturation, the photosynthetic response to light generally follows a linear pattern, indicating a direct relationship between growth rate and the daily light integral intercepted by the crop.

Light serves as the primary energy source for plant growth, driving the process of photosynthesis. Light intensity varies depending on location, typically ranging from zero at dawn to approximately 100 to 150 Klux (1000 lumen/m2) at midday. Cloudy days result in lower light intensity, leading to suboptimal levels of photosynthesis. The optimal light intensity for plants is around 32 Klux, with levels below 3.2 Klux and above 129 Klux considered unfavorable.

The design and construction of greenhouses prioritize solar radiation transmittance. Various factors such as greenhouse orientation and roof designs impact light transmittance. Generally, East-West orientation results in higher transmittance during winter months and lower transmittance during summer months compared to North-South orientation. Additionally, arched roof greenhouses typically exhibit better light transmittance than those with a 25-degree pitched roof.

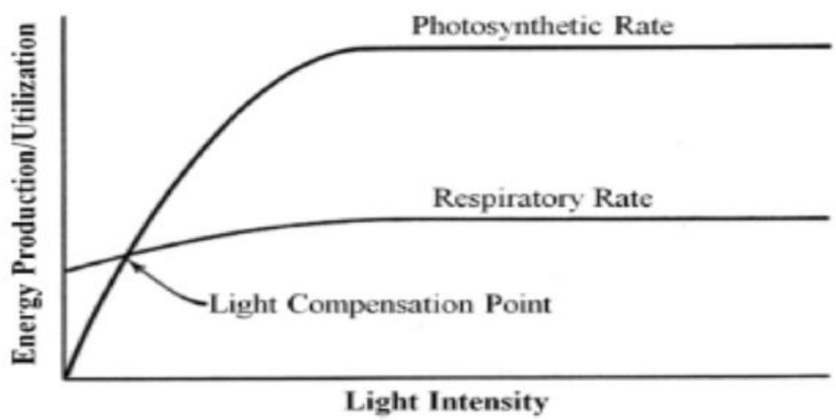


Fig I.7.3 In this graphic, photosynthetic and respiration rates are shown versuslight .

we see that plants have their normal growth and development controlled by the predictable day solar energy. More light means more photosynthesis is generated at a quicker pace. On the contrary, light intensity doesn't have any direct impact on photosynthesis, only one of its conditions. The graph would exhibit a gradual increase in photosynthesis rate as the light intensity increases without an explanation that these factors together with carbon dioxide levels, air temperature, and humidity contribute to the process of photosynthesis. In addition, we can conclude that the process of conversion of light into carbohydrates is proportional to other factors in plants that affect the outcome[11].

I. 7. 4 Carbon dioxide:

Carbon serves as a fundamental nutrient for plants, constituting a larger proportion of plant dry matter than any other nutrient, approximately 40%. Plants acquire carbon primarily from atmospheric carbon dioxide (CO2) through the process of photosynthesis. During photosynthesis, which occurs within the green chloroplasts of plant cells, CO2 from the air combines with water in the presence of sunlight to produce carbohydrates (sugars) and oxygen. This process can be represented by the equation:

$$3CO_2 + 6H_2O + Sunlight \rightarrow C_6H_{12}O_6 + 3O_2 \quad \text{(I-1)}$$

In recent years, atmospheric CO2 levels have been steadily increasing due to human activities such as combustion of fossil fuels and deforestation. Since 1880, CO2 concentrations have risen by approximately 1 to 2 parts per million (ppm) annually, with the current average concentration standing at around 345 ppm compared to approximately 294 ppm in 1880. Additionally, localized areas with decomposing organic matter, such as swamps and riverbeds, may exhibit elevated CO2 levels due to microbial respiration. It's important to note that while photosynthesis is the process by which plants utilize CO2 to produce carbohydrates and oxygen, plants, along with microorganisms and humans, also respire CO2 through the opposite process when consuming plant or animal-derived foods [11].

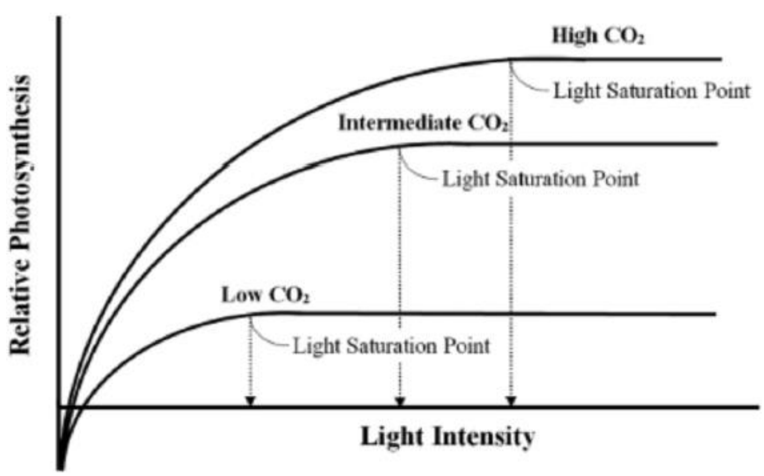


Figure I.7. 4: Photosynthesis and the effects of light and carbon dioxide [12].

Due to the increased atmospheric CO2 levels plants' photosynthetic activity increases as the carbon level is more abundant (see the Fig I. 7. 4). But on the other hand, high light intensity might be detrimental and can increase plant temperature inside the greenhouse, gradually reduce plant productivity.

I.8 *Greenhouse control*:

Commanding environmental control systems for plants poses a significant challenge due to the intricate interplay of various environmental factors impacting plant growth and yields. Addressing the critical issue of food production, which must adapt to shifting population demands, necessitates precise knowledge of the primary factors limiting production and the advanced technology showcased in Graph 5.1 exemplifies an ideal vegetation environment suitable for diverse climates. Greenhouses provide a refuge for crops susceptible to climatic fluctuations, ensuring consistent growth and yields. Leveraging computerized systems, these facilities optimize environmental conditions for plant health and productivity[11].

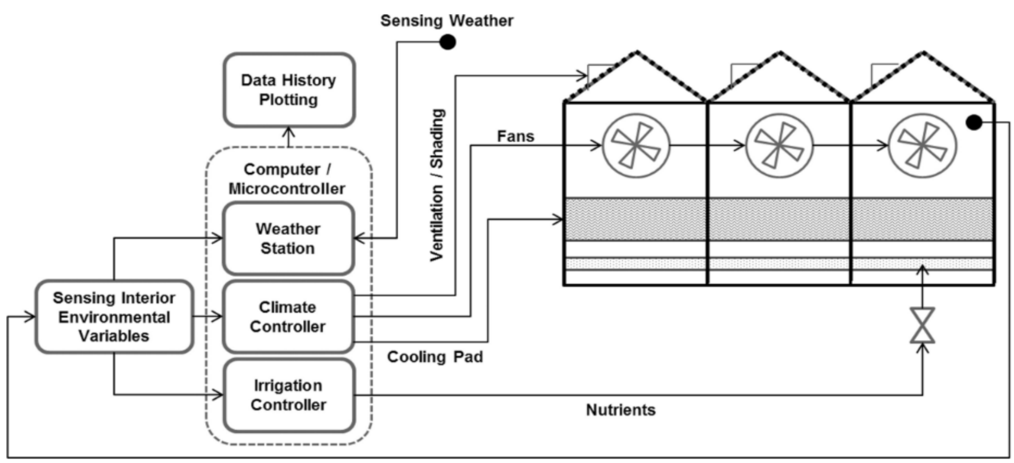


Figure I.8 Diagram of a Typical Hi-Tech Greenhouse [11].

I. 8. 1 TYPES OF CONTROLS:

In the agricultural greenhouse environment, efficiency and automation have become essential due to challenges such as labor costs, energy expenses, and fluctuating market demands. Environmental control technology plays a pivotal role in overcoming these challenges, impacting labor costs, energy consumption, and market competitiveness. Precise control of greenhouse environmental parameters is crucial for optimizing energy usage and increasing economic returns. Environmental control aims to maximize plant growth by regulating factors such as temperature, light, air ventilation, and soil conditions. While glass greenhouses offer partial climate control, fully automated systems are less common due to their high cost[12].

Environmental control systems for greenhouses have evolved through various stages, from manual control to advanced devices and microprocessors. Advanced systems provide the highest level of control but come with a higher cost.

- ***Manual controls:***

In the early 20th century, manual controls were commonly used in greenhouse operations. Night watchpersons were employed to regulate temperature by manually adjusting heating valves during nighttime rounds. Daytime temperature control relied on manual operation of ventilators. However, this method often led to significant temperature deviations, requiring skilled operators for stability .

- ***Thermostats and timers: (costing between 50 and 600 USD).***

Thermostats and timers, costing between 50 and 600 USD, are crucial components in greenhouse environmental control. Thermostats automatically trigger fans or heaters based on preset temperature thresholds but may lack precision and require calibration. For more precise control, microprocessor-based systems use sensors like thermocouples or thermostats, though at a higher cost.

In greenhouses, multiple thermostats and timers may be needed to control different zones for heating, cooling, irrigation, and lighting. Despite their low initial costs, thermostats and timers offer

limited control, lack coordination, and may have poor accuracy and energy efficiency. Investing in advanced control systems may yield greater long-term benefits .

Figure I.8.1 :36088 - Thermostat UT-72

- **Step controllers: (costing between 800 and 1800 USD):**

Step controllers, priced between 800 and 1800 USD, offer affordability, improved equipment coordination, and higher accuracy compared to traditional thermostats. They provide automatic sequencing of operations and remote sensing, replacing multiple thermostats with a single unit. Suitable for simpler greenhouse setups with around 6-8 stages of heating and cooling, they ensure synchronized temperature control.

By dividing greenhouse heating and cooling into distinct steps, step controllers prevent simultaneous operation of equipment, minimizing energy consumption and costs. Despite limitations in expandability, they offer efficient and cost-effective temperature control for smaller greenhouse operations.

- ***Computer :***

Computer systems offer comprehensive control over various environmental factors in greenhouse operations, including temperature, humidity, irrigation, fertilization, CO_2 levels, and light and shade levels, regardless of facility size. This precise control enables growers to achieve significant savings, ranging from 15 to 50%, in energy, water, chemical, and pesticide usage, by managing numerous devices such as vents, heaters, fans, irrigation valves, curtains, and lights, computers utilize input parameters like external and internal temperatures, humidity levels, wind direction and velocity, CO2 levels, and time of day or night. This contributes to greater plant uniformity, on-time production, improved overall plant quality, and environmental purity.

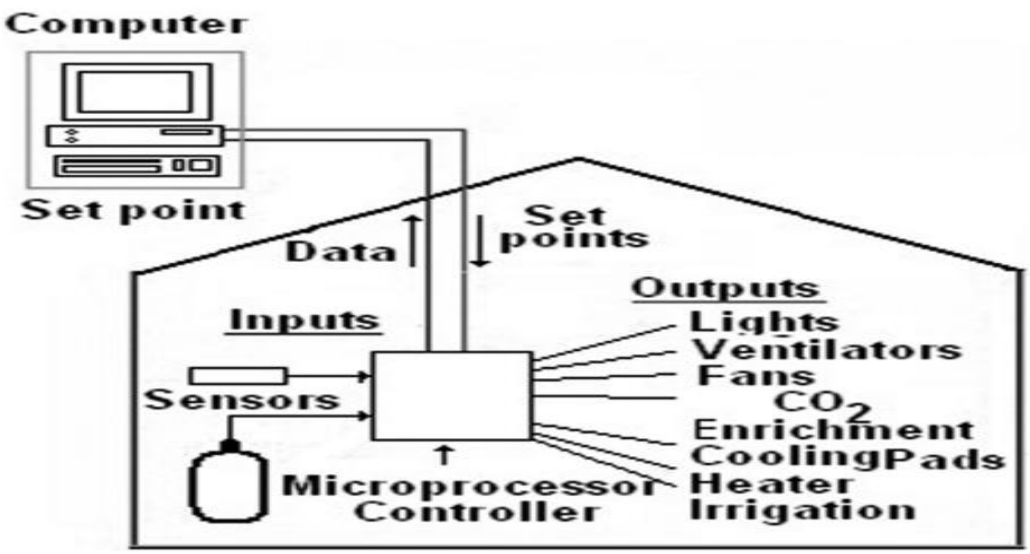


Figure I.8.1 : Computerized Control Systems in Greenhouse.

I. 8. 2 Control techniques:

The control system strategies for greenhouses that use advanced technology include non-linear methods, fuzzy logic, and neural networks. In the Approach, the non-linear methods are based on techniques such as the Sliding Modes and the Linearization control feedback/feed forward mentioned by the authors. Also, On/off and PID techniques of conventional control, for the purposes of comparison, are used. Here, I will explain the three techniques, which will be further discussed in the following sections.

1) Classical control:

- Bang-bang or on/off control:

For this type of controller, an on/off system has a binary feature in which the output is switched completely on or off depending on whether the control variable is greater than or lesser than a set-point of reference. For example, in heating control, the control system switches on when the room temperature falls below the set-point and turns off when it goes just above the set-point. Hysteresis or on-off differential is added to allow power to decelerate smoothly without rapid cycling and equipment damage. Such setting requires the system to wait for the temperature measurement to go beyond the set-point plus the margin before the output is specified. On-off control is a convenient solution for systems that do not require highly precise control, for ones that cannot manage energy toggling too quickly, were system mass limits changes of parameters, or as an alert signal.

- PID control :

Along with Proportional-Integral-Derivative (PID) controller, there is another feedback mechanism which is broadly applied in the control systems of industries. It minimizes difference between output from process variable sensor and set-point by altering control inputs for process. The PID controller algorithm incorporates three constant parameters: proportionality constant (P), occasionally known as integral value (I) and derivation (D). These parameters represent the current error, the accumulation errors over the past, and the future error estimates respectively, due to the rate of change. [11]

The PID controller's output, u(t), is determined by the following equation: The PID controller's output, u(t), is determined by the following equation:

$$u(t) = K_P e(t) + K_i \int_o^1 e(t)\, d\tau + K_d \frac{d}{dt} e(t) \quad \textbf{(I-2)}$$

Where:
Kp: Proportional gain, a tuning parameter,
Ki: Integral gain, a tuning parameter,
Kd: Derivative gain, a tuning parameter,
e: Error = Set-point – Process Variable,
t: Time or instantaneous time (the present),
τ: Variable of integration; takes on values from time 0 to the present t.

Advanced control:

Greenhouse cultivation in these days is not just limited to the regulation of temperature, humidity, light and CO_2 but now controlled technique heavily rely on very advance control systems to do the job or even optimize the environmental parameters. They usually rely on modern technology of sensors, actuators, control algorithms and sometimes control loops to manage resource consumption, make yield optimization possible and minimize loss during production.

Some common advanced control techniques include :Some common advanced control techniques include:

- Model Predictive Control (MPC):

MPC employs holistic dynamic models of the greenhouse environment and translates this information into future environmental conditions and therefore the optimum control actions. This involves taking into account multiple conflicting objectives of constraints so as to optimize its performance. [13]

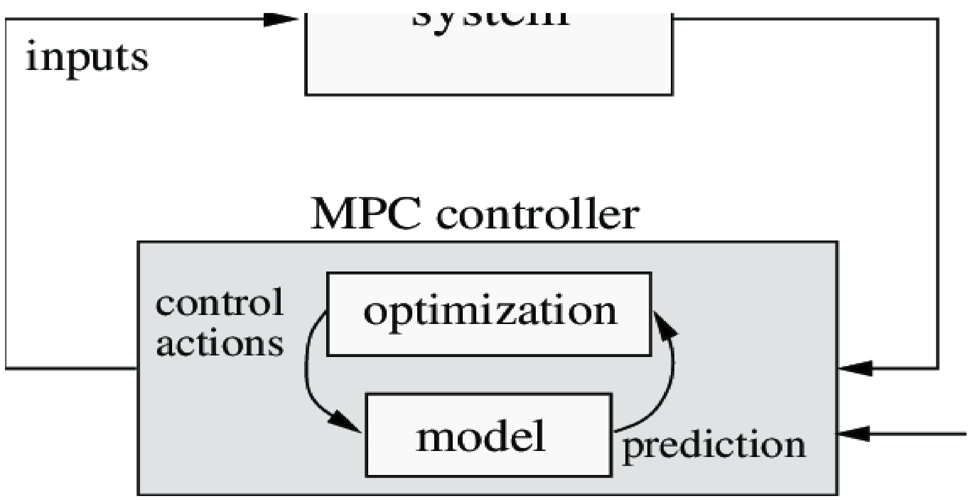


Figure (2): *Illustration of model predictive control.*

2) Adaptive control :

is a type of control system that adjusts its parameters or behavior in real-time based on the changes in the system it is controlling or the environment in which it operates. The key idea behind adaptive control is to continuously adapt to variations or uncertainties in the system dynamics, allowing for improved performance and robustness .In the context of greenhouse cultivation, adaptive control techniques can be applied to dynamically adjust environmental parameters such as temperature, humidity, light intensity, and CO2 levels to optimize plant growth and resource utilization. These techniques may involve the use of advanced sensors to monitor the greenhouse environment and algorithms that automatically adjust control parameters based on the observed changes.

- ***Robust control:***

Rigorous control is a field at the crossroads of control engineering and which deals with giving for such control systems the capability of being able to hold the desired performance and stability despite uncertainties and discrepancies among the system or environment. The main aim of the control loop with high robustness is to make sure that the system is not sensitive to uncertain parameters, and the purpose for which the system was created is achieved. For greenhouse farming, where anomalies in environmental components and characteristics matching plant responses happen dynamically, good data acquisition system is necessary to guarantee system performance[11].

3) Intelligent control:

- **Fuzzy logic control** :

Real-world dynamic systems often exhibit non-linear behavior, challenging the effectiveness of linear control methods. Linear controllers, reliant on small operating ranges, become unstable when applied to larger ranges due to system non-linearities and the need for accurate linear izable models. Conversely, Fuzzy Logic Controllers (FLCs) offer flexibility for complex, non-linear systems with uncertain parameters. Mimicking human expertise, FLCs analyze input-output relationships using linguistic variables, providing efficient solutions where traditional methods falter. Introduced by Lotfi A. Zadeh in 1965, Fuzzy Logic gained traction in the late 1980s for its successful applications across various domains. Unlike conventional logic, Fuzzy Logic mirror shuman thinking, making it suitable for modeling complex systems where fast but approximate solutions are required.

- **Artificial neural network:**

Artificial Neural Networks (ANNs) are complex computing systems with interconnected processing elements across input, hidden, and output layers, adept at responding dynamically to external inputs. Widely utilized in greenhouse cultivation, they excel in tasks like temperature prediction and environmental parameter modeling. For instance, Francik and Kurpaska (2020) applied ANNs for greenhouse temperature prediction, while Moon et al. (2021), Salazar et al. (2007), and Singh (2017) developed ANN models for various environmental factors, despite their efficacy, ANNs require extensive multidimensional datasets for robust training to mitigate extrapolation risks.

Huang (2009) introduced an improved neural network integrating fuzzy control theory and adaptive step-size algorithms, though this approach escalates the number of rules exponentially to enhance reliability.

I.9 *Climate management:*

Climate management in greenhouses is an essential element for achieving healthy plant growth and producing high-quality crops, while maintaining environmental sustainability and reducing energy consumption. This requires a set of procedures and techniques aimed at regulating heat and humidity, managing lighting and ventilation, providing optimal conditions for plant growth inside the greenhouse. This work aims to review the most important strategies and techniquesused in climate management within agricultural homes, with a focus on achieving a balance between productivity and environmental sustainability[16].

I. 9. 1 Cooling:

Cooling in greenhouse environments aims to maintain optimal temperatures for plant growth, particularly during hot seasons or in warm climates. Various cooling systems and strategies are employed, including natural and forced ventilation, fan-pad mixing, evaporative cooling, and shading techniques. These methods help remove excess heat and create a favorable microclimate for plants, Cooling greenhouses mitigate heat stress on plants, ensuring favorable conditions and higher productivity. They also regulate humidity, creating an ideal environment for plant growth. Overall, cooling systems in greenhouses support farming by providing growers with the conditions necessary for successful cultivation, contributing to the sustainability of food production [15].

1) Natural Ventilation Cooling

Natural ventilation cooling relies on passive airflow to regulate temperatures within the greenhouse. Vents, louvers, or roof openings are strategically positioned to allow hot air to escape while cooler air is drawn in from outside. This method promotes air circulation and prevents the buildup of heat, helping to maintain optimal growing conditions for plants.

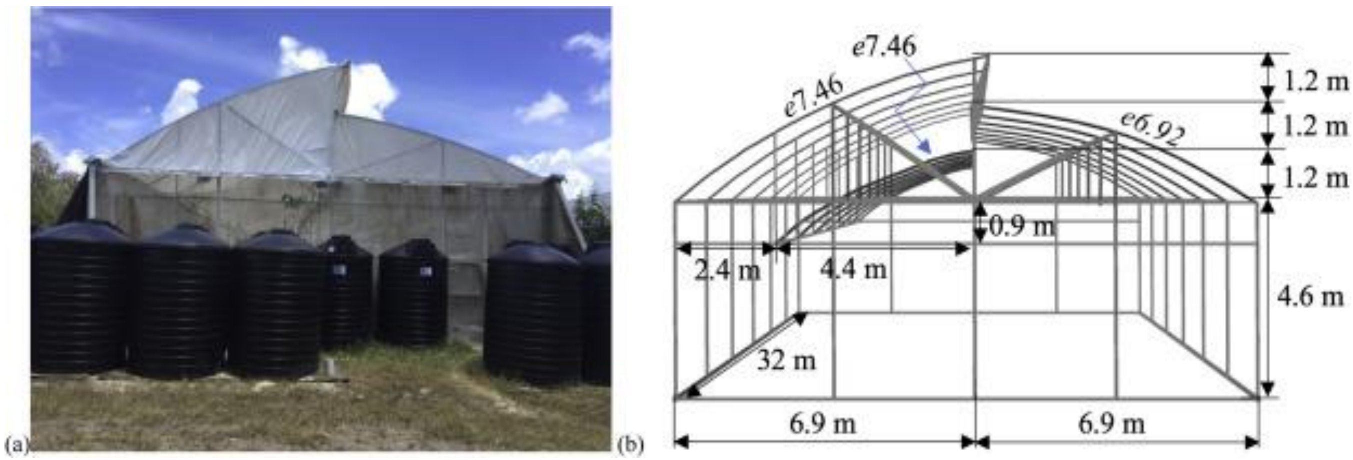


Figure I.9.1.1 Field trials of the Natural Ventilation Augmented Cooling (NVAC) greenhouse[15].

2) Forced Ventilation Cooling:

Forced ventilation cooling involves the use of mechanical fans to circulate air within the greenhouse. These fans expel hot air and draw in cooler air from outside, helping to reduce temperatures during periods of high heat. Forced ventilation systems are particularly effective in

climates with limited natural airflow or when additional cooling is required to prevent heat stress on plants.

Figure I.9.1.2. Forced ventilation [16].

3) Fan-Pad System:

The fan-pad system combines forced ventilation with evaporative cooling to lower temperatures inside the greenhouse. Water-soaked pads are installed at one end of the structure, and fans draw outside air through the pads, where it is cooled by evaporation before circulating through the greenhouse. This method provides efficient cooling while maintaining adequate humidity levels for plant growth.

4) Fog/Mist System:

Fog or mist systems utilize fine water droplets sprayed into the greenhouse, which evaporate and absorb heat from the air, lowering temperatures. This method is effective in arid regions or during periods of intense heat when traditional cooling methods may be insufficient. Fogging systems can also help to increase humidity levels, creating a more favorable environment for plants.

5) Shading:

Shading techniques involve the use of shade nets, curtains, or whitewash applied to greenhouse glazing to reduce the intensity of sunlight entering the structure. By blocking or diffusing sunlight, shading helps to lower temperatures and minimize heat stress on plants. Shading can be adjusted based on seasonal changes in sunlight intensity or specific crop requirements.

Figure I.9.1.5 Shading system[18].

I. 9. 2 Heating:

Heating greenhouses involves maintaining optimal temperatures for plant growth, especially during cooler seasons or in cold climates. Various methods such as air heating, geothermal energy, and solar energy are employed to provide consistent warmth to the greenhouse environment. The primary aim is to prevent cold stress on plants, extend the growing season, and ensure year-round cultivation. Heating greenhouses create controlled microclimates, enhancing yields, crop quality,

and agricultural productivity. They also protect plants from frost damage and optimize conditions for seed germination. Ultimately, heating greenhouses play a vital role in modern agriculture by supporting sustainable food production and ensuring food security regardless of external weather conditions. the techniques for heating greenhouses:

1.*Air heating: Air heating*: systems in greenhouses involve the use of heaters, such as gas or electric heaters, to warm the air within the structure. These heaters are typically placed strategically to ensure even distribution of heat, preventing cold spots that could harm sensitive plants. Air heating is a versatile method that allows growers to adjust the temperature based on plant requirements and external weather conditions.

2. Geothermal energy heating: Geothermal heating systems utilize the Earth's natural heat to warm greenhouse spaces. Pipes or tubing are installed underground, where the temperature remains relatively constant throughout the year. A heat transfer fluid circulates through these pipes, absorbing heat from the ground and transferring it to the greenhouse. This sustainable method of heating provides consistent warmth, reducing dependency on fossil fuels and lowering operational costs over time.

3.Solar energy heating: Solar energy heating harnesses the power of sunlight to warm greenhouse environments. Passive solar design principles, such as south-facing glazing and thermal mass, maximize heat absorption during the day and release it slowly at night. Additionally, active solar heating systems may incorporate solar collectors or solar panels to generate electricity for heating purposes. Solar energy heating is environmentally friendly and can significantly reduce energy expenses, especially in regions with ample sunlight.

I.10 *Conclusion:*

In this chapter, we have explored various types of agricultural greenhouses and identified the climatic factors that have the most significant influence on the greenhouse environment. Additionally, we have outlined the essential components necessary for effective management of the greenhouse climate. This crucial section has provided us with valuable insights into our initial idea, allowing us to understand the requirements of this sector and establish a clear set of specifications for the subsequent development of our prototype.

chapter II :Description of the Soft & Hard involved

II.1 *Introduction:*

After conducting both theoretical and practical studies, we are prepared to present a feasibility study. This chapter will outline the various components and software necessary for the implementation of our project. Our study draws inspiration from existing solutions and techniques in the field, with the goal of fulfilling the requirements outlined in the functional specifications, including the necessary service functions.

II.2 *Hard Party:*

II. 2. 1 Arduino:

Arduino is a platform for electronics on which you can base your projects on the easy-to-use hardware and software. It is a combination of a microcontroller board and development environment and hence, users are able to make interactive electronic projects. The prominent Arduino boards are the Arduino Uno, Arduino Mega, Arduino Nano, and Arduino Due. These boards differ in the size, the memory, and processing power, thus they are suitable for different project needs.[23]

The basic Arduino platform contains the following elements:

1) For USB connection

2) For cylindrical socket.

3) GND ,4) 5V

5) 3V , 6) Analog

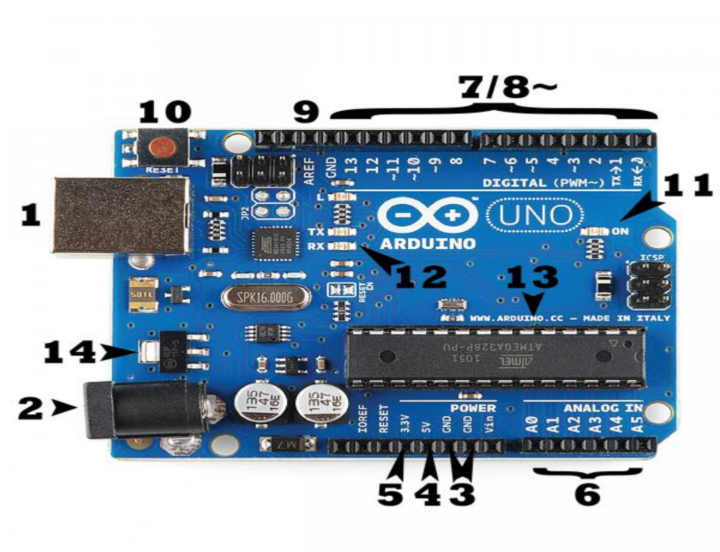
7) Digital and 8) PWM

9) AREF and 10) Reset Button ,

11) Power LED Indicator

12) TX and RX LEDs (TX RX LEDs)

13)Microcontroller



- ***The main Arduino boards:***

- Arduino Uno

- Arduino Leonardo0

- Arduino Due

- Arduino Mega 2560

- Arduino Nano

- Arduino Mini

II. 2. 2 SHT31 humidity and temperature Sensor:

This thing is a SHT31 Temperature & Humidity sensor that is housed in a weather casing. It is constructed to be waterproof hence suitable for water use. But it is better not to immerse the sensor in water. In the case of measurements, it would be better to use the DS18B20 Sensor.By using Sensation's CMO Sens® technology and integrated capacitive humidity and temperature sensing components the SHT31 provides performance with low power consumption, quick response time and strong resistance to interference. It communicates via I2C. Works well with 3. 3V/5V controllers such as Arduino, micro; bit and ESP32.The SHT31 belongs to the series. It has a ± 2%RH humidity accuracy from 0% RH to 100% RH at 25°C, as well as ±0. 2°C temperature precision from 0°C to 90°C, on average.[25]

Figure II.2.2 :SHT31 OUTDOOR TEMPERATURE & HUMIDITY SENSOR (-40℃~125℃) - I2C[25]

SPECIFICATION

- Operating Voltage: 3.3~5V
- Operating Current: <1.5mA
- Humidity Detection Range: 0%RH~100%RH
- Humidity Accuracy: ±2%RH@0%RH~100%RH(at 25℃)
- Temperature Detection Range: -40℃~125℃
- Temperature Accuracy: ±0.2℃@0℃~90℃ (Typical)
- Communication: I2C
- Cable Length: about 1m

II. 2. 3 Soil Moisture Sensor:

This soil moisture sensor module is utilized to detect the soil moisture. It is the volumetric content of water inside the soil and it gives us the moisture level as the output. The module has both digital and analog outputs and a potentiometer to change the threshold level, A sensor probe of a waterproof type with high corrosion resistance guarantees a lifetime of at least 6 months in the soil.[22]

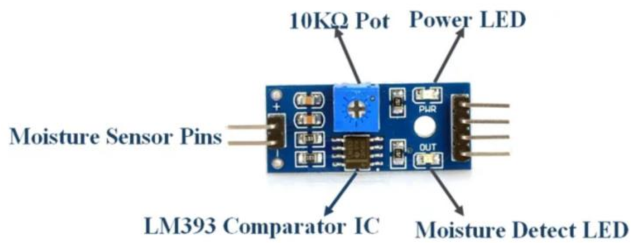


Figure II.2.3: Soil Moisture Sensor Detector Module Soil Moisture Humidity Test Sensor with 1.3M Cable[26]

Technical Characteristics:

- Operating Voltage: 3.3V to 5V DC
- Operating Current: 15mA
- Output Digital – 0V to 5V, Adjustable trigger level from preset
- Output Analog – 0V to 5V based on infrared radiation from fire flame falling on the sensor LEDs indicating output and power.
- PCB Size: 3.2cm x 1.4cm
- LM393 based design
- Easy to use with Microcontrollers or even with normal Digital/Analog ICSmall, cheap and easily available

II. 2. 4 ambient light sensor:

The transmitter is an optical precision photosensitive transmitter, and the output value unit is per Lux; furthermore, it is possible to use the waterproof wall-mounted enclosure with the wall-mounted installation, which has a high protection level. dio-20ma/0-10v/0-5v multimodal analogue output signal optional, power supply for 10-30V wide voltage, main usages in farms and greenhouses, plant production, agriculture lands electronic equipment production lines and so on such as the necessity for illumination monitoring areas[27].

Figure II.2.4 Light sensor 0-10V 0-5V 4-20mA RS485 200000Lux 65535Lux industrial intensity illumination acquisition transmitter [27].

Features:

- measuring range of high precision illumination measurement 0-6 million Lux, 0-20 million Lux Optional.
- 4-20ma/0-10v/0-5v multiple analog output signal optionnel
- wall-mounted waterproof shell, high protection level, can be used for outdoor or harsh on-site environment
- 10-30V DC wide voltage power supply

II. 2. 5 Water Pump 5V:

Horizontal Mini Submersible Water Pump 5V is highly essential for the purpose of experiments, aquariums, fish tanks, and fountains. To ensure that there is sufficient water to push, the water level should be slightly higher than the pump. Very low water level results in high pump temperature and excessive noise

produced by pump. Item(s) number includes the pump only which is without power supply, we suggest 5V power supply adaptor. It is able to be used with all Micro controller units, taken as Arduino, Raspberry PI and Node MCU. It is utilized in Fountain Garden Mini water circulation System, DIY Electronic project, smart irrigation system and so on[28].

Figure II.2.5: Horizontal Mini Submersible Water Pump 5V

Technical Specifications:

- Operating Voltage: 5V DC
- Rated Current: 100mA – 200mA
- Flow rate: 80-100L / H
- Wire Length: ~22 cm
- Material: plastic
- Mode driving: brushless cc design, magnetic driving

II. 2. 6 Stepper Motor 5V DC:

This is a 5v 28YBJ-48 Stepper Motor with a Gear Reducer, and thus, it has a high amount of torque considering its actual size, but its speed is rather slow by itself. This is the case because large series of these motors and drivers are produced for all kinds of devices that also include A/C units, fans, and duct controls, to name a few, which is why they are so cheap.[26]

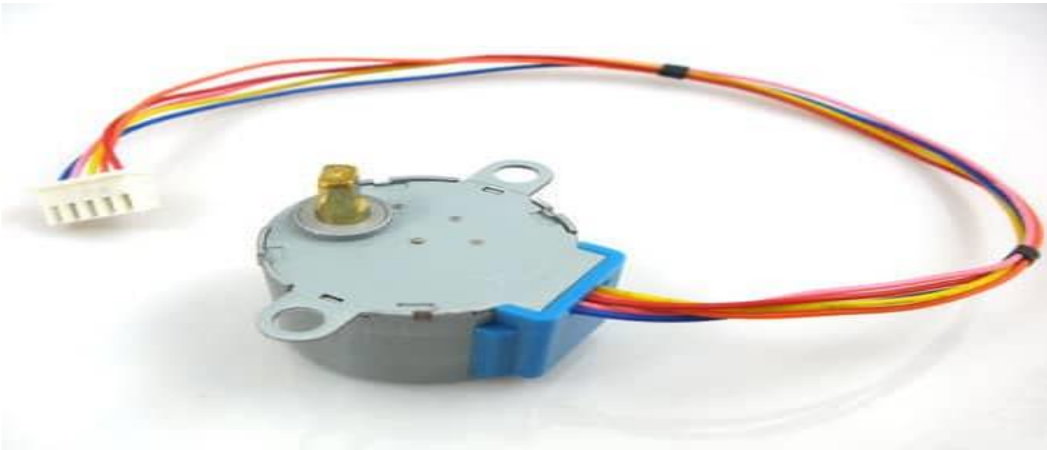


Figure II.2.6: Stepper Motor 5V DC[29]

Details:

- Product Name : Step Motor
- Voltage : DC 5V
- Resistance : 300 Ohm
- Step Angle : 5. 625 x 1/64
- Reduction Ratio : 1/64
- Body Size : 28 x 19 mm / 1. 1″ x 0. 75″ D*T
- Shaft Dia : 5 mm / 0. 2″
- Cable Length : 23 cm / 9″
- Main Material : Metal, Plastic
- Main Color : Silver ,Gray, Blue

II. 2. 7 DC 12V Linear Actuator:

Our compact and versatile linear actuator is made from high-quality aluminum alloy, featuring two built-in limit switches. It would provide consistent and reliable performance with minimal maintenance for all your automation projects. It comes with a silent yet powerful motor to accommodate a variety of applications that require precise movement in a linear motion.[30]

Specifications :

- Stroke Length: 6" / 150 mm
- Actuating Force: 900 N
- Travel Speed: 0.4" / 10 mm per second
- Material: Aluminum Alloy
- Input Voltage: DC 12V
- Rated Current: 3 amperes
- Duty Cycle: 25%"

Features:

- ✓ Flexible Stroke Length
- ✓ Excellent Construction
- ✓ Powerful Performance
- ✓ Quick & Easy Assembly

II. 2. 8 Relay:

Relay is an electrically driven switching means and its function is to open and close contacts of the switch by operating electric current. The one-way relay module is actually much more than a lousy relay it assembles all components that facilitate the connection and switching and act as the indicators to show if the module is powered and if the relay is active or not. [31]

Figure II.2.8: Relay [31].

- C: common contact
- NC (normally closed): Normally closed configuration
- NO (normally open): the normally open configuration operates

Specifications:

- ✓ Supply voltage – 3.75V to 6V
- ✓ Quiescent current: 2mA
- ✓ Current when the relay is active: ~70mA
- ✓ Relay maximum contact voltage – 250VAC or 30VDC
- ✓ Relay maximum current – 10A

I2C LCD1602:

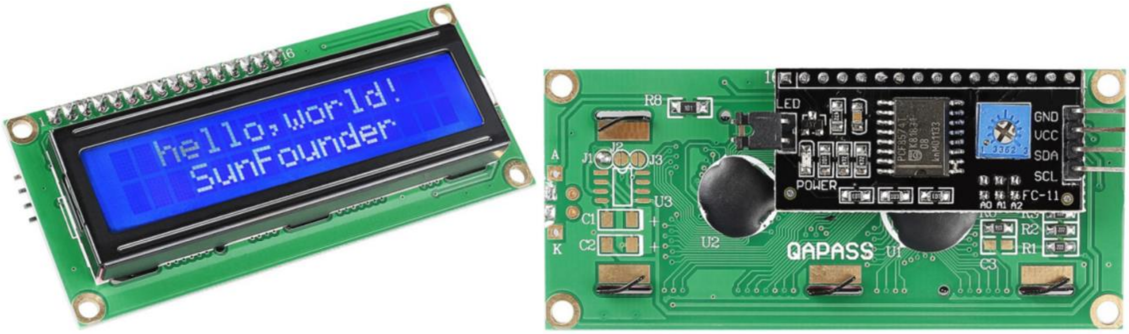


Figure II.2.9: I2C LCD1602[30]

- **GND**: Ground
- **VCC**: Voltage supply, 5V.
- **SDA**: Serial data line. Connect to VCC through a pull-up resistor.
- **SCL**: Serial clock line. Connect to VCC through a pull-up resistor.

As we all know, though LCD and some other displays greatly enrich the man-machine interaction, they share a common weakness. When they are connected to a controller, multiple IOs will be occupied of the controller which has no so many outer ports. Also it restricts other functions of the controller. Therefore, LCD1602 with an I2C module is developed to solve the problem. The I2C module has a built-in PCF8574 I2C chip that converts I2C serial data to parallel data for the LCD display.[32]

Example:

- 2.9 I2C LCD1602 Module (Arduino Project)
- 3.5 Access Control System (Arduino Project)
- 3.4 Guess Number (Arduino Project)
- 3.3 Overheat Monitor (Arduino Project)
- 2.4 LCD1602 (Scratch Project)

II. 2. 9 computer fan:

A computer fan is typically used in computer systems to cool internal components such as the central processing unit (CPU), graphics processing unit (GPU), power supply unit (PSU), and to provide general airflow within the case. However, computer fans can easily be used in other household applications such as plastic greenhouses for ventilation or cooling purposes.

Figure II.2.10: 120x25mm Computer Case Fan with PWM – Pulse Width Modulation Connector

II.3 *Soft Part:*

II. 3. 1 Arduino IDE

Arduino IDE (Integrated Development Environment) is an open-source development environment specifically designed for programming and developing Arduino-based hardware. It provides a simple and user-friendly interface that allows developers to create and upload programs to Arduino devices quickly and easily[33].

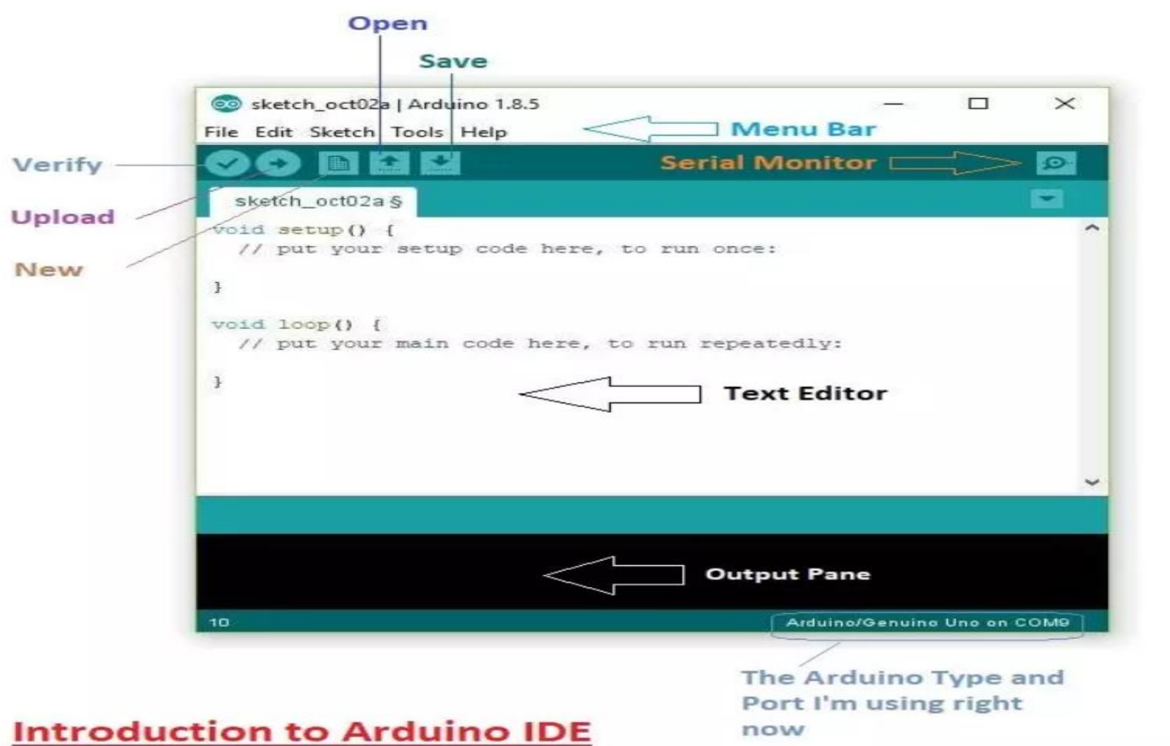
Here are some key features of Arduino IDE:

- Easy Programming: Arduino IDE provides a programming language based on Wiring, which is simple and easy to understand, facilitating quick learning.
- Text Editor: The IDE includes a text editor that allows developers to write and edit code easily, with features such as syntax highlighting and coloring to facilitate code readability and analysis.

- Compatible with Multiple Controllers: In addition to developing devices using standard Arduino controllers like Arduino Uno and Arduino Mega, Arduino IDE can be used to develop devices based on Arduino-compatible controllers from various companies.

Extensive Library: Arduino IDE comes with a large library of reusable components and libraries that make it easier to develop programs, saving time and effort.

Wide Community Support: Arduino IDE enjoys strong support from the global developer community, meaning there are many resources and assistance available online.



Introduction to Arduino IDE

II. 3. 2 Proteus:

Not everyone knows the name Proteus. If you work in the medical field, you probably know it as abacterium which includes the different species such as mirabilis or vulgarism which are found in the intestine. But in addition to microbiology, in software it is one of the preferred electronic circuit simulation software among engineering students and electricity professionals, capable of offering us advanced simulation of circuits and microprocessors[35].

II.3.2.1 Design and simulation of circuits on PC:

This is one of the most complete sets of digital tools on the market because version 8.5 (the latest) allows you to create on the PC all kinds of PCBs or printed circuits from almost 800 different microcontrollers, and simulate their real operation directly on the schematic view ofthe circuit. And of course, it integrates the necessary tools for drawing and simulating the Arduino environment, one of the most popular boards today.

II.3.2.2 The main components of Proteus Design Suite:

This software has two main components around which the entire operation of the same revolves:

- ISIS: these are the acronyms for Intelligent Schematic Input System and it is the program which allows you to draw on the plan of the electrical circuit, with all kinds of components such as resistors, coils, capacitors, power sources or even microprocessors.
- ARES: these are the acronyms for Advanced Routing and Editing Software and it is the tool dedicated to the drawing of printed circuits or PCBs, with options for routing, locating and editing electrical components.

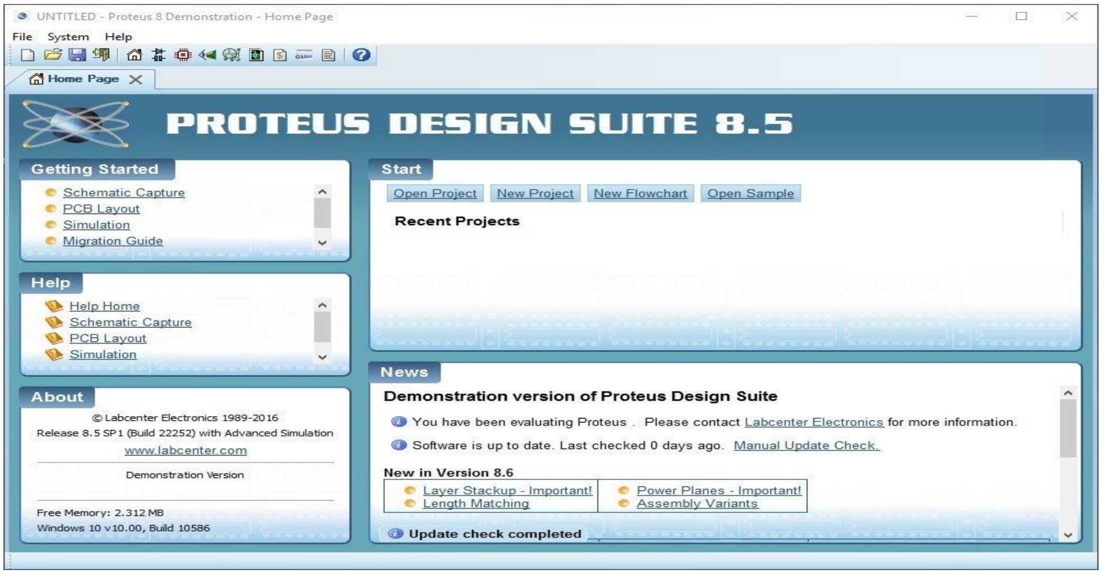


Figure II.3.2: Proteus Design Suit 8.1

II.4 ***Conclusion*:**

In this chapter, we focused on detailing Arduino, which serves as the primary tool in our project. We also mentioned and explained the necessary accessories for executing our project. Specifically, we elucidated the interactions between the computer and the external world through the Arduino board, which will enable us to manage a wide range of sensors and control motors to perform various tasks with minimal effort.

We will present the stages of creating our initial prototype, along with studying its evolution and parameters related to climate change in the next chapter.

chapter III REALISATION DU PROJET

III.1 *Introduction:*

After presenting the theory and necessary equipment for our project, this chapter will outline the various stages involved in designing and producing our system. First, we will introduce the comprehensive plan for the project. Then, we will detail the four services provided by our system, along with the connections for the different sensors and actuators. Finally, we will conclude by interpreting the results obtained from this process.

III.2 *Project implementation*:

III. 2. 1 Greenhouse Assembly:

Figure III.2.1:Smart greenhouse.

In this prototype, we developed an intelligent system to control some vital parameters inside the greenhouse that appear in the figure. These parameters include temperature, humidity, and soil moisture. By carefully controlling these parameters, we seek to improve the growing environment for crops and increase their efficiency.

III.3 ***Assemblies and Descriptions of Our Services***

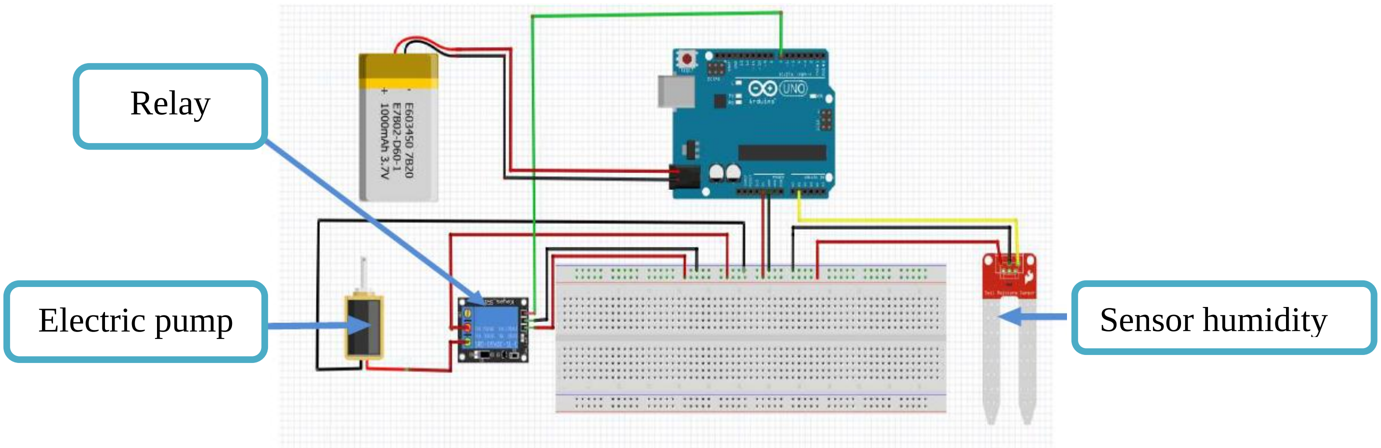
III. 3. 1 Automatic watering:

Figure III.3.1: Mounting the soil moisture sensor**.**

This is a service delivery where we take a proactive role to establish an automatic irrigation system to water plants instead of manual watering. This system seeks to prevent wastage of water by giving it at the right time when the plants are most likely to grow, especially those plants that are very sensitive to moisture, by setting appropriate constants.

We purchased a Spark Fun soil moisture sensor with screw terminals for this system for use in the project. The sensor consists of two rods which are required to be inserted into the soil and requires an electric current to flow through the rods. From this figure it is clear that the conductivity of soil is directly proportional to the amount of water content of the soil and inversely proportional to the water content of the soil.

Further, we incorporate an electric pump – the Jeneca brand IPF-3101 (220-240V, 50Hz/25W) was installed into the system. The most important component of the irrigation system is a pump that is switched on by a relay when the soil moisture becomes less than the optimum level. In our case, as soon as the meter hs = 90% the soil moisture, the Arduino board automatically stops the pump**.**



FigureIII.3.2: Mounting the soil moisture sensor.

Arduino code:

```
#include<LiquidCrystal_I2C.h>
LiquidCrystal_I2C  lcd (0x27, 16, 2);

Void setup(){
 Serial.begin(9600);
 lcd.init();
 lcd.backlight();
 lcd.clear();
 pin Mode(2, OUTPUT);
 digitalWrite(2, HIGH);
 delay(1000);
 lcd.setCursor(0, 0);
 lcd.print("IRRIGATION");
 lcd.SetCursor(0, 1);
 lcd.print("SYSTEM IS ON ");
   lcd.print("");
   delay(3000);
 lcd.clear();
}

voidloop(){
 int value = analogRead(A0);
 Serial.println(value);
 if(value >950){
   digitalWrite(2, LOW);
```

```
  lcd.SetCursor(0, 0);
  lcd.print("Water Pump is ON ");
 }else{
  digital Write(2, HIGH);
  lcd.setCursor(0, 0);
  lcd.print("Water Pump is OFF");
 }

 if(value <300){
  lcd.setCursor(0, 1);
  lcd.print("Moisture : HIGH");
 }elseif(value >300&& value <950){
  lcd.setCursor(0, 1);
  lcd.print("Moisture : MID ");
 }elseif(value >950){
  lcd.setCursor(0, 1);
  lcd.print("Moisture : LOW ");
 }
}
```

III. 3. 2 Temperature and humidity control:

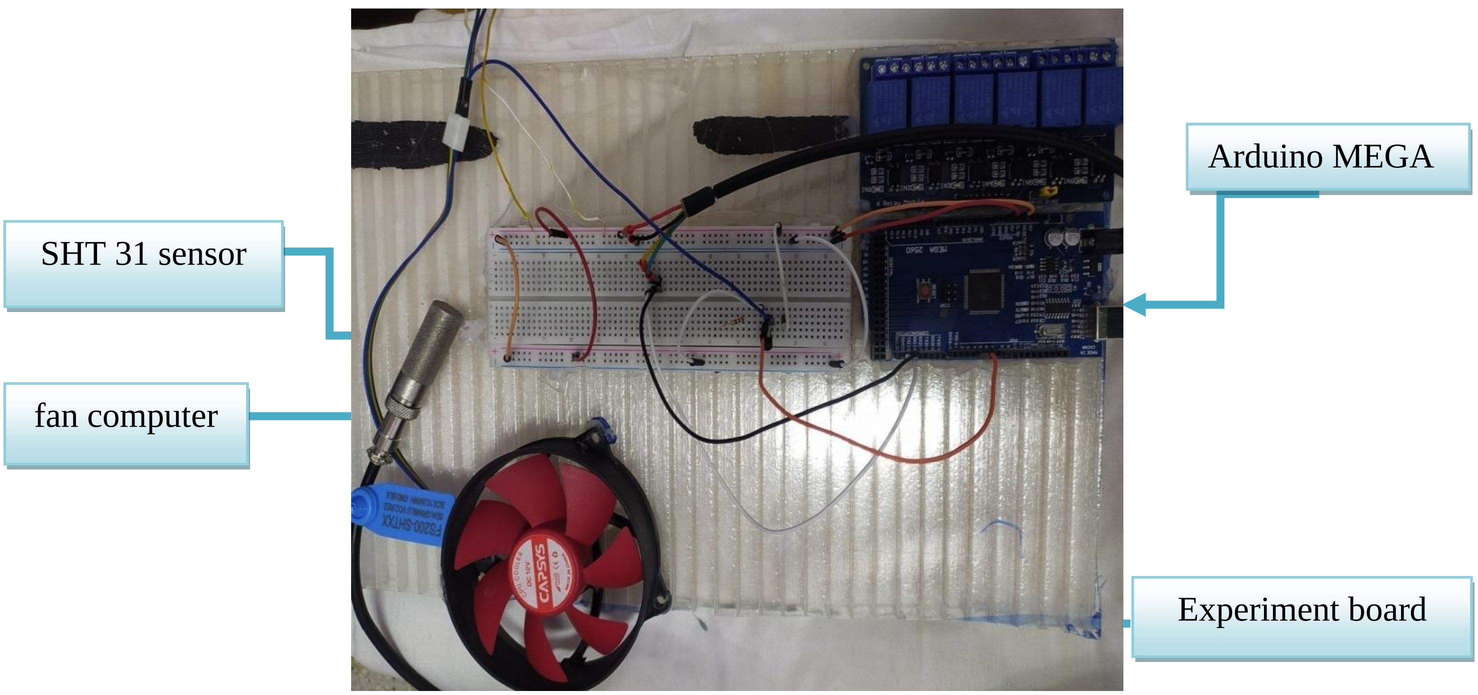


Figure III.3.2: Mounting the SHT 31 sensor

The schematic view of our service under the proteus software is shown in the figure III.3.2:

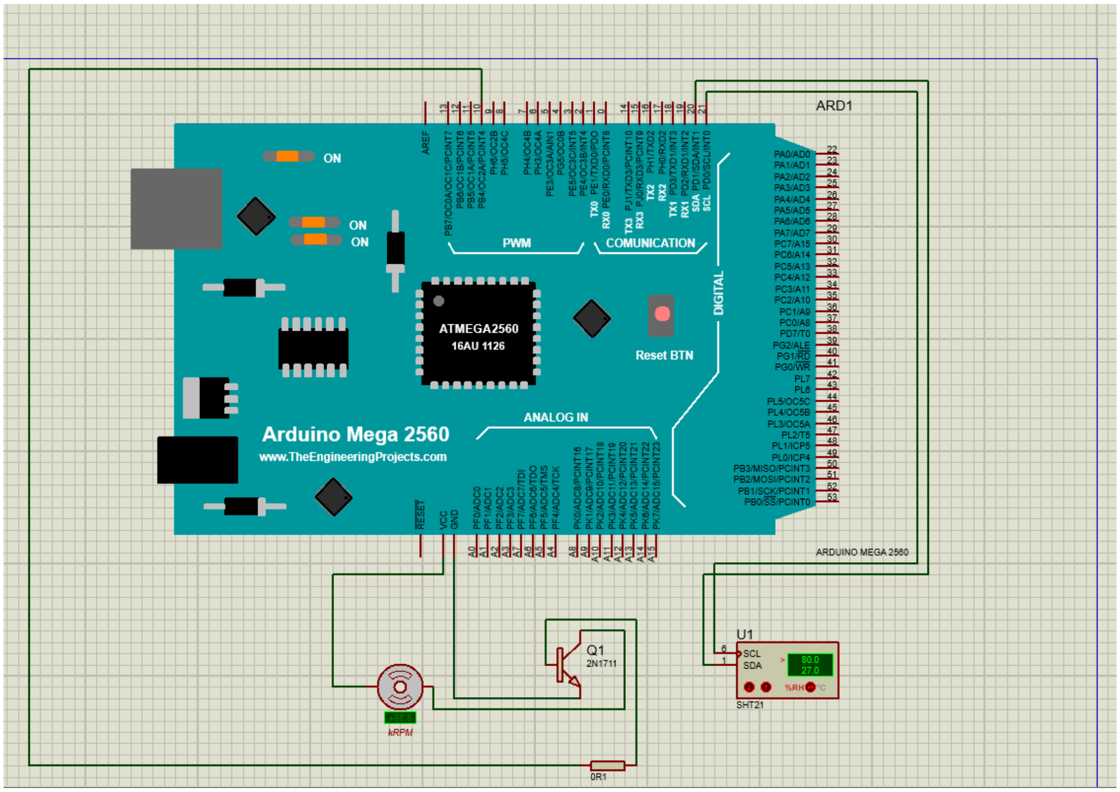


Figure III.3.2: Mounting the SHT31 sensor

Arduino code:

```
#include<Wire.h>
#include"Adafruit_SHT31.h"
Adafruit_SHT31 sht31 = Adafruit_SHT31();
// تعريف الدبوس الذي سيتم توصيله للتحكم في المروحة //
constintfanPin = 9;
// الحد الأقصى لدرجة الحرارة لتشغيل المروحة //
constfloattempThreshold = 30.0; // درجة مئوية
voidsetup(){
  Serial.begin(9600);
  PinMode(fanPin, OUTPUT);
  if(!sht31.begin(0x44)){
```

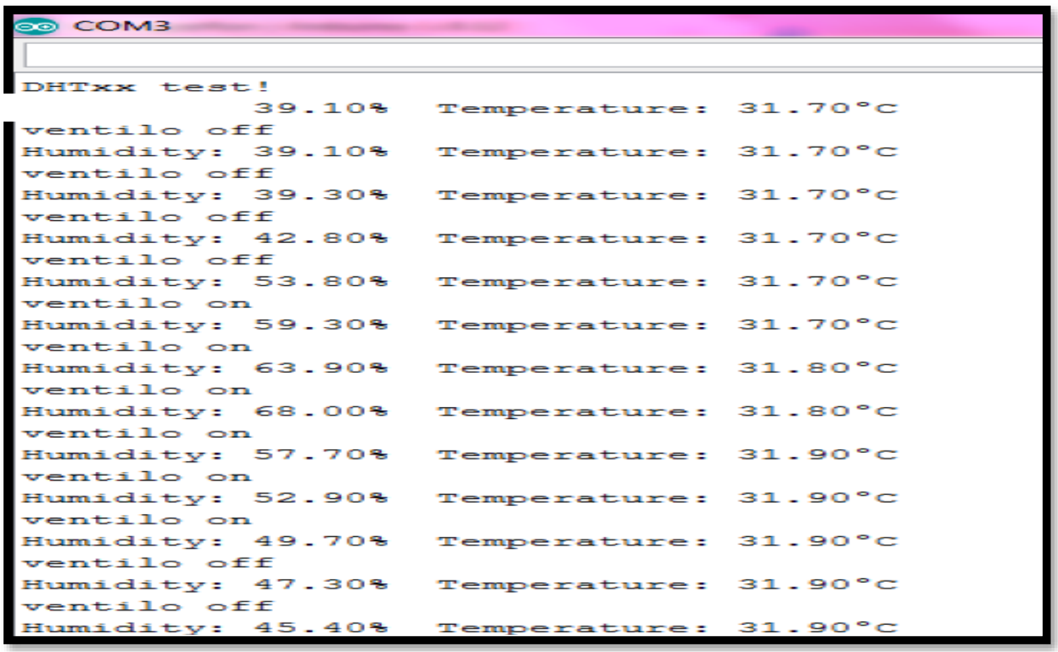
```
   Serial.println("Could not find a valid SHT31 sensor, check wiring!");


while(1)delay(1);
  }
}
voidloop(){
 float temperature = sht31.readTemperature();
 float humidity = sht31.readHumidity();
 if(!isnan(temperature)&& !isnan(humidity)){
   Serial.Print("Temp: ");
   Serial. Print(temperature);
   Serial.Print(" C");
   Serial.Print("Humidity: ");
   Serial. Print(humidity);
   Serial.println(" %");
   if(temperature >tempThreshold){
     digitalWrite(fanPin, HIGH); // تشغيل المروحة
   }else{
     DigitalWrite(fanPin, LOW); // إيقاف المروحة
   }
 }else{
   Serial.println("Failed to read from SHT31 sensor!");
 }
 delay(2000); // الانتظار لمدة 2 ثانية بين كل قراءة
}
```

Our secondary service is designed to manage two critical factors in agriculture: temperature together with relative humidity. The objective is to increase sales and availability of season products so that they are not restricted to a particular season. All these can cause damages on the crops; therefore, farmers need to be always in touch with the climate changes. To address this, a SHT31 sensor is used, and this comes with several functions that simplify programming, and these functions need to be contained in a software library.

The aim of this system is to regulate the climate (air state) in the greenhouse and maintain a moderate or a humid climate which is suitable for the plant growth.

- If the temperature is moderate, a value not exceeding 50 in our case, the fan is switched off.
- That is, if the indicated relative air humidity rises to or exceeds the set level, the fan will start working.



FigureIII.3.2.3: Temperature and humidity display

III. 3. 3 Shading system:

Shading systems are installed in greenhouses to control light intensity, reduce high temperatures, improve production quality and alleviate water deficits. The use of shading and natural ventilation systems is effective in cooling greenhouses in the summer. This approach not only eliminates the need for an energy-intensive fan-based cooling system, but also reduces water use for crop irrigation. Shade nets are one of the most effective ways to achieve the best results for favorable growing conditions and resource utilization in greenhouse farming.

In this system, a greenhouse was studied with white plastic shade nets placed parallel to the roof (50% coverage) under the roof at a height of 0.60 m. Each shade net was erected on an area with the

following dimensions: 0. 4 The bridge was designed to be 40 meters wide and 1. A white net is 1.25 meters long and extends vertically from the inner wall to the side wall. The exterior and interior views of the shading system are shown in Figure (a).

one stepper motors (shown in Figure (b)) was used to control the winding and unwinding of the shade net. This axis forms the upper pulley of the system, while at the other end of the shade net, a copper tube serves as a weight guide that rotates on three copper rods (Figure(b)). The shade net is used to cover the greenhouse roof from 8:00pm, so it should be opened between 12:00am and 5:00pm when the sun rises and remain closed on any other cloudy day.

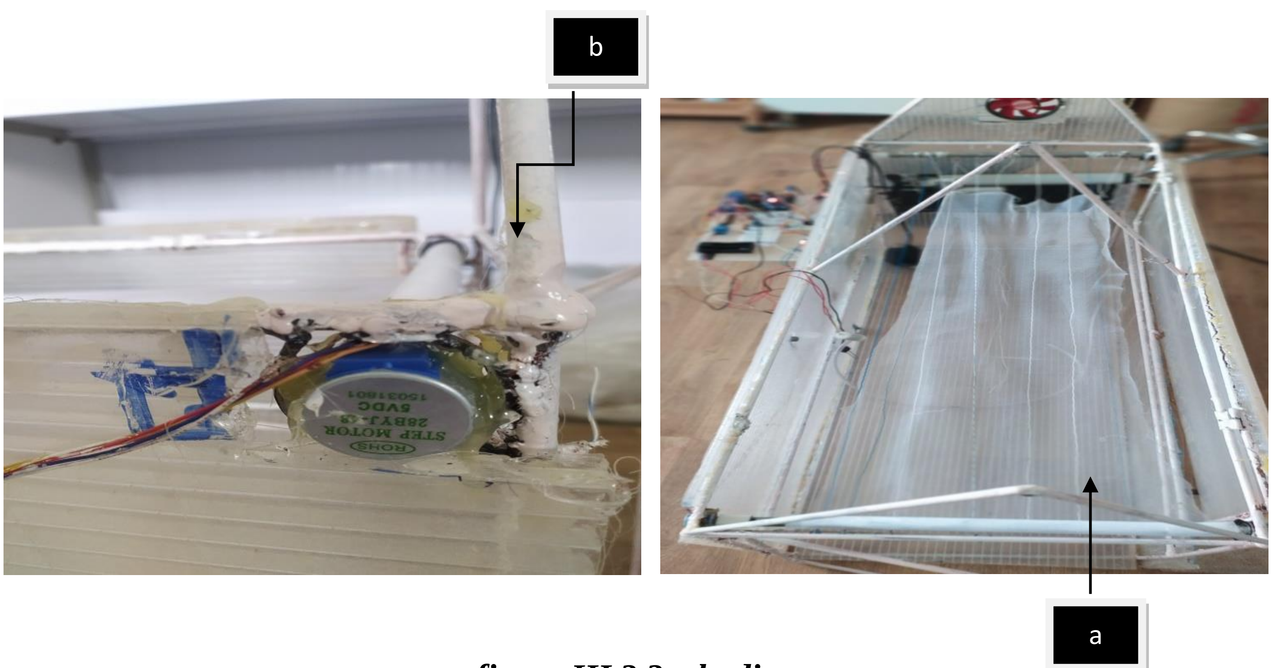


figure III.3.3: shading systeme

Arduino code:

```
DateTime now=rtc.now();
 staticintoldCW_rot=0;
 intnewCW_rot = oldCW_rot;

 if(now.hour()>=8&&now.hour()<17)
  {
   if(temperature > temperatureThreshold_stepper+0.5)newCW_rot =  -1;
   if(temperature > temperatureThreshold_stepper-0.5)newCW_rot = 1;


  }
 else
  {
   newCW_rot= 1;
  }
 if(oldCW_rot!=newCW_rot)
  {
   oldCW_rot=newCW_rot;
   if(newCW_rot==-1)Serial.println("Counter");
   Serial.println("Clockwise rotation");
   for(inti = 0; i<15; i++)myStepper.step(newCW_rot*stepsPerRevolution);
```

III. 3. 4 Operating of natural ventilation system:

The natural ventilation system includes a side opening to the greenhouse, and the design of the ventilation system is shown in Figure-III To control the opening, a linear drive system is used. The system mainly consists of unscrewing the plastic side wall. The linear actuator, shown in -Figure III-18, is responsible for opening and closing the ventilation openings. The data sheet for the linear actuators used in the natural ventilation system is shown in Table III.

Figure III.3.4: Operating of natural ventilation system

Table(4):linear actuator Data-sheet.

Silver color Input voltage: 12 V DC Stroke length: 30mm, 50mm, 100mm, 150mm, 200mm, 250mm, 300mm, 350mm, 400mm, 450mm, 500mm, 600mm, 700mm, 800mm, 900mm Thrust: 100N -2000N optional	Travel speed without load: 5 mm/s, 10 mm/s, 15 mm/s, 20 mm/s, 30 mm/s, 50 mm/s, 60 mm/s, 100 mm/s, 160 mm/s , Duty cycle: 25% Protection class: IP65 Operating temperature: -20ºC to 60ºC

Arduino Code:

```
#include<Wire.h>
#include<Adafruit_SHT31.h>
Adafruit_SHT31 sht31 = Adafruit_SHT31();
constintpinRelayA = 9;
constintpinRelayB = 10;
const float temperatureThreshold =25.0;
voidsetup()
```

```
{
 Serial.begin(9600);
 pinMode(pinRelayA, OUTPUT);
 pinMode(pinRelayB, OUTPUT);

 // preset relays to LOW
 digitalWrite(pinRelayA, LOW);
 digitalWrite(pinRelayB, LOW);

 if(!sht31.begin(0x44)){ // تهيئة الحساس مع العنوان الافتراضي
   Serial.println("Couldn't find SHT31");
   while(1)delay(1);
 }
intLA_state=0;


voidloop()
{
 float temperature = sht31.readTemperature(); // قراءة درجة الحرارة
 float humidity = sht31.readHumidity(); // قراءة الرطوبة (إذا كنت بحاجة إليها)

 if(!isnan(temperature))
  { // التحقق من أن القراءة صحيحة
   Serial.Print("Temperature: ");  Serial. Print(temperature);  Serial.println(" *C");
  }
 else
  {

 Serial.println("Failed to read temperature");
  }
```

```
// التحكم في الريليهات بناءً على درجة الحرارة //
if(temperature <temperatureThreshold)
 {
  if(LA_state!=1)
   {
       Serial.println("Temperature below threshold, extending actuator.");

    LA_state=1;
    extend Actuator();  delay(15000);  stop Actuator();
   }
   else
   {
    Serial.println("actuator is extended.");
   }

 }
Else


 {

  if(LA_state!=-1)
   {
    LA_state=-1;
    Serial.println("Temperature above threshold, retracting actuator.");
    retractActuator(); delay(15000); stop Actuator();
   }
   else
   {
    Serial.println("actuator is retracted.");
   }
```

```
  }

  delay(1000);   // الانتظار لمدة ثانية واحدة قبل القراءة التالية
// تفعيل الريليه A وإيقاف الريليه B
voidextend Actuator(){digitalWrite(pinRelayA, HIGH); digitalWrite(pinRelayB, LOW); }
// تفعيل الريليه B وإيقاف الريليه A
voidretractActuator(){digitalWrite(pinRelayA, LOW);  digitalWrite(pinRelayB, HIGH);}
// إيقاف كلا الريليه
voidstop Actuator(){   digitalWrite(pinRelayA, LOW); digitalWrite(pinRelayB, LOW);  }
```

III.4 *Conclusion:*

In this chapter we developed a prototype of a smart greenhouse based on a fully automated system. This system consists of sensors, an Arduino microcontroller and a motor, allowing us to monitor and regulate the climate factors inside the greenhouse without the need for human intervention.

chapter IV :Results and discussion

IV.1 *Introduction:*

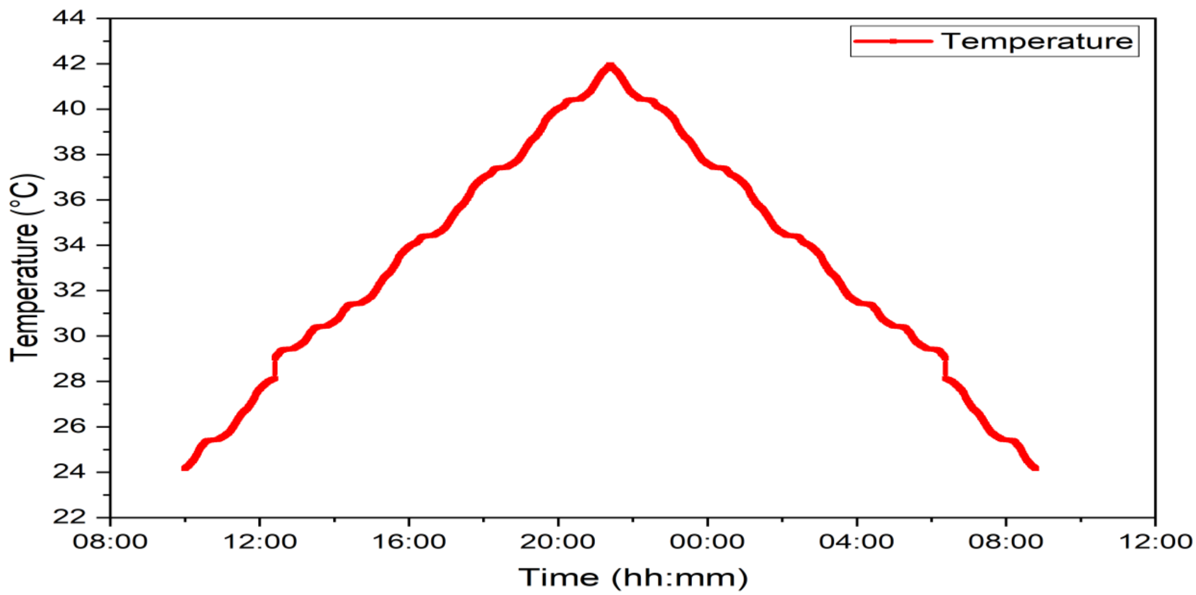
In this chapter, we will examine the results obtained during the design and development of an Arduino-based smart greenhouse prototype aimed at promoting sustainable agriculture in semi-arid regions. The primary objective of this chapter is to present and analyze the data collected during the implementation and testing phases of the project. By examining these results, we aim to evaluate the effectiveness, efficiency, and potential impact of the smart greenhouse system on agricultural practices in challenging environments.

The discussion section will interpret the significance of the results and compare them with existing literature and expectations. It will address the performance of the various sensors and components integrated into the system, such as the temperature and humidity sensors (SHT31).

IV.2 *Experimental results:*

IV. 2. 1 Recording without supervision:

Physical factors develop inside and outside the greenhouse without control:



Figure(1) :Temperature developments inside the greenhouse without control

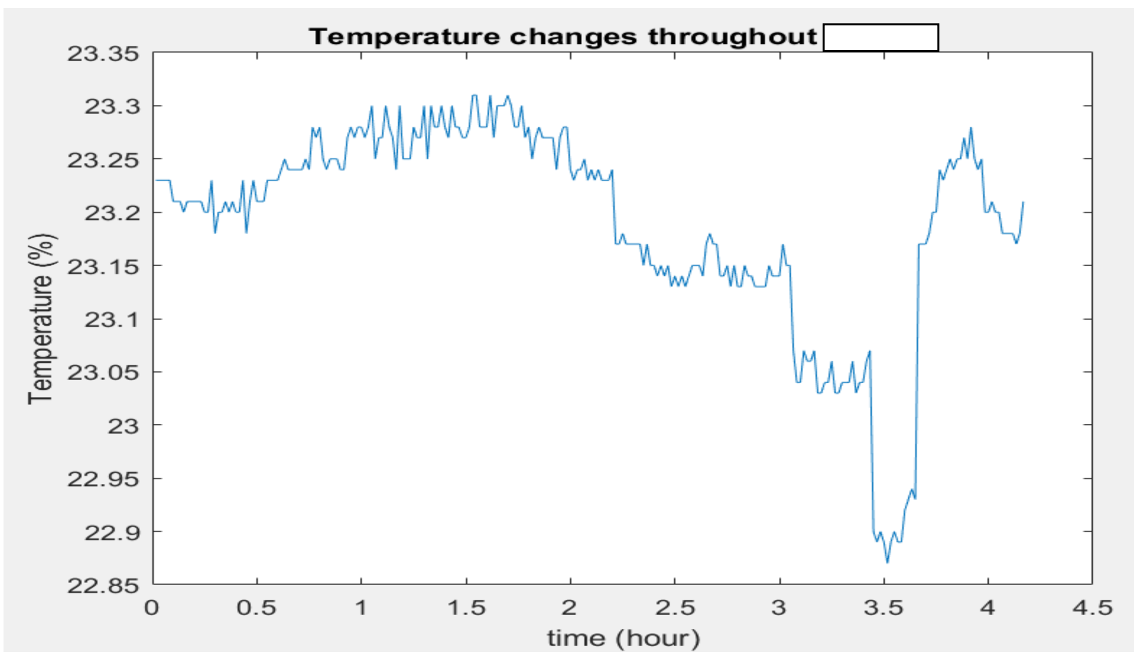


Figure (2): Temperature developments outside the greenhouse without control

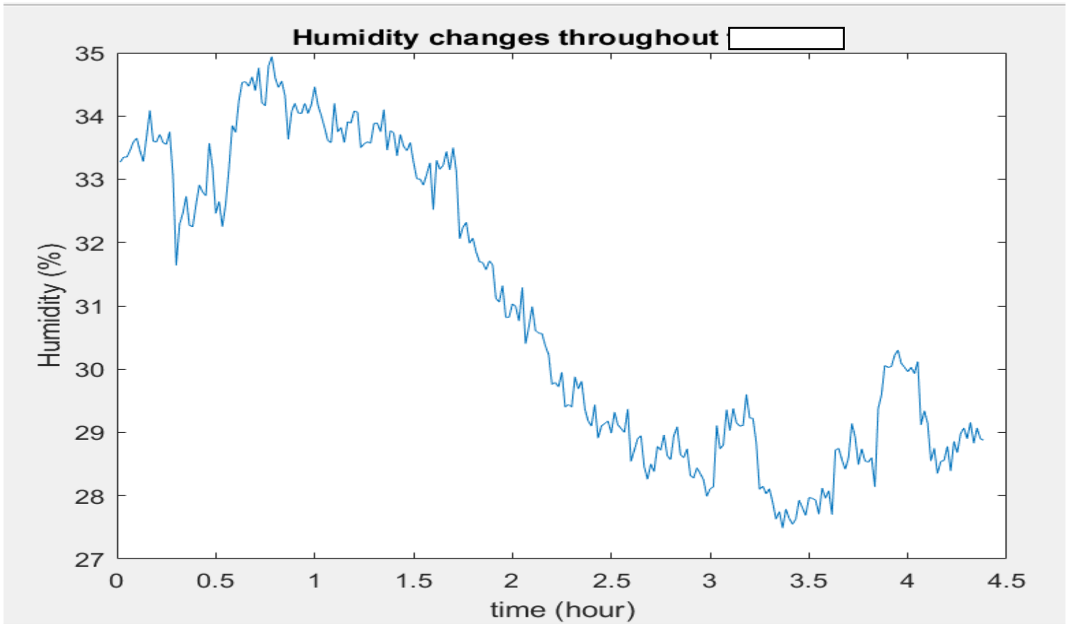


Figure (3): Humidity develops outside the greenhouse without control

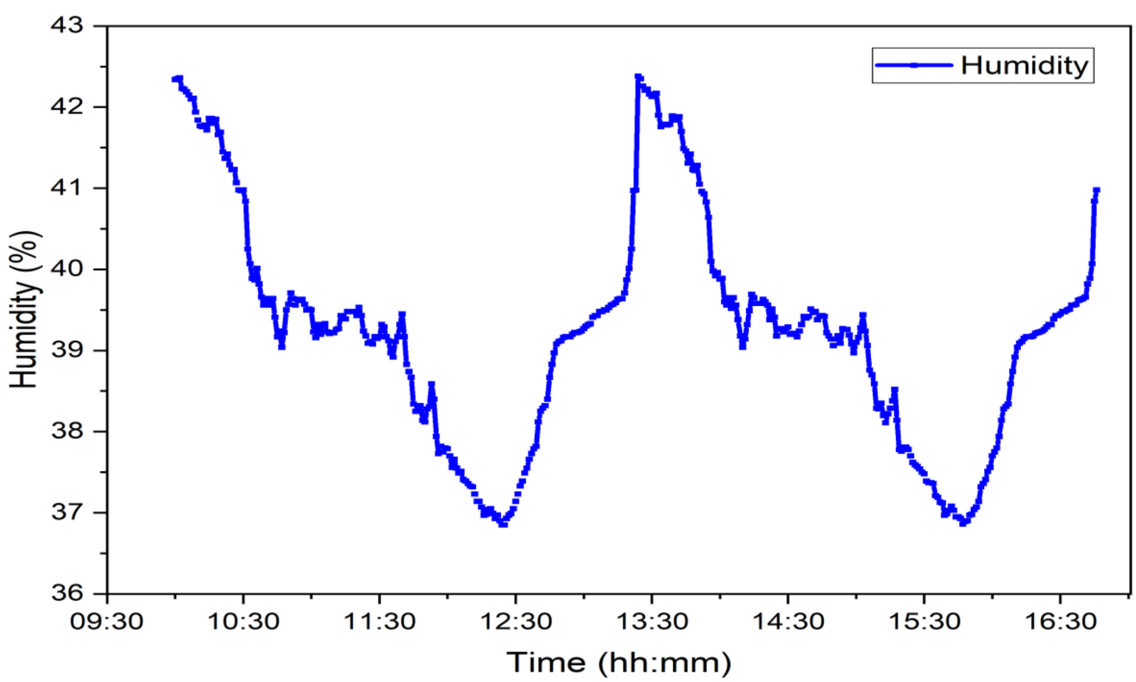


Figure (4): Humidity develops inside the greenhouse without control

IV. 2. 2 Explanation:

Inside the greenhouse without control ***Figure(1)***, temperatures start around 24.16 degrees Celsius and gradually increase to about 41.51 degrees Celsius. This reflects continuous heating due to the sun's influence and the absence of an effective cooling or ventilation system. Temperature stability is observed at specific values such as 25.42, 29.42, 34.42, and 40.42 degrees Celsius, indicating possible external factors like weather changes or partial shade during the day. Minor temperature fluctuations reflect natural changes during day and night, suggesting that the environment is not actively controlled but rather responds to external conditions.

Outside the greenhouse ***Figure(2)***, temperatures range between 22.89 and 23.31 degrees Celsius, indicating greater stability compared to inside the greenhouse. This reflects less influence of external factors on the open environment, where changes are less severe, with very slight fluctuations reflecting slow environmental changes.

A drop in air temperature is accompanied by an increase in its humidity relative.

IV. 2. 3 Registration with control:

In this section we present the results obtained after the installation of motors that help regulate the climate of the greenhouse, which involves the evolution of air temperature and humidity .We chose as a set point a temperature between 20°C and 30°C and a relative humidity between 60% and 80%.

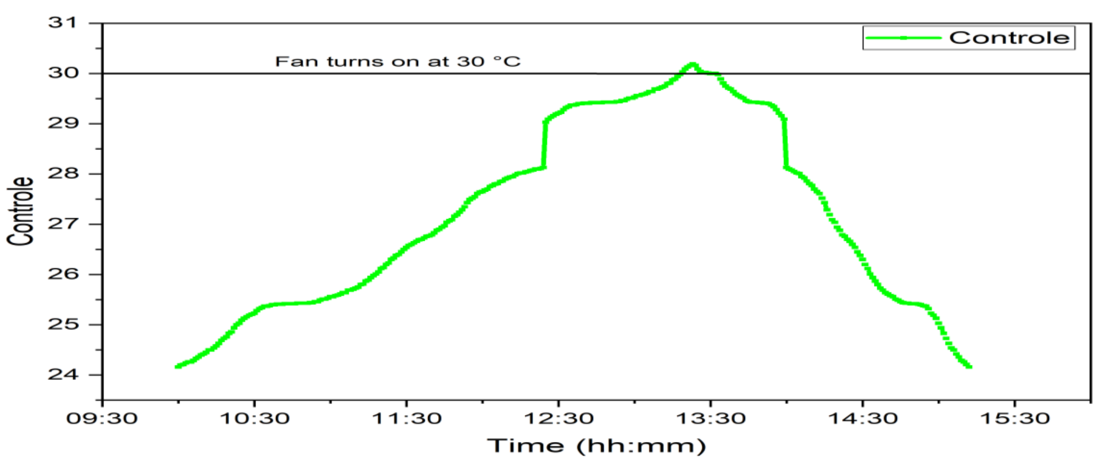


Figure (5): Temperature evolution in a greenhouse with control

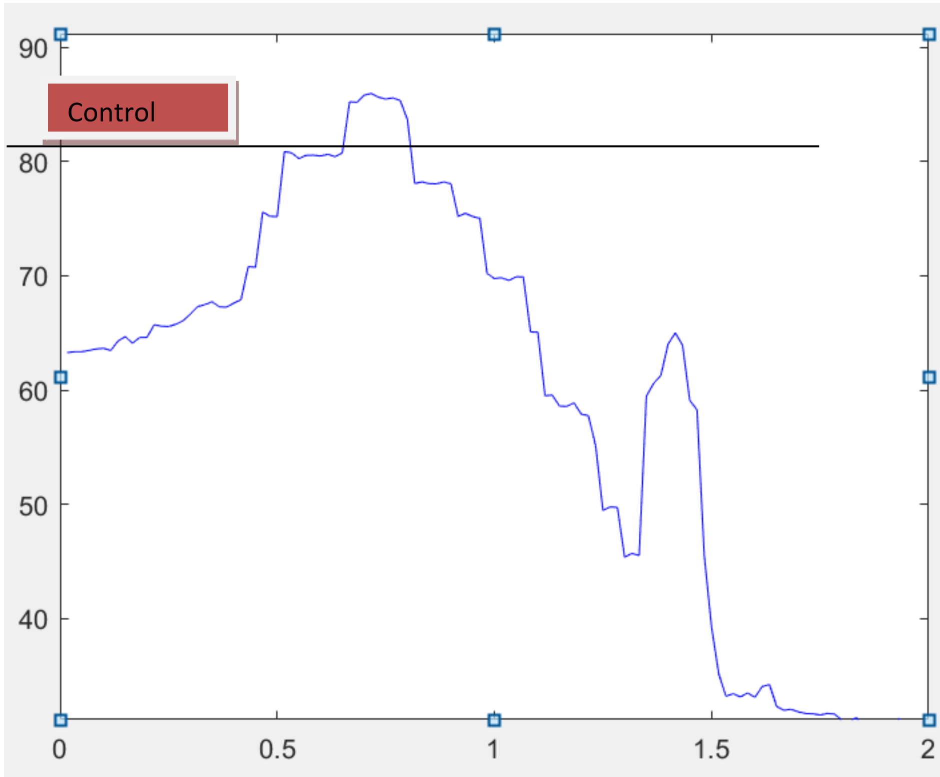


Figure III (6): *Evolution of humidity in a greenhouse with control*

we notice that the temperature varies between 20°C and 30°C and this is thanks to the extractor

which helps to lower the temperature and the lamp that we used as a resistanceto increase the temperature.

- humidity variation between 60% and 80%.

- the obstacles we encountered are:

Increased humidity in the air leads to a lowering of its temperature. This control is never complete, it is in fact difficult to act on an element of the environment without modifying another element.

IV.3 *Conclusion* :

In this chapter, we detailed the implementation of our project. We started by assembling the structure and installing the sensors and motors. Following this, we described the greenhouse's operation using a functional organizational chart that outlines the overall performance of our system. Finally, we concluded this chapter by presenting the results obtained during testing in the form of graphs.

General conclusions

General conclusions :

In the framework of our project, we developed a smart greenhouse designed to manage various tasks within an agricultural environment, providing an optimal climate for crop growth. Our journey began with an in-depth understanding of the concept and objectives of greenhouses. We conducted extensive research on the climatic impact of greenhouses and explored methods to enhance their performance. A critical decision in our project was selecting the Arduino module as our primary tool, which enabled us to program the system with great flexibility to meet our specific needs. We also incorporated various sensors to collect physical data and transmit it to the Arduino module, ensuring precise monitoring and control of environmental parameters. Our final focus was on managing different facilities based on the acquired data and their intended effects.

This project has significantly enhanced our theoretical and practical knowledge. The technical foundation we established during this project has paved the way for several future developments:

Transitioning from a prototype to full-scale implementation : Moving from a small-scale prototype to a fully operational smart greenhouse, ready for practical application in agricultural settings.

Adding features such as remote control : Implementing remote control capabilities via a personal website or mobile application to monitor and manage the greenhouse environment from anywhere.

Powering the greenhouse with solar energy : Making the greenhouse more sustainable by utilizing solar panels to power the entire system, reducing dependency on non-renewable energy sources.

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قسم الآلية والكهروميكانيك

Université de Ghardaïa

غرداية في 17/07/2024

إذن بالطباعة (مذكرة ماستر)

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الإذن بطباعة النسخة النهائية لمذكرة ماستر الموسومة بعنوان

Design and development of an Arduino-based smart greenhouse

إمضاء رئيس القسم

العلمي عبد اللطيف
رئيس قسم الآلية
و الكهروميكانيك

جامعة غرداية
قسم الآلية والكهروميكانيك -1-
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