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Development of a Remote-Controlled Smart Greenhouse System Using IOT For Enhanced Climate and Resource Management In Semi-Arid

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Dedication

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اهدي تخرجي الى ملهمي نجاحي: من ساندني بكل حب عند ضعفي وازاح عن طريقي المتاعب ممهداً لي الطريق زارعاً الثقة والإصرار بداخلي، سندي والكتف الذي استند عليه دائما لطالما كانوا الظل لهذا النجاح" إخوتي **محمد فتحي، سلاف، هند وسيرين"**

الى من احاطوا قلبي بالثقة والحب لمن كانوا الملاذ الامن في لحظاتي التعب عائلتي

الى اعز رفيقة وأجمل من لقتني بيه الصدف **"شيماء بوعامر"**
إلى رفاق الخطوة الأولى والخطوة ما قبل الأخيرة إلى من كانوا خلال السنين العجاف سحابا ممطرا، لمن ضحكة وبكيت معهم طوال 5 سنين ماضية زملائي وعائلتي الثانية

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الى من كان ملهمي ومصدر سعادتي شكرا لدعمك مستمر ووقوفك دائم معي

وأحب ان اختم الإهداء إلى صديقة الرحلة والنجاح إلى من وقفت بجانبي**"برغايد زهرة"**

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Dedication

All thanks to Allah — the one who made this possible and helped me reach this special moment. After years of effort and patience, my dream has come true.

I proudly dedicate this achievement to those who supported me with love and care.

To my dear parents, **Ramdan** and **Khadidja**, Thank you for your endless love, support, and prayers. You are my strength and comfort.

To my brothers: **Soufiane, Oussama, and Mohamed**, you are my strong team, and I'm so thankful for each of you.

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To everyone who shared this path with me — thank you from my heart.

This graduation is for all of you.

BERRIGHAID Fatima Zahra

Abstract

At the present time, with the great technological development that we are witnessing, it has become necessary to combine technology in daily life in modern societies, as technological developments advance daily and intervene in all areas of life. This thesis presents a smart greenhouse project designed for semi-arid areas with remote control capabilities, in the context of smart agriculture.

This thesis aims to benefit from the technologies of the Internet of Things (IoT) and Arduino by designing an integrated, automatic system that controls climatic conditions inside the greenhouse, to facilitate agriculture, provide the ideal environment, and develop sustainable development. The goal of this project is to design and build a functional a smart greenhouse adapted to semi-arid regions. This prototype serves as a foundation for a potential future product that could be commercialized to support sustainable agriculture, with the long-term goal of launching a startup that offers smart farming solutions.to reduce excessive water consumption, maintain plant humidity, and increase yields, thus reducing the manual workload of farmers. Smart greenhouses offer an effective solution for farmers and individuals seeking to increase crop yields and reduce manual labor. These automated systems enable users to monitor and control climate factors remotely, promoting food security and more efficient resource use. This is made possible through the integration of advanced technologies such as the Internet of Things (IoT).

KEYWORDS: Smart Greenhouses, Automation, Semi-Arid Areas, Control, the Internet of Things (IoT), Arduino, Sensor.

Résumé

À l’heure actuelle, avec le grand développement technologique auquel nous assistons, il est devenu nécessaire de combiner la technologie dans la vie quotidienne des sociétés modernes, car les développements technologiques progressent quotidiennement et interviennent dans tous les domaines de la vie. Ce mémoire présente un projet de serres intelligentes dans les zones semi-arides avec télécommande dans le contexte de l’agriculture intelligente.

Ce mémoire vise à bénéficier des technologies de l’Internet des objets (IoT) et d’Arduino en concevant un système automatique intégré qui contrôle les conditions climatiques à l’intérieur de la serre, pour faciliter l’agriculture, fournir l’environnement idéal et développer le développement durable. L’objectif est de concevoir et mettre en œuvre un prototype de système de serre intelligent et automatique pour une utilisation dans les zones semi-arides, afin de réduire la consommation excessive d’eau, maintenir l’humidité des plantes et augmenter les rendements, réduisant ainsi la charge de travail manuelle des agriculteurs. Les serres intelligentes sont la solution pour les agriculteurs et même les personnes qui veulent augmenter les rendements et réduire les charges manuelles. Ces serres intelligentes automatisées offrent un moyen efficace pour les gens de contrôler et de superviser à distance les facteurs climatiques, favorisant ainsi la sécurité alimentaire des cultures et une utilisation plus efficace des ressources. Et à travers des technologies avancées comme l’internet des objets et Arduino.

MOTS-CLÉS : Serres intelligentes, automatisation, zones semi-arides, contrôle, l’Internet des objets (IoT), Arduino, Capteur.

ملخص

في الوقت الحاضر، مع التطور التكنولوجي الكبير الذي نشهده، أصبح من الضروري دمج التكنولوجيا في الحياة اليومية في المجتمعات الحديثة، حيث تتقدم التطورات التكنولوجية يومياً وتتدخل في جميع مجالات الحياة. تقدم هذه الأطروحة مشروع دفيئات ذكية مصممة للمناطق شبه القاحلة مع إمكانيات التحكم عن بعد، في سياق الزراعة الذكية.

تهدف هذه المذكرة إلى الاستفادة من تقنيات إنترنت الأشياء (IoT) و Arduino من خلال تصميم نظام متكامل وآلي يتحكم في الظروف المناخية داخل الدفيئة، لتسهيل الزراعة وتوفير البيئة المثالية وتطوير التنمية المستدامة. الهدف من هذا المشروع هو تصميم وبناء دفيئة ذكية وظيفية تتكيف مع المناطق شبه القاحلة. هذا النموذج الأولي هو أساس لمنتج مستقبلي محتمل يمكن تسويقه لدعم الزراعة المستدامة، مع هدف طويل الأمد يتمثل في إطلاق شركة ناشئة تقدم حلول الزراعة الذكية، لتقليل الاستهلاك المفرط للمياه، والحفاظ على رطوبة النباتات، وزيادة الغلة، وبالتالي تقليل عبء العمل اليدوي على المزارعين. توفر الصوبات الزراعية الذكية حلاً فعالاً للمزارعين والأفراد الذين يسعون إلى زيادة غلة المحاصيل وتقليل العمل اليدوي. تتيح هذه الأنظمة الآلية للمستخدمين مراقبة العوامل المناخية والتحكم فيها عن بُعد، مما يعزز الأمن الغذائي واستخدام الموارد بشكل أكثر كفاءة. وقد أصبح ذلك ممكناً من خلال دمج تقنيات متقدمة مثل إنترنت الأشياء.(IoT)

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List of abbreviations

$: dollar.

% : percent.

°C : degrees Celsius.

ADC : Analog To Digital Converter.

CO_2 : Carbon Dioxide.

AI : Artificiel intelligence.

LED : Light Emitting Diode

. **DC :** Direct Current.

DHT22 : Digital Humidity Temperature type 22.

HAF : Horizontal Airflow Fans..

ESP32 : Espressif Systems Part 32.

FAO : Food And Agriculture Organization.

GMO : Genetically Modified Organism.

GND : Ground.

GPIO : General Purpose Input/Output.

GPS : Global Positioning System.

GSA : Global Smart Agriculture.

h : hour.

N_3PO_4 **:** Acide Phosphorique.

I2C : Inter Integrated Circuit.

I2S : Inter-IC Sound.

IDE : Integrated Development Environment.

INRA :NIAR: National Institute Of Agronomic Research .

IoS : Internet of Services.

IoT : Internet of Things.

ITCMI : Technique Institute Of Vegetable And Industrial Crops In Algeria .

KB : KiloBytes.

KHz : KiloHertz.

L : Liter.

LDR : Light Dependent Resistor.

LM393 : Linear Monolithic 393.

MAC : Media Access Control.

MB : MegaByte.

mm : :millimeter

MMC : Multi Media Card.

MMU : Memory Management Unit.

MPU : Memory Protection Unit.

mS : milli Seconds.

NH_3 : ammonia.

NOx : nitrogen oxides.

O_2 : Oxygen .

PH : Potential of Hydrogen .

PWM : Pulse Width Modulation.

V : Voltage.

VCC : Positive Power Supply Voltage.

General Introduction

The smart greenhouse is an innovative agricultural structure adaptable to various crops and climatic conditions, harnessing advanced technology to improve plant growth conditions, which integrates a variety of IoT technologies, automated systems, sensors and data analytics to create a highly efficient and responsive growing environment. This integration allows real-time monitoring and management of critical factors such as temperature, humidity, light levels, soil moisture and carbon dioxide, ensuring that plants have optimal growing conditions at all times.

The concept of smart greenhouses is rooted in the need to address the challenges faced by modern agriculture, including climate variability, resource scarcity, and the increasing demand for food. As the world's population continues to rise, the pressure on agricultural systems to produce more food with fewer resources becomes more pronounced. Smart greenhouses offer a solution through the use of technology to maximize resource efficiency, reduce waste, and improve crop productivity. By automating processes such as irrigation, ventilation and heating, these greenhouses not only save time and labor, but also reduce the environmental impact of agriculture.

Furthermore, smart greenhouses are designed to be adaptable to various crops and growing conditions, making them suitable for a wide range of agricultural applications. Whether used for commercial production, research or urban gardening, smart greenhouses can be designed to meet specific needs and goals. The ability to collect and analyze data allows farmers to make informed decisions, leading to better management practices and improved crop performance.

In addition to their practical benefits, smart greenhouses also represent a shift towards more sustainable farming practices. By reducing dependence on chemical fertilizers and pesticide

Chapter I:

General Overview of Smart Greenhouses in Semi-Arid Regions

Chapter I : General Overview of Smart Greenhouses in Semi-Arid Regions

I. 1 Introduction

In recent years, agriculture has undergone a major transformation due to technological advances [1]. This transition is particularly crucial in areas facing environmental and climatic constraints, such as semi-arid regions. These areas, which are characterized by erratic rainfall, high temperatures, and water loss, impose several restrictions on traditional agricultural practices. To ensure food security, promote sustainable agriculture, and improve plant growth conditions, it is necessary to find innovative solutions [2]. Among the most promising approaches is the integration of Internet of Things (IoT) and Arduino technologies into agricultural systems [3]. This chapter presents the motivation behind the study, identifies existing challenges, identifies the main objectives of the proposed project, and provides an overview of the smart greenhouse system and the methodology used to design and implement it.

I. 2 Definition of Smart Greenhouse

A smart greenhouse is an innovative advanced agricultural structure that is adaptable to different crops and climatic conditions, using automated systems, sensors, and data analytics systems to create and improve a highly efficient and responsive growing environment for the plant optimize plant, while reducing the use of resources (water, energy, and fertilizers). Unlike traditional greenhouses, smart greenhouses integrate Internet of Things (IoT), artificial intelligence (AI) technologies, and climate control systems to monitor and adjust environmental conditions (temperature, humidity, light, carbon dioxide, and soil moisture) in real time through sensors, actuators, and controllers.

Figure I-1: Smart Greenhouse System [1].

I. 3 History of Smart Greenhouse

The development of smart greenhouses represents a remarkable technological journey that parallels humanity's agricultural and industrial advancements. This history can be divided into distinct eras:

Mechanization Era (Early-Mid 20th Century) :

1927: First automated ventilation systems introduced in Dutch greenhouses.

1940s: Widespread adoption of polyethylene film (developed for WWII) as cheaper alternative to glass.

Digital Transformation (Late 20th Century) :

1980s: Microprocessors enable basic environmental control systems.

1995: First commercial greenhouse climate computers introduced (Priva, Hoogendoorn).

1998: Early adoption of hydroponics in Dutch greenhouse operations.

Smart Greenhouse Revolution (21st Century) :

2005-2010: Integration of IoT sensors for environmental monitoring.

2007: First solar-powered greenhouse prototype (University of Arizona).

2012: Emergence of cloud-based greenhouse management platforms.

2014: Commercial launch of vertical farming greenhouses (AeroFarms).

2015: Widespread adoption of LED grow lights with spectral tuning.

2018: AI-powered predictive climate control systems.

2020s: Fully autonomous greenhouses with robotic harvesting.

2021: First quantum dot-enabled smart glass greenhouses.

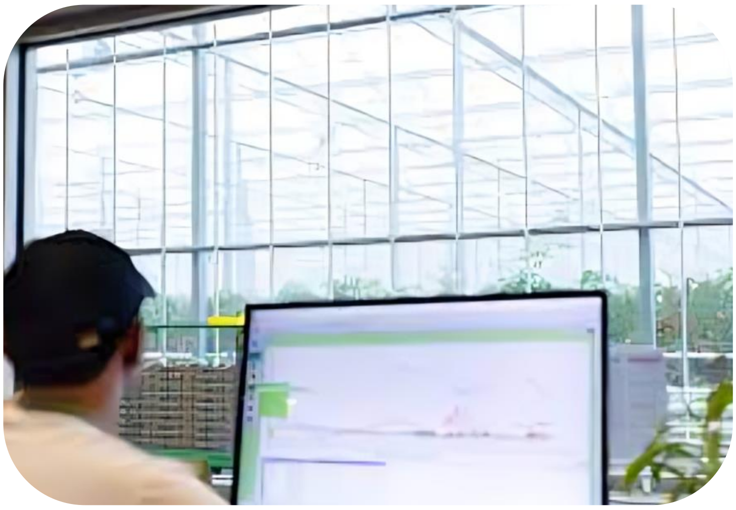


Figure I-2: priva greenhouse climate computers [2].

Figure I-3: University of Arizona greenhouse prototype [3].

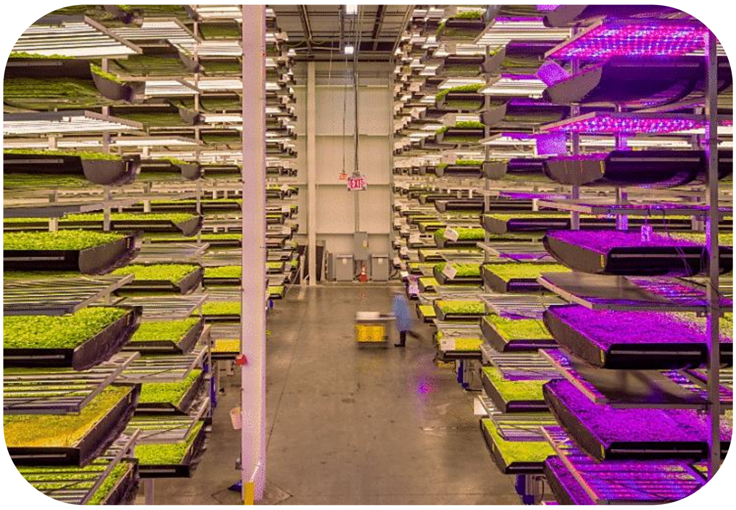


Figure I-4: AeroFarms [4].

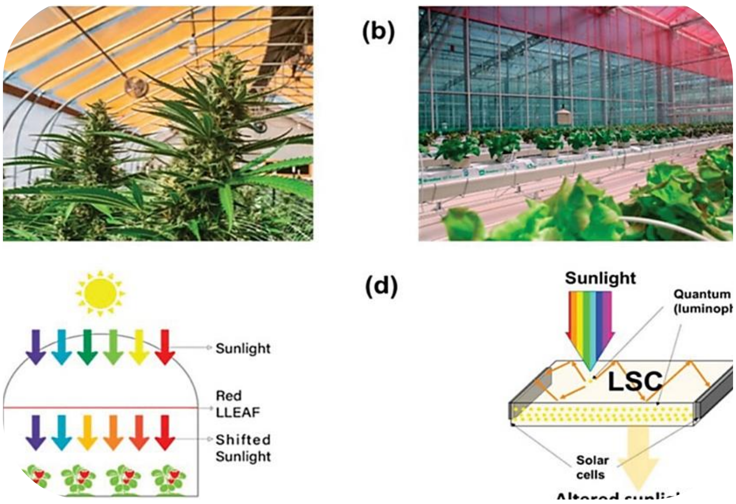


Figure I-5: quantum dot-enabled smart glass greenhouses [5].

I. 4 the main causes and challenges facing agriculture in semi-arid areas

Agriculture in semi-arid regions faces significant obstacles due to climatic conditions, water scarcity, and environmental degradation. Below are the primary causes and challenges:

✓ Water Scarcity and Erratic Rainfall: Low and unpredictable rainfall rates, high evaporation rates, frequent droughts leading to poor yields, and water pressure on crops and plant wealth.

✓ Soil Degradation and Erosion: Overgrazing, deforestation and unsustainable agricultural practices lead to loss of arable land, desertification and reduced agricultural productivity.

✓ Poor Soil Quality: Semi-arid soil lacks organic matter and nutrients, is less fertile and suitable for growing crops. Consequently, agricultural flexibility decreases and agricultural diversity decreases.

✓ High Temperatures and Extreme Weather: Climate change is intensifying heat waves and temperature fluctuations. Hence, thermal stress on crops and plant wealth led to increased water demand and decreased growing seasons.

✓ Limited Access to Modern Farming Techniques: Small farmers often lack knowledge, technology or financial resources. This leads to a decrease in the adoption of drought-resistant seeds, effective irrigation, and smart farming methods.

✓ Pests and Diseases: Warm, dry conditions favour the appearance of certain pests (such as locusts) and crop diseases. This results in crop losses, increased pesticide use, higher production costs and food insecurity.

✓ Economic and Infrastructure Constraints: Poor market access, lack of storage facilities and limited government support. They cause post-harvest losses, reduced profitability, food waste and economic instability.

Figure I-6: Smart Greenhouse in Semi-Arid Regions [6].

I. 5 Environmental Conditions in Greenhouses

The growth of plants in greenhouses requires special climatic conditions. These conditions are presented in a general way below:

I. 5. 1 Temperature

- ✓ **Challenges:**

Excessive daytime heat (requires cooling).

Cold nights (requires heating in winter).

- ✓ **Control Methods:**

Cooling: Shade nets, evaporative cooling pads, ventilation (natural or fan-assisted).

Heating: Geothermal systems, biomass heaters, or solar thermal collectors.

I. 5. 2 Humidity

- ➢ **Challenges:**

High humidity → Fungal diseases (e.g., powdery mildew).

Low humidity → Water stress (common in arid regions).

- ✓ **Control Methods:**

Increase Humidity: Misting systems, foggers, or water evaporation.

Reduce Humidity: Dehumidifiers, ventilation, or heat exchangers.

I. 5. 3 Light (Solar Radiation)

- ➢ **Challenges:**

Excessive sunlight → Leaf burn, overheating.

Low light in winter → Slow growth.

- ✓ **Control Methods:**

Reduce Light: Shade nets, whitewashing, or retractable screens.

Increase Light: LED grow lights (for cloudy days or winter).

I. 5. 4 Carbon Dioxide (CO_2) Levels

- ✓ **Challenges:**

Low CO_2 in sealed greenhouses (limits growth).

High CO_2 waste if not regulated.

- ✓ **Control Methods:**

CO_2 generators (burning propane, natural gas).

Ventilation (to replenish CO_2 naturally).

I. 5. 5 Air Circulation & Ventilation

- ✓ **Challenges:**

Stagnant air → Mold, weak plant stems.

Excessive wind → Crop damage (in naturally ventilated greenhouses).

- ✓ **Control Methods:**

Horizontal Airflow Fans (HAF) → Improves circulation.

Automated Roof/Side Vents → Regulates airflow.

I. 5. 6 Soil Moisture

- **Challenges:**

Excessive moisture → Root rot, fungal diseases, oxygen deprivation.

Insufficient moisture → Plant wilting, stunted growth, yield loss.

Uneven distribution → Dry spots or waterlogged zones in the same greenhouse.

- ✓ **Control Methods:**

Reduce Moisture: Automated drainage systems, dehumidifiers or increased ventilation.

Increase Moisture: Drip irrigation with soil moisture sensors, subsurface watering or capillary mats.

Smart Monitoring: IoT enabled sensors + AI-based irrigation scheduling, Self-regulating hydrogels in growing media.

Figure I-7: Cooling system [7].

Figure I-8: Dehumidification system [8].

Figure I-9:lighting systeme [9].

Figure I-10: Natural ventilation system [10].

Figure I-11: irrigation system [11].

I. 6 Types of Greenhouses in Semi-Arid Regions:

In semi-arid regions, greenhouses must balance temperature control, water efficiency, and durability to withstand hot days, cool nights, and occasional strong winds. The most popular greenhouse structures in these areas are:

Table I-1: Types of Greenhouses.

Feature	Quonset Greenhouse	Garden Greenhouse	Multi_chapel Greenhouse	Geothermal_ cooled Dome
Structure	Semi-circular hoops	Rectangular frame	Peaked roof bays	Geodesic dome
Covering Material	Polyethylene film	Polycarbonate/glass	Glass/polycarbonate	ETFE membrane /geothermal pipes
Cost (per sqft)	$5-$15	$15-$40	$30-$100	$80-$200
Lifespan	3-8 years	10-15 years	25-30 years	30+ years
Energy Use	Low	Moderate	High	Ultra-low (60-75% savings)
Cooling Efficiency	Basic	Moderate	Good	Excellent (no AC needed)
Best Climate	Arid/coastal	Semi- arid	All climates	Extreme hot/dry climates
Automation	Basic	Moderate	Advanced	AI-optimized
Best For	Seasonal vegetables	Home gardening	Commercial crops	Desert agriculture
Unique Feature	Wind-resistant	Space-efficient	High productivity	Self-cooling architecture

Figure I-12: Quonset Greenhouse [12].

Figure I-13: Garden Greenhouse.

Figure I-14: Multi_chapel Greenhouse [13].

Figure I-15: Geothermal_ cooled Dome.

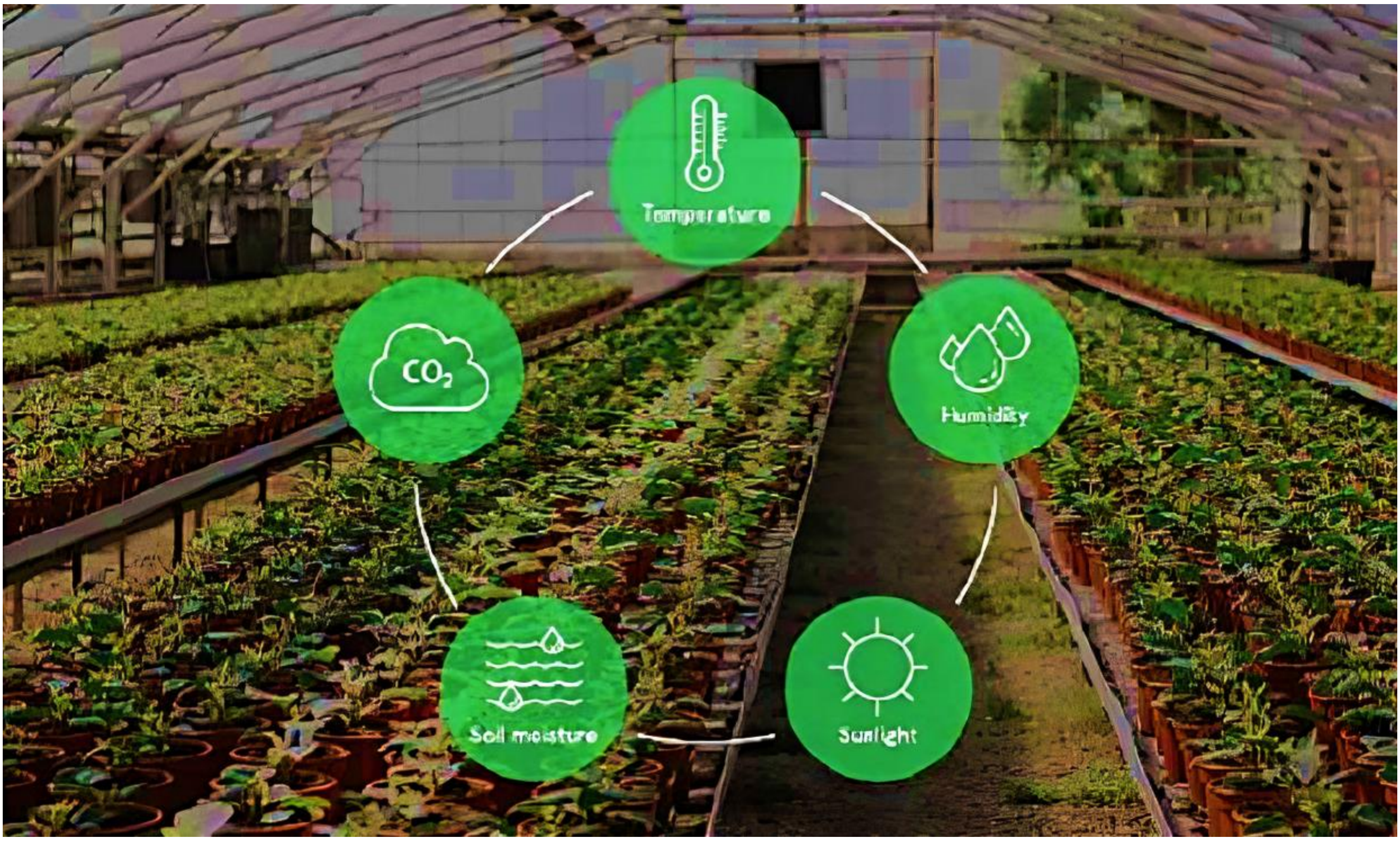
I. 7 The Advantages of Greenhouse Automation

Greenhouse automation offers the following advantages:

- Maintaining and controlling an internal temperature in the greenhouse environment to protect plants from high temperatures, and to avoid damaging plants.
- Protecting plants from diseases, and maintaining the health and prosperity of plants by providing the best possible growing environment.
- Providing vegetables and flowers outside the regular season and during periods of absence (production throughout the year in harsh climates).
- The automatic control system can monitor all environmental changes, equipment status and malfunctions in real time.
- monitor conditions such as humidity fluctuations, safety violations, heating, fan, equipment and power outages.

- Monitor the greenhouse remotely and stay informed of weather conditions.
- Lower labor costs through automation.

Greenhouse automation transforms semi-arid agriculture by maximizing efficiency, sustainability, and profitability [4] . It's a game-changer for food security in water-scarce



regions.

Figure I-16: Smart Automatic Greenhouse [14].

I. 8 Project Objectives

This project aims to design a low-cost smart Greenhouse based on Arduino and IOT technology and specifically designed for semi-arid regions, with the following objectives:

Automatic Climate Control:

Maintain optimal temperature and humidity with Arduino-powered motors.

Water Saving Irrigation:

Deploy soil moisture sensors to operate irrigation only when needed, reducing water use by ≥40%.

Real-Time Monitoring:

Transmission of sensor data to a cloud platform (MQTT Explorer) for remote access via smartphones.

Scalability:

Designing a modular system that is adaptable to small farms and scalable in the future [5].

I. 9 Conclusion

In conclusion, this chapter allowed us to learn about the environmental conditions of semi-arid regions, as well as to learn about the smart greenhouse, its types, the necessary requirements within it, its importance and its advantages. We have seen that growing inside smart greenhouses instead of traditional agriculture provides higher productivity, conserves water, and creates favorable climate conditions for plants to grow faster.

We also found that the smart greenhouse is one of the modern solutions, but it requires careful planning and analysis by specialists to determine the appropriate situation for the crops [6], that will be planted before starting investment.

Chapter II :

IOT Technologies for Smart Greenhouses in Semi-Arid Regions

Chapter II: IoT Technologies for Smart Greenhouses in Semi-Arid Regions

II.1 introduction

The way we interact with the world around us has completely changed thanks to Internet of Things (IoT) technology and microcontrollers like Arduino. Which has improved comfort, efficiency and connectivity in our lives everywhere from our homes to our workplaces. The management of greenhouse systems is one area where the Internet of Things and microcontrollers are having a significant impact. Better yields, lower costs, year-round crop production and a more sustainable future can be achieved by monitoring and providing an ideal environment for plants to grow within the greenhouse. This chapter provides an in-depth study of the following:

- Concepts and infrastructures Internet of Things technology and the Arduino microcontroller.
- Its applications in agriculture.
- Integrated IoT and Arduino solutions for the intelligent management of greenhouses [7].
- Current challenges and future technological trends.

II.2 Definition of The Internet of Things

The Internet of Things, or IoT, is a network of interconnected devices that connect and exchange data with other IoT devices and the cloud. IoT devices are typically embedded with technology such as sensors and software and can include mechanical and digital machines and consumer objects [8].

These appliances include everything from everyday household items to complex industrial tools. Increasingly, organizations in a variety of industries are using IoT to operate more efficiently, provide improved customer service, improve decision-making and increase business value [8].

With the Internet of Things, data can be transmitted over a network without the need for human-human or human-computer interactions [9].

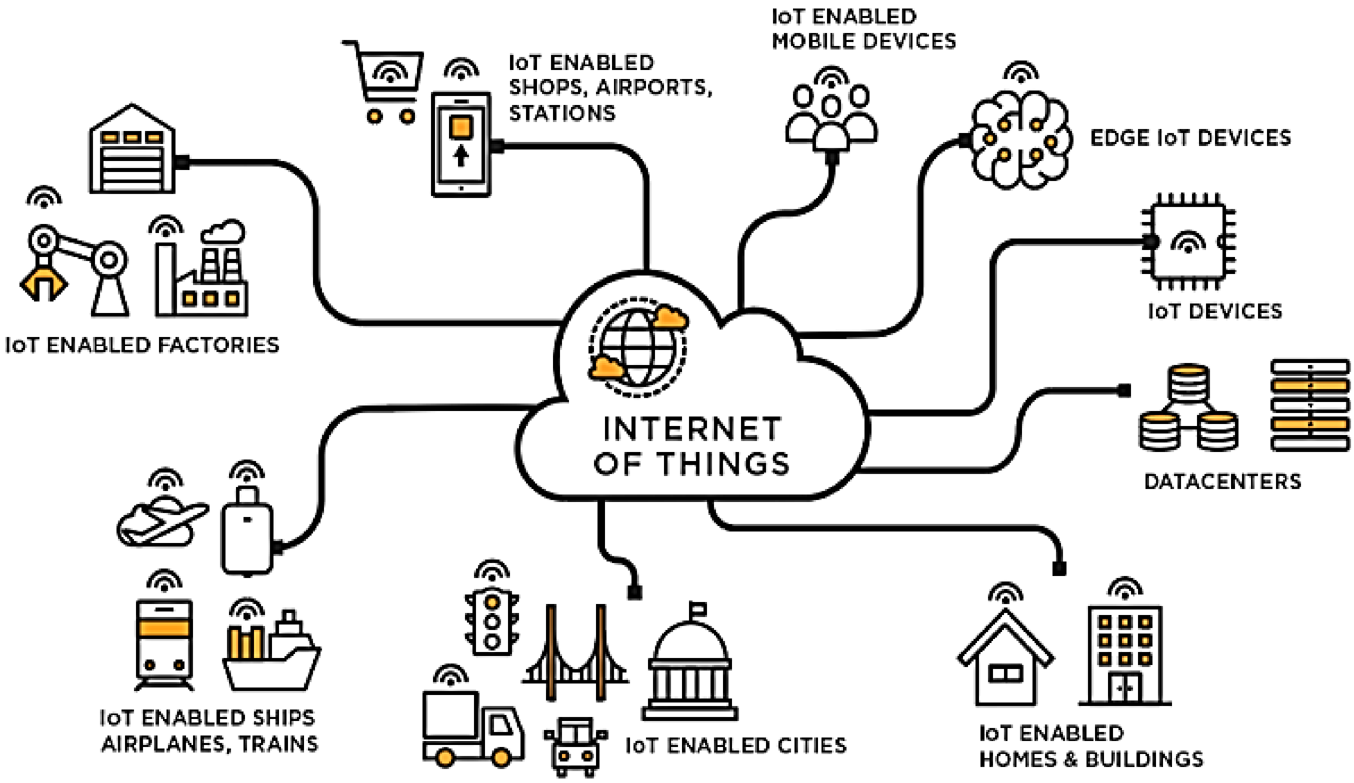
An object in the Internet of Things could be a car with built-in sensors, AI voice assistants like Alexa, or any other man-made object that can be assigned an Internet [10], Protocol address and can transmit data over a network [8].

II.3 Application Areas of IOT

The potential offered by the Internet of Things and its ubiquitous aspect make it possible to develop numerous applications [11]. However, only a few applications have been published at the moment. The use of the Internet of Things will allow the development of many smart applications in the future that will mainly affect:

- Smart Cities & Urban Infrastructure.
- Smart Homes & Building Automation.
- Energy & Utility Management.
- Transportation & Logistics.
- Healthcare & Medical IOT (IOMT).
- Industrial IOT (IIOT) & Smart Manufacturing.
- Smart Agriculture & Precision Farming.

In order to measure or detect media, sensors send an output signal, and have the ability to



display, record and/or control the process of changing media attributes to suit the application.

Figure II-1: Application areas of The Internet of Things [15].

II. 4 Internet of Things (IOT) in Agriculture

II. 4. 1 IOT System Architecture for Smart Greenhouses

A comprehensive IoT architecture for agricultural applications consists of four distinct layers:

- **Perception Layer :**

Environmental sensors (DHT22, BME280).

Soil monitoring probes (capacitive moisture, NPK sensors).

Crop health sensors (multispectral, thermal imaging).

Actuators (solenoid valves, servo motors, relays).

- **Network Layer:**

- ***Communication Protocols:***

Short-range (Bluetooth, Zigbee).

Medium-range (LoRaWAN, WiFi).

Long-range (GSM, NB-IoT).

- ***Gateway Devices (Raspberry Pi, ESP32):***

- **Cloud Processing Layer:**

Data storage (AWS IoT, Google Cloud).

Analytics platforms (ThingSpeak, Node-RED).

Machine learning models for predictive analytics.

- **Application Layer:**

User interfaces (mobile apps, web dashboards).

Alert systems (SMS, email notifications).

Automated control algorithms.

II. 4. 2 IOT Applications in Semi-Arid Smart Greenhouses

- **Climate Control Automation:**

- ***Temperature regulation:***

Temperature-triggered ventilation control using threshold logic

Evaporative cooling systems

Thermal curtain management

- ***Humidity optimization:***

Fogging systems with RH feedback.

Condensation prevention algorithms.

➢ **Precision Irrigation Management:**

Soil moisture-based scheduling.

Plant evapotranspiration models.

Fertigation integration (pH/EC control).

➢ **Energy Optimization:**

Solar-powered sensor nodes.

Duty cycling for power conservation.

Predictive lighting control.

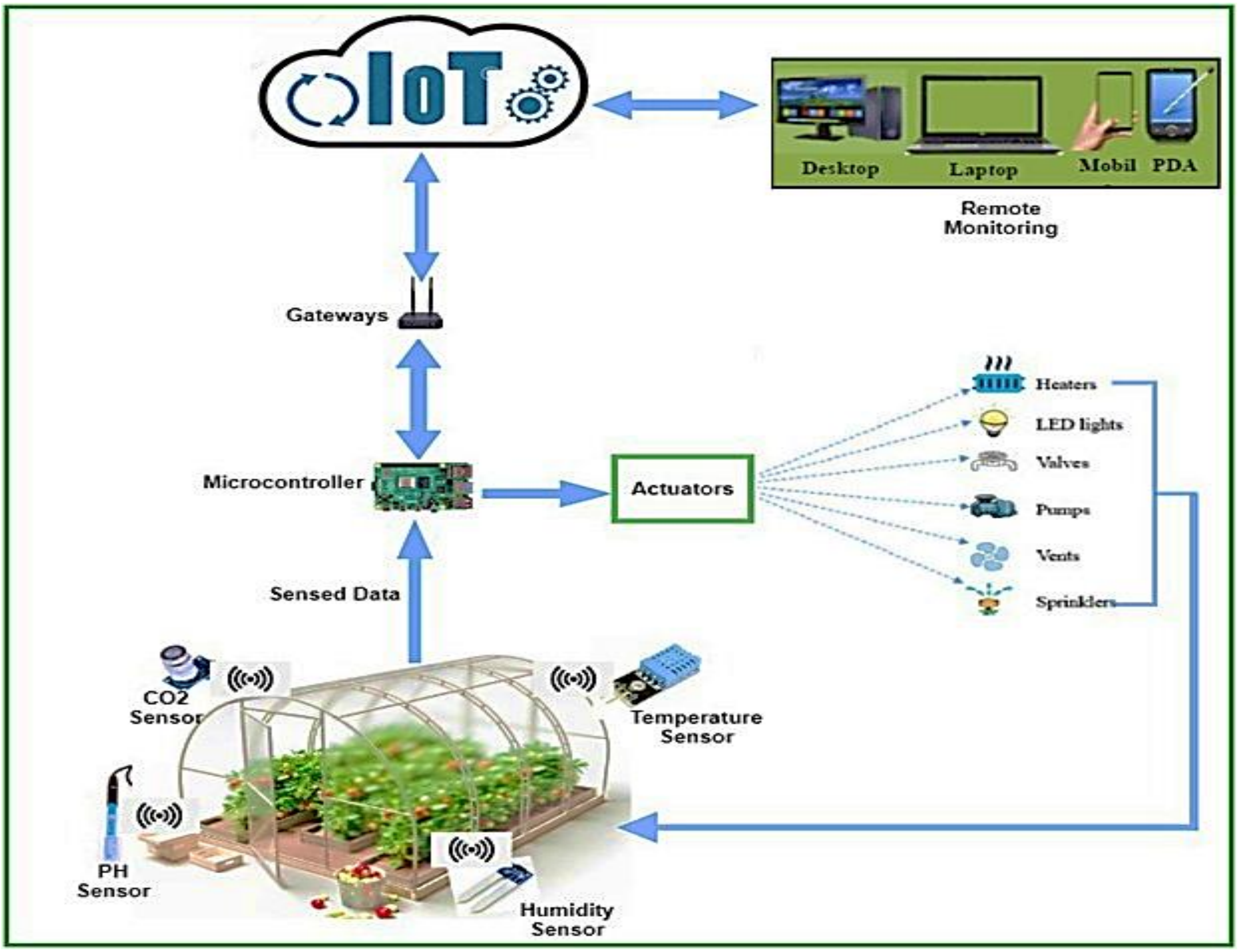


Figure II-2: The Internet of Things in Smart Greenhouse [16].

II.5 Definition of Arduino

Arduino is an open-source electronics platform based on easy-to-use hardware (microcontroller boards) and software (Integrated Development Environment - IDE) [12]. It is designed for prototyping interactive projects, enabling users to read inputs (from sensors, buttons, etc.) and control outputs (motors, LEDs, displays, etc.) through programmable logic.

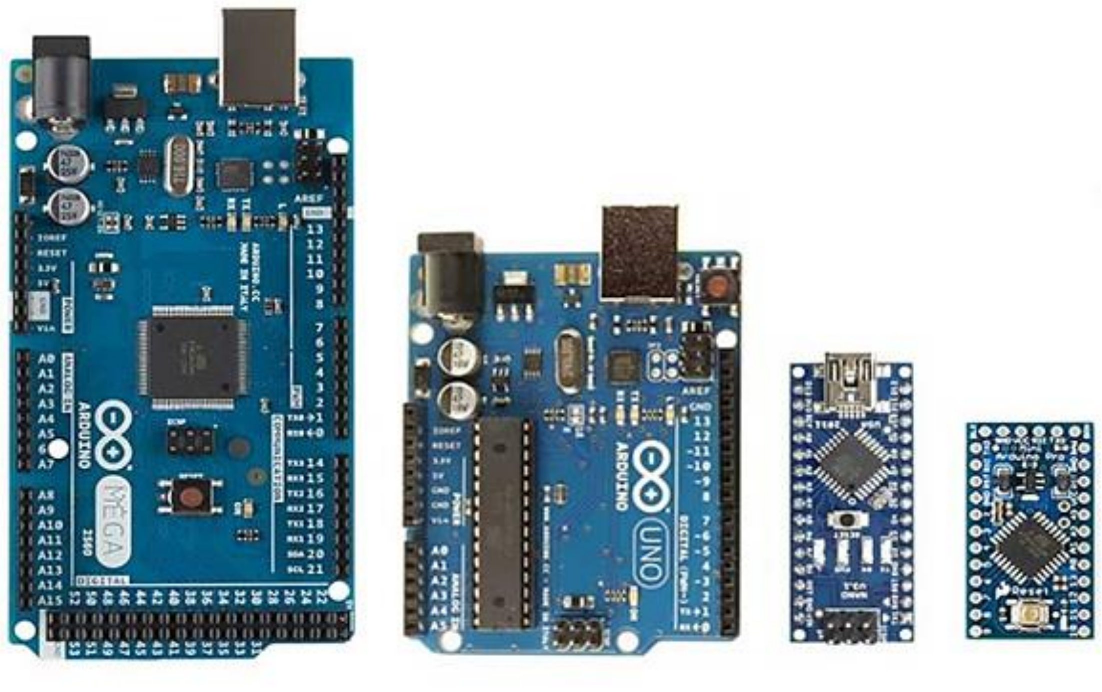


Figure II-3: Types of Arduino Boards [17].

II.6 Key Features of Arduino

- **Hardware Components:**

Microcontroller (ATmega328P in Arduino Uno).

Digital & Analog I/O Pins (for connecting sensors & actuators).

USB Interface (for programming & power).

Power Options (USB, battery, or external power supply).

- **Software (Arduino IDE):**

Simple C/C++ based programming.

Cross-platform (Windows, macOS, Linux).

Library Support (thousands of pre-written codes for sensors & modules).

Serial Monitor (for debugging & data logging)

➢ **Open-Source Ecosystem:**

Community-driven development (free schematics & code sharing).

Compatible with third-party shields (expansion boards for Wi-Fi, GPS, motor control, etc.).

II. 7 The Different Types of Controller Hardware

Microcontroller	Clock Speed	Flash Memory	Key Features	Greenhouse Applications
Arduino Uno	16MHz	32KB	14 Digital I/O, 6 Analog	Basic monitoring
Arduino Mega	16MHz	256KB	54 Digital I/O, 16 Analog	Multi-zone control
ESP32	240MHz	4MB	WiFi/BT	IoT edge node
Arduino Nano	16MHz	32KB	Compact	Sensor modules

Table II -1: The Different types of Microcontrollers.

II. 8 Applications of Arduino

Arduino is a versatile open-source electronics platform used across industries for prototyping and developing interactive projects [13]. Here's his key application:

- Home Automation (smart lights, security systems).
- Robotics (motor control, sensor-based navigation).
- IoT Projects (weather stations, smart agriculture).
- Wearable Tech (fitness trackers, health monitors).

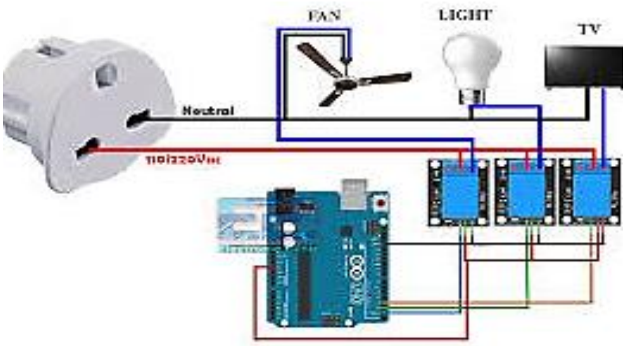


Figure II-4: Smart Home with Arduino [18].

Figure II-5: Arduino Robotic Arm [19].

II. 9 Integrated IOT-Arduino Solutions

II. 9. 1 System Architecture for Semi-Arid Regions

- **Key Design Considerations :**

Solar power Autonomy (72-hour backup).

Soil moisture-based watering (saves 40-60% water).

Dust-proof sensor enclosures.

Redundant communication (LoRa + GSM).

Real-time dashboards (ThingSpeak, Blynk).

SMS alerts for critical events (frost, dry soil).

- **Data Flow :**

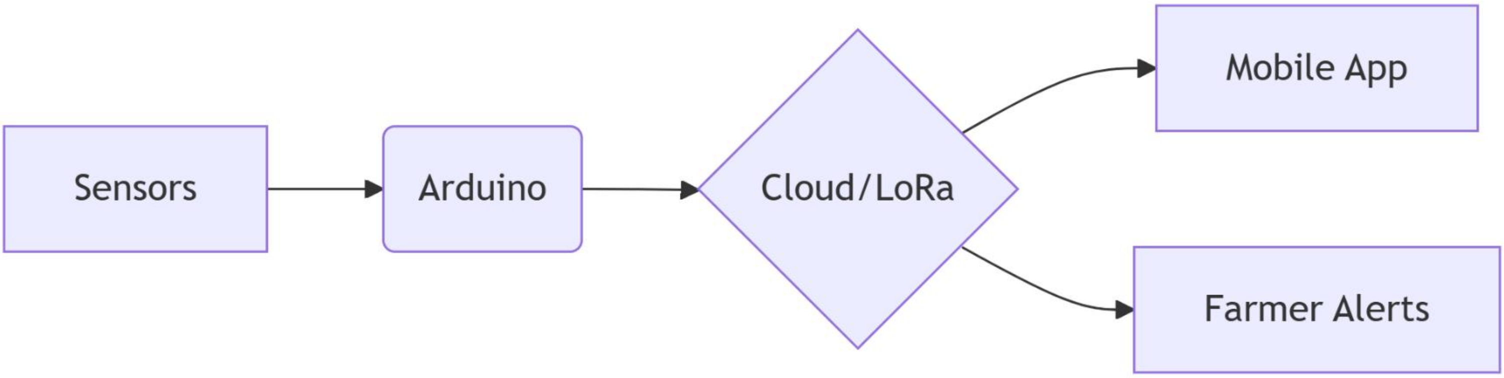


Figure II-6: Datasheet Arduino uno.

II. 9. 2 Performance Metrics

Parameter	Traditional	IoT-Arduino	Improvement
Water Use	45 L/m²/day	18 L/m²/day	60%
Yield	8 kg/m²	12 kg/m²	50%
Energy	5 kWh/day	2.3 kWh/day	54%
Labor	High	Low (automated)	Good
Climate Resilience	Low	High	Good

Table II -2: Comparison between the Performance of Traditional & using IOT.

II. 9. 3 Case Study: Implementation in Algeria

Location: University of Tebessa (semi-arid region) [14].

Results:

Reduce water consumption by 70-90%

Barley production increased by 26%

Energy saving 9% [14].

Parameter	Smart Greenhouse	Traditional Soil-Based
Yield (g)	120	95
Time to Maturity (weeks)	10	12
Average Plant Height (cm)	65	55
Total Tillers	20	15

Figure II-7: Comparison between Smart Greenhouse and traditional [20].

II. 10 Challenges and Future Directions

II. 10. 1 Implementation Barriers

➢ **Technical:**

Sensor calibration drift.

Power management in remote areas.

Data latency issues.

➢ **Socioeconomic:**

High initial investment ($15/m²).

Technical training requirements.

Cybersecurity concerns.

II. 10. 2 Emerging Technologies

- Edge AI for real-time decision making.
- Blockchain for supply chain integration.
- Digital Twins for predictive modeling.
- Robotics for automated harvesting.

II. 11 Conclusion

The integration of IoT technologies provide cost-effective and scalable solutions for smart greenhouses and transformative improvements for agriculture in semi-arid regions. By combining real-time monitoring, automation, and renewable energy, these systems provide several benefits, the most important of which are:

- Careful management of resources (water, energy, nutrients).
- Enhancing crop productivity by improving microclimates.
- Climate adaptability in the face of extreme weather patterns [15].

Future developments in artificial intelligence, robotics, and renewable energy integration will further enhance the capabilities of smart greenhouse systems, making them indispensable for sustainable agriculture in water-scarce regions such as semi-arid regions.

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Chapter III:

Hardware, Software
&
Development Environment

Chapter III : Hardware, Software & Development Environment

III. 1 Introduction

This chapter details the hardware architecture and software framework of the IoT-based smart greenhouse system. The system integrates Arduino-based sensors, actuators, and cloud connectivity to enable automated monitoring and control of environmental parameters. The design focuses on real-time data acquisition, energy efficiency, and scalability.

III. 2 Hardware Components

In this section, we will discuss in detail the hardware components used in the project. We will give an illustrative description of each component and its particular functions. The hardware components used in the project are as follows:

III. 2. 1 Core Controller: Arduino Uno

The Arduino Uno is an open-source microcontroller development board widely regarded as the flagship model in the Arduino ecosystem. Designed for ease of use, flexibility, and accessibility, it serves as an ideal platform for beginners, hobbyists, and professionals in electronics, robotics, and embedded systems [12].

III. 2.1.a) Technical Specifications:

- **Microcontroller:** ATmega328P (8-bit AVR architecture).
- **Operating Voltage:** 5V (regulated from input supply).
- **Recommended Input Voltage:** 7–12V (via DC barrel jack or Vin pin).
- **Analog Input Pins:** 6.
- **Digital I/O Pins:** 14 (with 6 capable of Pulse-Width Modulation (PWM) for analog-like output).
- **DC Current per I/O Pin:** 20 mA (40 mA max, but not recommended for prolonged use).
- **Flash Memory:** 32 KB (0.5 KB used by bootloader).
- **SRAM (Dynamic Memory):** 2 KB (for variable storage during execution).

- **EEPROM (Non-volatile Memory):** 1 KB (for storing data after power-off).
- **Clock Speed:** 16 MHz
- **USB Connection:** For programming and power (via USB Type-B).
- **Communication Protocols:** UART (Serial) – Via USB or pins 0 (RX) and 1 (TX).
- **Power Pins:**
  5V – Regulated output for external components.
  3.3V – Limited current (150 mA max).
  GND – Ground connections.
  Vin – Raw input voltage (if not using USB).
- **Reset Button:** Manually restarts the microcontroller.
- **ICSP (In-Circuit Serial Programming) Header:** Allows direct flashing of the ATmega328P without the bootloader.

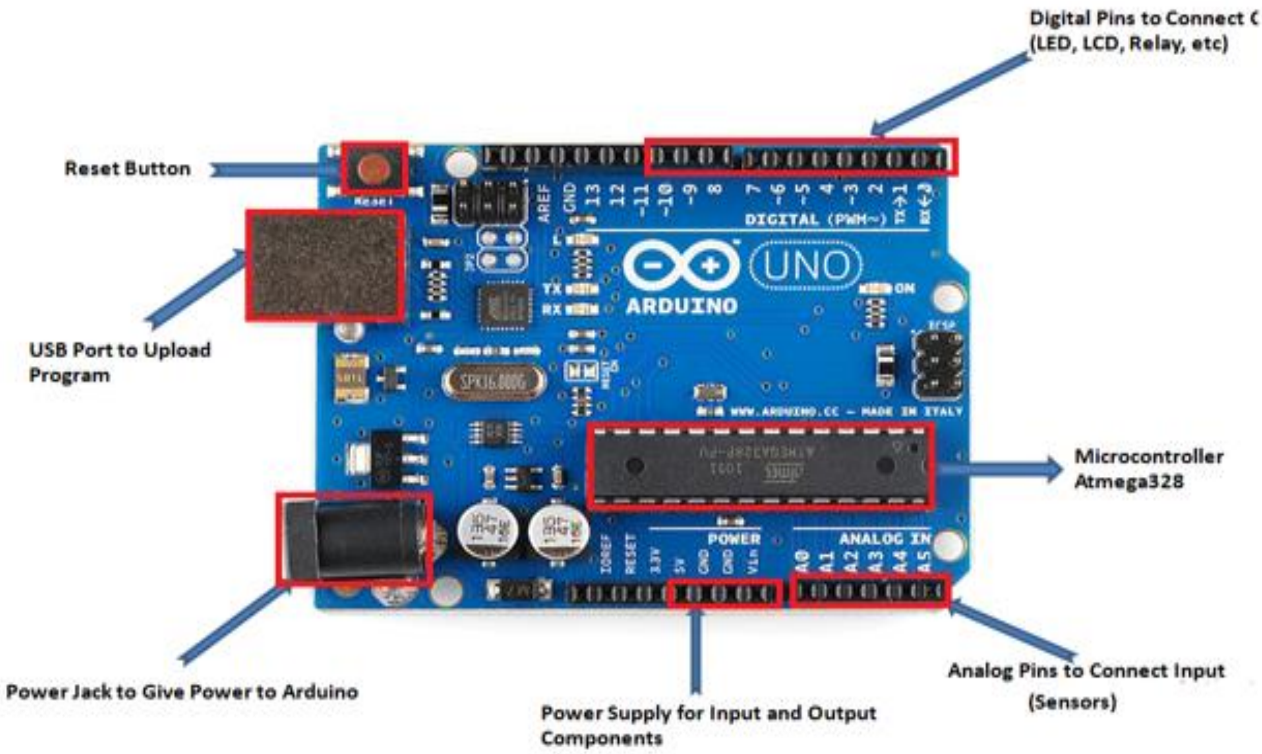


Figure III-1: Diagram of Arduino Uno [17].

III. 2. 2 The Different Types of Sensors

III. 2.2.1 OUTDOOR SENSORS

III.2.2.1.a) Light Sensor:

➢ **Definition:**

The GL-5528 is a light-dependent resistor (LDR) or photoresistor commonly used to detect light intensity in electronic circuits. It changes its resistance based on the amount of light it receives, making it useful for light-sensing applications like automatic night lights, solar trackers, and brightness control systems [16].

➢ **How the GL-5528 Works:**

The GL-5528 changes its resistance based on light intensity:

Bright light → Low resistance (~1kΩ to 10kΩ)

Darkness → High resistance (~100kΩ to 1MΩ or more)

Often It is commonly used in light-sensing projects like automatic night lights, solar trackers, etc.

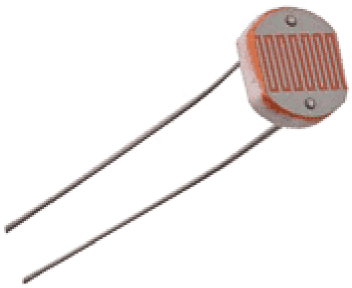


Figure III-2: GL-5528 Sensor [21].

III.2.2.1.b) Rain Sensor:

➢ **Definition:**

The YL-83 is a rain detection sensor module commonly used in Arduino and other microcontroller-based projects to detect rainfall or water presence. It consists of a conductive sensing pad that reacts to water and a control board with a comparator circuit for digital and analog output.

- **Key Features of YL-83:**

- ***Rain Sensing Pad:***

A PCB with exposed copper traces that change resistance when water droplets bridge them. More water → Lower resistance → Higher conductivity.

- ***Analog & Digital Output:***

Analog Output (A0): Provides variable voltage (0V–5V) depending on water intensity.
Digital Output (D0): Gives a HIGH/LOW signal based on a threshold (adjustable via potentiometer).

- ***Adjustable Sensitivity:***

A built-in potentiometer allows setting the threshold for the digital output.

- ***LED Indicators:***

Power LED (Red): Indicates module is powered.
Digital Trigger LED (Green): Lights up when rain exceeds the set threshold.

- ***Operating Voltage:***

Typically, 3.3V–5V (compatible with Arduino, ESP8266, ESP32, etc.).

- **How the YL-83 Works:**

- ***When no water is detected:***

The sensor has high resistance → Analog output near 5V (1023 in Arduino).
Digital output remains LOW (0V).

- ***When water is detected:***

Resistance decreases → Analog output drops (e.g., 2V = ~400 in Arduino).
If the signal crosses the threshold → Digital output goes HIGH (5V).

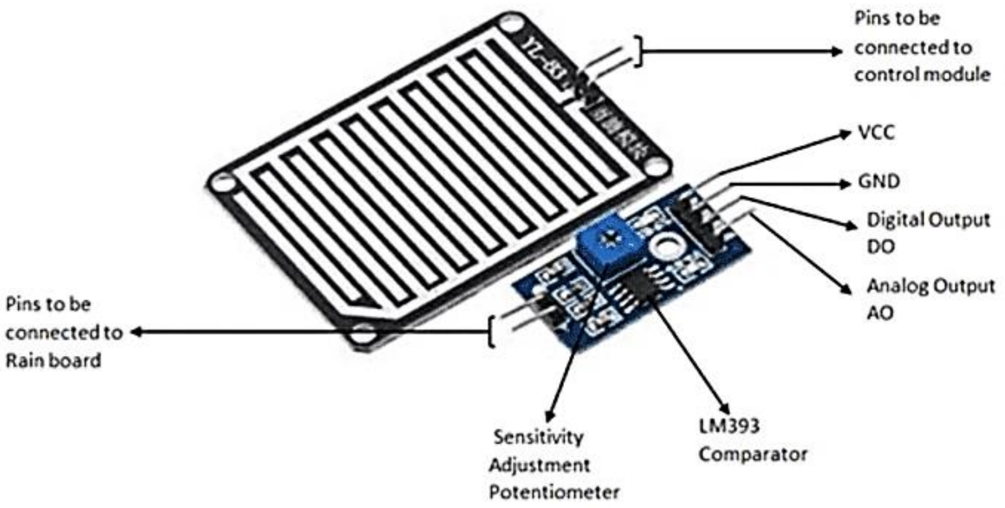


Figure III-3: Yl-83 Rain Detector [22].

III. 2.2.2 INDOOR SENSORS

III.2.2.2.a) Temperature/Humidity Sensor:

➢ **Definition:**

The DHT22 (also known as AM2302) is a low-cost, digital humidity and temperature sensor widely used in electronics projects, IoT applications, and environmental monitoring systems [17]. It provides high-precision measurements and communicates via a single-wire digital signal, making it easy to interface with microcontrollers like Arduino, ESP8266, ESP32, and Raspberry Pi.

➢ **Key Features of DHT22:**

- ***Measures:***

Temperature range: -40°C to 80°C (±0.5°C accuracy).

Humidity range: 0% to 100% RH (±2% accuracy).

- ***Digital output (uses a single-wire serial interface).***
- ***Low power consumption.***
- ***Long-term stability.***
- ***Interchangeability (no calibration needed).***

➢ **How the DHT22 Works:**

The DHT22 consists of:

A capacitive humidity sensor (measures humidity via moisture absorption).

A thermistor (measures temperature).

An onboard microcontroller (converts analog signals to digital).

Figure III-4: DHT22 Sensor [23].

III.2.2.2.b) Air Quality Sensor:

➢ **Definition:**

The MQ-135 is a semiconductor-based gas sensor designed to detect air quality and hazardous gases such as [18]:

- Ammonia (NH_3).
- Nitrogen oxides (NO_x).
- Carbon dioxide (CO_2).
- Benzene (C_6H_6).

- Smoke & other harmful volatile organic compounds (VOCs).

It is widely used in air quality monitoring systems, pollution detectors, and smart home devices.

➢ **Key Features & Specifications of MQ-135:**

Table III -1: Basic Parameters of MQ-135 Sensor.

Parameter	Details
Detection Range	10–1000 ppm (depends on gas type)
Operating Voltage	5V DC
Heater Consumption	~800 mW
Output Signal	Analog (0–5V) & Digital (TTL)
Preheat Time	≥24 hours (for stable readings)
Response Time	<10 sec (to detect gas presence)
Operating Temp	-10°C to 50°C
Humidity Range	≤95% RH (non-condensing)

➢ **How the MQ-135 Works:**

Uses a tin dioxide (SnO_2) semiconductor layer that changes resistance when exposed to gases.

A heating element inside the sensor improves sensitivity.

Outputs an analog voltage (higher voltage = higher gas concentration)

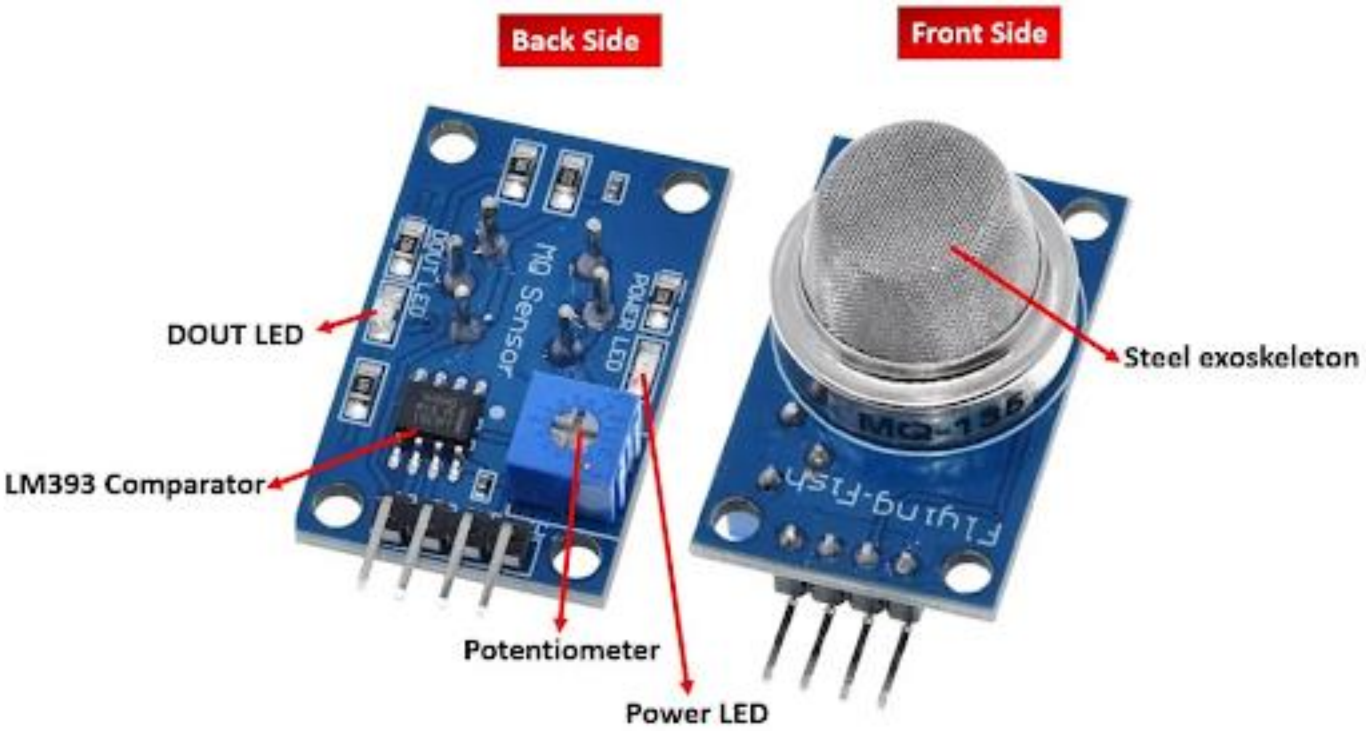


Figure III-5: MQ-135 Sensor [24].

III.2.2.2.c) Soil Moisture Sensor:

➢ **Definition:**

The FC-28 Soil Moisture Sensor is an electronic device designed to measure the volumetric water content in soil. It is widely used in precision agriculture, smart irrigation systems, greenhouse monitoring, and IoT-based farming applications. The sensor helps automate watering systems by detecting soil moisture levels and trigger watering when needed, providing real-time feedback to microcontrollers like Arduino, ESP8266.

➢ **Key Features of FC-28:**

- ***Dual Output Modes:***

Analog Output (AO): Provides a continuous voltage signal (0–5V or 0–3.3V) proportional to soil moisture, Ideal for precise moisture monitoring.

Digital Output (DO): Outputs HIGH/LOW based on a user-adjustable threshold (set via potentiometer), Useful for simple on/off control (e.g., triggering a water pump).

- ***Corrosion-Resistant Probes:***

Nickel-plated electrodes (in some models) to reduce oxidation.

- ***Adjustable Sensitivity:***

Includes a built-in potentiometer to set the moisture threshold for the digital output.

Allows customization for different soil types (clay, sand, loam).

- ***LM293 Comparator IC:***

Power LED (Red): Indicates module is powered.

Digital Trigger LED (Green): Lights up when rain exceeds the set threshold.

- ***Visual Indicators:***

Power LED: Confirms the sensor is active.

Digital Output LED: Lights up when moisture drops below the set threshold (dry soil).

➢ **How the FC-28 Works:**

The FC-28 operates on the principle of electrical conductivity:

Dry Soil: Poor conductivity → High resistance → Higher output voltage.

Wet Soil: Better conductivity → Low resistance → Lower output voltage.

- ***Analog Mode (Precise Measurement):***

The sensor outputs an analog voltage (0–5V or 0–3.3V) inversely proportional to soil moisture.

A microcontroller (e.g., Arduino) reads this value via an ADC (Analog-to-Digital Converter).

Example:

0–300 (Wet Soil).

300–700 (Moist Soil).

700–1023 (Dry Soil). (Values may vary based on soil type)

- ***Digital Mode (Threshold-Based Detection):***

The LM293 comparator compares soil moisture against a preset threshold (adjusted via the potentiometer).

Outputs HIGH (3.3V/5V) when dry (below threshold).

Outputs LOW (0V) when wet (above threshold).

Useful for simple on/off control (e.g., triggering a water pump).

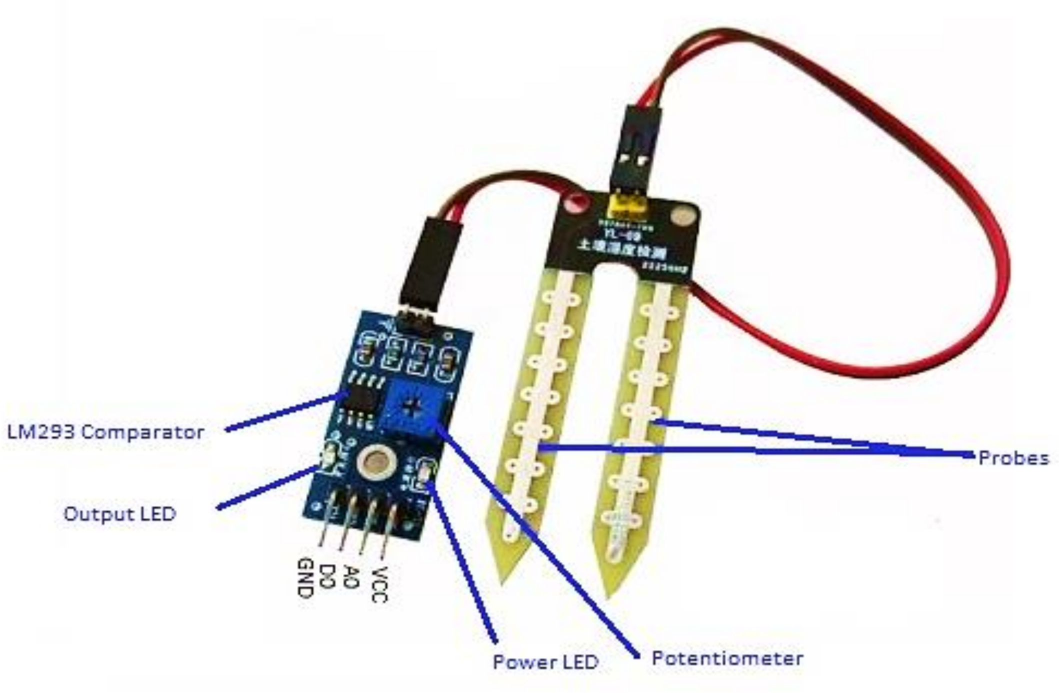


Figure III-6: FC-28 Sensor [25].

III.2.2.2.d) Flame Sensor:

➢ **Definition:**

A flame sensor is an electronic or optical device designed to detect the presence of a flame or fire by monitoring specific physical and chemical properties associated with combustion. These sensors are critical in fire detection, industrial safety, and automated control systems, ensuring rapid response to potential fire hazards [19].

➢ **Key Features of Flame Sensor:**

- ***Detection Range:*** 1–30 meters (adjustable sensitivity).
- ***Response Time:*** <500 ms (millisecond-level reaction for critical safety systems).
- ***Outputs:***

Digital (TTL, HIGH/LOW) for microcontrollers (Arduino, PLCs).

Analog (0–5V) for flame intensity measurement.

Relay (industrial shutdown/alarm triggering).

- ***False Alarm Mitigation:***

Rejects sunlight, hot objects, and steady IR sources.

- ***Environmental Robustness:***

Operates in -40°C to 85°C (industrial-grade models).

IP65/IP67 options for dust/water resistance.

➢ **How the Flame Sensor:**

- ***IR Radiation Detection:***

When a flame burns, it emits IR waves (2.7–4.3 μm).

The sensor's photodiode (or pyroelectric sensor) captures this radiation.

- ***Signal Filtering & Amplification:***

An optical bandpass filter blocks non-flame IR (e.g., from sunlight).

The weak signal is amplified for further processing.

- ***Flicker Frequency Analysis:***

Flames flicker at 1–20 Hz due to turbulence.

The sensor's MCU/comparator checks if the signal matches this pattern to avoid false alarms.

- ***Output Trigger:***

If a flame is confirmed, the sensor sends:

Digital output (e.g., HIGH signal for Arduino).

Analog output (voltage proportional to flame intensity).

Relay activation (for alarms/suppression systems).

Figure III-7: FC-28 Sensor [26].

III. 2. 3 Display: LCD I2C 16×4

➢ **Definition:**

An LCD I2C 16×4 is a liquid crystal display (LCD) module that combines a 16-column by 4-row character-based screen with an I2C (Inter-Integrated Circuit) interface module, significantly simplifying its integration with microcontrollers and embedded systems.

➢ **Core Components & Structure:**

- ***The LCD Display (16×4 Character LCD):***

Display Type: Alphanumeric LCD with a 16×4 character grid (64 total characters).

Controller: Typically uses the Hitachi HD44780 (or compatible) driver, which manages character generation and display control.

Character Set: Supports ASCII characters, custom symbols.

Backlight: Usually LED-based (blue, green, or white).

- ***The I2C Interface Module (Backpack/Adapter):***

Primary Chip: Often a PCF8574 (or PCF8574A) I/O expander, converting I2C signals to parallel LCD control

➢ **Key Features of LCD Display:**

Reduces required connections from 6+ pins (in parallel LCDs) to just 2 (SDA & SCL).

Analog & Digital Output.

➢ **How The LCD I2C 16×4 Works:**

- ***Communication Protocol (I2C):***

I2C (I²C): A two-wire serial protocol (SDA = data line, SCL = clock line).

Addressing: Each I2C device has a unique address (e.g., 0x27), Multiple LCDs can be used by changing addresses.

Data Transmission: Sends commands (e.g., clear screen) and text data via I2C, which the backpack converts to parallel signals for the LCD.

- ***Power Requirements:***

Voltage: Typically, 5V (some variants work at 3.3V).

Current: ~20mA (backlight may consume extra power).

Figure III-8: LCD I2C 16×4 [27].

III. 2. 4 The Different Actuator

III. 2.4.1 FAN

- **Definition:**

A fan is an electrically powered cooling device designed to operate on 12 volts DC (Direct Current), commonly used for ventilation, cooling, and airflow management in electronics, computers, automotive systems, and industrial applications.

- **Key Parts of a Fan:**

Blades/Impeller – Rotates to move air (typically 3-9 blades).

Motor – A brushless DC (BLDC) motor for efficient, long-lasting operation.

Frame/Housing – Holds components together (plastic or metal).

Bearings – Reduce friction (sleeve, ball, or fluid dynamic bearings).

Wiring – Usually 2-wire (+, -) or 3-wire (+, -, RPM sensor).

➢ **How It Fan Works:**

- ***Power Supply:***

Runs on 12V DC (from batteries, adapters, or PC power supplies).

- ***Speed Control:***

Voltage Control: Lower voltage = slower speed

PWM Control: Uses a digital signal for precise speed adjustment.

- ***Airflow Direction:***

Intake (Pulling air in): Often used for cooling components.

Exhaust (Pushing air out): Used for heat dissipation.

Figure III-9: Fan 12v [28].

III. 2.4.2 WATER PUMP

➢ **Definition:**

A water pump is a small, electrically powered device designed to move liquids (typically water) using 5 volts DC (Direct Current). These pumps are commonly used in DIY projects, aquariums, cooling systems, and automated irrigation due to their compact size, low power consumption, and compatibility with microcontrollers like Arduino, Raspberry Pi, and ESP boards [20].

- **Key Parts of Water Pump:**

Motor – A DC motor (often brushless) that drives the impeller.

Impeller – Rotates to create water flow (plastic or metal blades).

Housing – Contains the motor and water channels (usually plastic).

Inlet & Outlet – Tubes or nozzles for water intake and discharge.

Wiring – Typically 2 wires (Red: +5V, Black: Ground).

Useful for simple on/off control (e.g., triggering a water pump).

- **How It Water Pump Works:**

- ***Power Supply:***

Runs on 5V DC (USB power, battery, or microcontroller).

- ***Flow Mechanism:***

Centrifugal force (submersible pumps) or diaphragm action (peristaltic pumps).

- ***Control Options:***

On/Off Switching – Simple power control.
PWM (Pulse Width Modulation) – Adjusts speed for variable flow.

Figure III-10: Water Pump [29]

III. 2.4.3 SERVO MOTOR

➤ **Definition:**

The MG90S is a compact, high-performance amateur servo motor that represents a major development in compact motion control technology. As part of the popular MG (Metal Gear) series, this servo combines robust construction with precise positioning capabilities, making it one of the most widely used servos in the manufacturer community and applications for robotics, remote-controlled vehicles and electronics that are manufactured in-house.

➤ **Key Parts of Servo Motor MG90s:**

- Case - Plastic shell with mounting ears.
- DC Motor - Brushed 3-pole motor (6V max).
- Metal Gears - 3-stage reduction.
- Potentiometer - 5kΩ position sensor.
- Control Board - Processes PWM signals.
- Output Shaft - 25T spline with bearings.
- Wires - Power (red), Ground (brown), Signal (orange).

➤ **How It Servo Motor MG90s Works:**

- PWM Signal Input → Control board receives pulse width (1ms–2ms).
- Position Comparison → Potentiometer reports current angle.
- Error Correction → Control IC adjusts motor direction/speed.
- Gear Reduction → Motor torque is amplified 60x via metal gears.
- Output Shaft Movement → Moves to desired angle (0°–180°).

Figure III-11: Servo Motor MG90s [30].

III. 2.4.4 DRIVER MOTOR

- **Definition:**

The PCA9685 is a sophisticated and cost-effective 16-channel, 12-bit PWM (Pulse Width Modulation) controller designed to drive servomotors, LEDs and DC motors over an I²C connection. It acts as an intermediate drive, allowing microcontrollers (such as the Arduino or Raspberry Pi) to control multiple motors/servos with minimal wiring [21].

- **Key Parts of a PCA9685:**

16 Independent PWM Outputs – Controls up to 16 servos or motors.

12-bit Resolution – Allows 4096 PWM steps (for precise positioning).

I²C Interface – Works with 3.3V & 5V logic (addressable 0x40-0x7F).

Adjustable Frequency – 40Hz to 1000Hz (default 50Hz for servos).

External Power Support – Can power motors separately (2.3V–5.5V logic, 5V–6V servo power).

- **How It Fan PCA9685:**

Microcontroller sends commands via I²C (SDA/SCL pins).

PCA9685 generates PWM signals on selected channels.

PWM signals control motors/servos (e.g., 1-2ms pulses for servos).

External power supply drives motors (avoiding MCU power limits).

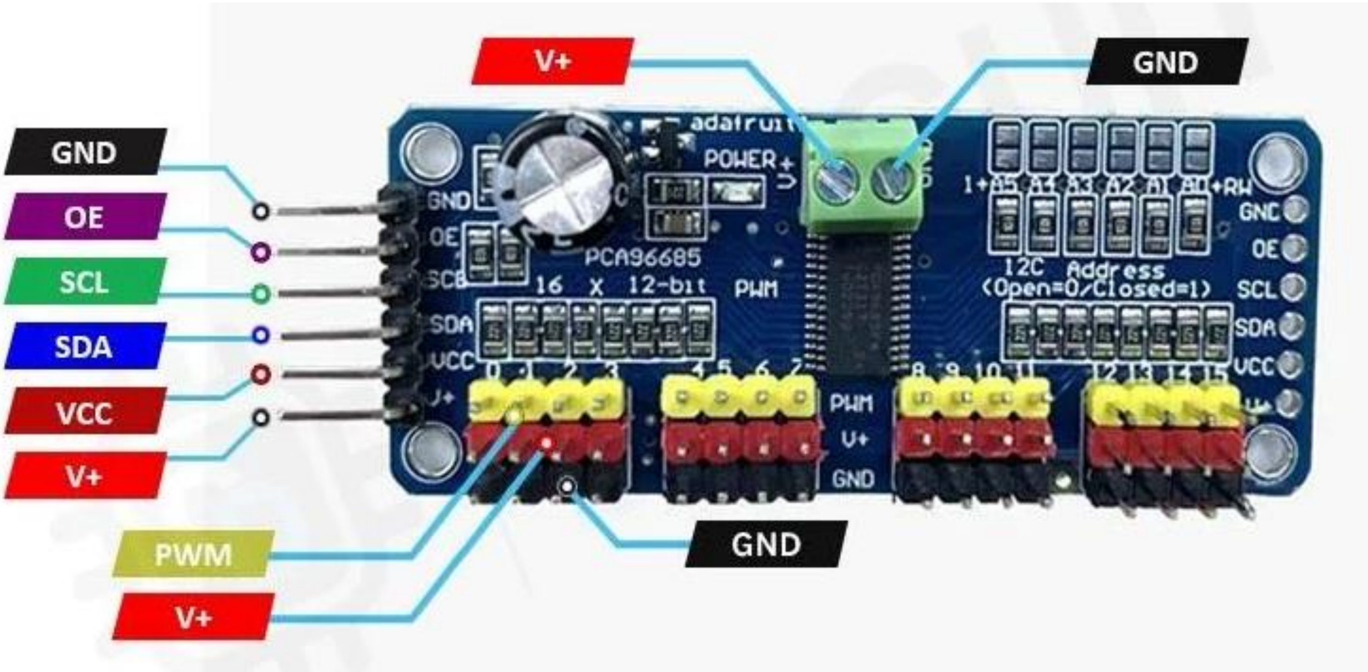


Figure III-12: Driver Motor PCA9685 [31].

III. 2.4.5 STEPPER MOTOR

➢ **Definition:**

The 28BYJ-48 is a small, cost-effective monopole stepper motor that has become ubiquitous in hobbyist electronics and small-scale automation applications. This engine's unique combination of compact 5V DC powertrain, integrated internal gear reduction system and simple control interface makes it particularly suitable for educational projects, prototyping and low-torque precision motion applications [22].

➢ **Key Parts of 28BYJ-48 Stepper Motor:**

- Type: Unipolar (5-wire).
- Voltage: 5V DC.
- Step Angle: 5.625° per step (64 steps/revolution).
- Gear Ratio: 1:64 (4096 total steps per output revolution).
- Speed: ~15 RPM (no load).
- Torque: ~30 gf.cm (varies with voltage).
- Wiring: 5 wires (color-coded for driver boards).
- Requires a driver board (like ULN2003) and PWM signals for precise step-by-step movement.
- Example Arduino code available for precise positioning.

- **How It 28BYJ-48 Stepper Motor Works:**

- ***Driver IC:***

ULN2003 (or similar Darlington array).

- ***Step Modes:***

Full-Step (64 steps/rev, higher torque).

Half-Step (128 steps/rev, smoother motion).

Wave Drive (Single-coil, lower power).

- ***Microcontroller Compatibility:***

Arduino (Stepper.h or AccelStepper.h libraries).

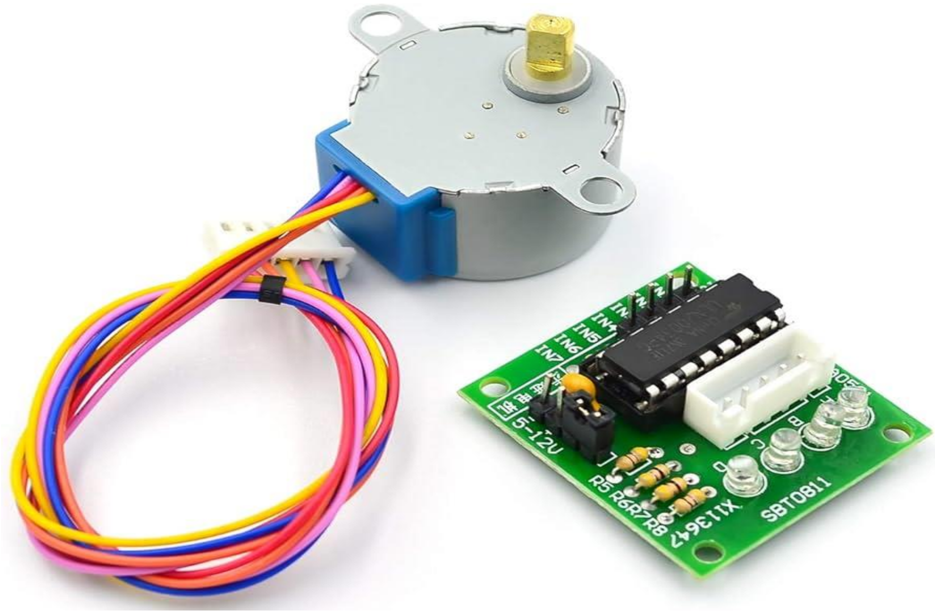


Figure III-13: Stepper Motor 28BYJ-48 [32].

III. 2.4.6 RELAY

- **Definition:**

Relay modules are devices that can switch high voltage or high current devices on and off using a 5V signal from Arduino. They can be used to control devices such as lights, fans, motors, solenoids, etc. relay has three high voltage terminals (NC, C, and NO) which connect to the device you want to control. The other side has three low voltage pins (Ground, Vcc, and Signal) which connect to the Arduino [23].

➢ Key Parts of Relay

- Circuit Isolation – Galvanic separation for safety and noise reduction.
- Signal Amplification – Control high-power devices with microcontrollers (Arduino, PLCs).
- AC/DC Switching – Compatible with both alternating and direct current systems.
- Fail-Safe Modes – Normally Open (NO) / Normally Closed (NC) configurations.
- Durability – Long operational lifespan (SSR: 1M+ cycles; EMR: 50k+ cycles).
- Fast Response Time – SSR: Microsecond switching; EMR: Millisecond precision.

➢ How It Relay Works:

- ***Energizing the Coil:*** When a small voltage is applied to the relay's coil, it generates a magnetic field.
- ***Magnetic Attraction:*** This magnetic field attracts a movable armature, which is attached to the coil.
- ***Contact Switching:***

The movement of the armature either makes or breaks a connection with the electrical contacts. In a normally open (NO) relay, the circuit is open until the relay is activated. In a normally closed (NC) relay, the circuit is closed until the relay is activated.

- ***Circuit Control:***

This mechanical movement allows the relay to control the connected circuit by opening or closing the contacts, thereby managing the flow of current.

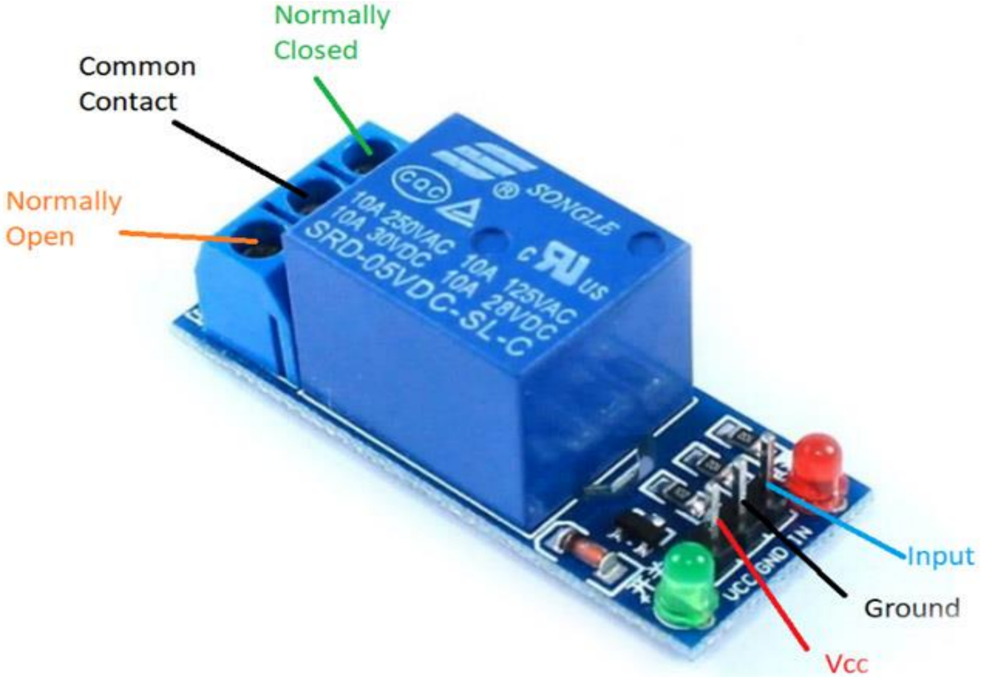


Figure III-14: Relay [33].

III. 2.4.7 ARTIFICIAL LIGHT

- **Definition:**

Artificial light allows controlled lighting, providing an optimal environment for plant growth throughout the year, despite climatic or even seasonal conditions. This is a technology that allows light spectra to be tailored to the needs of different plants, promoting their growth and increasing crop yields. In addition, artificial light helps reduce dependence on natural conditions that may be unexpected or inappropriate.

Figure III-15: Artificial light [34].

III. 2. 5 Communication Part

III. 2.5.1 ESP 32

- **Definition:**

The ESP32 is a highly integrated, low-power, 2.4 GHz Wi-Fi and Bluetooth combo microcontroller unit (MCU) developed by Shanghai-based Espressif Systems [23]. As the successor to the popular ESP8266, this system-on-chip (SoC) solution has become a dominant force in IoT development due to its exceptional combination of wireless connectivity, processing power, and peripheral integration [24

➢ Core Components of ESP32:

- ***Dual-Core Xtensa LX6 CPU (up to 240 MHz):***

Can run FreeRTOS for multitasking.

- ***Wireless Connectivity:***

Wi-Fi (802.11 b/g/n) – Supports both station (client) and access point (AP) modes.

Bluetooth (BLE 4.2 + Classic).

- ***Memory:***

520KB SRAM (for runtime data).

4MB–16MB Flash (for storing programs).

- ***Peripherals:***

GPIO (General-Purpose Input/Output) pins for sensors, LEDs, etc.

ADC (Analog-to-Digital Converter) for reading analog sensors.

DAC (Digital-to-Analog Converter).

UART, I2C, SPI, PWM, CAN, and more for communication.

Touch sensors (capacitive sensing).

Hall effect sensor (detects magnetic fields).

➢ How It ESP32 Works:

- ***Power On:***

When powered, the ESP32 runs the bootloader from flash memory, which loads the main firmware.

- ***Program Execution:***

The firmware (written in C/C++ with Arduino, ESP-IDF, or MicroPython) controls the chip's operations.

- ***Wireless Communication:***

Wi-Fi: Connects to a network or acts as an access point.

Bluetooth: Enables BLE (Bluetooth Low Energy) or classic Bluetooth for device pairing.

- ***Peripheral Interaction:***

Reads sensors (via I2C/SPI/ADC), controls motors (PWM), and communicates with other devices (UART, CAN)

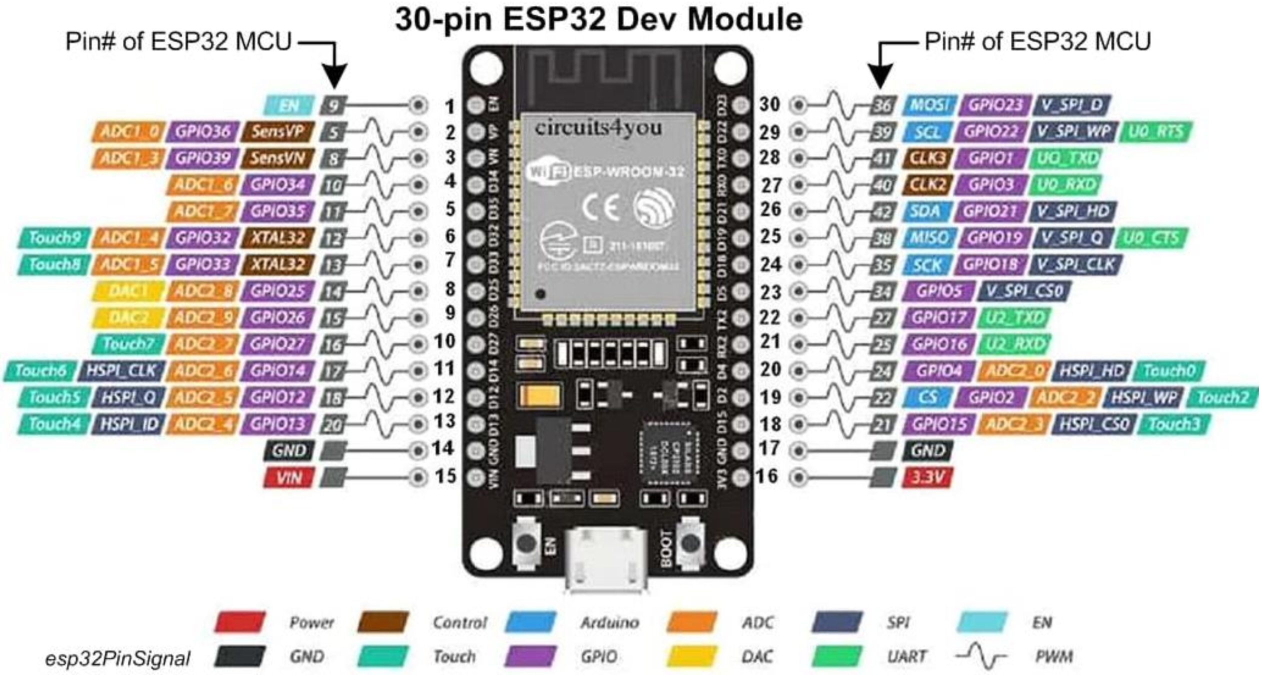


Figure III-16: ESP32 Datasheet [34].

III. 2.5.2 LORA

➢ **Definition:**

LoRa (Long Range) is a low-power, wide-area networking (LPWAN) technology designed for long-range wireless communication with minimal power consumption. It operates in sub-GHz license-free bands (e.g., 433 MHz, 868 MHz in Europe, 915 MHz in North America) and is ideal for IoT (Internet of Things) applications where devices need to transmit small amounts of data over several kilometers.

➢ **Key Features of LORA:**

- ***Long Range:*** Can transmit data up to 10+ km (line-of-sight) and 3–5 km in urban areas.
- ***Low Power:*** Optimized for battery-operated devices (years of operation).
- ***Low Data Rate:*** Suitable for small, intermittent data packets (e.g., sensor readings).
- ***License-Free:*** Uses ISM (Industrial, Scientific, Medical) bands

- **How It LORA Works:**

LoRa is a form of lower power wide area network and works by using radio frequencies. LoRa sends information via radio waves and through chirp spread spectrum modulation or CSS. A chirp spread spectrum is similar to the way that bats and dolphins communicate and has a wave flow that is a linear and sinusoidal wave that can increase or decrease in frequency over time. It is on this chirp spread spectrum that information is encrypted and sent [25]

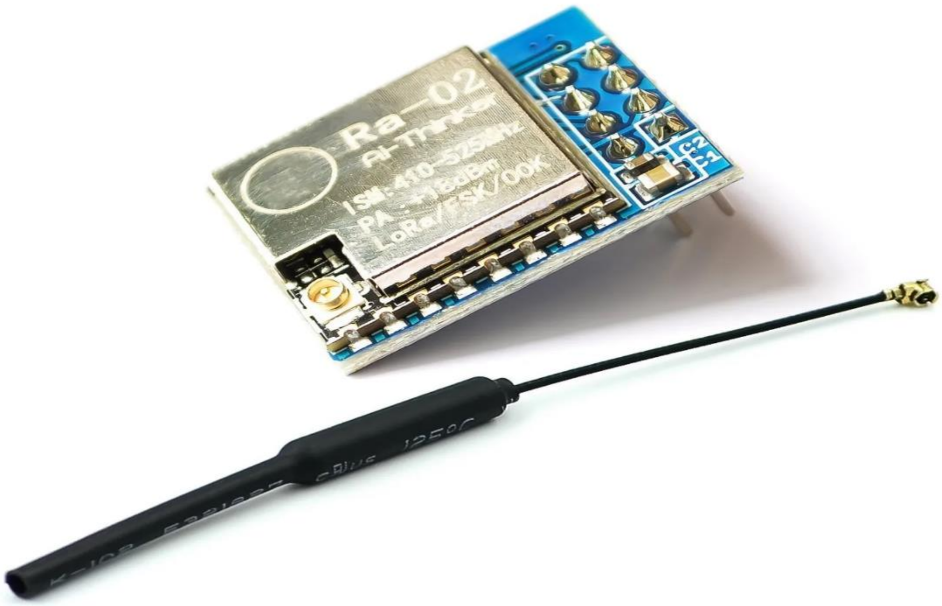


Figure III-17: lora [35].

III. 3 Software Design

III. 3. 1 The Arduino IDE

- **Definition:**

The Arduino Integrated Development Environment (IDE) is a cross-platform software application designed for writing, compiling, and uploading code to Arduino-compatible microcontroller boards (such as Arduino Uno, Nano, and ESP32). It provides a user-friendly interface for developers, hobbyists, and students to program embedded systems without requiring advanced knowledge of low-level hardware programming.

- **Key Features of Arduino IDE:**
  - ***Simplified Programming (Based on C/C++):***

Uses a simplified version of C++ with Arduino-specific libraries.

Abstracts complex microcontroller operations (e.g., register manipulation).

- ***Cross-Platform Compatibility:***

Works on Windows, macOS, and Linux.

Written in Java (runs on any OS with Java support).

- ***Built-in Library Manager:***

Supports third-party libraries (e.g., DHT.h, PubSubClient for MQTT).

Easy installation via Sketch → Include Library → Manage Libraries.

- ***Serial Monitor & Plotter:***

Serial Monitor: Displays real-time data from Arduino (debugging).

Serial Plotter: Visualizes sensor data in graphs.

- ***Board & Port Management:***

Supports multiple Arduino boards (Uno, Mega, Nano, ESP32, etc.).

Automatic detection of USB/UART ports.

- ***One-Click Compilation & Upload:***

Verify (Compile): Checks code for errors.

Upload: Transfers compiled binary to the microcontroller via USB.

➢ **Arduino IDE Workflow:**

- Write Code (. ino sketch) → Uses Arduino-specific functions (setup (), loop ()).
- Verify (Compile) → Converts code into machine-readable hex file.
- Upload → Sends the compiled code to the connected Arduino board.
- Debug → Monitors output via Serial Monitor.

Figure III-18: The Arduino IDE [36].

III. 3. 2 MQQT Explorer

III. Definition:

MQTT Explorer is an open-source, graphical user interface (GUI) tool designed for monitoring, testing, and debugging MQTT (Message Queuing Telemetry Transport) networks. It provides a user-friendly way to interact with MQTT brokers, visualize topic hierarchies, publish/subscribe to messages, and analyze IoT device communications in real time.

➢ **Key Features of MQQT Explorer:**

- ***Topic Visualization (Tree Structure):***

MQTT topics in an expandable folder-like hierarchy.

```
greenhouse/
├── sensors/
│   ├── temperature
│   └── humidity
└── actuators/
    └── pump
```

Figure III-19: Visualization of MQQT Explorer.

- ***Publish & Subscribe to Messages:***

Subscribe to topics to monitor incoming data.

Publish messages manually (JSON, plain text, or binary).

- ***Retained Message Handling:***

Views and deletes retained messages stored on the broker.

- ***Lightweight & Cross-Platform:***

Runs on Windows, macOS, and Linux.

No installation required (portable executable available).

- ***Connection Management:***

Supports MQTT 3.1.1 and MQTT 5.0.

Configurable authentication (username/password, TLS/SSL)

- ***Message History & Search:***

Logs past messages for debugging.

➢ **MQQT Explorer Workflow:**

- Connects to an MQTT Broker (e.g., Mosquitto, HiveMQ, AWS IoT Core).
- Subscribes to Topics (e.g., sensors/temperature).
- Displays Real-Time Data in a structured view.
- Publishes Test Messages (e.g., {"status": "ON"} to actuators/light).

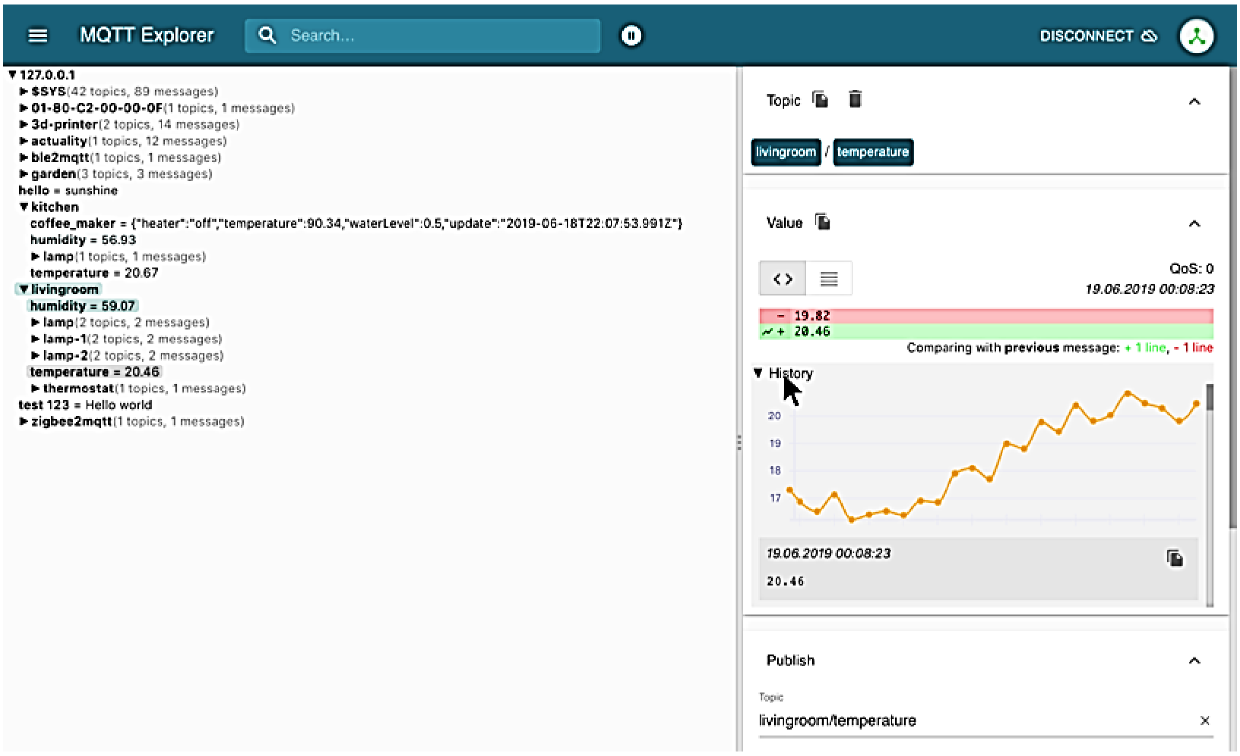


Figure III-20: MQQT Explore [37].

III. 3. 3 Blynk

➢ **Definition:**

Blynk is an IoT (Internet of Things) platform that enables users to remotely control and monitor hardware devices (like Arduino, ESP8266, Raspberry Pi) through mobile apps and web dashboards. It provides a drag-and-drop interface for creating custom UIs, real-time data visualization, and cloud-based automation without requiring advanced programming skills.

➢ **Key Features of Blynk:**

- ***Drag-and-Drop Mobile App Builder:***

Create custom IoT dashboards with widgets (buttons, sliders, graphs, notifications).

- ***Multi-Platform Support:***

Mobile Apps: iOS & Android.

Hardware Compatibility: Works with Arduino, ESP32, Raspberry Pi, and more.

- ***Cloud & Local Server Options:***

Blynk Cloud: Free for basic use (limited energy)

Blynk.Local: Self-hosted server for privacy/offline use.

- ***Automation (Blynk.Actions):***

Trigger events based on conditions (e.g., turn on a fan if temperature > 25°C).

- ***Real-Time Data Monitoring:***

Live sensor data (temperature, humidity, etc.) displayed on widgets.

Historical data logging (with Blynk.Energy or external databases).

- ***Notifications & Alerts:***

Push notifications (e.g., "Temperature exceeds 30°C!").

Email/SMS alerts (via IFTTT integration).

➢ **Blynk Workflow:**

- ***Connects to Blynk Cloud/Server:***

Uses HTTP/MQTT to link hardware (Arduino/ESP) with Blynk's infrastructure.

- ***Binds Hardware Pins to Virtual Pins (V0-V127):***

Maps physical sensors/actuators to abstract "virtual pins".

- ***Displays Real-Time Data in Mobile/Web Dashboard:***

Drag-and-drop widgets (gauges, charts) show:
Sensor values (updated via virtualWrite).
Device status (online/offline).

- ***Publishes Control Commands:***

Mobile app buttons send instructions.
Triggers hardware actions via BLYNK_WRITE callbacks.

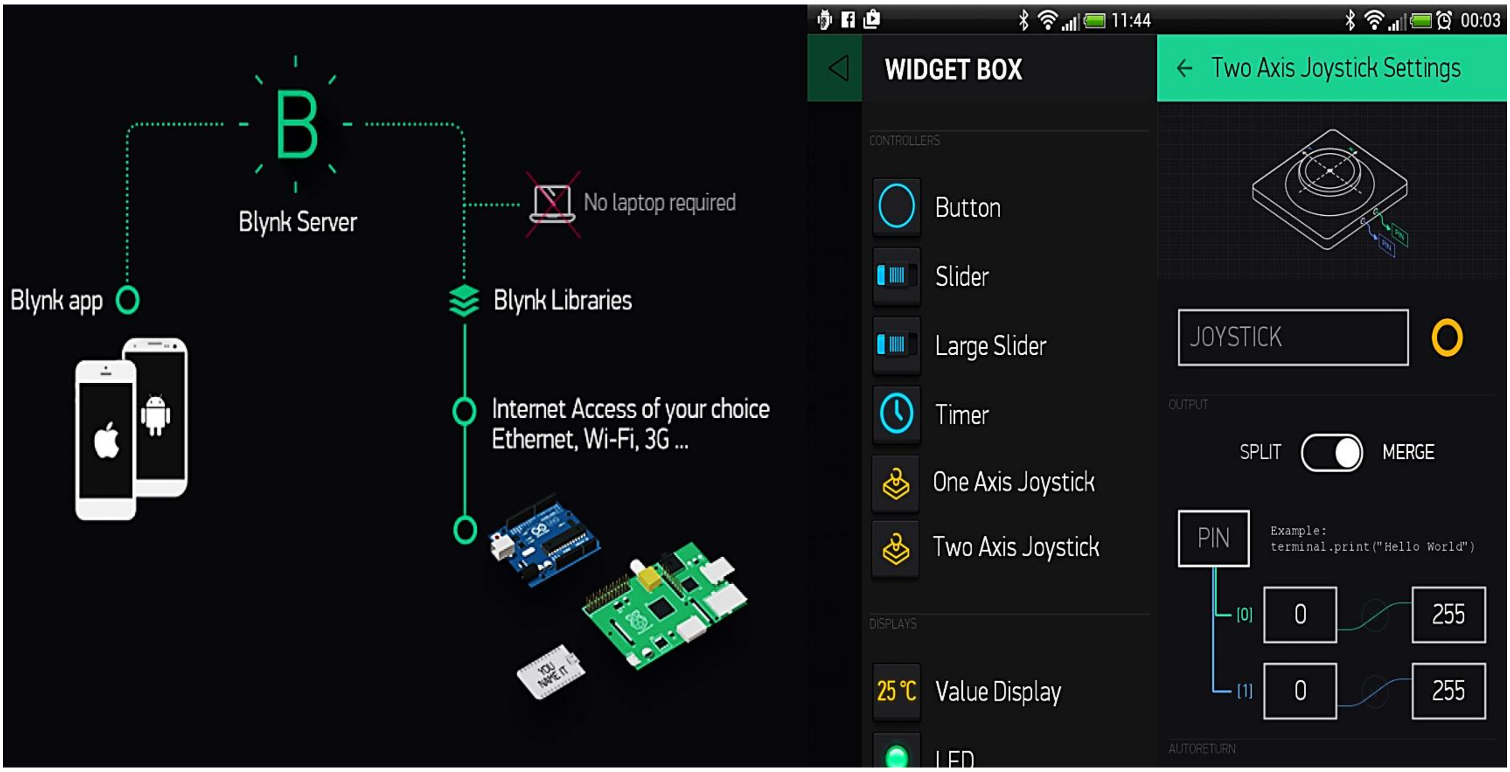


Figure III-21: Blynk [38].

III. 4 Conclusion

This chapter presented the hardware and software architecture of the smart greenhouse system based on the Internet of Things and designed for semi-arid regions. We provided a detailed explanation of the set of sensors, actuators, microcontrollers, as well as the software used, how it works, and its most prominent features in this project.

Chapter IV:

The Systems Embedded In The Prototype

Chapter IV: The Systems Embedded In the Prototype

IV. 1 Introduction

Smart agriculture is all about integrating automation and the Internet into things Agriculture and crop production. Smart greenhouses, in particular, face the following:

● The climatic conditions are harsh and constantly changing.

● Diverse agricultural requirements for different plants.

● High cost of producing greenhouses.

● Determine the type of sensors for each greenhouse.

● Create a connection for greenhouses to the Internet.

● Complex and difficult interfaces for human-system interaction.

In this project, we tried to provide solutions to these challenges as much as possible using multiple systems. This chapter provides a comprehensive background on these systems and how they work, and their components, including sensors and actuators.

IV. 2 Mounting sensors and actuators

IV. 2. 1 Cooling System:

This system ensures automatic and efficient cooling of greenhouses while displaying accurate data to farmers.

➢ **System components:**

- DHT22 sensor for thermometry.
- Arduino Uno microcontroller.
- 2 cooling fans to regulate temperature.
- LCD screen to display readings.
- Power source for operation.

➢ **How The System Working:**

The cooling system in greenhouses works using a DHT22 sensor, cooling fans (2 Fan) and an LCD screen according to the following steps:

- ***Temperature sensor:***

The DHT22 sensor reads the temperature inside greenhouses and sends the data to the Arduino Uno controller.

- ***Data processing and decision making:***

The controller checks the temperature reading:

If it is higher than 30°C: Turns on the fans (2 Fan) to reduce the temperature.

If less than or equal to 30°C: Keeps fans off.

- ***Display data on LCD screen:***

The current temperature is displayed on the LCD screen continuously to monitor environmental conditions.

- ***Automatically repeat the process:***

The system continues to monitor data and adjust the operation of fans as needed to maintain a suitable climate for plants.

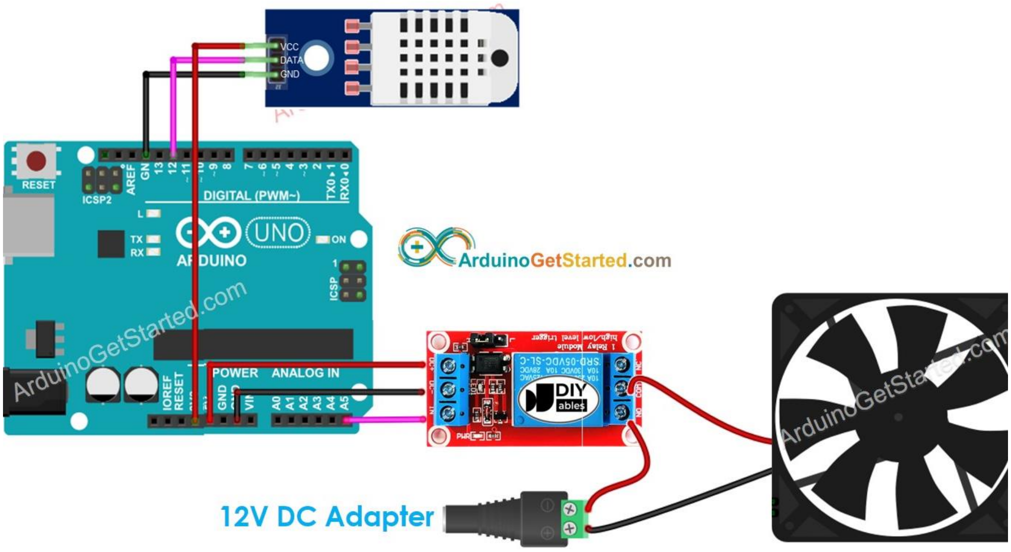


Figure IV-1: Wiring diagram [39].

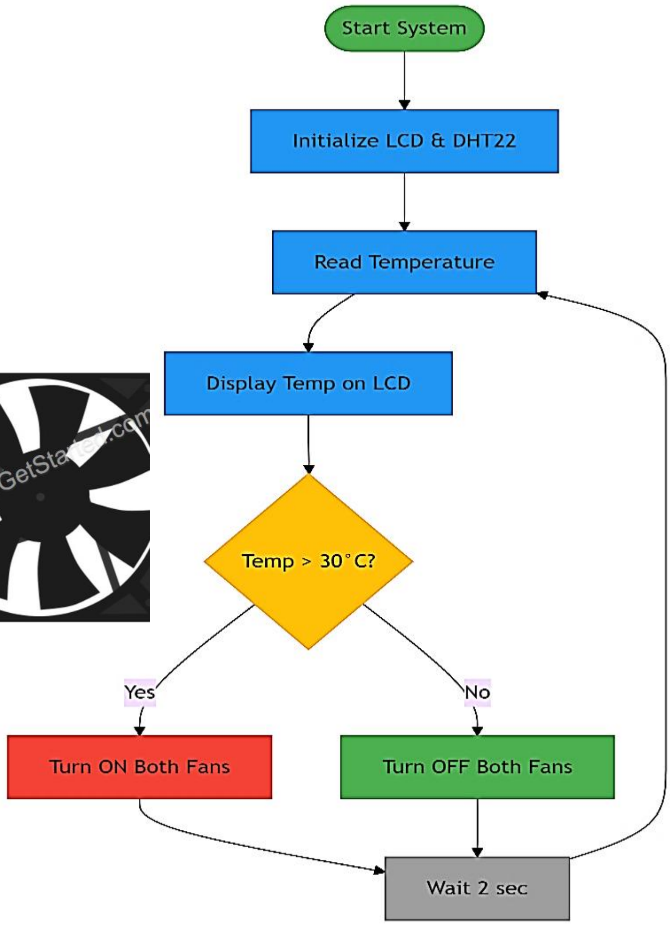


Figure IV-2: Diagram of Cooling System

IV. 2. 2 Natural Ventilation System:

This system automatically controls the windows of the greenhouse based on humidity, where a DHT22 sensor is used to measure humidity, and Servo motors are connected to the PWM Driver Motor to open and close the windows, in addition to displaying the data on the LCD screen.

➢ **System components:**

- DHT22 sensor for measuring humidity.
- Servo motor for moving greenhouse windows.
- Arduino Uno microcontroller for data processing and PWM signal transmission.
- LCD screen to display humidity.
- Power source for operation.

➢ **How The System Working:**

- ***Continuous humidity reading:***

The DHT22 sensor measures the humidity inside the greenhouse and sends the data to the Arduino Uno controller.

- ***Decision making based on humidity:***

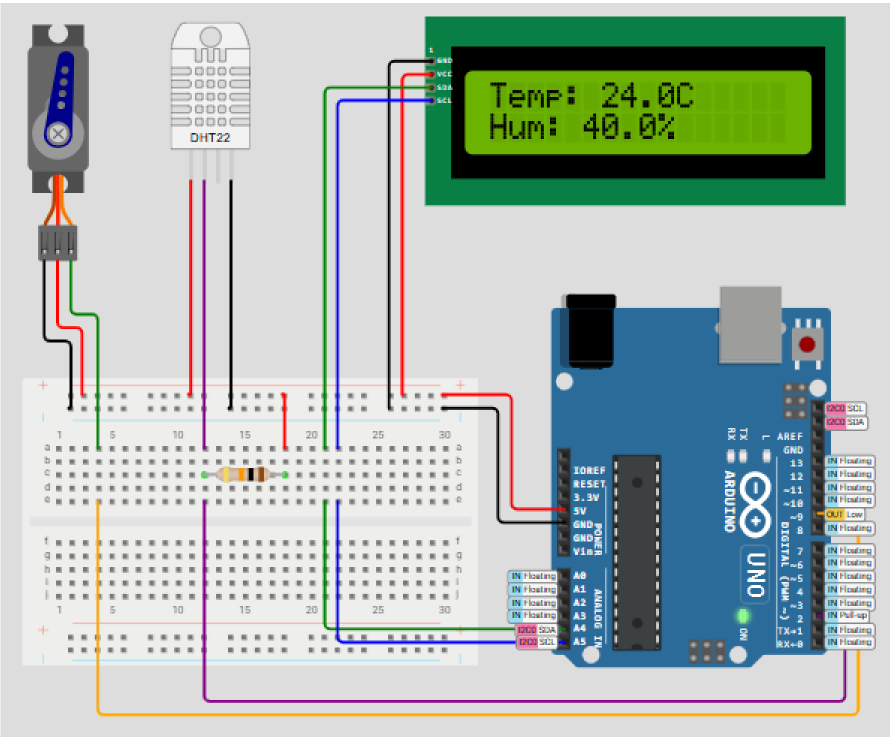
If the humidity is moderately less than the required limit:
The Servo motor stays at a 90 degree angle and the window is closed.
If the humidity rises above the permissible limit:
The Servo motor moves to a 160 degree angle with the window open to improve ventilation.

- ***Display data on LCD screen:***

The humidity level is continuously displayed on the LCD screen to monitor the environmental conditions inside the greenhouse.

- ***Automatic control via PWM signal:***

The Servo angle is controlled using the PWM signal from the controller, ensuring smooth and precise movement of the windows.



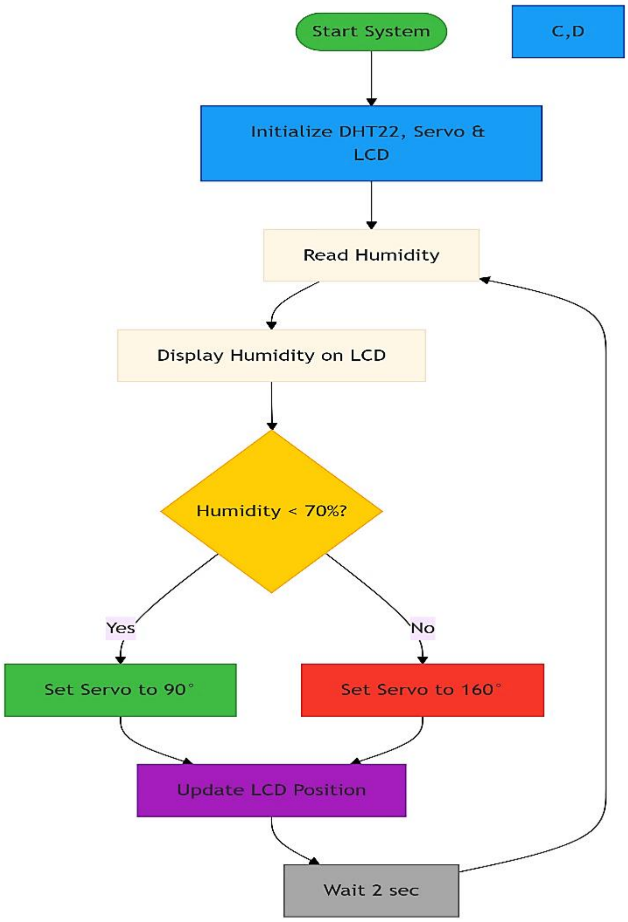


Figure IV-3: Wiring diagram [40].

Figure IV-4: Diagram of Natural Ventilation System.

IV. 2. 3 Irrigation System:

This system automatically controls the process of irrigating plants inside greenhouses based on actual soil needs.

➢ **System components:**

- Soil moisture sensor to measure soil moisture.
- Water pump for watering plants.
- Arduino microcontroller to process data and send relay signal.
- LCD screen to display soil humidity and pump status.
- Power source for operation.

➢ How The System Working:

- ***Continuous humidity reading:***

The soil moisture sensor measures the percentage of soil moisture inside the greenhouse and sends the data to the Arduino Uno controller.

- ***Decision making based on humidity:***

If the soil moisture is moderate more than the threshold:

The water pump remains off.

If soil moisture rises below the threshold:

The water pump is turned on to water the plant.

- ***Display data on LCD screen:***

The soil humidity and pump status are continuously displayed on the LCD screen to monitor the environmental conditions inside the greenhouse.

- ***Automatic control via Relay:***

The pump is controlled on and off using the Relay signal from the controller, ensuring accurate execution.

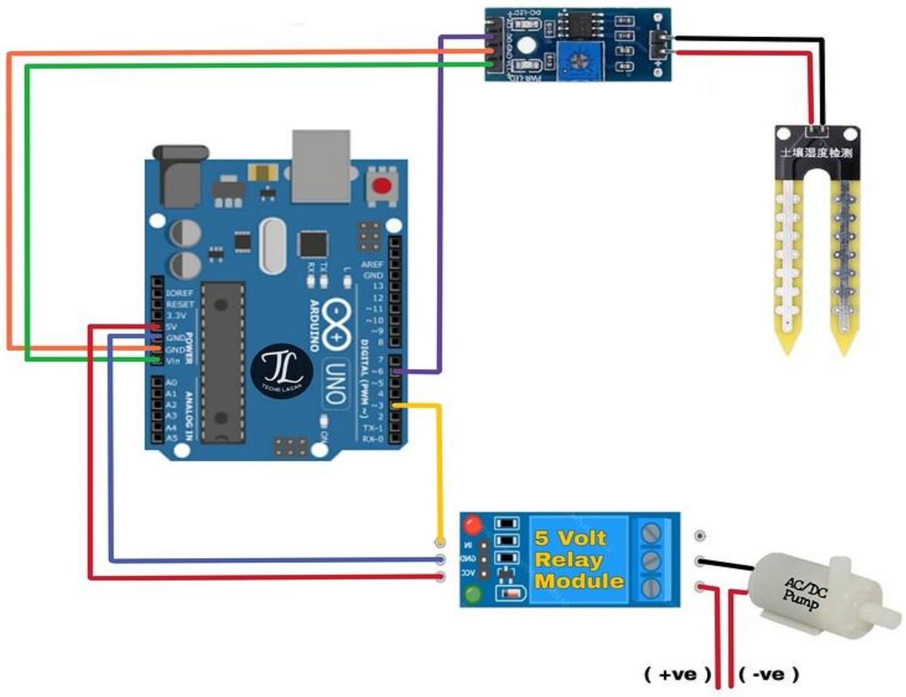


Figure IV-5: Wiring diagram [41].

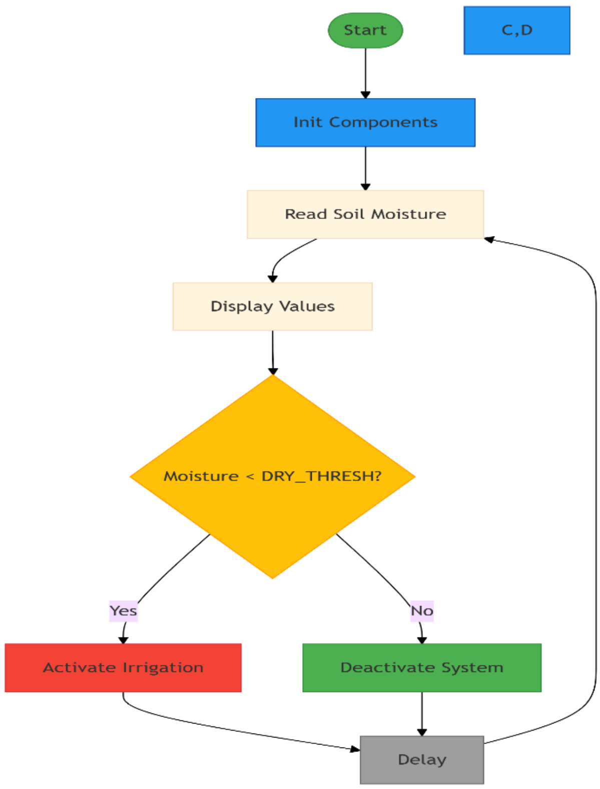


Figure IV-6: Diagram of Irrigation System.

IV. 2. 4 Lighting System:

This system automatically controls the lighting of greenhouses based on the intensity of natural light.

- **System components:**

- LDR sensor to measure light intensity.
- Artificial LED for lighting the greenhouse.
- Arduino microcontroller to process data and send relay signal.
- LCD screen to display light intensity and Artificial LED status.
- Power source for operation.

- **How The System Working:**

- ***Continuous light intensity reading:***

The LDR sensor measures the intensity of lighting inside the greenhouse and sends the data to the Arduino Uno control unit.

- ***Decision making based on lighting intensity:***

If the lighting intensity is more than the threshold:

The artificial LED remains off.

If lighting intensity drops below the threshold:

Artificial LED is operated to light the greenhouse.

- ***Display data on LCD screen:***

The lighting intensity and artificial LED status are continuously displayed on the LCD screen to monitor the environmental conditions inside the greenhouse.

- ***Automatic control via relay:***

Artificial led on and off is controlled using relay signal from controller, ensuring precise execution.

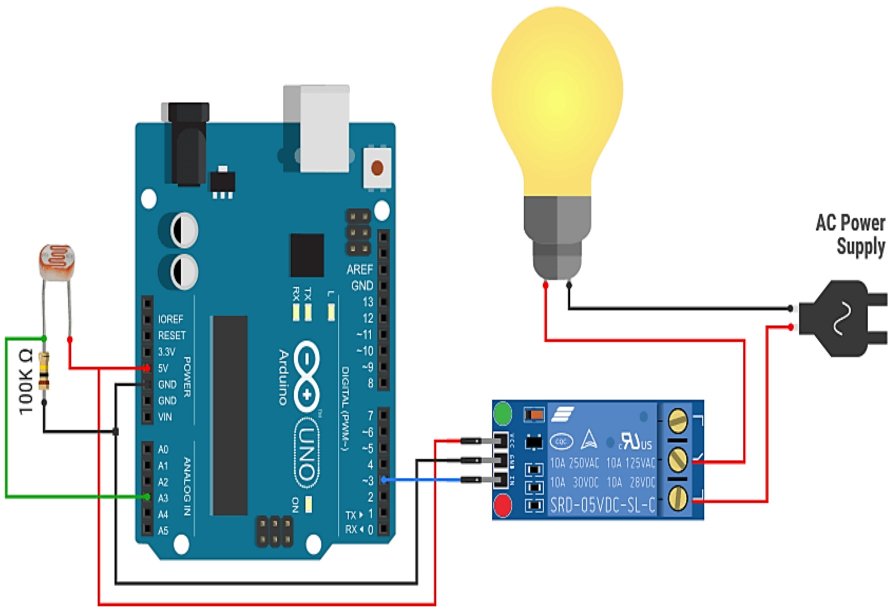


Figure IV-7: Wiring diagram [42].

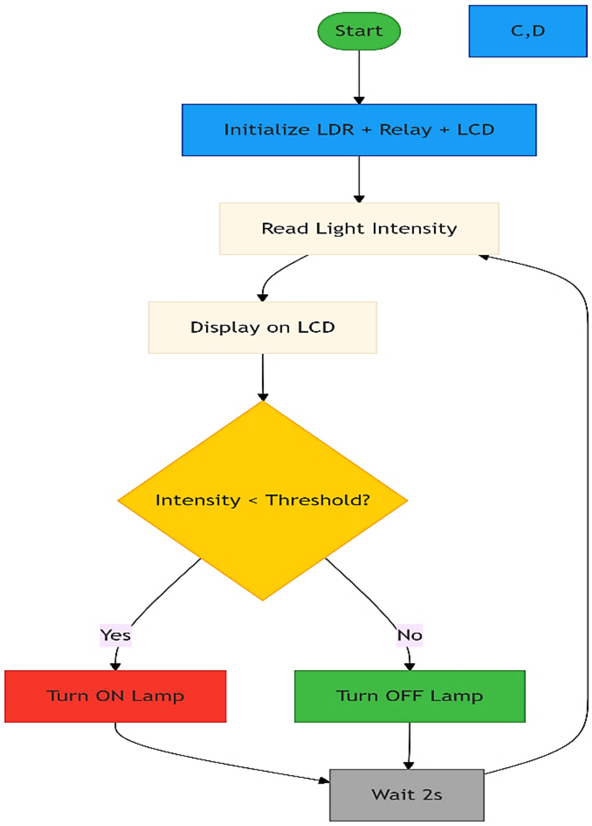


Figure IV-8: Diagram of Lighting System.

IV. 2. 5 Shading System:

This system automatically controls shade curtains in greenhouses based on the intensity of natural lighting.

➢ **System components:**

- LDR sensor to measure light intensity.
- 2 Stepper Motor for open the shade curtains in the greenhouse.
- Arduino microcontroller to process data and send Driver Motor signal.
- LCD screen to display light intensity and Stepper Motor status.
- Power source for operation.

➢ **How The System Working:**

- ***Continuous light intensity reading:***

The LDR sensor measures the intensity of lighting inside the greenhouse and sends the data to the Arduino Uno control unit.

- ***Decision making based on lighting intensity:***

If the lighting intensity is less than the threshold:

The Stepper Motor remains off.

If lighting intensity more than threshold:

Stepper Motor is operated to open the shade curtains in the greenhouse.

- ***Display data on LCD screen:***

The lighting intensity and Stepper Motor status are continuously displayed on the LCD screen to monitor the environmental conditions inside the greenhouse.

- ***Automatic control via Driver Motor:***

Stepper Motor on and off is controlled using Driver Motor signal from controller, ensuring precise execution.

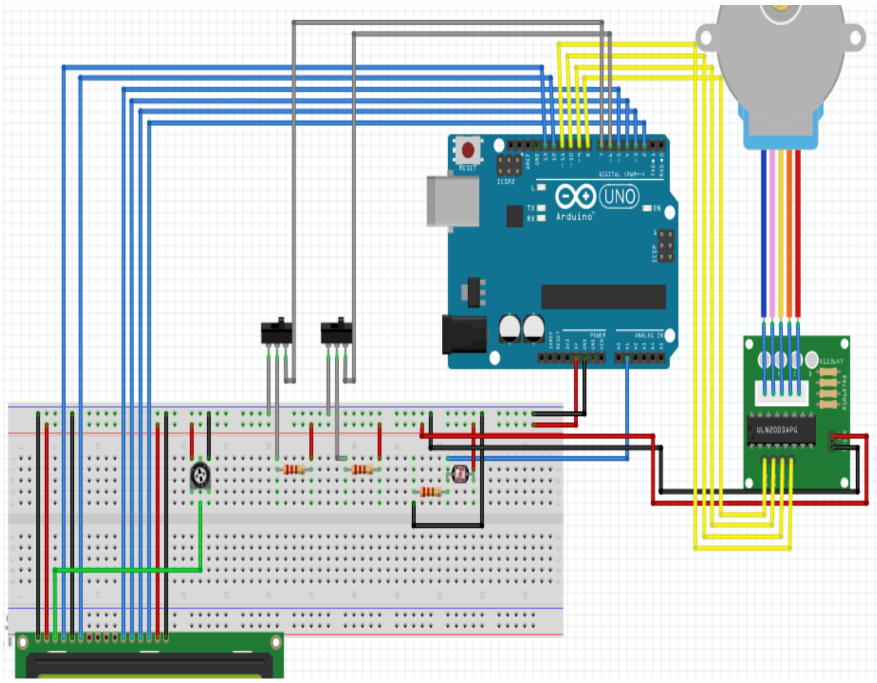


Figure IV-9: Wiring diagram [43].

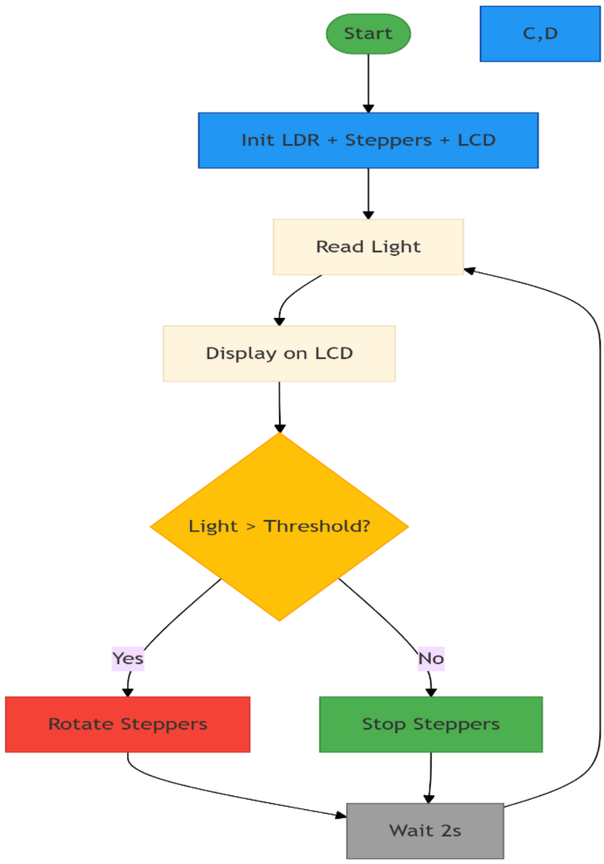


Figure IV-10: Diagram of Shading System.

IV. 2. 6 Rainfall System:

This system automatically protects crops inside greenhouses when it rains.

- **System components:**

- rain sensor for detection Rain.
- Servo motor for moving greenhouse windows.
- Arduino Uno microcontroller for data processing and PWM signal transmission.
- Power source for operation.

- **How The System Working:**

- ***Continuous rainfall reading:***

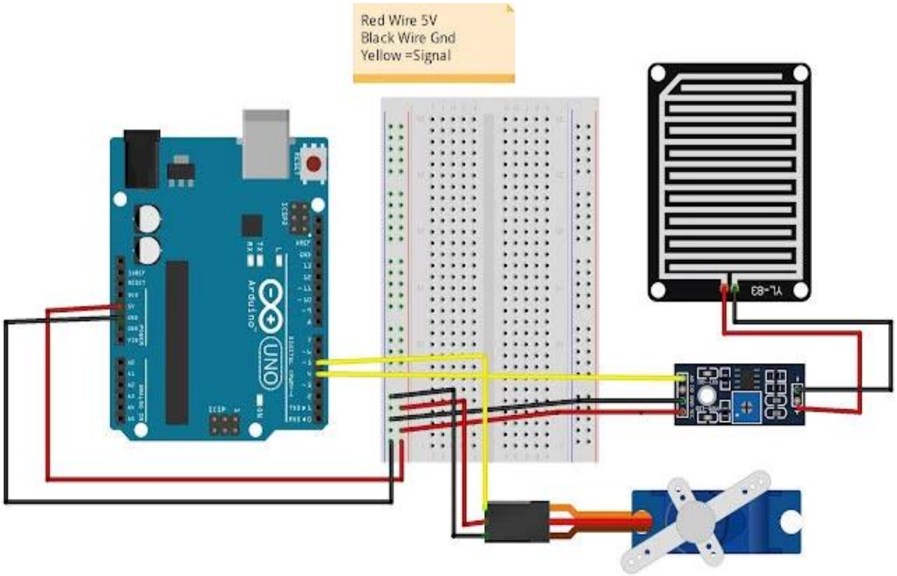
The Rain sensor detection the rainfall outside the greenhouse and sends the data to the Arduino Uno controller.

- ***Decision making based on rainfall:***

If the sensor detects rainfall :
The Servo motor moves to a 90 degree angle and the window is closed.
If the sensor does not detects rainfall:
The Servo motor stays at the same angle as before.

- ***Automatic control via PWM signal:***

The Servo angle is controlled using the PWM signal from the controller, ensuring smooth and precise movement of the windows.



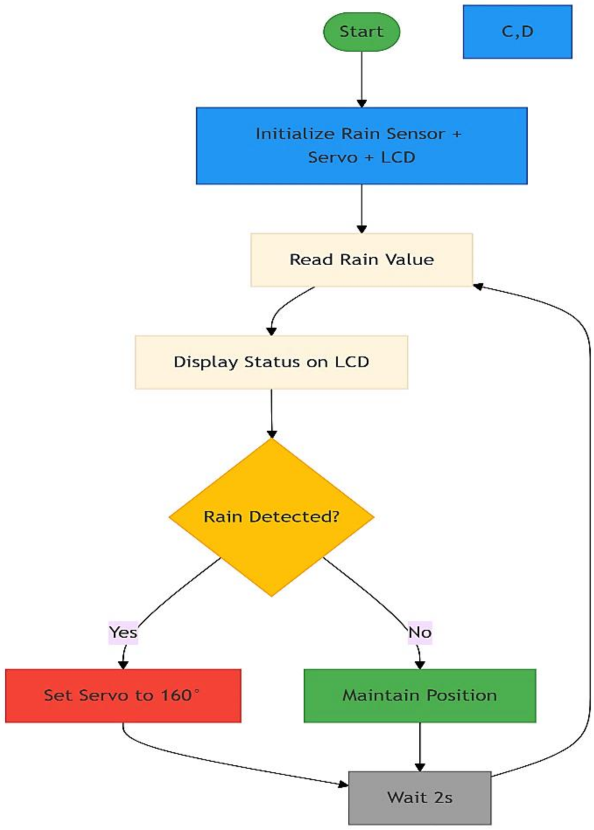


Figure IV-11: Wiring diagram [44]. **Figure IV-12:** Diagram of Rainfall System.

IV. 2. 7 Security System:

This system provides fire protection in greenhouses by instantly detecting the fire and setting off an audio alarm.

➢ **System components:**

- Flame sensor for detection Fires.
- Buzzer for sound an alarm.
- Arduino Uno microcontroller for data processing.
- Power source for operation.

➢ **How The System Working:**

- ***Continuous flame reading:***

The Flame sensor detection the Smoke inside the greenhouse and sends the data to the Arduino Uno controller.

- ***Decision making based on flame:***

If the sensor detects Smoke :

The Buzzer issues an audible alarm to warn of fire.

If the sensor does not detects Smoke:

The Buzzer stays off.

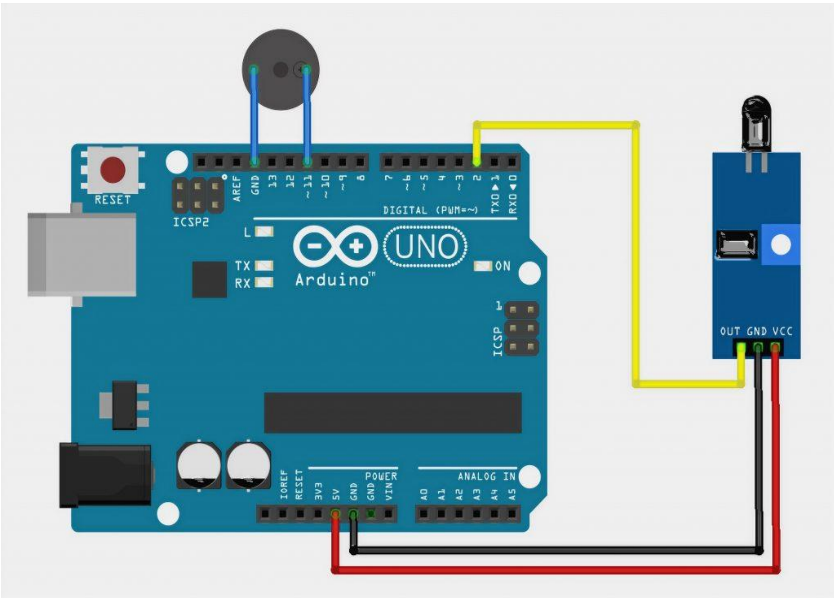


Figure IV-13: Wiring diagram [45].

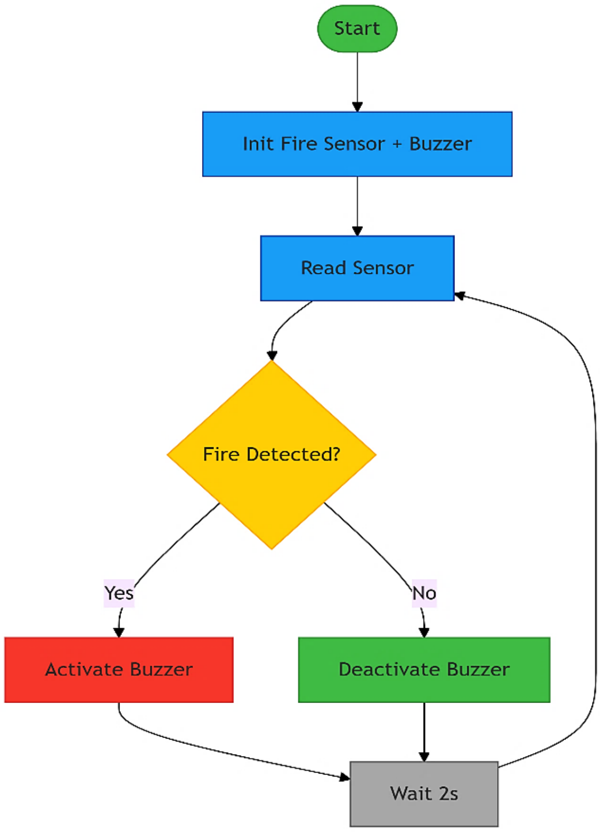


Figure IV-14: Diagram Security System.

Chapter V:

Prototype Implementation

Chapter V: Prototype Implementation

V. 1 Introduction

Through this chapter, we discuss the stages of building the project, as well as pictures of systems integrated into the greenhouse that were collected during the implementation and testing phases of the project, highlighting their role in achieving the intended functionality and performance of the smart greenhouse.

V. 2 Problems raised

- ***Extreme climate changes***
- ***Water shortage***
- ***Soil degradation***
- ***Shortening the agricultural seasons***
- ***Low quality and productivity***
- ***Pests and diseases***

V. 3 Solutions provided by the project

- ***Design and development:***

Design of an IoT system that integrates sensors (temperature, humidity, soil), communication modules and actuators (pumps, fans, lighting).

- ***Programming and interface:***

Mobile/web application development for monitoring and control.

Implementation of automation algorithms to optimize processes based on collected data.

V. 4 The Prototype

- ***Prototype:*** Manufacture of a physical model (dimensions: 1.5m x 1m x 1m).
- ***Testing and optimization:*** Test in real conditions in the semi-arid region of Ghardaia.
- ***How to make a greenhouse:***

The greenhouse is designed from a structure made entirely of PVC pipes, precisely cut and assembled using special joints to form a stable frame in the shape of a tiny house. After installing the frame, the lower part of the structure was covered using a transparent plastic film intended for greenhouses, as this film provides good protection and retains the heat and moisture necessary for plant growth.

The upper part was covered with panels of transparent polycarbonate, a durable and light material that allows natural light to penetrate, and at the same time provides good thermal insulation. Ventilation windows have also been integrated into the ceiling to facilitate temperature control inside the house, in addition to integrating an integrated electronic system (as shown in the pictures) to automatically control the internal environment, which makes this plastic house an automated and integrated project.

Figure V-1: Structure of Prototype.

V. 5 Integrated Systems in Prototype

V. 5. 1 Cooling System:

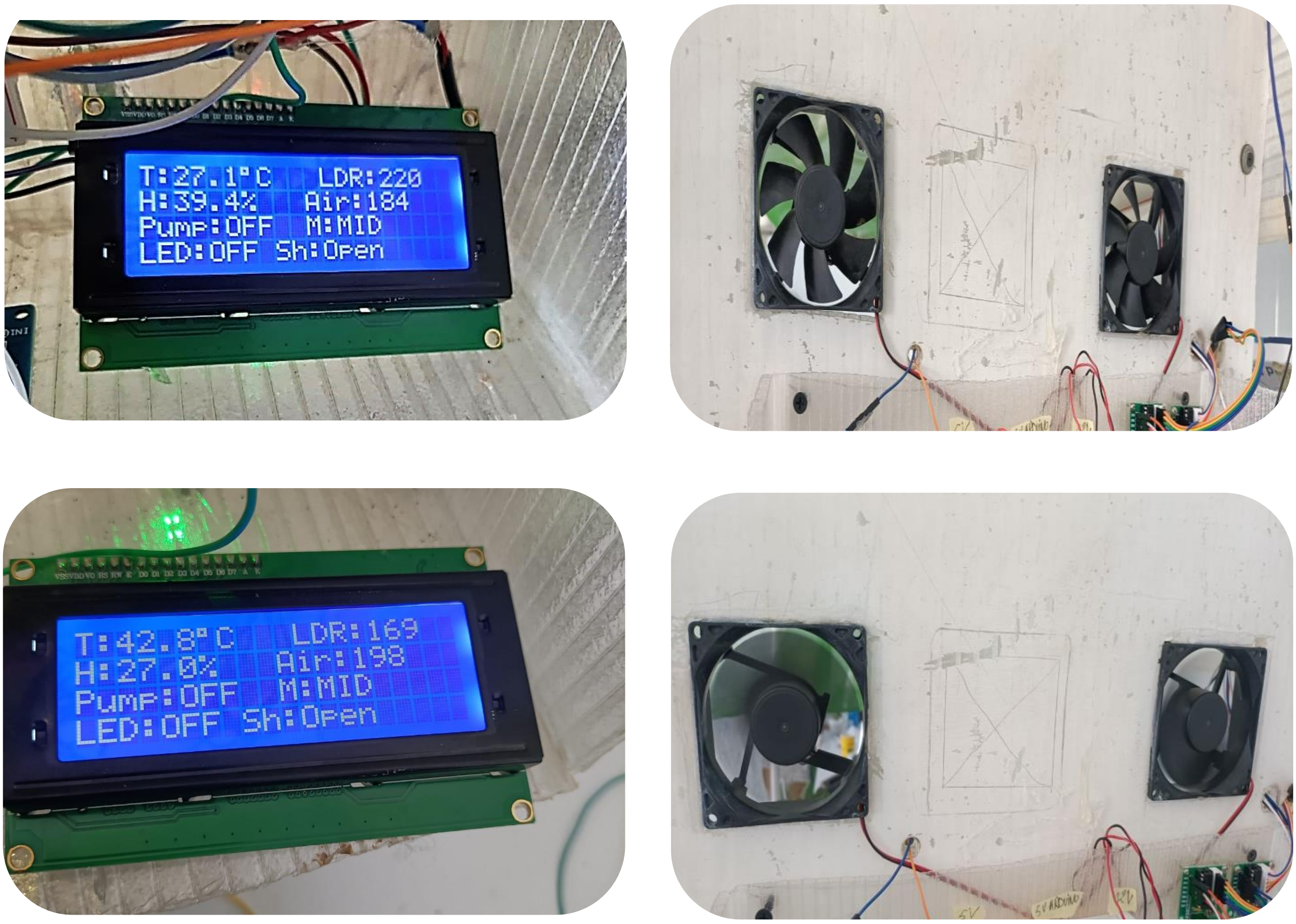


Figure V-2: Cooling System

V. 5. 2 Natural Ventilation System

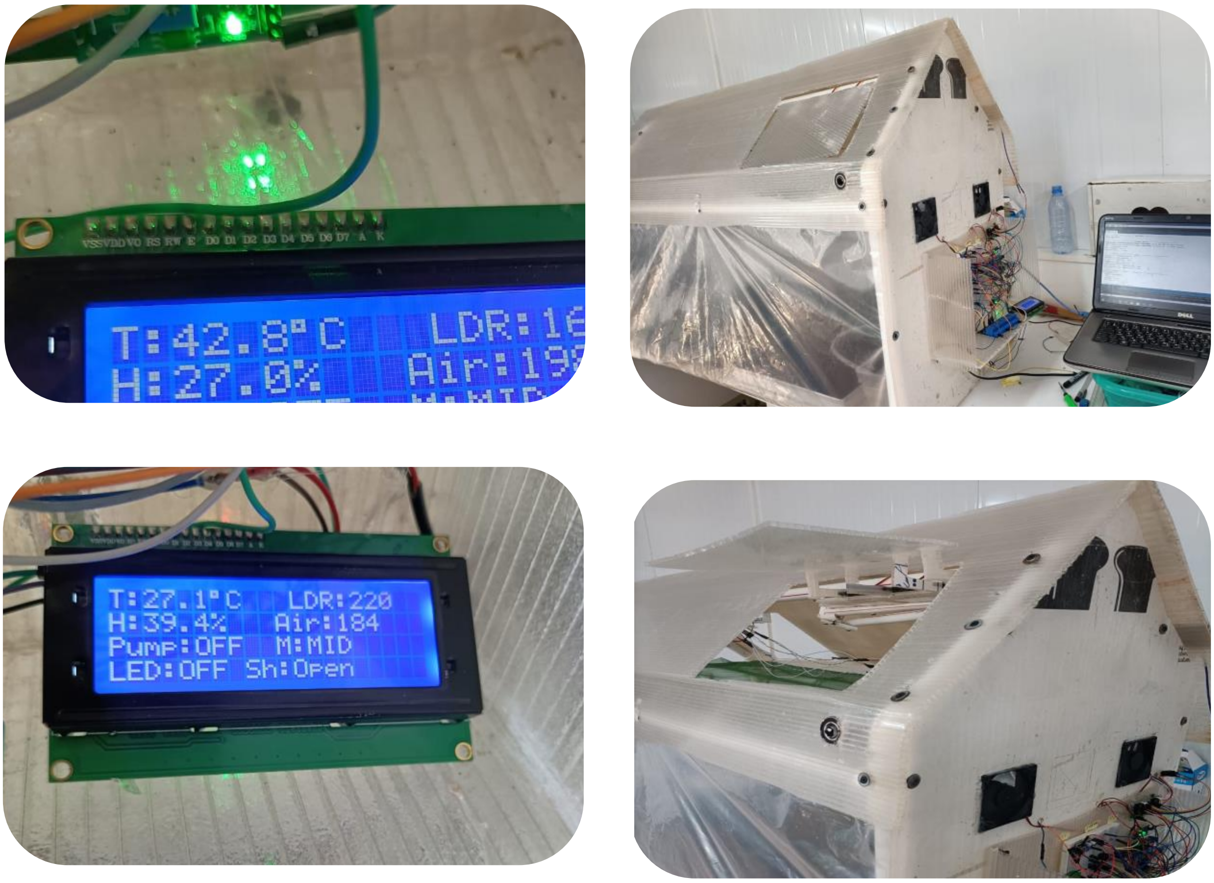


Figure V-3: Natural Ventilation system

V. 5. 3 Irrigation System:

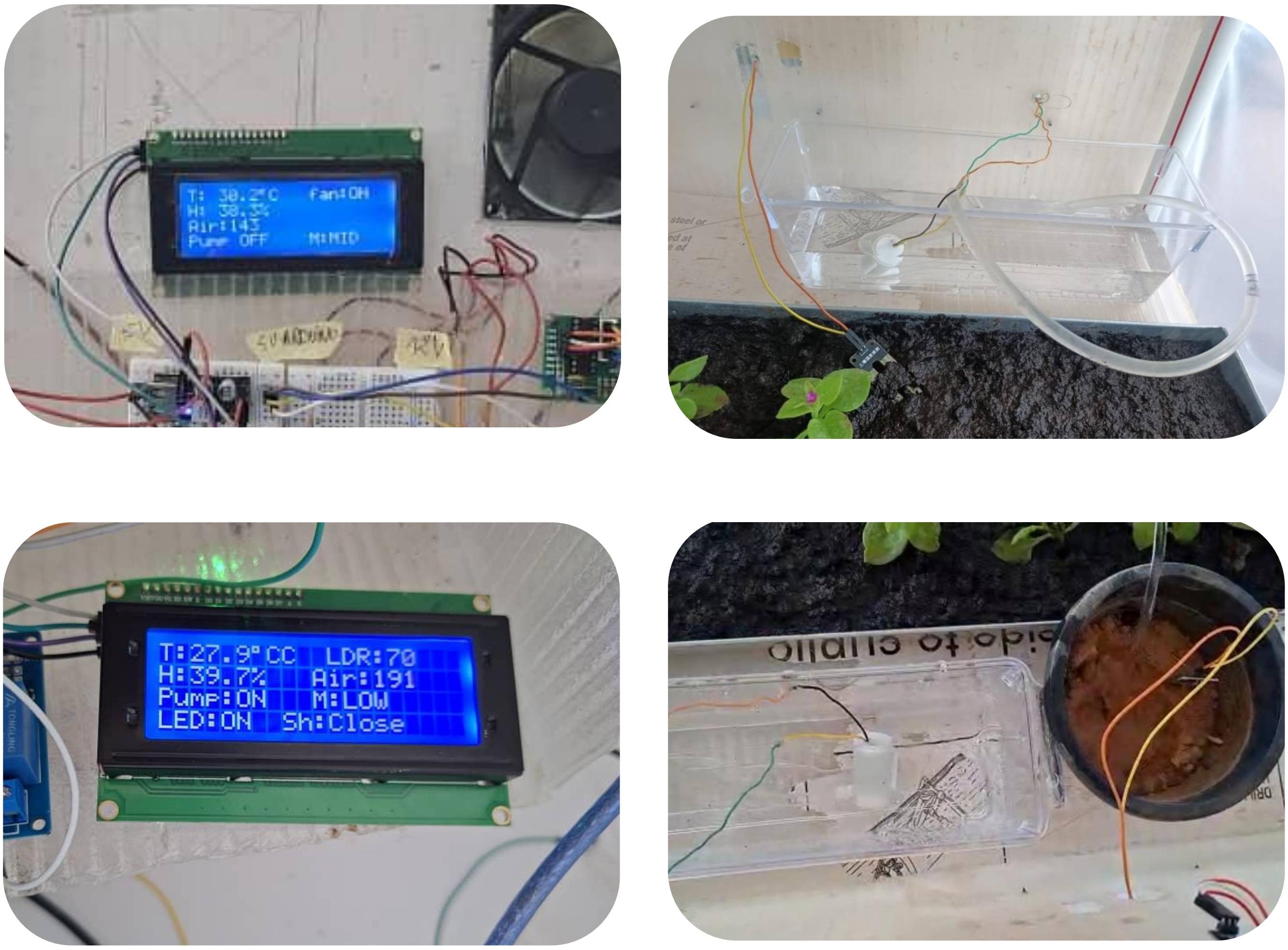


Figure V-4: Irrigation system

V. 5 4 Lighting System:

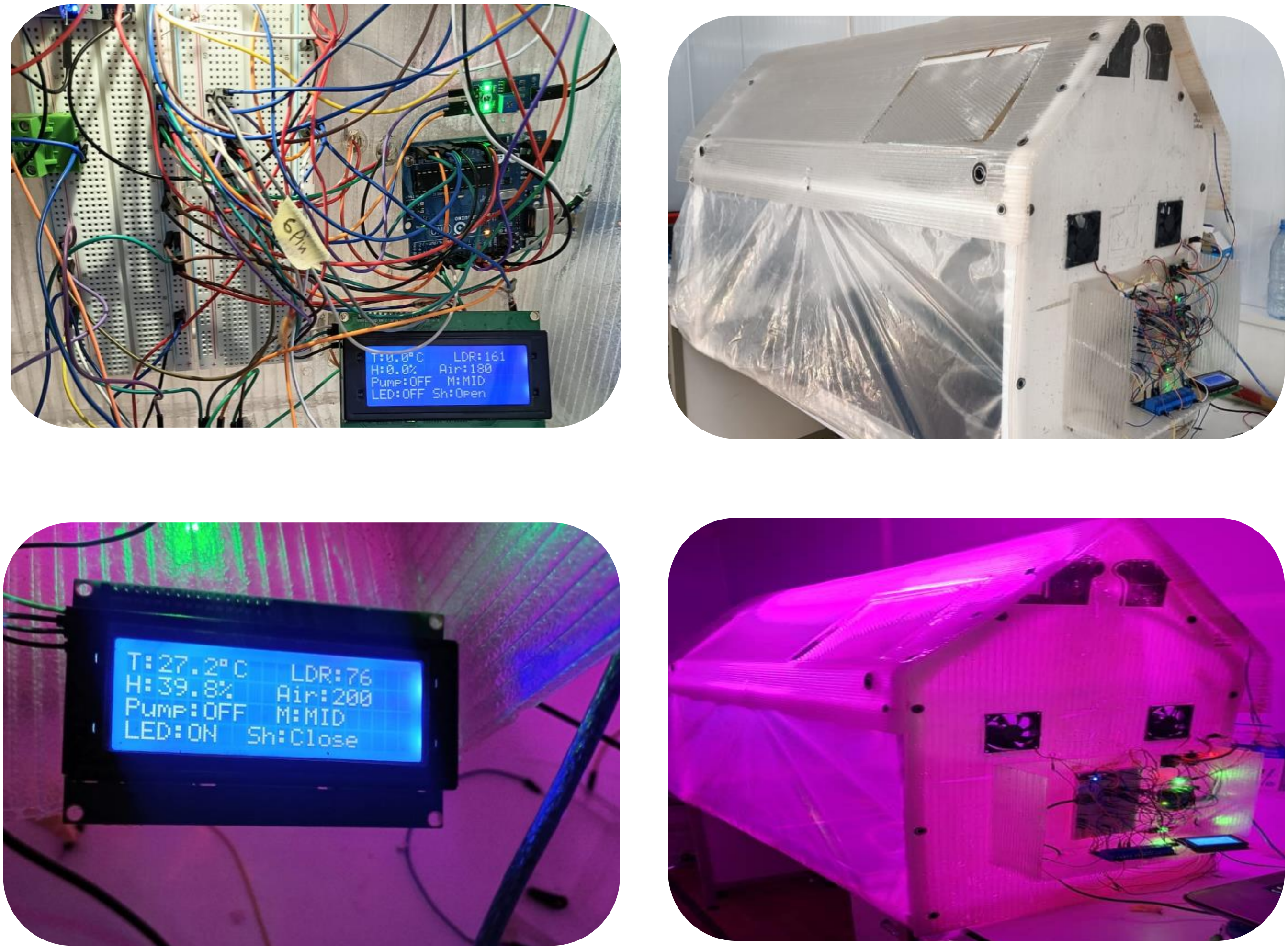


Figure V-5: Lighting system

V. 5 5 Shading System:

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Figure V-6: Shading system

V. 5. 6 Rainfall System:

Figure V-7:Rainfall system.

General Conclusion

The smart greenhouse developed in this project is designed to support sustainable agriculture by automating the monitoring and control of environmental conditions. The system includes various sensors to measure temperature, humidity, soil moisture, gas concentration, and light intensity. Based on threshold values, it activates fans, irrigation pumps, artificial lighting, and shading components to maintain appropriate conditions for plant growth.

The system was designed to operate in both manual and automatic modes, providing flexibility in operation and control. It also supports remote monitoring and control over long distances, using wireless communication technologies to enable users to interact with the system without being physically present.

By using Arduino and low-cost electronic components, the prototype remains accessible and replicable for small-scale applications, particularly in semi-arid regions where environmental control is crucial.

By continuously monitoring environmental variables, the system can react immediately to unfavorable conditions, reducing crop losses and improving growth quality. The prototype demonstrates how smart agriculture can reduce labor costs, improve yields, and support sustainable food production.

In conclusion, this smart greenhouse is a practical and scalable solution that merges traditional farming knowledge with modern IoT technology. It paves the way for digital agriculture, offering great potential to enhance productivity, conserve resources, and ensure food security in a changing climate. As a next step, adding mobile connectivity or AI prediction can further increase its impact and usability for real-world applications.

Future Work

As part of the future development of the smart greenhouse project, crops can be scaled up and artificial intelligence and solar energy technologies can be adopted to enhance innovation and efficiency in agriculture. The system can be added based on high-efficiency solar panels to generate the energy needed to operate all components of the greenhouse, including the lighting system, pumps and control devices, while using batteries to store excess energy for use during periods of low sunlight. AI will play a key role in analyzing sensor data to automatically manage light, water and nutrient levels for any type of crop to be planted and predict harvest using machine learning algorithms to predict optimal harvest times and potential yields based on historical data and current growing conditions. This improves plant health through image analysis for early detection of diseases or nutrient deficiencies, as well as plant health analysis through the introduction of computer vision techniques to analyze plant images and identify any signs of disease or nutrient deficiencies.

The voice control interface can be developed and different planting styles can be customized to meet the specific goals of the greenhouse, such as rapid growth, water conservation, and increased planting density. The use of energy-efficient LED lighting and a smart energy management system will ensure high efficiency and sustainable operation while reducing operating costs and reliance on conventional electricity. These improvements make the system more sustainable and reliable, increasing the productivity of the greenhouse and its attractiveness to consumers and investors alike. These future initiatives will contribute to promoting smart and sustainable agriculture and provide innovative solutions to global food security challenges.

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اسم المشروع

Development of a Remote-Controlled Smart Greenhouse System Using IoT and Arduino Technology for Enhanced Climate and Resource Management in Semi-Arid Regions

مشروع في اطار القرار الوزاري **1275**

Eco Grow Solutions

Defended publicly on 21/06/2025

السنة الجامعية: 2025/2024

بطاقة المعلومات

1. فريق الإشراف:

الاسم واللقب	الرتبة	التخصص
عبد الوهاب بن صديق	مدير بحث	طاقويات
بدر الدين بزة	ملحق بحث	الكترونيك
صالح بوهون	أستاذ بحث ب	الكترونيك

2. فريق العمل:

فريق المشروع	التخصص	الكلية
الطالبة: برغايد فاطمة الزهراء	آلية وأنظمة	لعلوم والتكنولوجيا
الطالبة: ددوش شيماء	آلية وأنظمة	لعلوم والتكنولوجيا

فهرس المحتويات

المحور الأول:
تقديم المشروع

1. فكرة المشروع (الحل المقترح):

مشروع "البيت البلاستيكي الذكي" يهدف إلى تطوير نظام زراعي ذكي يستخدم تقنيات إنترنت الأشياء للتحكم التلقائي في البيئة الزراعية داخل بيوت بلاستيكية. يتم ذلك من خلال مجسات وأجهزة تحكم تقوم بمراقبة وتنظيم العوامل البيئية مثل الحرارة، الرطوبة، الإضاءة، التهوية، والري، لضمان نمو مثالي للمحاصيل بأقل استهلاك للمياه والطاقة.

2. الحلول المقترحة:

- نظام مراقبة مناخية ذكي لقياس الحرارة، الرطوبة، الإضاءة، وجودة الهواء.
- نظام ري تلقائي يعتمد على قياسات رطوبة التربة لتقليل استهلاك الماء.
- أنظمة تهوية وتبريد وتظليل تعمل تلقائيًا حسب الظروف المناخية.
- نظام إضاءة لدعم نمو النبات عند غياب الإضاءة الطبيعية.
- وحدة تحكم لاسلكية (Wi-Fi) تُمكّن المستخدم من التحكم والمتابعة عن بُعد.
- نظام تنبيهات فوري لتفادي أي خلل أو ظروف غير مناسبة للنبات.
- تصميم منخفض التكلفة، سهل التركيب، ومناسب للمزارعين المحليين.

3. القيمة المضافة:

1. تقليل استهلاك المياه بنسبة تصل إلى 50٪ بفضل الري الذكي.
2. تحسين إنتاجية المحاصيل من خلال التحكم الأمثل في المناخ.
3. تقليل تكاليف التشغيل والاعتماد على العمالة.
4. حلول ذكية وسهلة الاستخدام مصممة خصيصًا للمزارعين الصغار والمتوسطين.
5. تمكين المزارعين من التحكم الكامل عن بُعد.
6. تعزيز الزراعة المستدامة وتحقيق عوائد اقتصادية أفضل.

4. أهداف المشروع:

الهدف الرئيسي:

- تطوير نظام ذكي ومنخفض التكلفة يمكن تطبيقه في الصوبات الزراعية في المناطق شبه القاحلة.
- تصميم وتطوير نظام ذكي للتحكم الآلي في ظروف البيئة الزراعية داخل البيوت البلاستيكية (حرارة، رطوبة، إضاءة ...)

- رفع كفاءة الإنتاج الزراعي وتحسين جودة المحاصيل مع تقليل استهلاك الموارد (الماء والطاقة).
- تقديم حل محلي مبتكر وذو تكلفة منخفضة موجه للفلاحين والمزارع الصغيرة.
- المساهمة في التحول الرقمي للزراعة ودعم الزراعة المستدامة في الجزائر.

الأهداف الفرعية:

- تصميم نظام قادر على مراقبة البيئة الداخلية في الوقت الفعلي.
- تحسين استخدام المياه والطاقة داخل الدفيئة.
- تقليل التكاليف وتحسين جودة الزراعة.
- تسهيل صيانة النظام وتشغيله من قبل المستخدم.
- توفير واجهة تحكم عن بعد تدعم عملية اتخاذ القرار.

5. فريق العمل:

يتكون فريق العمل من:

الطالبة 1: برغايد فاطمة الزهراء ، قام بدورات في إطار حاضنة الأعمال لجامعة غرداية.

- اختيار وتركيب أجهزة الاستشعار والمحركات.
- إجراء الاختبارات في ظروف حقيقية.
- تحليل البيانات لتقييم الأداء وتحسين النظام.

الطالب 2: ددوش شيماء، قام بدورات في إطار حاضنة الأعمال لجامعة غرداية.

- برمجة الميكروكونترولر (Arduino).
- دمج وحدات الاتصال اللاسلكي (ESP8266/ESP32).
- تطوير تطبيق الهاتف المحمول/الويب ودمج البيانات في الوقت الفعلي.

6. الجدول الزمني لتحقيق المشروع:

يعرض الجدول التالي تسلسل مراحل تنفيذ مشروع "البيت البلاستيكي الذكي" خلال سبعة أسابيع. تبدأ المرحلة الأولى بالدراسات الأولية واختيار مقر الوحدة الإنتاجية، يليها طلب التجهيزات من الخارج، ثم

تجهيز مقر الإنتاج وتركيب المعدات. في المراحل الأخيرة، يتم اقتناء المواد الأولية، وصولًا إلى بداية إنتاج أول منتج. هذا التدرّج يسمح بتنظيم العمل وضمان تنفيذ المشروع في الوقت المحدد وبكفاءة عالية.

			1	2	3	4	5	6	7
1		الدراسات الأولية: اختيار مقر الوحدة الإنتاجية، تجهيز الوثائق المطلوبة	✓	✓					
2		طلب التجهيزات من الخارج		✓	✓				
3		بناء مقر للإنتاج			✓	✓			
4		تركيب المعدات			✓	✓			
5		اقتناء المواد الأولية			✓	✓	✓		
6		بداية إنتاج أول مُنتج					✓	✓	✓

الجدول الزمني لتحقيق المشروع

المحور الثاني:
الجوانب الابتكارية

1. طبيعة الابتكار:

- دمج تقنيات الاستشعار والذكاء الاصطناعي في الزراعة التقليدية.
- نظام آلي متكامل منخفض التكلفة.
- تصميم مرن قابل للتطوير حسب نوع المحصول.

2.مجالات الابتكار:

- الزراعة الذكية.
- الحفاظ على الموارد الطبيعية.
- الحلول البيئية والمستدامة.
- التحول الرقمي في القطاع الفلاحي.

المحور الثالث:
التحليل الاستراتيجي للسوق

1.عرض القطاع السوقي:

- الفلاحون وأصحاب البيوت البلاستيكية.
- أصحاب المشاريع الفلاحية الناشئة.
- التعاونيات الفلاحية والبلديات الريفية.
- شركات التصدير الزراعي.

2.قياس شدة المنافسة:

- وجود منتجات مستوردة لكنها مرتفعة السعر.
- ضعف في الحلول المحلية المتكاملة.
- إمكانياتنا في توفير حل أرخص وأكثر توافقًا مع الواقع الجزائري.

3.الاستراتيجية التسويقية:

- عروض ميدانية تجريبية.
- شراكات مع تعاونيات فلاحية.
- حملات توعية في المعارض الزراعية.
- التواصل عبر وسائل التواصل الاجتماعي.

المحور الرابع:
خطة الإنتاج والتنظيم

1.عملية الإنتاج:

- تصميم إلكتروني للنظام.
- تجميع المجسات والمحركات والوحدات الإلكترونية.
- اختبار النظام في بيت بلاستيكي تجريبي.
- التعديل والتطوير حسب الحاجة

تمر عملية إنتاج البيوت البلاستيكية الذاتية التشغيل بالمراحل التالية:

المسؤوليات	الأنشطة الرئيسية	المرحلة
فريق الهندسة + فريق المشتريات.	-دراسة المتطلبات الزراعية (المحاصيل، المناخ، المساحة). -شراء المواد (الهيكل المعدني، البلاستيك الزراعي، أنظمة الري، الحساسات). -تصميم النموذج الأولي مع دمج أنظمة التشغيل الذاتي (الري، التهوية، التحكم بالمناخ).	1.التصميم والاقتناء
فريق الإنتاج + فريق التركيب.	-تجميع الهيكل المعدني وتغطيته بالبلاستيك الزراعي. -تركيب أنظمة الري الآلي والتهوية (مروحية/طبيعية). -تركيب الحساسات (رطوبة، حرارة، إضاءة).	2.التصنيع والتركيب
فريق البرمجة + فريق الذكاء الاصطناعي.	-تطوير نظام تحكم (مثل استخدام Arduino أو Raspberry Pi). -برمجة الحساسات للتفاعل مع البيئة (ري أوتوماتيكي عند جفاف التربة، فتح النوافذ عند ارتفاع الحرارة). -تدريب نموذج ذكاء اصطناعي (اختياري) للتنبؤ بأمراض النبات أو تحسين الظروف.	3.برمجة أنظمة التشغيل الذاتي
فريق الجودة + فريق التقنية.	-اختبار الأنظمة في ظروف محاكاة (مثل زيادة الحرارة صناعياً لفحص التهوية). -مراقبة أداء النظام لمدة محددة قبل التسليم.	4.الاختبار والتشغيل
فريق العمليات + خدمة العملاء.	-تعبئة المنتج (إذا كان قابلاً للنقل). -توفير دليل استخدام وصيانة. -تقديم خدمة ما بعد البيع (ترقية البرامج، إصلاح الأعطال).	5.التسليم والصيانة

.

مخطط لعملية الإنتاج Production Process

2.التموين:

- يتم شراء القطع الإلكترونية اللازمة لتصنيع الدرون من السوق المحلية فيما توفر من القطع أو عبر استيرادها مباشرة أو عن طريق التسوق الإلكتروني عبر الإنترنيت.
- يتم يتم شراء المواد الأولية للمواد المخمدة للحرائق من السوق المحلي خاصة أن استراتيجيتنا تهدف إلى إنتاج مواد صديقة للبيئة.

3. اليد العاملة والتكوين:

يوفر مشروع **البيوت البلاستيكية الذكية** ما مجموعه **13منصب شغل مباشر**، تشمل تخصصات متعددة تضمن التكامل بين الجانب التكنولوجي، الزراعي، والتسييري. التفاصيل كما يلي

العدد	نوع المنصب
2	الإدارة (بما فيهم أصحاب المشروع)
1	مهندس إلكترونيات (للتحكم بالحساسات والمشغلات)
1	مهندس ميكانيك (لتصميم الهياكل والأنظمة المتحركة)
1	مهندس آلية (لأتمتة الأنظمة)
1	مهندس برمجيات (لبرمجة نظام التحكم والمراقبة)
1	مهندس ذكاء اصطناعي (لتحليل البيانات واتخاذ قرارات ذكية)
1	مهندس كيميائي (لمتابعة جودة التهوية والتربة والرطوبة)
1	مهندس اختبارات (لتجربة واختبار الأنظمة)
1	مشرف صيانة وتشغيل ميداني
1	محاسب
1	عون تسويق
1	سائق
1	عون أمن
1	عون اتصالات ودعم فني

4.التكوين والتدريب المستمر:

نظراً للطبيعة التقنية المتقدمة للمشروع، نعتمد على تعزيز قدرات الفريق من خلال برامج تكوين مستمرة تشمل:

- تكوين في أنظمة التحكم الذكية وإنترنت الأشياء.(IoT)
- دورات في الذكاء الاصطناعي وتحليل البيانات الزراعية.
- تدريبات ميدانية لتشغيل وصيانة البيوت البلاستيكية الذكية.
- ورشات تسويق بيئي لفريق التسويق.
- تحديثات دورية حول الابتكارات في الزراعة الذكية.

تهدف هذه البرامج إلى ضمان التطوير المهني المستمر للفريق وتحقيق جودة عالية في تنفيذ المشروع وخدماته.

5.الشراكات الرئيسية:

يعتمد نجاح مشروع **البيوت البلاستيكية الذكية** على التعاون مع عدد من الشركاء الرئيسيين الذين يساهمون في مختلف مراحل التصميم، الإنتاج، والتوزيع، ومن بينهم:

- **مصنّعو القطع الإلكترونية**
  لتوفير الحساسات) مثلDHT22 ، LDR، حساس الرطوبة(...، المتحكمات الدقيقة) مثل ESP32 أو(Arduino ، والمشغلاتmotors) ، مضخات.(...
- **منصات الذكاء الاصطناعي**
  مثل Google AI وTensorFlow، لتدريب وتحسين نماذج التنبؤ الذكي بالمناخ الزراعي واحتياجات التربة.
- **مزودو خدمات الاتصالات**
  لتأمين الربط اللاسلكي بين البيوت البلاستيكية ومنصات التحكم عن بعد، سواء عبر الإنترنت أو تقنيات.IoT
- **مزودو الخدمات اللوجستية والتوزيع**
  لتسهيل نقل المواد الأولية، الأجهزة، والنماذج الجاهزة إلى المستخدمين أو الفلاحين في مختلف المناطق.
- **شركات الأمان والسلامة والاختبار**
  لضمان مطابقة الأنظمة للمعايير التقنية والبيئية، ولإجراء اختبارات الأداء والجودة قبل الإطلاق التجاري.
- **شركات متخصصة في الطاقة الشمسية (عند الحاجة)**
  لدعم تشغيل البيوت البلاستيكية الذكية في المناطق المعزولة عبر الطاقة المتجددة.

المحور الخامس:
الخطة المالية

1. التكاليف والأعباء:

- تكاليف تأسيسية: عتاد الورشة ، عتاد المكتب ،
- تكاليف تشغيلية: أجرة العمال –الكراء – الإشهار

التكاليف (دج)	القيمة (السنة)
عتاد الورشة	600000.00
عتاد المكتب	100000.00
أجرة العمال	12 * 800000.00
الكراء	300000.00
الإشهار	200000.00
المجموع	**10800000.00**

2.الإيرادات

يعتمد نموذج الإيرادات الخاص بمشروعنا على تقديم **أنظمة ذكية مخصصة للبيوت البلاستيكية الموجودة مسبقًا** لدى الزبائن، دون الحاجة لتصنيع بيت بلاستيكي كامل. يُركز النموذج على بيع حلول تقنية متكاملة وخدمات مصاحبة، وفقاً لما يلي:

- **بيع وتركيب أنظمة ذكية حسب الطلب**

نقوم بتوفير وتركيب مجموعة من الحساسات، أنظمة الري الذكية، التهوية، والمراقبة عن بعد، بحسب احتياجات كل زبون.

- *(متوسط الطلب = 250,000 دج × 40 زبون = 10,000,000 دج سنوياً)*
-
- **خدمة الدراسة الميدانية والتوصيف التقني**

تشمل زيارة موقع الزبون وتحليل احتياجاته، ثم تقديم خطة مخصصة لتحويل بيته البلاستيكي إلى بيت ذكي.

(20,000 دج × 40 زبون = 800,000 دج)

- **خدمة الصيانة والمتابعة التقنية السنوية**

تتضمن مراقبة الأداء، التدخل عند الأعطال، وتحديثات دورية.

(30,000 دج × 30 زبون = 900,000 دج)

- **اشتراك سنوي في منصة المراقبة الذكية**

تمكّن الزبائن من تتبع المعطيات البيئية والتحكم عن بعد بأنظمتهم.

(100,000 دج × 25 زبون = 2,500,000 دج)

2. رقم الأعمال:

يوضح الجدول التالي التوقعات المالية المتعلقة بمبيعات ثلاثة منتجات أساسية تقدمها شركة **Eco Grow Solutions** خلال السنوات الثلاث الأولى:

- **المنتج A:** بيت بلاستيكي ذكي متكامل
- **المنتج B:** نظام ري ذكي مستقل
- **المنتج C:** أجهزة استشعار ذكية للتنبؤ والمراقبة

السنة الأولى:(N)

- بيع **30وحدة من المنتج A** بسعر 250,000 دج، بمجموع **7,500,000دج**
- بيع **20وحدة من المنتج B** بسعر 100,000 دج، بمجموع **2,000,000دج**
- بيع **20وحدة من المنتج C** بسعر 40,000 دج، بمجموع **800,000دج**

رقم الأعمال الإجمالي في السنة الأولى: **10,300,000** دج

السنة الثانية:(N+1)

- من المتوقع تقريبًا مضاعفة عدد الوحدات المباعة بفضل زيادة الطلب وتوسّع قاعدة الزبائن.
- **رقم الأعمال المتوقع: 21,000,000** دج

السنة الثالثة:(N+2)

- مع اتساع السوق وتحسن سمعة المنتجات، يُتوقع نمو قوي في المبيعات، خصوصًا للمنتج A.
- **رقم الأعمال المتوقع: 40,800,000** دج

تعكس هذه الأرقام تطورًا ملحوظًا في حجم الطلب وثقة الزبائن في الحلول المقدمة، مما يعزز فرص **نجاح المشروع وتوسّعه المستقبلي**.

	Realisation	Prévision	
Produit A destiné Client	**N**	**N+1**	**N+2**
Quantité produit A	30	60	120
Prix HT produit A	250,000	240,000	230,000
Ventes produit A	7,500,000	14,400,000	27,600,000
Quantité produit B	20	50	100
Prix HT produit B	100,000	100,000	100,000
Ventes produit B	2,000,000	5,000,000	10,000,000
Quantité produit C	**20**	**40**	**80**
Prix HT produit C	40 000	40 000	40 000
Ventes produit C	800,000	1,600,000	3,200,000
CHIFFRE D'AFFAIRES GLOBAL	10,300,000	21,000,000	40,800,000

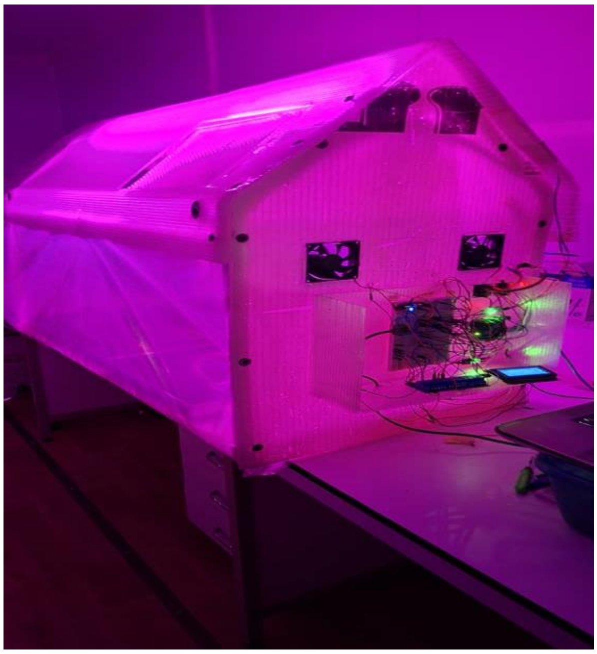
المحور السادس :
النموذج الاولي التجريبي

قمنا بإنجاز نموذج أولي مصغر للبيت البلاستيكي الذكي لاختبار فعالية النظام في المراقبة والتحكم البيئي. يشمل النموذج حساسات (حرارة، رطوبة، غاز، تربة)، مروحة، مضخة ري، نظام تظليل، وشاشة عرض، مدمجة بوحدة تحكم قابلة للبرمجة.

تم ربط المكونات بمنصة تحكم عن بعد تُظهر المعطيات وتتيح التشغيل اليدوي أو التلقائي.

أظهرت التجارب الأولية استجابة فعالة للظروف المناخية، مما يؤكد قابلية المشروع للتطوير نحو نسخة نهائية أكثر كفاءة.

الشكل 1: صور للنموذج الأولي للبيت البلاستيكي الذكي



الملحق1:
نموذج مخطط الأعمال
BMC

Business Model Canvas
نموذج الأعمال التجاري

1 Customer Segments
شرائح العملاء

- الفلاحون أصحاب البيوت البلاستيكية التقليدية
- المستثمرون الزراعيون في البيوت الذكية
- التعاونيات الفلاحية
- مراكز البحث والتجريب الزراعي
- أصحاب المشاريع البيئية المستدامة

4 Customer Relationships
علاقات العملاء

- دعم فني مستمر وخدمة ما بعد البيع
- تدريب الزبون على استخدام النظام الذكي
- تواصل دوري من خلال منصة المراقبة أو الهاتف
- تقديم تحديثات وتحسينات للنظام حسب التجربة

3 Channels
قنوات التوزيع

- التواصل المباشر مع الفلاحين والمستثمرين
- منصات التواصل الاجتماعي والإعلانات الرقمية
- شراكات مع تعاونيات فلاحية ومؤسسات زراعية
- موقع إلكتروني رسمي به طلبات وعروض خدمات

2 Value Proposition
القيمة المقترحة

- تحويل البيوت البلاستيكية التقليدية إلى ذكية وفعالة
- تحسين الإنتاج الزراعي بتكلفة أقل وجهد أقل
- مراقبة تلقائية للعوامل البيئية (حرارة، رطوبة، تربة)
- حلول ذكية صديقة للبيئة
- نظام مرن حسب ميزانية واحتياجات الزبون

7 Key Activities
الأنشطة الرئيسية

- دراسة وتصميم الأنظمة حسب كل زبون
- تركيب وتكوين ميداني
- تطوير وتحسين منصة المراقبة
- الصيانة والمتابعة التقنية بعد التركيب

6 Key Resources
الموارد الرئيسية

- فريق هندسي متعدد التخصصات (إلكترونيات، برمجة، ميكانيك...)
- مخزون القطع الإلكترونية والحساسات
- منصة إلكترونية ذكية للمراقبة والتحكم
- وسائل نقل وتقنيات التركيب الميداني

8 Key Partners
الشراكات الرئيسية

- مورّدو العتاد الإلكتروني والحساسات
- منصات الذكاء الاصطناعي (Google AI, TensorFlow...)
- مزوّدو خدمات الإنترنت والاتصال
- شركات نقل لوجستي وموزّعين
- شركاء في الطاقة الشمسية عند الحاجة

5 Revenue Streams
مصادر الإيرادات

- بيع النظام الذكي حسب الطلب
- اشتراكات سنوية لمنصة المراقبة عن بعد
- خدمات التركيب والصيانة والدعم الفني
- دراسات وتوصيفات ميدانية حسب الطلب

9 Cost Structure
هيكل التكاليف

- شراء وتخزين العتاد الإلكتروني
- أجور الفريق الفني والإداري
- تطوير وصيانة منصة المراقبة الذكية
- النقل والزيارات الميدانية
- التكوين والتدريب والمواد الترويجية

الملحق2:
شهادة التوطين بالحاضنة الجامعية

الجمهورية الجزائرية الديمقراطية الشعبية
وزارة التعليم العالي والبحث العلمي
جامعة غرداية
حاضنة أعمال جامعة غرداية

رقم: **273/ ح.أ.ج.غ/2025**

شهادة توطين مشروع مبتكر وفق القرار008 المعدل والمتمم للقرار1275

أنا الممضي أسفله، السيد: **د/ طالب أحمد نور الدين**

مسير حاضنة الأعمال: **جامعة غرداية**

المقر الاجتماعي/ العنوان: **المنطقة العلمية، ص ب 455، غرداية، 47000، الجزائر**

رقم علامة الحاضنة: **1004253146** بتاريخ: **2025/04/10**

طبيعة المشروع: **مؤسسة ناشئة**

أشهد أن الطالب(ة) / الطلبة التالية أسماؤهم:

الإسم واللقب	الطور الدراسي	التخصص	الكلية
فاطمة الزهراء برغايد	M2	آلية وأنظمة	العلوم والتكنولوجيا
شيماء ددوش	M2	آلية وأنظمة	العلوم والتكنولوجيا

تحت إشراف الأستاذ(ة)/الأساتذة التالية أسماؤهم:

الإسم واللقب	الرتبة	التخصص	URER
عبد الوهاب بن صديق	مدير بحث	طاقويات	وحدة الطاقات المتجددة
بدر الدين بزة	ملحق بحث	إلكترونيك	وحدة الطاقات المتجددة
صالح بوهون	أستاذ بحث ب	إلكترونيك	وحدة الطاقات المتجددة

تم توطينه على مستوى حاضنة أعمال جامعة غرداية - بمشروع تحت اسم: **Devlopment of remote controlled smart greenhouse system using IOT and arduino technology for enhanced climate and resource managment in semi arid regions.**

خلال السنة الجامعية: **2025/2024**

سلمت هذه الشهادة بطلب من المعني للإدلاء بها في حدود ما يسمح به القانون.

حرر في غرداية بتاريخ: 2025/06/18

مدير الحاضنة

مسؤول حاضنة الأعمال
د. طالب أحمد نور الدين

الجمهورية الجزائرية الديمقراطية الشعبية

وزارة التعليم العالي والبحث العلمي

Université de Ghardaïa Faculté des Sciences et de la technologie	جامعة غرداية كلية العلوم والتكنولوجيا قسم :الآلية والكهروميكانيك

شعبة : الآلية

تخصص: آلية وأنظمة

غرداية في : 2025/07/08

شهادة ترخيص بالتصحيح والايداع:

أنا الاستاذ(ة): ناصرحسن

بصفتي المشرف المسؤول عن تصحيح مذكرة تخرج (ليسانس/ماستر/دكتورا) المعنونة بـ:

Development of a Remote-Controlled Smart Greenhouse System Using IOT For Enhanced Climate and Resource Management In Semi-Arid

من انجاز الطالب (الطلبة):

- برغايد فاطمة الزهراء

- ددوش شيماء

التي نوقشت بتاريخ : 2025/06/30

أشهد ان الطالب/الطلبة قد قام /قاموا بالتعديلات والتصحيحات المطلوبة من طرف لجنة المناقشة وقد تم التحقق من ذلك من طرفنا .

وقد استوفت جميع الشروط المطلوبة.

امضاء المسؤول عن التصحيح

مصادقة رئيس القسم

رئيس قسم الآلية والكهروميكانيك

عـــزاوي محـــمد

جامعة غرداية - كلية العلوم و التكنولوجيا - قسم الآلية والكهروميكانيك