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THÈME

Intelligent Management of a Hydroponic Greenhouse Powered by a PV System Using Internet of Things and Artificial Intelligence

Préparé par :

ZAATOUT Amira

Devant le Jury composé de :

Nom et prénoms	Grade	Qualité
MAASKRI Mustapha	MCA	Président
BOUMEDIENE Hamid	MCB	Examinateur
OUARED Rahal	MCB	Examinateur
ALLAOUI. Tayeb	Pr	Encadrant
DRIAS Souhil	Doctorant	Invité

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List of abbreviations

IOT: Internet of Things.

PPM: Parts Per Million.

TDS: Total Dissolved Solids.

DWC: Deep Water Culture.

NFT: Nutrient Film Technique.

PH: Potential Hydrogen.

DWC: Deep Water Culture.

NFT: Nutrient Film Technique.

ICT: Information and Communication Technology.

IT: Information Technology.

AI: Artificial Intelligence.

Wi-Fi: Wireless Fidelity.

LPWA: Low-Power Wide-Area.

LoRa: Low Range.

EPC: Electronic Product Codes.

IPv4 : Internet Protocol Version 4.

IPv6 : Internet Protocol Version 6.

6LoWPAN: IPv6 Low power Wireless Personal Area Networks.

ID: Identification.

IP: Internet Protocol.

RFID: radio frequency identification.

IPA: IoT Physical Architecture.

ILA: IoT Layered Architecture.

NB-IoT: Narrowband IoT.

List of abbreviations

RDF: Resource Description Framework.

uCode : Ubiquitous Code.

OWL : Web Ontology Language.

WWW: World Wide Web**.**

RNN: Recurrent Neural Network.

ANNs: Artificial Neural Networks.

ML: Machine Learning.

NLP: Natural Language Processing.

CNN: Convolutional Neural Network.

FC: Fully Connected.

ReLU: Rectified Linear Unit.

IDE: Integrated Development Environment.

REPL: Read-Eval-Print-Loop.

General Introduction:

General Introduction

Sustainable food production is one of the major challenges of the 21st century due to the rapidly increasing world's population and climate change. By 2050, the world's population is expected to hit a total between 9.4 and 10.1 billion people and food demand is projected to increase by 70.

This study, as part of our professional master's training in Automation and Industrial Computing at the Ibn Khaldun University of Tiaret (Algeria), aims to demonstrate how the Internet of Things (IoT) technology can be used in smart farming to improve the efficiency of agricultural production. We present a systematic review on the state-of-the-art of IoT adoption in smart agriculture and strive to identify the most appropriate communication and network protocols, hardware devices and technologies and their applicability to the proposed solutions. This thesis complements the project already carried out last two years a smart hydroponic greenhouse powered by a PV panel, by adding an ESP32 controller to provide a connection to the cloud via Wi-Fi. Using this communication network, data detected by sensors will be sent and stored in firebase database and then displayed using a dedicated Android App to allow a real-time monitoring and supervision of the greenhouse.

The proposed IoT design architecture for smart farming applications is based on four layers (perception, network, processing, and application. In recent years, there has been an increasing use of modern techniques and technologies for processing the collected data such as machine learning and artificial intelligence. Moreover, this work contributes to the existing body of literature by proposing a new approach for data processing, while in previous works most of the proposed decision support systems used simple processing mechanisms to handle data collected in real-time. More recent work showed an increasing number of management systems that use complementary technologies based on cloud and big data computing for processing large amounts of data. In terms of research domain, this work addresses the agriculture sector, including indoor and outdoor agriculture (greenhouse, hydroponics). However, the indoor and outdoor livestock farming was not considered in this study due to its impact on nature, associated mobility, different species deserves a separated and specific review [1].

The main goal of this work is the design, development, and field testing of the IoT application to demonstrate how the technology can be embedded into the greenhouse. The system allows users to remotely control and monitor crop growth and environmental conditions.

This thesis consists of four main chapters which are briefly summarized below:

- Chapter 1: presents an overview on agricultural greenhouse, hydroponics and Artificial Intelligence (AI).
- Chapter 2: provides a global view about IoT technology and AI and some of its applications.
- Chapter 3: presents a description of the hardware and software developed in this project.
- Chapter 4: is dedicated to the setup of the system, its validation and testing and the results obtained and some recommendations for future work.

Chapter I: Hydroponics Greenhouses

Chapter I: Hydroponics Greenhouses

I.1. Introduction:

Human beings are unconditionally dependent on plant growth as a food production source. As the world population continues to increase, so does the need for improvements on the efficiency of crop growth. On the other hand, the concentration of human population around urban areas tends to limit the agriculture practice close to where people live. Nevertheless, there has been an increase of public awareness on the source of food and a growing desire to eat fresh and locally.

Taking these issues into account, an engineering problem arises: how to make the growth of plants more efficient and possible in different and challenging environments, such as where soil is limited**.** Greenhouse is the most practical method of achieving the objectives of protected agriculture, where the natural environment is modified by using sound engineering principles to achieve optimum plant growth and yields [1]. Hydroponics is the method of growing plants without soil. This way, the plants' roots will get the nutrients and oxygen from water oxygenated solution with dissolved mineral nutrients. Greenhouses and hydroponics are not a novelty, but there is a lot of room for improvement with the advance of technology. By using sensors and actuators, autonomous crop growth can be done [2], reducing thus the burden of time-consuming and physically challenging agriculture tasks. It also allows increasing production efficiency, operating in an optimal way by reducing acting costs and maximizing crop growth. Growing plants in extreme conditions, where natural crop growth would not be possible at all, is another interesting possibility. Places with extremely adverse weather conditions - even in space - are motivational examples.

In this section, some of the most common greenhouses hydroponic technologies are listed and explained in order to give an insight on available methods and the ones that best suit this work.

I.2. Greenhouse:

I.2.1. Definition:

The greenhouse is a pseudo-closed structure intended to house crops of ornamental plants, vegetable or fruit, and sometimes -for experimental or educational purposes- of all other plants, in conditions more favorable or safer than in the open air. [3]

A greenhouse is a structure that can be perfectly closed; it is generally intended for agricultural production. The aim is to create an environment conducive to their development by taking advantage of the influences of the climate, by creating a micro climate, for a better management of the needs of plants, to accelerate their growth or to produce them independently of the seasons despite the changing weather conditions (wind, cold, rain…). This is increasingly important now as the world grapples with a future of climate uncertainty. [4]

I.2.3. Interest of agricultural greenhouse:

Climate change is one of the many factors that drive greenhouse farming around the world, but there are many other advantages that have drawn farmers to greenhouses over the years. In addition to being environmentally-friendly, a controlled environment is highly efficient in reducing the usage of water and other resources like fertilizer or pesticides. Fewer resources and treatments help farmers save costs while creating healthier produce for consumption. Crops are able to thrive in any kind of weather through climate-controlled greenhouses; it is designed to create an environment (microclimate). It allows air and root heating, irrigation control and fertilization, CO_2 enrichment and moisture control. It plays an economic role presenting products on the market in off-season. External conditions like weather and location won't affect operations. Greenhouse farming makes it possible to enjoy year-round plant production and profits. [5]

Figure I. 1: Example of agricultural greenhouse [6].

I.2.3. Greenhouses architectures:

Greenhouse structures of various types are used successfully for crop production. Although there are specific advantages in each type for a particular application, in general there is no single type greenhouse, which can be considered as the best. Different types of greenhouses are designed to meet the specific needs [7].

Figure I. 2: Most Common Greenhouse Designs [8].

1. The lean-to greenhouse:

Shares a wall with a building and relies on the building structure to provide some support for the greenhouse roof.

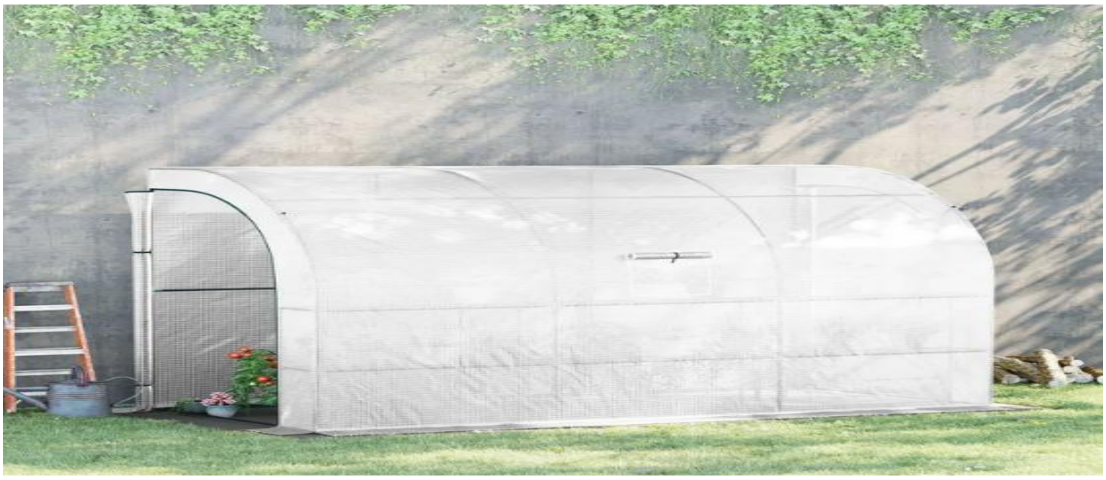


Figure I. 3: The lean-to greenhouse [9].

2. Traditional/Even-span/Gable greenhouse:

Structures are single houses that have roofs with an even pitch and an even width.

– A common even-span greenhouse that uses arching pipes for the framework is called a hoop house.

Figure I. 4: Gable greenhouse [10].

2. Uneven-span greenhouses:

Have unequal pitches and widths.

Figure I. 5: Uneven greenhouse [11].

3. Ridge-and-furrow greenhouse:

Structures consist of a number of greenhouses connected along the length of the house.

– The shared interior walls reduce energy costs and allow for large interior spaces. Ridge-and-furrow greenhouses are best oriented north and south to reduce permanent shadows on the crops, which are created by the gutters.

Figure I. 6: Ridge-and-furrow greenhouse [12].

4. Retractable-roof greenhouse:

Designs allow the roof to be opened and closed. When open, they provide plants with increased light levels and fresh air.

Figure I. 7: Retractable-roof greenhouse [13].

5. Shade houses:

These structures used to protect plants from wind, heat, and light intensity.

– Synthetic shade cloth is the most widely used covering material.

– It can be purchased with varying degrees of shade, depending on the grower's needs.

Figure I. 8: Shade houses [14].

6. Cold farms:

Are structures used to protect plants from wind, cold, and light intensity.

Figure I. 9: Cold farms [14].

For its simplicity and easy to build design, the traditional greenhouse shape was adopted. The advantages of straight lines allowed an easier handling of the building materials. This shape also permits passive and active ventilation, increasing the control capabilities.

I.2.4. Cover and structure materials:

The major shift in the post-World War II period has been the adoption and widespread use of plastics as a covering. In the early years, plastic did not offer a qualitative improvement over glass concerning environmental control. Plastic covered houses are now in wide use throughout the world and represent the largest share of new greenhouse construction. The plastic has several advantages, it is easy to work with, to transport, and is also cheaper. Although, over time it can have some downsides that wisely have been overtaken. Single layers of plastic covering are not as effective as glass in reducing heat loss. Furthermore, single-layer coverings also collect a large amount of condensation underneath reducing light transmission and sometimes leading to disease problems. By adding a second layer of plastic helps reducing heat losses and condensation [15].

The most commons options are below:

a. Glass.
b. Polyethylene (plastic).
c. Polycarbonate.
d. Solexx.

I.2.5. Greenhouse monitoring:

Inside a greenhouse temperature, humidity, carbon dioxide (CO_2), light incidence, root involving conditions and crop weight are some variables with great significance concerning plant growth. [16]

a-Temperature:

Temperature exerts a significant influence on the rate of photosynthesis. Generally, the higher the temperature, assuming carbon dioxide and light are abundant, the faster photosynthesis takes place. While the greenhouse structure slightly reduces incident light, it compensates by helping retaining radiant heat. However, there are some limits to the process as different plants have different optimum temperatures. Heating the main original purpose of the greenhouse is to raise, in a controlled way, the temperature of plant growing environment. The air, soil and other objects inside the house absorb this heat and re-radiate a fraction of it.

b- Heating:

The main original purpose of the greenhouse is to raise, in a controlled way, the temperature of plant growing environment. The air, soil and other objects inside the house absorb this heat and re-radiate a fraction of it.

c- Cooling:

Plants themselves have a built-in cooling system in the form of transpiration by releasing water vapor. About 50 percent of the radiant energy received by the plant is lost this way [17]. The cooling process may be increased by the use of passive or forced ventilation, by sprinkling the outside of the glass with water or using heat exchangers. Ventilation is by far the most common method, once it is cheaper and easier to control. Both active and passive ventilation were adopted in this project implementation. The greenhouse has a controlled aperture on the roof and one air opening at the bottom with a fan attached to it. Therefore, allowing air to flow with the thermal gradient or by active ventilation the air flux can be controlled. Greenhouse temperature control can get expensive. More recent studies aim to control the greenhouses with sustainable energies instead of fossil energy.

d-Light:

Light is essential for photosynthesis. In this process, sunlight is converted into sugars to provide fuel for plant growth. Photosynthesis is more pronounced in red (600-680nm) and blue and violet (380-480nm) wavelengths of light spectrum, reflecting green light, that is why plants appear green.

e-Humidity:

The relative humidity in a greenhouse is usually higher than in open air. While plants produce water vapor in the course of transpiration, relative humidity in greenhouses builds up to higher levels than in the field because of the heavier plant populations and reduced air movement. Humidity is generally controlled by ventilation, but it can be increased by misting devices and reduced by use of heating.

f-Carbon Dioxide:

The gaseous composition of the atmosphere has a significant influence on plant growth. It has long been recognized that greenhouses need to be ventilated to provide adequate carbon dioxide.

g-Root zone:

Plants absorb through their roots all of the water, most of the nutrients, and some of the oxygen they use. Hence, plants require root mediums with adequate moisture, fertility, and aeration. Using soil, this is done by watering, fertilizing and trusting the soil ability of air retention. In some facilities, the fertilization is done via the watering system. On the other hand, a hydroponic system is a soil-free crop grows method where plants grow in an inert substrate. This solution allows the enhancement of crop growth and level of control, and this is the main reason why it was adopted.

h-Crop growth:

For plant growth evaluation, plant weight is an important and commonly used indicator. Traditional plant weight measurements are destructive and laborious. In order to measure and record the plant weight during crop production, some non-invasive methods have been developed.

I.2.6. Classifying greenhouses:

Greenhouse structure of various types is used for crop production. Although there are advantages in each type for a particular application, in general there is no single type greenhouse, which can be constituted as the best. Different types of greenhouses are designed to meet the specific needs. The different types of greenhouses based on shape, utility, material and construction are briefly given below: [18]

- ✓ **Greenhouse type based on shape:**

For the purpose of classification, the uniqueness of cross section of the greenhouses can be considered as a factor.

- ✓ **Greenhouse type based on Utility:**

Classification can be made depending on the functions or utilities. Of the different utilities, artificial cooling and heating are more expensive and elaborate. Hence based on this, they are classified in to two types.

a) Greenhouses for active heating.
b) Greenhouses for active cooling.

- ✓ **Greenhouse type based on construction:**

The type of construction predominantly is influenced by structural material, though the covering material also influences the type. Higher the span, stronger should be the material and more structural members are used to make sturdy tissues.

- ✓ **Greenhouse type based on covering material:**

Covering materials are the important component of the greenhouse structure. They have direct influence on greenhouse effect, inside the structure and they alter the air temperature inside. The types of frames and method of fixing also varies with covering material. The structural requirements and the cost per unit area for different models of low-cost green houses for cultivation of vegetables are detailed below with diagrams to enable an interested entrepreneur to construct a, low cost green house on his own accord. However, the local weather conditions and the individual's necessity play a major role in the selection of the model.

I.2.7. Advantages of greenhouses:

The yield may be 10-12 times higher than that of outdoor cultivation depending upon the type of greenhouse, type of crop, environmental control facilities [19].

- Throughout the year four to five crops can be grown in a greenhouse due_to availability of required plant environmental conditions.
- The productivity of the crop is increased considerably.
- Superior quality produce can be obtained as they are grown under suitably controlled environment.
- Gadgets for efficient use of various inputs like water, fertilizers, seeds and plant protection chemicals can be well maintained in a green house.
- Effective control of pests and diseases is possible as the growing area is enclosed.
- Percentage of germination of seeds is high in greenhouses.
- The acclimatization of plantlets of tissue culture technique can be carried out in a green house.
- Agricultural and horticultural crop production schedules can be planned to take advantage of the market needs.

- Different types of growing medium like peat mass, vermiculate, rice hulls and compost that are used in intensive agriculture can be effectively utilized in the greenhouse.
- Export quality produce of international standards can be produced in a greenhouse.
- When the crops are not grown, drying and related operations of the harvested produce can be taken up utilizing the entrapped heat.
- Greenhouses are suitable for automation of irrigation, application of other inputs and environmental controls by using computers and artificial intelligence techniques.
- Self-employment for educated youth [20].

I.2.8. Greenhouse Effect:

In general, the percentage of carbon dioxide in the atmosphere is 0.035% (345 ppm). But, due to the emission of pollutants and exhaust gases into the atmosphere, the percentage of carbon dioxide increases which forms a blanket in the outer atmosphere. This causes the entrapping of the reflected solar radiation from the earth surface. Due to this, the atmospheric temperature increases, causing global warming, melting of ice caps and rise in the ocean levels which result in the submergence of coastal lines. This phenomenon of increase in the ambient temperature, due to the formation of the blanket of carbon dioxide is known as greenhouse effect. The greenhouse covering material acts in a similar way, as it is transparent to shorter wave radiation and opaque to long wave radiation. During the daytime, the shorter wave radiation enters into the greenhouse and gets reflected from the ground surface. This reflected radiation becomes long wave radiation and is entrapped inside the greenhouse by the covering material. This causes the increase in the greenhouse temperature. It is desirable effect from point of view of crop growth in the cold regions [20].

I.3. Hydroponic Farming:

The agriculture industry is going through fast and progressive changes, and one among those changes is “Hydroponic Farming.”

Figure I. 10: Hydroponic Farming. [21]

I.3.1. Definition:

Hydroponic Farming is growing plants by using nutrient solutions (water-containing fertilizers) with or without utilizing an artificial medium such as sand, gravel, rock wool, vermiculite, perlite, peat moss, coir, sawdust, coir dust, coconut fiber, etc. to provide mechanical support. This type of farming is also called aquaculture, nutriculture, soilless culture, or tank farming.

The term hydroponics was derived from the Greek word's "hydro", which means water, and" ponos", which means labor or water work. [22]

This farming is further categorized into two main types:

- **Open Hydroponic Farming:** The nutrient solution supplied to the plants is not reused.
- **Closed Hydroponic Farming:** Excess nutrient solution is recovered, replenished, and recycled.

I.3.2. Different types of hydroponic system:

1- Semi hydroponic system or drip hydroponic:

The Wick hydroponic system does not require electricity, pump, or aerators. Here, the plants are placed in artificial/absorbent mediums such as coco coir, vermiculite, perlite with a nylon wick which runs into a reservoir filled with nutrient solution from the roots of the plants. The supply of water or nutrient solution to the plants from the pool is accomplished through capillary action. This most straightforward system is suitable for small plants, herbs, and spices but does not work where a massive quantity of water is needed [22].

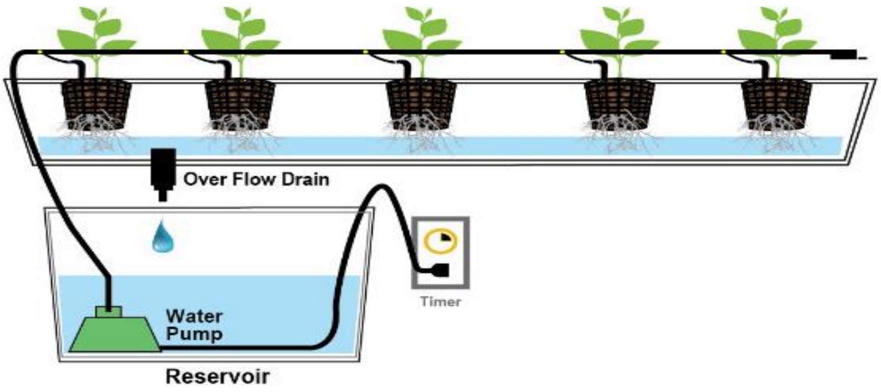


Figure I. 11: Drip System [23].

2- Ebb and Flow System (Flood and Drain System):

Flood and drain principles are applied for the Ebb & Flow Hydroponic System. A water pump is used to flood nutrient solution and water from the reservoir to grow bed until a certain level is reached and retained there for a certain period. General problems like root rot, algae, and mold can be avoided by making slight modifications and using a filtration unit to grow various types of crops [22].

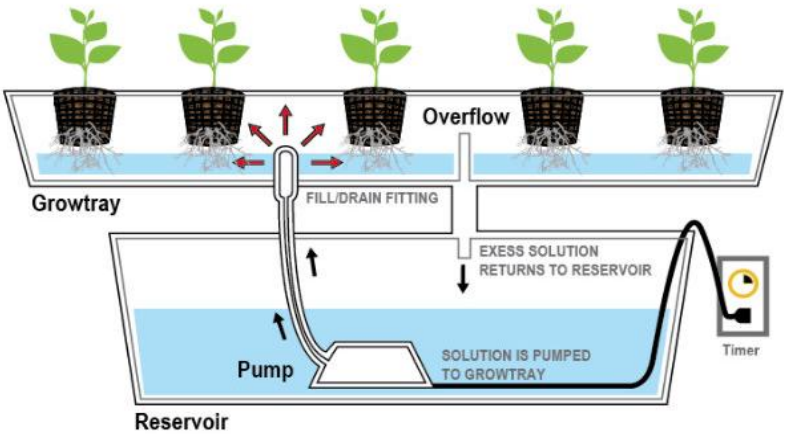


Figure I. 12: Ebb and Flow System [23].

3- Wick Hydroponics:

The wick system is the most simplistic type of hydroponic system requiring no electricity, pumps, or aerators. Among the different type of hydroponic systems, it's the only one that can be a completely passive system, meaning no electricity is needed.

In most systems, plants are placed in an absorbent grow medium like coco coir, vermiculite, or perlite, with a nylon "wick" running from the plants into a reservoir of nutrient solution. [24]

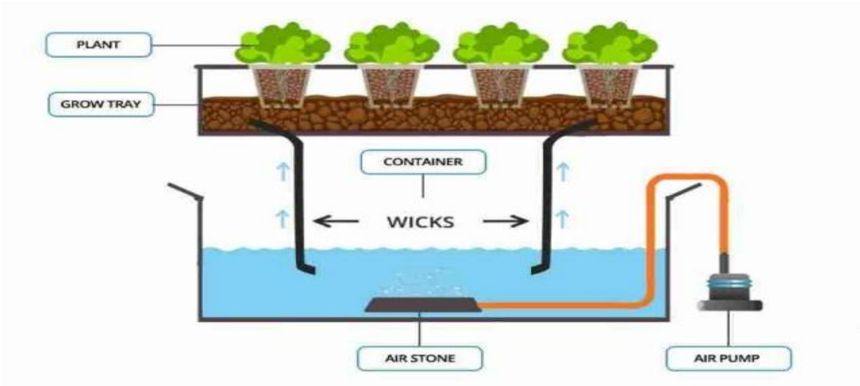


Figure I. 13: Wick System [25].

4- Nutrient Film Technique (NFT):

NFT or nutrient film technique systems are characterized by a permanent flow of nutrients in a thin "film" around the roots. A pump transports the nutrient solution on an inclined plane (e.g. a tube), on which the plant roots lie. They are continuously watered and supplied with nutrients. The constant flow prevents nutrient accumulation.

Owing to the special construction of NFT systems, oxygen is inserted into the nutrient solution, usually through downpipes or vortex systems. In most cases no substrate is used, so that the roots have unhindered access to nutrients and oxygen and can grow quickly [26].

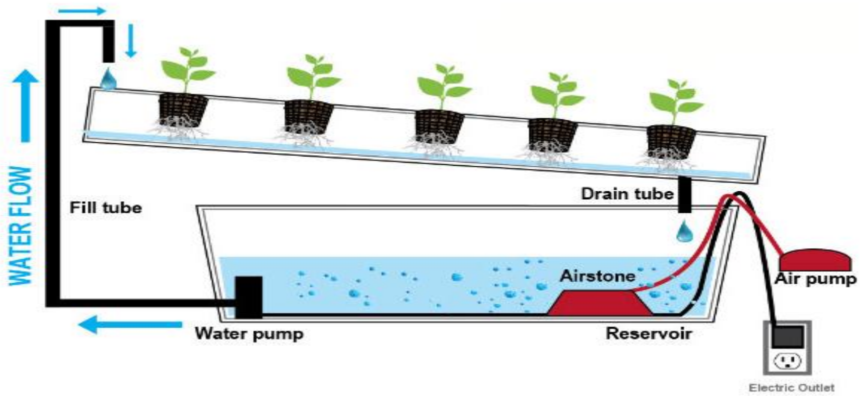


Figure I. 14: NFT System [23].

5-Deep Water Culture System:

Hydroponics buckets system' is the finest example of a Deep-Water Culture System. Here, the roots of the plants placed in net pots are suspended in the nutrient solution, and an air stone is used to supply air directly to the roots as algae and molds can overgrow in the reservoir the concentrations of oxygen and nutrient, salinity, and pH levels are regulated. Large plants are suitable for growing using this type of system [22].

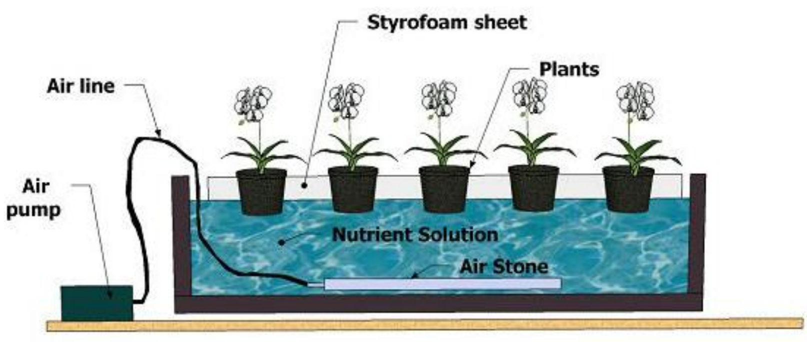


Figure I. 15: Deep Water Culture System [23].

6-Aeroponics System: Aeroponics - Roots are sprayed or misted through water nozzles:

In an aeroponic farming system, the roots of cuttings or plants do not hang in a liquid but in a mist of nutrient solution. The plants are hung with net pots in a chamber where the roots are sprayed or misted through water nozzles / mist nozzles with nutrient solution.

Aeroponic systems provide the optimal roots supplys with everything they need to grow. Such systems work very effectively and provide maximum plant growth. However, the technical complexity is high because of the high water pressure for the nozzles or nebulizers used. In addition, technical measures must be taken to prevent clogging of the nozzles. The disadvantage is that a failure of the nebulizer is not long time tolerated by the freely hanging roots [26].

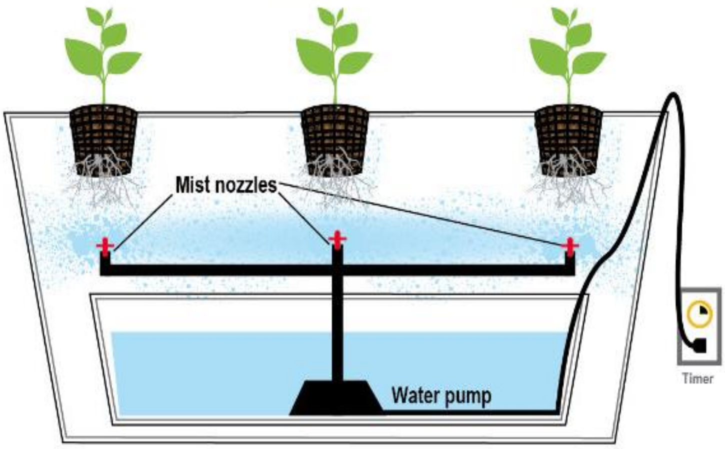


Figure I. 16: Aeroponics System [23].

7-Aquaponics - Plant and Fish Farming:

Aquaponics is a term made up of aquaculture (fish farming) and hydroponics (plant breeding), so two cultivation systems are combined. Fish excrements are used to provide the plants with nutrients; they are recycled and used as fertilizer.

The transformation of the excretions into nutrients suitable for plants is done with the help of microorganisms. At the same time a cleaning of the water takes place so that it can be returned to the fish tank and the fish have good living conditions. This creates a cycle with a win-win situation. In addition to growing salad and vegetables, fish are bred as food or ponds are kept clean with ornamental fish. [26]

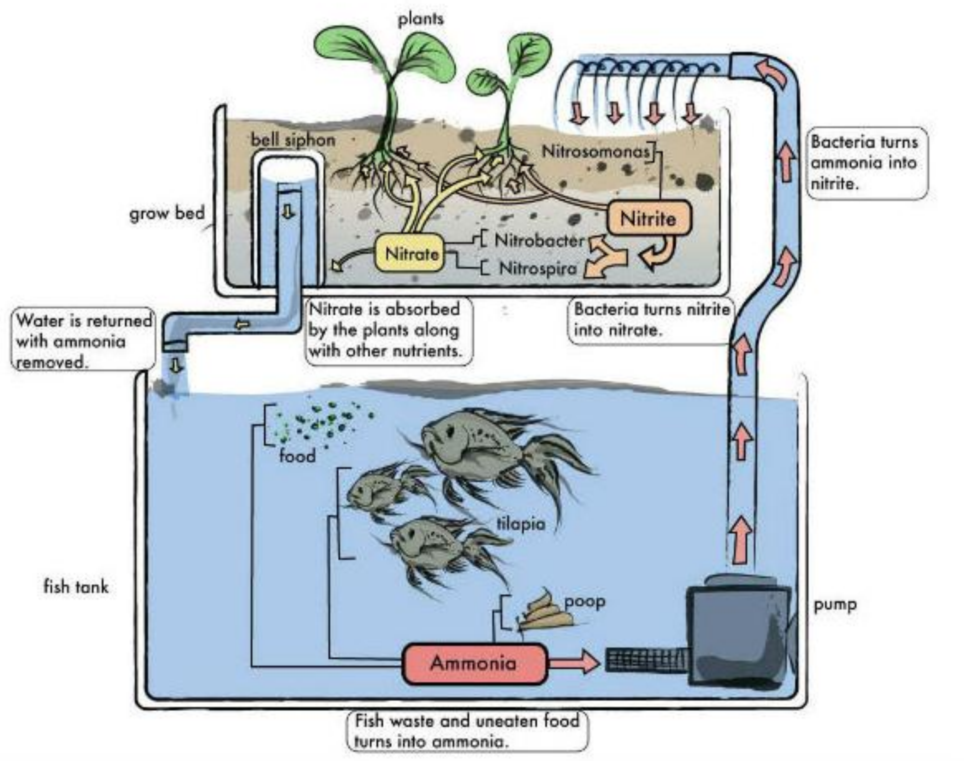


Figure I. 17 : Aquaponics System [23].

I.3.3. Hydroponics System Work:

In a hydroponics growing system, plants are either suspended directly in the aqueous solution or grown in a soil-free medium such as coconut coir, rock wool, LECA, vermiculite, or perlite. The plant's roots receive the nutrient solution in either an active system or a passive system. [27]

- **Active systems:** use pumps to circulate and aerate nutrient solutions, delivering the nutrients to the plant's root zone for uptake.
- **Passive systems:** have no pumps or moving parts. The nutrient solutions are fed to the root zone through flooding, gravity, or capillary action.

I.3.4. Environmental conditions in Hydroponic:

To control a hydroponic medium some intrinsic variables should be tracked. Water conductivity, PH., and temperature are the main crucial variables to consider [16].

a-Water conductivity:

The easiest way to keep on top of the nutrient solution is to take a measurement of parts per Million (PPM) and Total Dissolved Solids (TDS). These measurements are related with Electrical Conductivity (EC) of a solution and can be used as its proxy. There are various methods to measure PPM, but the most accurate and straightforward method is by doing a digital measurement of the water impedance, which is the most suitable approach for automatic systems.

b-Water Ph:

The PH level of the soil or hydroponic solution determines on how much of the essential elements the plant will be able to absorb, the PH is a measure of the acidity or alkalinity, if the PH solution is less than seven it is acidic, seven is neutral, and greater than seven is alkaline or basic.

Most plants prefer a PH between 6.0 and 7.0 for optimum nutrient uptake regardless of whether it is the soil solution or a nutrient solution, specific crops require different optimum PH ranges for example, lettuce likes a PH between 5.5 and 5.8, whereas tomatoes, peppers, and cucumbers prefer a PH from 6 to 6,4. There are several ways of measuring PH solution in home solutions using tapes that get colored according to PH levels are very popular due to its cheap and simple application.

There are electrical sensors able to measure water pH level, however, this tend to be quite expensive with a short lifetime and requiring periodic calibrations.

c-Water temperature:

The nutrient solution temperature should never exceed 30°C, the ideal value should be in a range from 16°C to 24°C whenever in summer and from 10°C to 16°C in winter. Temperatures outside this range can cause damages to the plants, decreasing its capability of absorbing nutrients.

I.3.5. Hydroponics advantages:

Hydroponics has extremely evolved in recent decades and today it is widely used in extensive agriculture. Thanks to these industrial developments, many tools and know-how exist today to enjoy hydroponics at home. The biggest advantages of hydroponics are: [28]

- When the roots receive the optimal nutrients supply, they do not need to grow in search of water. Therefore, the plant needs less space for its growth. The result is more plants in less space.

- If no soil is used, you reduce the weight of the pots. This is ideal for vertical structures.

- If no soil is used, fewer soil particles will be released, making it a cleaner system.

- With hydroponics, nutrient and water can be reused many times. This allows savings in water and nutrients of up to 50% compared to conventional cultivation.

- By optimizing light, water, nutrients and space, crop production will highly increase.

I.3.6. Hydroponics disadvantages:

Everything has its advantages and disadvantages; Hydroponics too, the disadvantages of hydroponics are: [28]

- **A stricter control of irrigation is required**: it must be adjusted to the needs of the plant and the environment.

- Irrigation control is easily achieved with automatic irrigation, which requires the use of electricity.

- **The cost of installation** is higher. A conventional pot does not have the same cost as a self-watering hydroponic system.

I.4. Plant disease identification:

The practice of agriculture has been used for centuries to procure sustenance, and it remains essential to the livelihoods of people worldwide. Food is a basic human need that no one can survive without, and both humans and animals rely on plants for sustenance and other vital resources like oxygen. Governments and experts are working tirelessly to improve food production, with promising results in the field. However, when a plant suffers from a disease, it can impact the entire environment. These afflictions can manifest in different areas of the plant, such as the stem, leaf, or branch, and may take different forms like bacterial or fungal infections, depending on factors such as climate. These issues pose a significant problem for food security, as poor crop output can leave many people hungry. Climate change further exacerbates the problem by affecting plant growth and development, causing natural calamities. Early detection and prevention of plant disease are necessary to avoid massive crop losses. Farmers must apply the right chemicals to protect crops, avoiding overuse, and seeking expert advice when necessary. Researchers are working to develop tools for automated disease detection that will benefit farmers of all sizes. One such tool utilizes Deep Convolutional Neural Network technology to detect and diagnose illnesses in plants, using images of both healthy and infected leaves to train the model.

I.4.1. Plant Disease Detection Using CNN:

Plant disease detection using Convolutional Neural Networks (CNN) involves training a model to recognize certain patterns in images of infected plants. The process involves the following steps:

1. Collecting a dataset of images of healthy and infected plants.
2. Pre-processing the images to remove noise and anomalies.
3. Splitting the dataset into training, validation, and testing sets.
4. Building a deep learning model using CNN architecture such as VGG, ResNet, or Inception.
5. Training the model on the training set and validating it on the validation set.
6. Evaluating the performance of the model on the testing set.
7. Using the trained model to make predictions on new images of plants.

The accuracy and effectiveness of the model depend on several factors, such as the quality of the dataset, the complexity of the architecture, and the size of the model. However, with careful selection and tuning of the parameters, CNNs can be very accurate in detecting plant diseases and thus prevent crop damage. With the help of this technology, farmers can take preventive measures and save their crops from getting destroyed.

I.5. Conclusion:

This section outlines and traces the major information's about hydroponic farming and greenhouses culture and how it has been viewed as a good system for developing various harvests as it allows growing short-length crops like vegetables throughout the year in highly restricted spaces with minimal work.

In addition, we have discussed the hydroponic greenhouse technologies, impact of environmental factors on hydroponic greenhouse cultivation, advantages and challenges of hydroponic greenhouse system.

Chapter II: Internet of Things and Artificial Intelligence

Chapter II: Internet of things and Artificial Intelligence

I.1. Introduction:

Integrating livestock management with the required devices and sensors is now seen as a critical factor in the agricultural sector's long-term success.

The findings revealed that the agricultural business sector is open to implementing Information and Communication Technology (ICT) solutions, so the aim of this work is to determine how advantageous it is for Romanian farmers to invest in a project that employs smart cattle farming methods that incorporate Artificial Intelligence AI and the Internet of Things IOT. An unstructured interview was used to gather empirical evidence during a focus group meeting. Analyzing the selected primary performance metrics, it was projected that the farm's profitability would increase by 19 percent, productivity would increase by 21 percent, and the farm's environmental impact would decrease by 22 percent. Automation and remote work would help minimize the farm's worker burden while also making control panels, decision-making files, and data analysis more available. In order for the domain to be as prosperous as possible, farmers must be made aware of the benefits of using these emerging technologies for closing the gap between farmers and Information Technology (IT) solution providers, and this can be accomplished through continuous training for both farmers and their technology vendors.

Figure II. 1: internet of things [29].

II.2. Overall view on internet of things:

II.2.1. Definition of IoT:

The concept of term IoT can be expressed by different definitions in our work we have choose the definition proposed by Oracle corporation, the Internet of Things (IoT) describes the network of physical objects— "things"—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet. These devices range from ordinary household objects to sophisticated industrial tools. With more than 7 billion connected IoT devices today, experts are expecting this number to grow to 10 billion by 2020 and 22 billion by 2025. [30]

The term Internet of Things (IoT) according to the 2020 conceptual framework is expressed through a simple formula such as:

IoT= Services+ Data+ Networks + Sensors [31]

II.2.2. Features of IOT:

As shown in figure II.2 there are 7 IoT characteristics of IOT technology. [32]

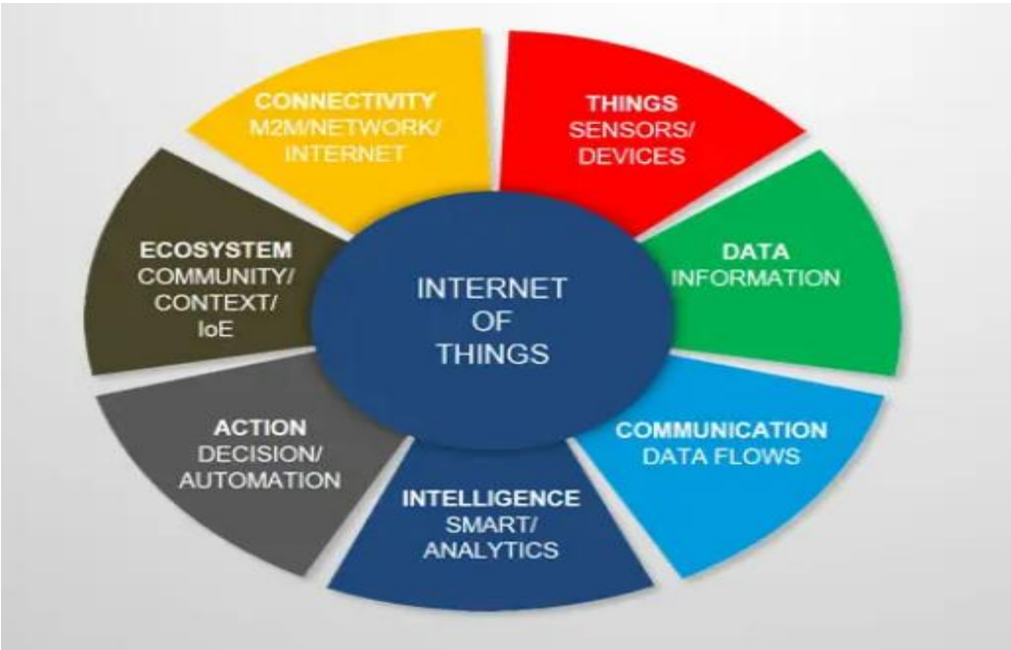


Figure II. 2: Characteristics of internet of things [32].

1) **Connectivity**: This doesn't need too much further explanation. With everything going on in IoT devices and hardware, with sensors and other

electronics and connected hardware and control systems there needs to be a connection between various levels.

2) **Things:** Anything that can be tagged or connected as such as it's designed to be connected. From sensors and household appliances to tagged livestock. Devices can contain sensors or sensing materials can be attached to devices and items.
3) **Data:** Data is the glue of the Internet of Things, the first step towards action and intelligence.
4) **Communication:** Devices get connected so they can communicate data and this data can be analyzed. Communication can occur over short distances or over a long range to very long range. Examples: Wi-Fi, LPWA network technologies such as Lora or NB-IoT.
5) **Intelligence:** The aspect of intelligence as in the sensing capabilities in IoT devices and the intelligence gathered from big data analytics (also artificial intelligence.
6) **Action:** The consequence of intelligence, this can be manual action, action based upon debates regarding phenomena (for instance in smart factory decisions) and automation, often the most important piece.
7) **Ecosystem:** The place of the Internet of Things from a perspective of other technologies, communities, goals and the picture in which the Internet of Things fits; the Internet of Everything dimension, the platform dimension and the need for solid partnerships.

II.2.3. IoT Elements:

Understanding the IoT building blocks helps to gain a better insight into the real meaning and functionality of the IoT. In the following sections we discuss six main elements needed to deliver the functionality of the IoT as illustrated in

Figure II.3. [33] [34]

Figure II. 3: IoT Elements [35].

1.Identification:

Identification is one of the important elements which are used to uniquely identify the device and provide required service to it in IoT network. The different identification methods are used to identify IoT objects like as electronic product codes (EPC) and ubiquitous codes (uCode) [36]. IPv6 and IPv4 are used for addressing methods of IoT objects. The IPv6 header is compressed with 6LoWPAN compression mechanism that makes IPV6 efficient for low power wireless networks [37] [38]. Furthermore, addressing the IoT objects is critical to differentiate between object ID and its address. Object ID refers to its name such as "T1" for a particular temperature sensor and object's address refers to its address within a communications network. In addition, addressing methods of IoT objects include IPv6 and IPv4. 6LoWPAN [39], [40] provides a compression mechanism over IPv6 headers that makes IPv6 addressing appropriate for low power wireless networks. Distinguishing between object's identification and address is imperative since identification methods are not globally unique, so addressing assists to uniquely identify objects. In addition, objects within the network might use public IPs and not private ones. Identification methods are used to provide a clear identity for each object within the network.

2.Sensing:

The IoT sensing means gathering data from related objects within the network and sending it back to a data warehouse, database, or cloud [41]. The collected data is used to take respective action. Various IoT sensors are available in the market such as smart sensors, actuators, etc. For example, a company like Smart-Things used smart hubs and mobile application to control home appliances and make a home as smart home. In a smart home, people can monitor and control thousands of devices with their Smartphone [42], [43]. The devices like Raspberry PI, Beagle Bone Black are integrated with sensors and used as IoT devices and provide required data to the customer.

3.Communication:

IoT communication element is used to connect different IoT objects to each other. IoT devices have low power and noisy communication link. RFID tag is a label attach to the specific device. Its readers send a query signal to RFID tag and receive signal send by tag. Then, it is passed to database which is processed by connected processing center and the object is identified in a particular range. Wi-Fi is another communication technology used to exchange data in 100 m range [44]. It can communicate and exchange data without using a router. Bluetooth is also a communication technology used to exchange data between devices over a short distance. It uses short-wavelength radio to minimize power consumption [45].

4.Computation:

Hardware like microcontrollers, microprocessors, and software applications are used for the computation of IoT. Various Hardware platforms have been developed for IoT like Arduino, Raspberry PI, Gadgeteer, Beagle Bone, Cubie board, etc. Various Software platforms have been developed like RTOS operating System.

5.Services:

Overall, IoT services can be categorized under four classes [46]: Identity-related Services, Information Aggregation Services, Collaborative-Aware Services and Ubiquitous Services. Identity-related services are the most basic and important services that are used in other types of services. Every application that needs to bring real world objects to the virtual world has to identify those objects.

6. Semantic:

Semantic in the IoT refers to the ability to extract knowledge smartly by different machines to provide the required services, includes discovering and using resources and modeling information also recognizing and analyzing data to make sense of the right decision to provide the exact service [47]. Thus, semantic represents the brain of the IoT by sending demands to the right resource. This requirement is supported by Semantic Web technologies such as the RDF and the OWL.

II.2.4. Most Common IoT Architectures:

The Internet of Things is considered as the third wave of the World Wide Web (WWW) after static web pages and social networking's-based web. The IoT is a worldwide network that connects different type of objects at anytime and anywhere via a popular internet protocol named Internet Protocol (IP) [48, 49]. According to most of the researcher's opinions about conventional IoT architecture, it is considered as two main layers: IoT layered architecture (ILA) and IoT physical architecture (IPA).

i. IoT Layered Architectures (ILA):

Currently, there is no single reference architecture, and creating one is proving very complicated despite many standardization efforts. The main problem lies in the natural fragmentation of possible applications, each of which depends on many very often different variables and design specifications. In Figure II.2 below, it is possible to see some of most common IoT Architecture used.

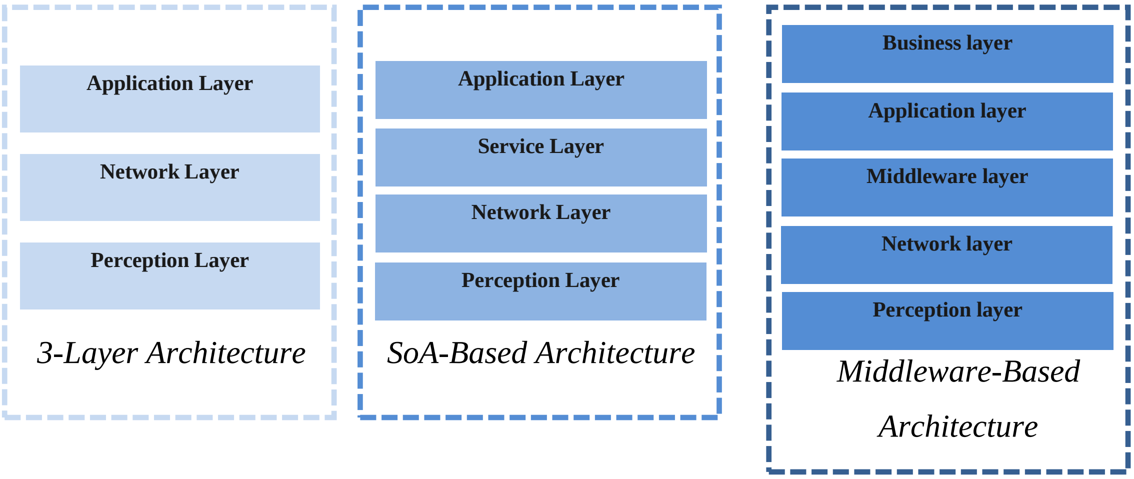


Figure II. 4: Most common IoT architectures.

A. IoT (3) Layered Architecture:

Three-level architecture is the common and generally known structure, a generic high-level architecture composed of three layers has been introduced in the early stages of research. It indicates three levels: perception, network, and application.

1. **Perception Layer (**the recognition layer**):** represents the physical level of objects and interacts with the surrounding environment by collecting and processing information [50]. This level includes objects that, being able to interact with the external world and being equipped with computing capabilities, become in a certain sense "intelligent" or "smart", where smart refers to the technological aspects (the smart technologies used), while intelligent refers to

the functional aspects (self-identification, self-diagnosis, self-testing, etc.) of the sensor [51].

2. **Network Layer:** is responsible for connecting to other smart things, network devices, and servers. It has the task of transporting the data provided by the perception level to the application layer and includes all the technologies and protocols that make this connection possible and should not be confused with the network layer of the ISO/OSI model, which only routes data within the network along the best path [50].
3. **Application Layer:** is considered as a top layer of conventional IoT architecture, it provides the personalized based services according to user relevant needs [52]. This layer's main responsibility is to link the major gap between the users and applications and combines the industry to attain the high-level intelligent applications type solutions such as the disaster monitoring, health monitoring, transposition, fortune, medical and ecological environment, and handled global management relevant to all intelligent type applications.

B. IoT (4) Layered Architecture:

4. **Service Management Layer:** Service Management or Middleware (pairing) layer pairs a service with its requester based on addresses and names. This layer enables the IoT application programmers to work with heterogeneous objects without consideration to a specific hardware platform. Also, this layer processes received data, makes decisions, and delivers the required services over the network wire protocols [51].

C. IoT (5) Layered Architecture:

5. **Business Layer:** The business (management) layer manages the overall IoT system activities and services. The responsibilities of this layer are to build a business model, graphs, flowcharts, etc. based on the received data from the Application layer. It is also supposed to design, analyze, implement, evaluate, monitor, and develop IoT system related elements. The Business Layer makes it possible to support decision-making processes based on Big Data analysis. In addition, monitoring and management of the underlying four layers is achieved

at this layer. Moreover, this layer compares the output of each layer with the expected output to enhance services and maintain users' privacy [53].

ii. IoT Physical Architectures:

The architecture is quite different from the typical web system and involves several layers as showing the figure:

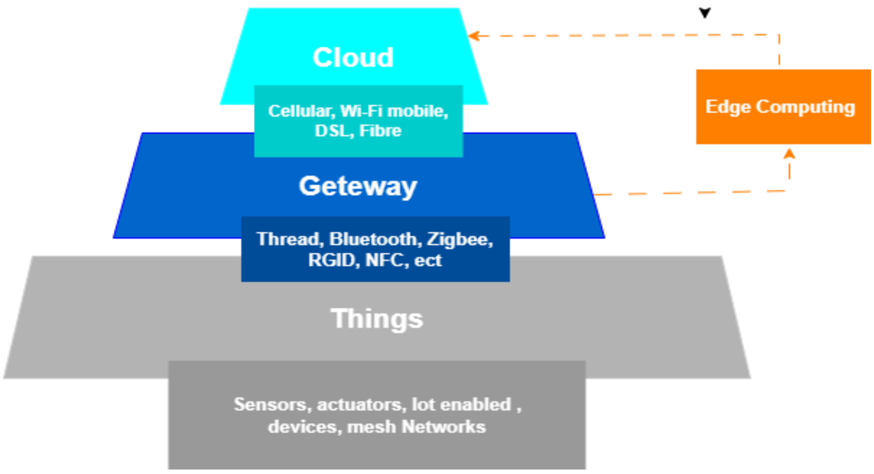


Figure II. 5: IoT blocks.

A. The things: sensors and devices

This stage is about the actual devices in the IoT solutions. These devices could be sensors or actuators in the Perception layer. Those devices will generate data (in the case of sensors) or act on their environment (in the case of actuators). The data produced is converted in a digital form and transmitted to the internet gateway stage. Unless a critical decision must be made, the data is typically sent in a raw state to the next stage due to the limited resources of the devices themselves.

B. Internet gateways:

The internet gateway stage will receive the raw data from the devices and pre-process it before sending it to the cloud. This internet gateway could be physically attached to the device or a stand-alone device that could communicate with sensors over low power networks and relay the data to the internet.

C. Edge or fog computing:

In order to process data as quickly as possible, you might want to send your data to the edge of the cloud. This will let you analyze the data quickly and identify if something requires immediate attention. This layer typically would only be concerned with recent data that is required for time-critical operations. Some pre-processing might be done at this stage, too, to limit the data that is ultimately transferred to the cloud.

D. Cloud or data center:

In this final stage, the data is stored for later processing. The application and business layers live in this stage, where dashboards or management software can be fed through the data stored in the cloud. Deep analysis or resource-intensive operations such as machine learning training will happen at this stage.

II.2.5. How does IoT work:

An IoT ecosystem consists of web-enabled smart devices that use embedded systems, such as processors, sensors and communication hardware, to collect, send and act on data they acquire from their environments. IoT devices share the sensor data they collect by connecting to an IoT gateway or other edge device where data is either sent to the cloud to be analyzed or analyzed locally. Sometimes, these devices communicate with other related devices and act on the information they get from one another. The devices do most of the work without human intervention, although people can interact with the devices -- for instance, to set them up, give them instructions or access the data [54].

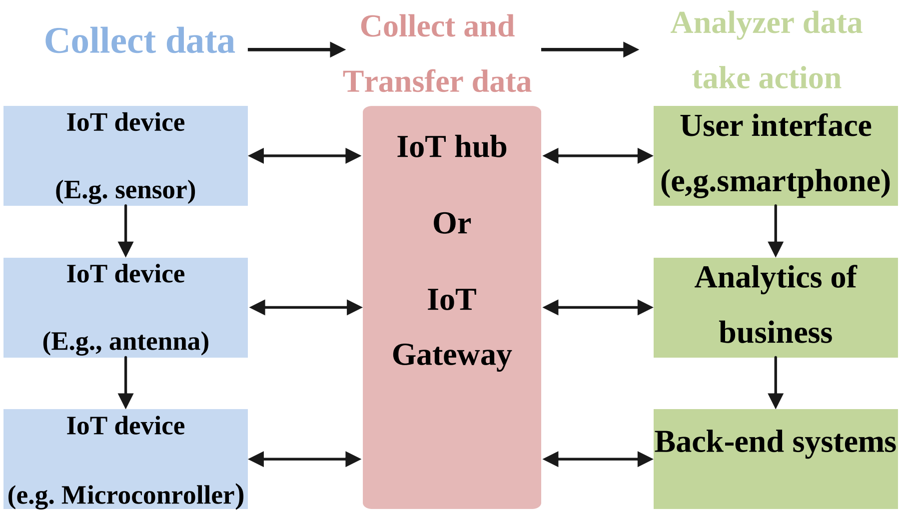


Figure II. 6: Example of how IoT system works from collecting data to acting [54].

II.2.6. Possible Applications of IoT:

The IoT can find its applications in almost every aspect of our daily life. Bellow are some examples : [55]

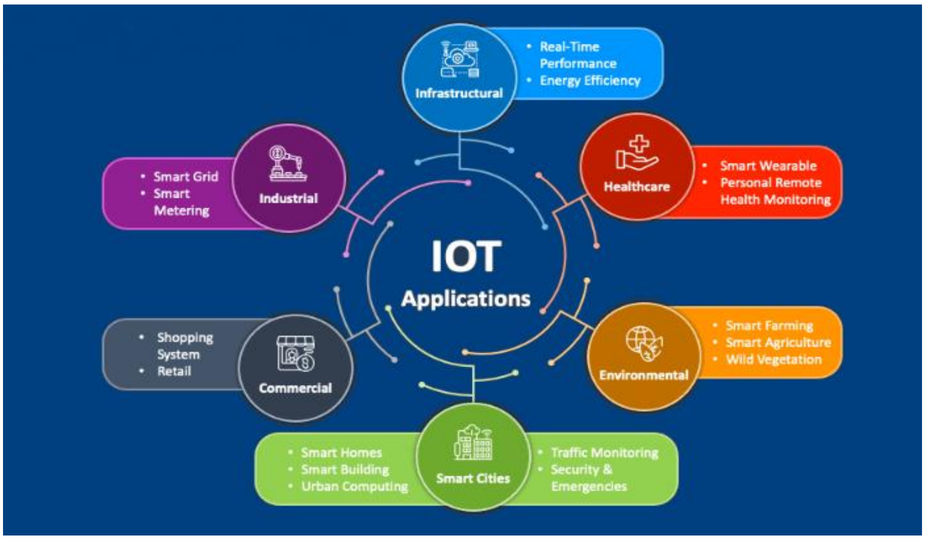


Figure II. 7: Some IoT Applications [56].

1. **Prediction of natural disasters:**

The combination of sensors and their autonomous coordination and simulation will help to predict the occurrence of land-slides or other natural disasters and to take appropriate actions in advance.

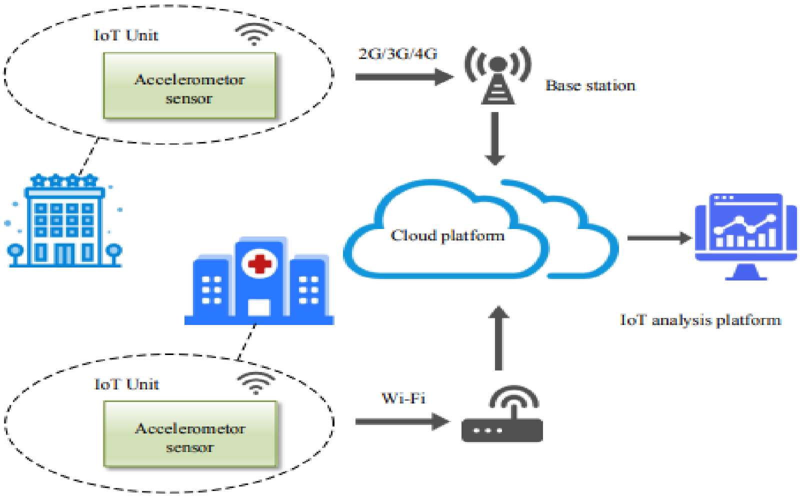


Figure II. 8: Structure of disaster management framework based on IoT [57].

2. **Industry applications:**

The IoT can find applications in industry e.g., managing a fleet of cars for an organization. The IoT helps to monitor their environmental performance and process the data to determine and pick the one that need maintenance.

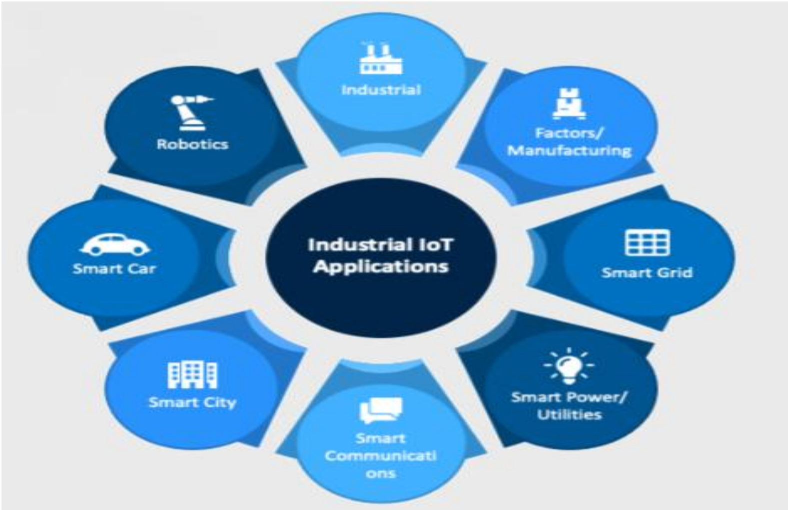


Figure II. 9: Industrial IoT Applications [58].

3. **Water Scarcity monitoring:**

The IoT can help to detect the water scarcity at different places. The networks of sensors, tied together with the relevant simulation activities might not only monitor long term water interventions such as catchment area management, but may even be used to alert users of a stream, for instance, if an upstream event, such as the accidental release of sewage into the stream, might have dangerous implications [59]**.**

Figure II. 10: IoT in Agriculture [60].

4. **Design of smart homes:**

The IoT can help in the design of smart homes e.g., energy consumption management, interaction with appliances, detecting emergencies, home safety, finding things easily and home security.

5. **Medical applications:**

The IoT can also find applications in medical sector for saving lives or improving the quality of life e.g., monitoring health parameters, monitoring activities, support for independent living, monitoring medicines intake etc.

6. **Agriculture application:**

A network of different sensors can sense data, perform data processing and inform the farmer through communication infrastructure e.g., mobile phone text message about the portion of land that need particular attention. This may include smart packaging of seeds, fertilizer and pest control mechanisms that respond to specific local conditions and indicate actions. Intelligent farming system will help agronomists to have better understanding of the plant growth models and to have efficient farming practices by having the knowledge of land conditions and climate variability. This will significantly increase the agricultural productivity by avoiding the inappropriate farming conditions.

Figure II. 11: Smart farming illustration [61].

7. **Intelligent transport system design:**

The Intelligent transportation system will provide efficient transportation control and management using advanced technology of sensors, information and network. The intelligent transportation can have many interesting features such as non-stop electronic highway toll, mobile emergency command and scheduling, transportation law enforcement, vehicle rules violation monitoring, reducing environmental pollution, anti-theft system, avoiding traffic jams, reporting traffic incidents, smart beaconing, minimizing arrival delays etc.

8. **Design of smart cities:**

   The IoT can help to design smart cities e.g., monitoring air quality, discovering emergency routes, efficient lighting up of the city, watering gardens etc.

9. **Smart metering and monitoring:**

   The IoT design for smart metering and monitoring will help to get accurate automated meter reading and issuance of invoice to the customers. The IoT can also be used to design such scheme for wind turbine maintenance and remote monitoring, gas, water as well as environmental metering and monitoring.

10. **Smart Security:**

    The IoT can also find applications in the field of security and surveillance e.g., surveillance of spaces, tracking of people and assets, infrastructure and equipment maintenance, alarming etc.

II.3. Overview on Artificial Intelligence:

II.3.1. Definition of AI:

The number of definitions of artificial intelligence (AI) has surfaced over the last few decades and becomes more and more institutionalized in the 21st Century [62], the term "Artificial Intelligence" was first introduced in the 1955 Dartmouth Conference.

Artificial Intelligence is the process of building intelligent machines from vast volumes of data. Systems learn from past learning and experiences and perform human-like tasks. It enhances the speed, precision, and effectiveness of human efforts. AI uses complex algorithms and methods to build machines that can make decisions on their own. Machine Learning and Deep learning forms the core of Artificial Intelligence [63].

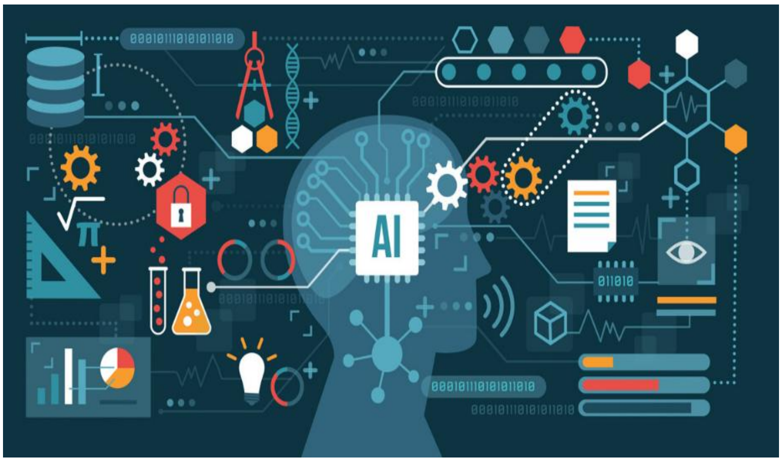


Figure II. 12: Artificial Intelligence Technologie [64].

II.3.2. How AI works:

To begin with, an AI system accepts data input in the form of speech, text, image, etc. The system then processes data by applying various rules and algorithms, interpreting, predicting, and acting on the input data. Upon processing, the system provides an outcome, i.e., success or failure, on data input. The result is then assessed through analysis, discovery, and feedback. Lastly, the system uses its assessments to adjust input data, rules and algorithms, and target outcomes. This loop continues until the desired result is achieved, the figure below shows details [65]:

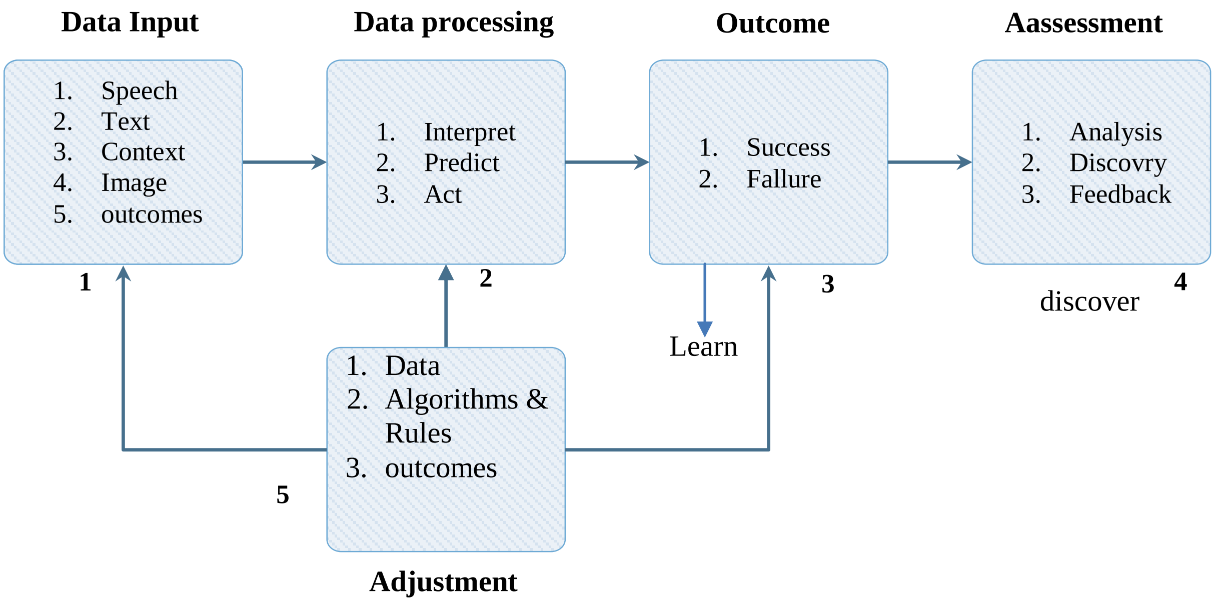


Figure II. 13: How AI works.

II.3.3. Machine learning (ML):

Machine learning (ML) is a process that allows a system to become more accurate at predicting outcomes without being explicitly programmed to do so. In intelligent tutors, ML methods are applied to gather fresh insight on learners, detect their aptitudes, and explore innovative pedagogical strategies. By consistently monitoring the responses of students and drawing conclusions about the particular subject matter or students themselves, they are able to enhance the effectiveness of their teaching methods. ML techniques play a crucial role in a tutor's ability to autonomously monitor and assess their performance. Smartly rephrased: By carefully analyzing the interactions between numerous students and their tutors, ML educators tailor their teaching methodologies using various components. The component that enhances the teacher's performance makes use of observations of teacher/student interactions and feedback from the students to determine the necessary adjustments to improve the teacher's future performance. Sophisticated machine learning methods are employed to discern the learning approaches of pupils, including their commonly preferred activities and their sequential sequence. Through the analysis of students' behavior, tutors can obtain valuable diagnostic data that helps to generate feedback and ultimately enhances the students' learning outcomes. [66]

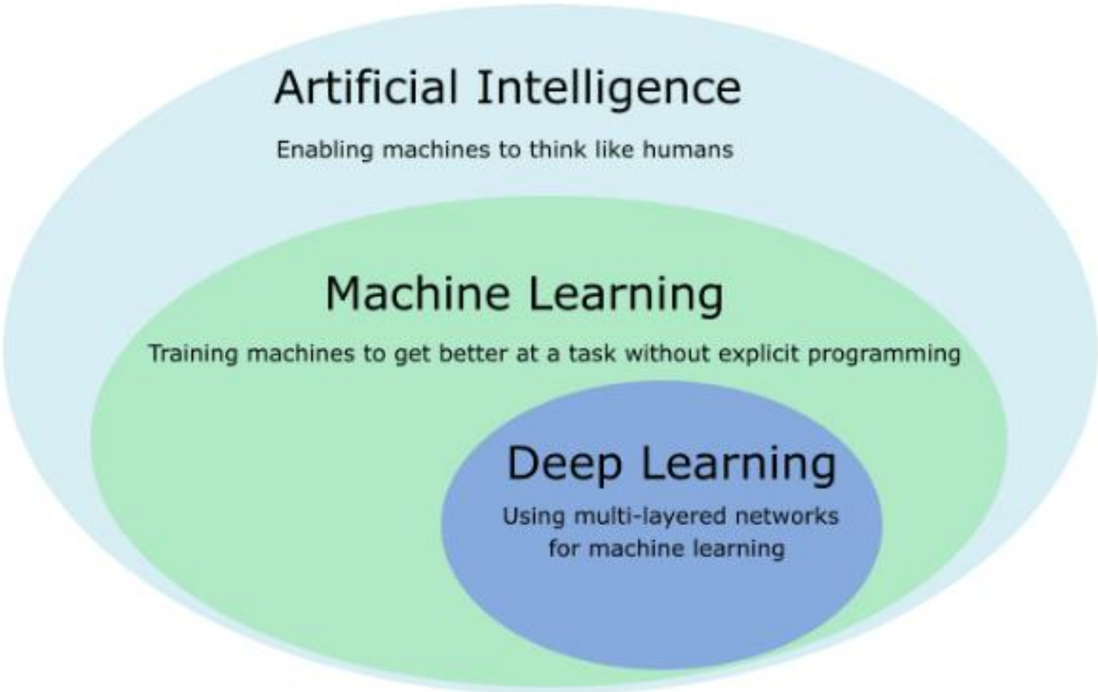


Figure II. 14: The confusion between AI vs. Machine Learning vs. Deep Learning. [67]

II.3.4. Artificial neural networks (ANNs):

Artificial neural networks (ANNs) or simulated neural networks (SNNs), which are a type of machine learning technology, are the foundation of deep learning algorithms and are commonly referred to as neural networks. Their nomenclature and configuration are patterned after the human brain, emulating the manner in which biological neurons communicate with each other.

Artificial neural networks (ANNs) are composed of layers of nodes, which consist of an input layer, one or multiple hidden layers, and an output layer. Every artificial neuron, also known as a node, links to another neuron and possesses a specific threshold and weight. If any specific node's output exceeds the designated threshold, it becomes activated and transmits information to the following layer of the network. If not, there won't be any transferring of information to the succeeding layer in the network. After carefully adjusting the learning algorithms to ensure precision, they become potent assets in the realm of computer science and artificial intelligence, enabling us to rapidly categorize and group data. The time required to perform speech or image recognition tasks can be significantly reduced from hours to mere minutes in comparison to the manual identification carried out by human specialists. Google's search algorithm is widely recognized as one of the most prominent neural networks. [68]

II.3.5. Inside convolutional neural networks:

Deep learning algorithms rely heavily on artificial neural networks (ANNs), which are an integral component of such algorithms. One common form of an ANN is the recurrent neural network (RNN), which operates using sequential or time series data as input, and is especially well-suited for applications in natural language processing (NLP), speech recognition, language translation, and image captioning.

A neural network that is particularly useful for detecting important details in image data and time series information is the CNN. For image-focused tasks, CNNs are highly prized due to their ability to recognize images, classify objects within them, and recognize patterns. To identify patterns within an image, CNNs use principles from linear algebra, such as matrix multiplication. Additionally, CNNs are capable of classifying audio and signal data. [54]

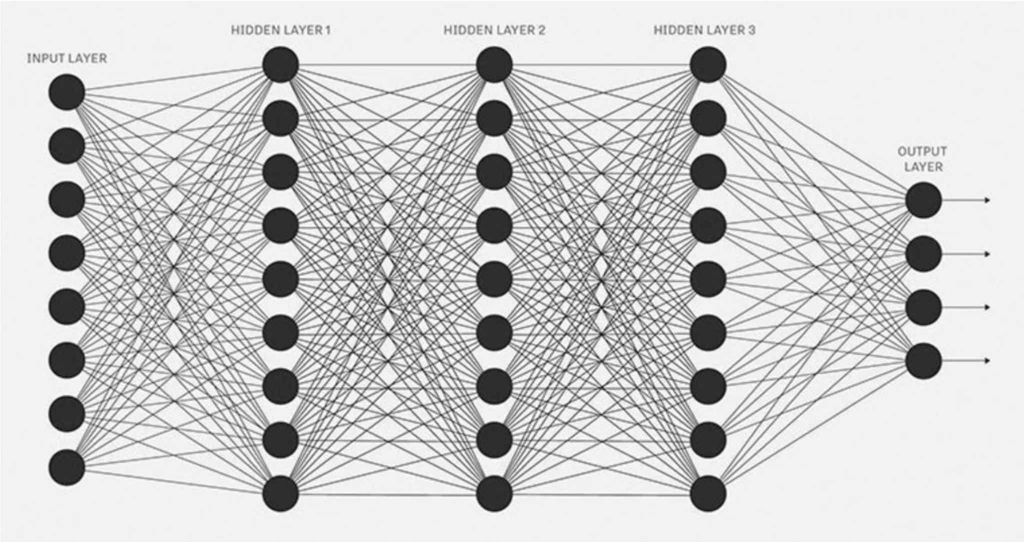


Figure II. 15: Diagram illustrating how a neural network processes data. [54]

II.3.6. Convolutional Neural Network (CNN):

The CNN is a model for deep learning that processes data presented in grid pattern formats, such as images. Its design is inspired by the organization of the visual cortex in animals, and its primary objective is to learn hierarchies of spatial features, ranging from low-level to high-level patterns, in an automated and adaptive manner. The CNN is a mathematical construct that is usually comprised of three different kinds of layers or building blocks: the convolution, pooling, and fully connected layers. The first two layers, convolution and pooling, are responsible for feature extraction, while the third layer, the fully connected layer, maps the extracted features to a final output, such as classification. In convolutional neural networks (CNNs), a pivotal component is the convolution layer. This layer comprises a series of mathematical functions, including a specialized linear operation referred to as a convolution. In digital imaging, pixel values are registered in a two-dimensional grid, or array of numbers and a small group of optimizable feature extractors known as kernels are applied at each position within the grid. This feature allows CNNs to be exceedingly efficient for image processing, as features can be detected anywhere within the image. Extracted features are hierarchically and progressively advanced as they are fed from one layer to the next. To optimize parameters such as kernels, a process called training is performed, which employs optimization algorithms such as back propagation and gradient descent to minimize the discrepancy between outputs and ground truth labels. The CNN algorithm includes four distinct layers. Their respective names are Convolution Layer, ReLU Layer, Pooling Layer, and Fully Connected Layer. [69]

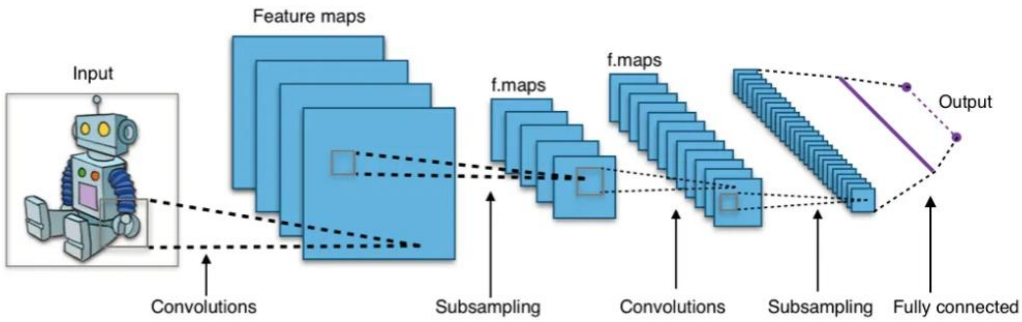


Figure II. 16: Schematic representation of a convolutional neural network Architecture. [70]

II.3.7. CNN layers:

The neural network architecture known as a deep learning CNN is composed of five distinct layers. The first layer is the convolutional layer, followed by the pooling layer, output layer, ReLU layer and lastly, the fully connected (FC) layer. It is worth noting that the convolutional layer is the initial layer and the FC layer is the final layer.

The CNN's complexity increases from the convolutional layer to the FC layer. The increasing complexity is what enables the CNN to identify larger and more intricate features of an image in succession until it can identify the entire object. [54]

1. Convolutional layer:

Everyone knows that a Convolutional Neural Network (CNN) is made up of convolutional layers. The primary layer, the one that does most of the work, is the 'convolutional layer.' It's essential to the success of a CNN, and it's responsible for lots of computations. A second convolutional layer can be added to 'follow' the initial one - this process is commonly referred to as 'convolution'. What happens here is a special kind of kernel or filter moves across different parts of an image, verifying if any significant features exist.

2. Pooling layer:

The pooling layer has a similar process to the convolutional layer, using a kernel or filter as it traverses through the input image. Its function, however, is distinct as it serves to minimize the input parameters to a degree where some information is lost. However, this tradeoff brings about the advantage of simplicity, ultimately improving the CNN's effectiveness.

3. Fully connected layer:

In a CNN, image classification takes place in the FC layer, which builds upon the features that have been extracted in earlier layers. The term "fully connected" implies that every input or node from one layer is linked to each activation unit or node in the following layer. The CNN's layers are not fully connected, as this would lead to an overly dense network. This would negatively impact the output quality, increase losses, and result in a computationally expensive process.

4. Output Layer:

This consists of a layer that is fully connected, which is then followed by an activation function called SoftMax, which determines the output classes. [72]

5. ReLU Layer:

The last step in acquiring the feature maps is transferring them to a layer of ReLU. This rectified linear unit must be utilized. The ReLU commonly referred to as a process in the convolutional neural network, does not function as an individual component. Finishing the procedure that was previously discussed requires an extra step, as mentioned in the last tutorial. It's worth noting that certain educators and authors have varying methods, in our case, we will group both phases as a single component for discussion purposes, despite their individuality. Discussing the two processes independently is a common topic among educators and authors when it comes to our technique. [72]

II.3.8. Status of AI applications in agriculture:

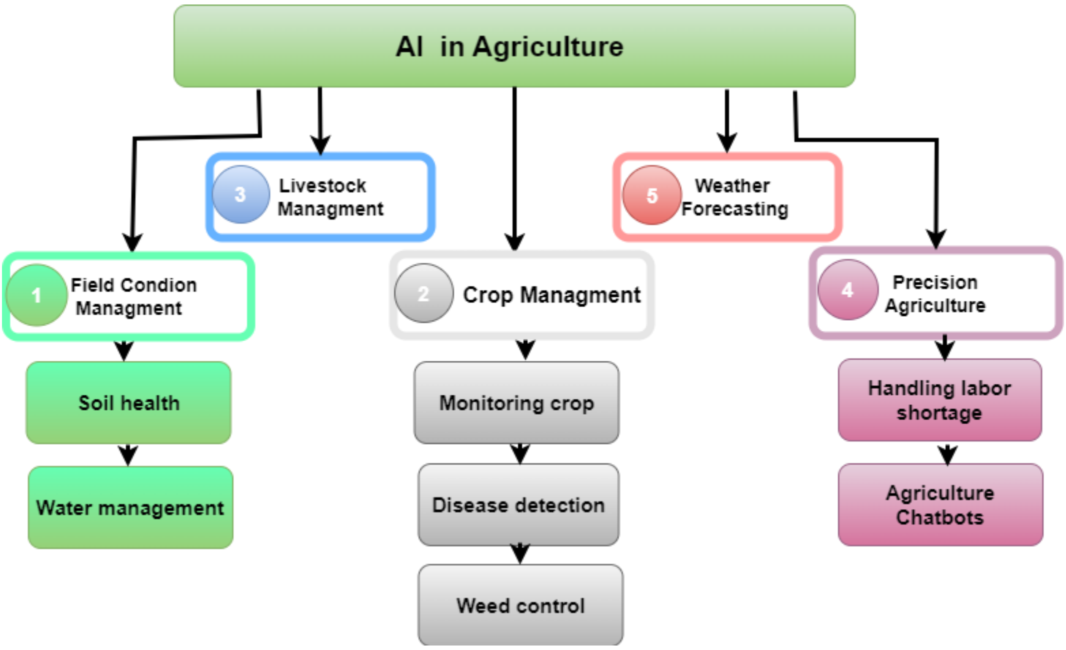


Figure II. 17: Uses of AI in agriculture.

1.AI for Field Condition Management:

Smart Farmers are using computer vision and deep-learning algorithms to scan fields and create a field map for in-depth analysis to increase productivity and reduce costs. [73]

- **Soil health:** AI is efficiently used to monitor soil health and provide information such as moisture level, PH level, or nutritional deficiencies in the soil.
- **Water management:** Agronomists are using AI-based applications to make effective use of irrigation systems and predict dew point temperature.

2.AI for Crop Management:

AI technologies help farmers produce abundant yields by determining crop choices, seed choices and resource utilization.

- **Monitoring crop:** Farmers are leveraging AI and drone-based solutions to monitor and assess the health of crops. Sky Squirrel Technologies Inc is a company using AI algorithms to provide a detailed health analysis report of vineyards.

- **Disease detection:** Farmers aims to diagnose diseases, pests, and plant nutrition levels on farms. Its software can inform growers where fertilizers are needed and in what quantity.

3.AI for Livestock Management:

Artificial intelligence helps farmers to monitor the health of farm animals and enable early detection of diseases and injuries. Farmers are using robotic milking machines and AI-based sensing systems are used to assess milk quality of cows.

4.AI for precision agriculture:

The Concept of precision agriculture is emerging and is making productive use of artificial intelligence to reinforce agribusiness, precision farming takes advantage of key AI-powered technologies to obtain guidance about crop rotation, nutrient management, right sowing and harvesting time, and so on.

- **Handling labor shortage:** Most farms are dealing with the problem of workforce shortage as fewer people are interested in the farming profession. AI-powered machines are now assisting farmers to solve this issue. To give a clear example, Harvest CROO Robotics has created a robot to aid strawberry farmers harvest their yields. It has increased the proficiency of the growers.
- **Agriculture Chat bots:** Farmers are using chat for getting advice and recommendations to solve farming problems.

5.AI for weather forecasting:

AI-based models are used by farmers to predict weather patterns and improve agricultural accuracy. Many companies, a Where is using AI models and satellite feeds to forecast weather and analyze crop sustainability.

AI-based machines are observing all agricultural activities in real-time, thinking about what to do next base on the data collected, and executing appropriate actions, AI has the potential to revolutionize the future of agriculture.

II.3.9. Conclusion:

AI and IoT are the future of the agriculture industry. The benefits of AI in agriculture are undeniable. It enables more strategic operations by helping to detect crop pests and diseases while improving product quality, improving efficiency and reducing production costs. Using artificial intelligence to accurately predict crop yields will help countries achieve food security.

IoT is a revolutionary technology that represents the future of computing and communications. Most of the people over all worlds depend on agriculture this has helped bridge the gap between production and quality and quantity yield. Data Ingested by obtaining and importing information from the multiple sensors for real time use or storage in a database ensures swift action and less damage to the crops. With seamless end to end intelligent operations and improved business process execution, produce gets processed faster and reaches supermarkets in fastest time possible. Precision agriculture sensor monitoring network is used greatly to measure Agri-related information like temperature, humidity, soil PH, soil nutrition levels, water level etc. so, with IoT farmers can remotely monitor their crop and equipment by phones and computers.

With that said AI and IoT adoption comes with several challenges, including a lack of diverse datasets, solve bottlenecks in the agriculture industry and foster increased food production and a lengthy learning curve. Other challenges include privacy and security concerns and digital illiteracy.

Chapter III: Hardware and Software Description

Chapter III: Hardware and Software Description

III.1. Introduction:

This project presents a hydroponic planting process monitoring system based on the internet of things. This device uses an ESP32 microcontroller board as the main controller. The parameters that were monitored and acquired were the conditions of the hydroponic growing media. Those parameters are; water pH, water temperature, water turbidity level, and ambient air temperature and humidity, the five parameters are measured by analog sensors integrated with the ESP32. These parameters affect the growth process and the quality of crop yields. Measurement result data is uploaded and saved to the real-time database. Then paired by Android-based applications. This application was created to be used by hydroponic farmers who use this device. Thus, the results of f monitoring can be used to optimize the process of growing hydroponic plants. Objectives and concept of the proposed solution

III.2. Objectives and concept of the proposed solution:

Our project aimed to analyze, design and develop a hydroponic system that monitors the hydroponic environment to ease up hydroponic farmers. The objectives of this project are shown below:

1. Develop a smart hydroponic system that monitors hydroponic environment in real time.
2. Allow users to check the condition of their hydroponic system environment through Smartphone to keep themselves updated.
3. Enable system to regulate the hydroponic system automatically by pumping the required solution into the reservoir to achieve the desired environment.
4. Enable system to send notification to alert the user about abnormal PH level and conductivity in the water of hydroponic system.

III.3. System Planning:

The design of the tool system is made to simplify and assist in the process of making tools as we can be seen in the image below.

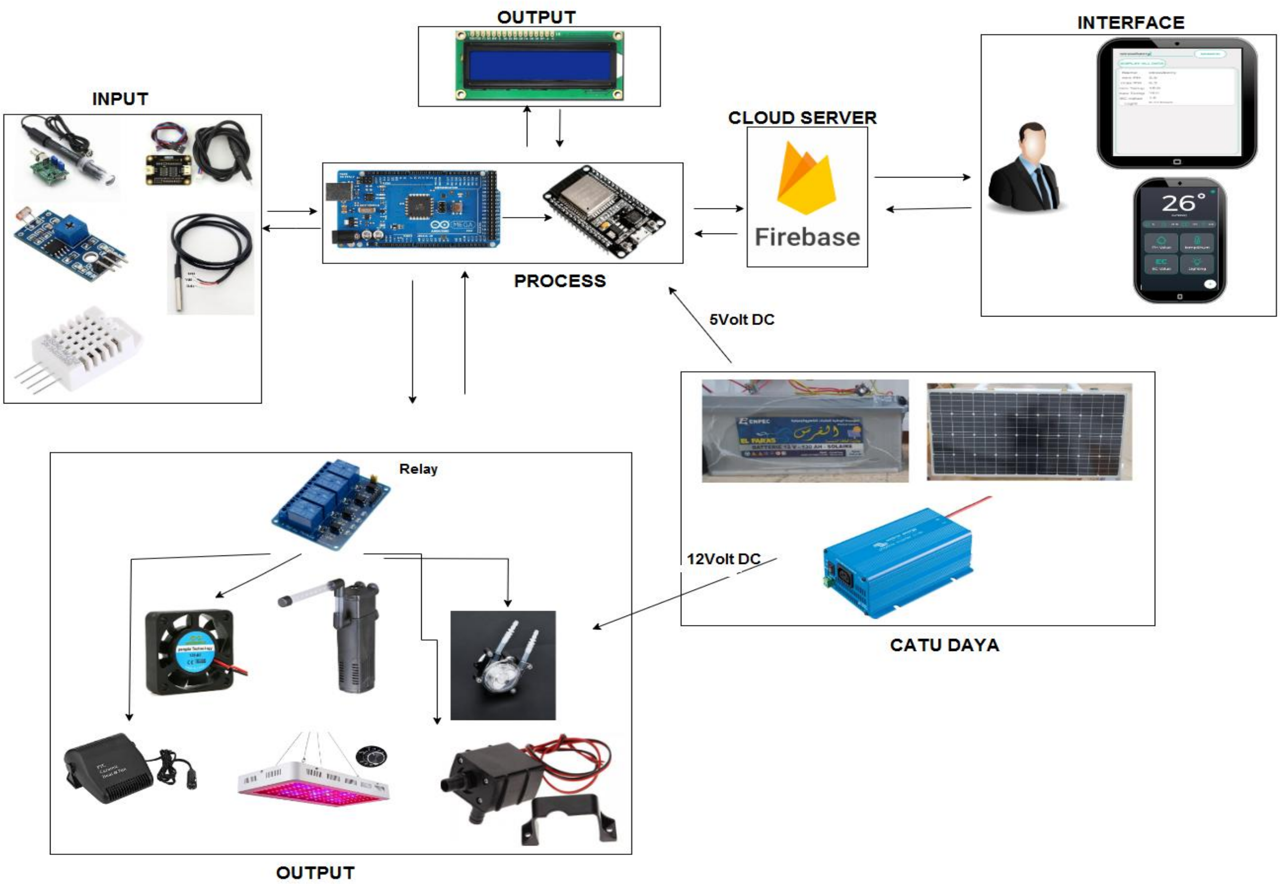


Figure III. 1: System Flow Design.

III.4. Hardware part:

III.4.1. Internal architecture of ESP32:

We choose ESP32 because it has a low-cost System on Chip (SoC) Microcontroller from Espressif Systems, ESP32-WROOM-32 is a powerful, generic Wi-Fi + Bluetooth® + Bluetooth LE MCU module that targets a wide variety of applications, ranging from low-power sensor networks to the most demanding tasks [74]. The figure below shows the main functional blocks within an ESP32.

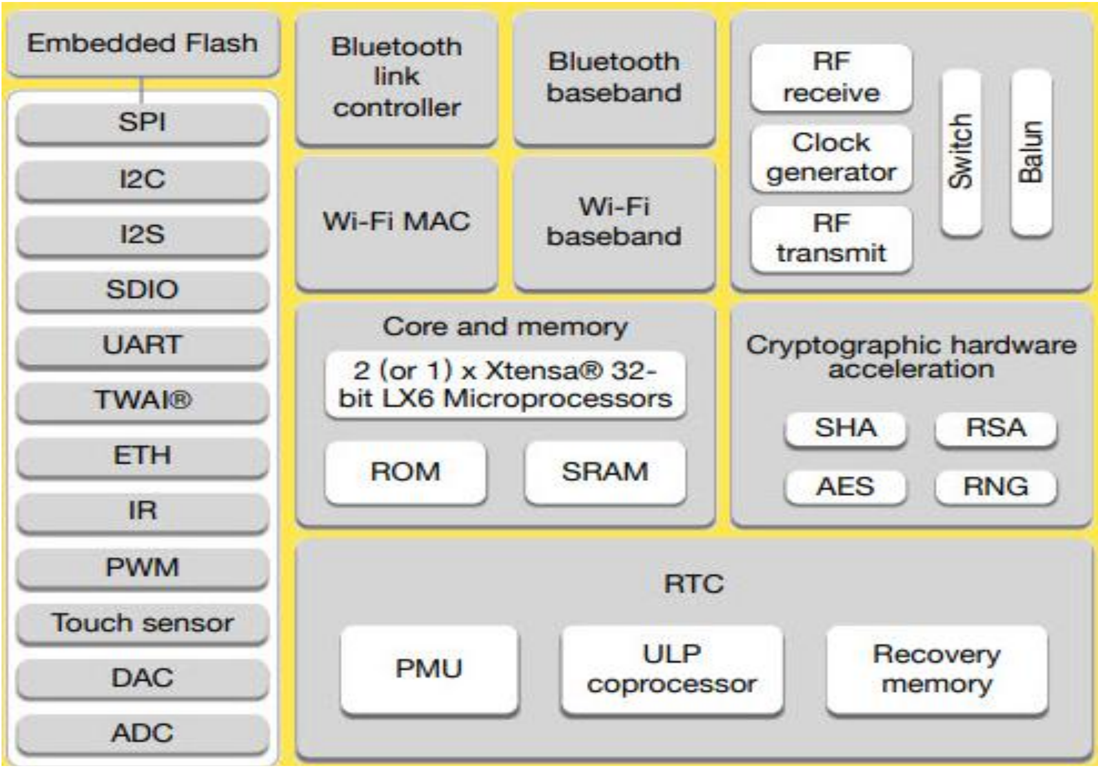
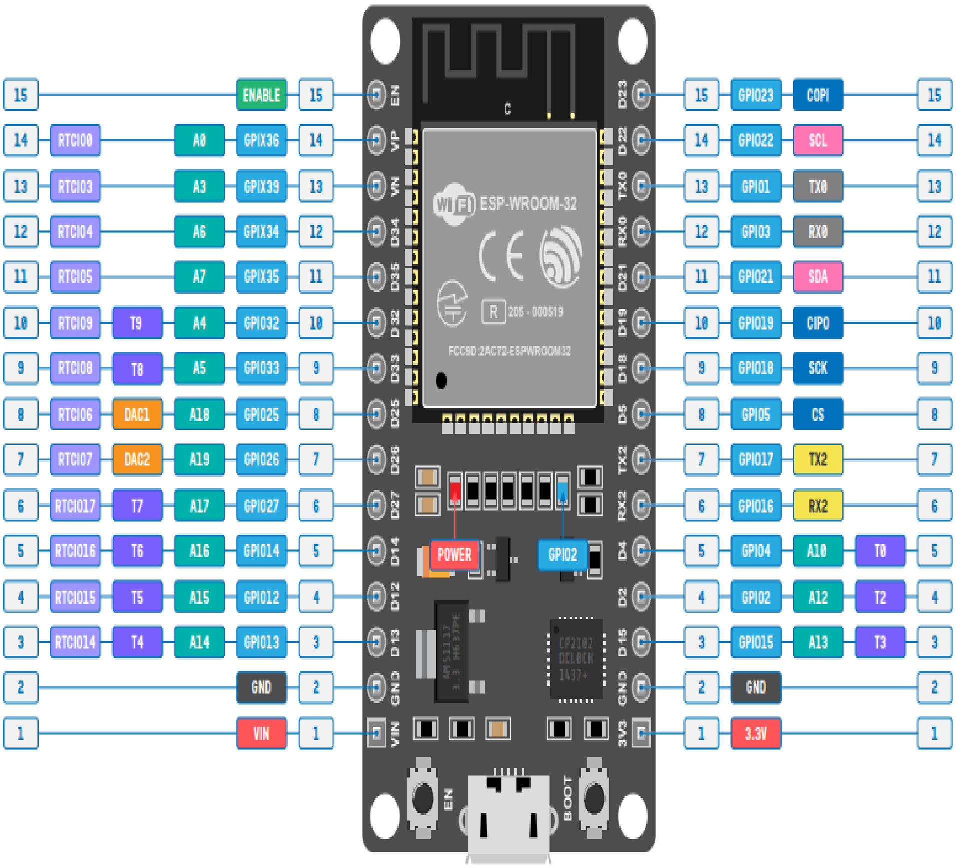


Figure III. 2: Internal architecture of ESP32 [75].

III.4.2. Pinout of ESP32 Board:



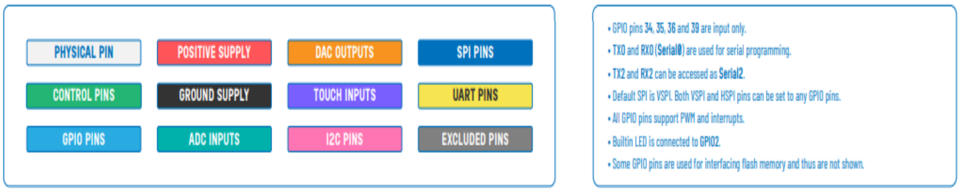


Figure III. 3: ESP32Dev Board Pinout [76].

III.4.3. Sensors:

III.4.3.1 Temperature & Humidity Sensor:

The DHT11 and the DHT22 are the two most widely used sensors in the DHTxx series. They look kind of the same and have the same pinout, but their specs are different. Of the two, the DHT22 is more expensive and, undoubtedly, has better specifications. The DHT22 can measure temperatures from -40°C to +125°C with an accuracy of ±0.5°C, while the DHT11 can measure temperatures from 0°C to 50°C with an accuracy of ±2°C. In addition, the DHT22 sensor can measure relative humidity from 0 to 100% with an accuracy of 2-5%, while the DHT11 sensor can only measure relative humidity from 20 to 80% with an accuracy of 5%.[77]

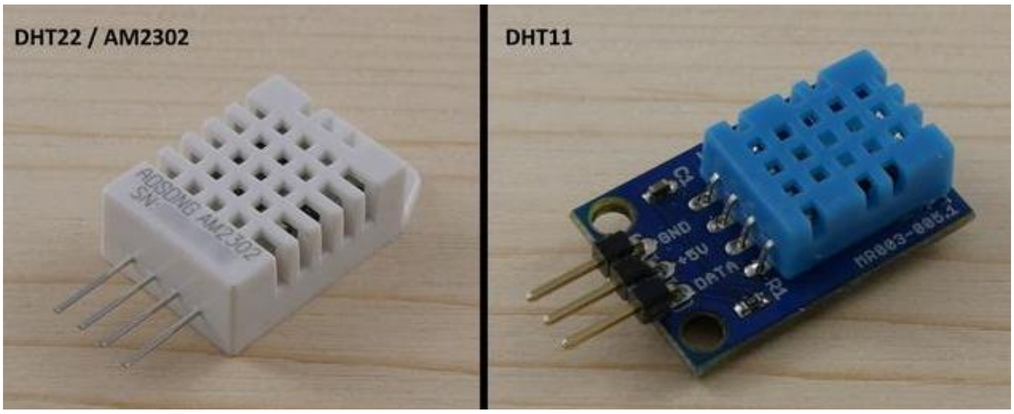
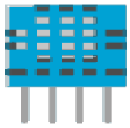
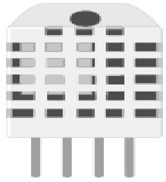


Figure III. 4: DHT11 and DHT22 sensors [78].

Here are the specifications:

Table III. 1: DHT11 and DHT22 sensors data sheet [77].





DHT11 **DHT22**

Parameter	**Value**	
Operating Voltage	3 to 5V	3 to 5V
Max Operating Current	2.5mA max	2.5mA max
Humidity Range	20-80% / 5%	0-100% / 2-5%
Temperature Range	0-50°C / ± 2°C	-40 to 80°C / ± 0.5°C
Sampling Rate	1 Hz (reading every second)	0.5 Hz (reading every 2 seconds)
Body size	15.5mm x 12mm x 5.5mm	15.1mm x 25mm x 7.7mm
Advantage	Ultra low cost	More Accurate

III.4.3.2 TDS (Total Dissolved Solids) sensor:

TDS (Total Dissolved Solids) indicates that how many milligrams of soluble solids dissolved in one liter of water. In general, the higher the TDS value, the more soluble solids dissolved in water, and the less clean the water is. Therefore, the TDS value can be used as one of the references for reflecting the cleanliness of water. [79]

Figure III. 5: TDS sensor [80].

Here are the specifications:

Table III. 2: TDS data sheet.

Parameter	**Value**
Product name	Gravity Analog TDS Sensor
Input Voltage	3.3 ~ 5.5V
Output Voltage	0 ~ 2.3V
Working Current	3 ~ 6mA
TDS Measurement Range	0 ~ 1000ppm
TDS Measurement Accuracy	± 10% F.S. (25 ℃)
Module Size	42 * 32mm
Module Interface	PH2.0-3P
Electrode Interface	XH2.54-2P

III. 4.3.3 Light sensor: LDR (Light Dependent Resistor) sensor:

Is one type of variable resistor, also known as a photoresistor. LDR is designed to provide the maximum possible contact area with two metal films. The Light Dependent Resistor (LDR) works on the principle of "Photo Conductivity"**.** When light intensity increase on the LDR surface, then the LDR resistance will decrease and the element conductivity will increase. When light intensity decrease on the LDR surface, then the LDR resistance will increase and the element conductivity will decrease. [81]

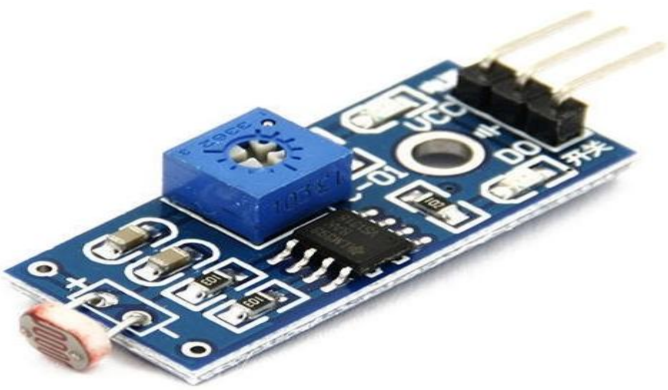


Figure III. 6: LDR module sensor. [82]

Here are the specifications:

Table III. 3: LDR data sheet. [81]

Parameter	Value
Operating voltage	5V or 3.3V DC
Comparator chip	LM393
Module Pins	3 pins
Output type	Digital outputs (D0)
Sensitivity	Adjustable
Indicator LED	Output and power LED indicator
PCB size	3 cm *1.6 cm
Fixed Hole Diameter	3 mm

III. 4.3.4 PH sensor:

Before working with PH metering we must know that PH values range is from [0-14]. PH 0 is very acidic, PH 7 neutral and PH 14 very alkaline. Water is near a PH 7 and this is usually around here that we will need to monitor PH of many things. Hydroponics systems for example around 6 (for optimum plant nutrition take-up). [83]

Figure III. 7: PH sensor. [84]

Here are the specifications:

Table III. 4: PH data sheet.

Parameter	Value
Heating voltage	5±0.2V (AC. DC)
Working current	5-10Ma
Detectable concentration range	PH0-14
Detection Temperature range	0-80 ℃
Response time	≤5s
Component Power	≤0.5W
Settling Time	≤60s
Humidity	95% RH (nominal humidity 65% RH)
Working temperature	-10-50 ℃ (nominal temperature 20°C)
Module Size	42mm *32mm *20mm

III.4.3.5 DS18B20 Arduino Temperature sensor:

The DS18B20 is a widely used 1-Wire waterproof digital temperature sensor that comes in the form of a Stainless-steel probe. it is manufactured by Dallas Semiconductor (acquired by Maxim Integrated). This sensor is perfect for measuring temperature in wet conditions, beneath the ground, underwater, or something far away. [85]

Figure III. 8: DS18B20 Arduino Temperature sensor. [86]

Here are the specifications:

Table III. 5: DS18B20 Arduino Temperature sensor data sheet.

Parameter	Value
Sensor Type	Programmable Digital Temperature Sensor
Operating voltage	5V - 3.3V DC
Operating Current	1A
Measuring temperature range	-55ºC to +125ºC (-67°F to +257°F)
Accuracy	±0.5°C Accuracy from -10°C to +85°C
Programmable Resolution	9 to 12 bit (Selectable)
Conversion Time	< 750ms
Sensing Probes	Stainless Steel tube
Cable Length/ Diameter	36 Inch / 91cm long, 4mm Diameter

III. 4.4 Actuators:

III.4.4.1 water pump:

Our system needs pump water a 12V Mini DC Brushless Pump because it is suitable for our greenhouse. It has high efficiency, a small size, with high life, low noise, no commutation sparks low consumption, low cost, and most importantly without pollution which is important for our work. [87]

Figure III. 9: Water Pump. [87]

Here are the specifications:

Table III. 6: Water pump data sheet.

Parameter	Value
Operating voltage	12V DC
Start voltage	10V DC
Working voltage range	10V-14V DC
Power	4.8W
Rated current	400±20mA
Max static water head	300±20 cm
Working Enviroment	PH Value : PH5-10(weak acid and weak base)
Max Working temperature	0- 75℃
Max static flow rate	240±20L/H

III.4.4.2 Fan:

The main role of fan in our greenhouse is to reduce the temperature of in the greenhouse if it is higher than the values at which the plant grows in the correct way.

Figure III. 10: Fan. [88]

Here are the specifications:

Table III. 7: Fan data sheet. [88]

Parameter	Value
Rated Voltage	12V DC
Rated Current	0.08A
Revolution	4500 ± 10% RPM
Noise	18 dBA
Wind speed:	1.5 M/s
Air volume	15.5 CFM
Bearing	Oil bearing
Expected life	30000 hours
Size	50mm x 50mm x 10mm(L x W x H)

III.4.4.3 Peristaltic pump:

To control the value PH and EC in water we use this type of actuator. It is suitable for our work, made of high-quality material, durable and long service life, the size of motor is 32x23mm, easy to install and remove, and the flow direction of the peristaltic pump depends on the positive and negative wiring of the power supply. [89]

Figure III. 11: Peristaltic Pump. [89]

Here are the specifications:

Table III. 8: Peristaltic pump data sheet. [89]

Parameter	Value
Applicable	12V DC
Max Working temperature	0-40℃
Flowing Range	0-23ml/min 0-65ml/min 0-150ml/mi
Speed Range	0.1-60rpm
Current	250-300Ma
Motor Diameter	Approx 32mm / 1.3in
Height	Approx 23mm / 0.9in
Installation Hole Center Distance	48.5mm / 1.9in

III.4.4.4 Air pump:

The air pump is use to control the humidity in the greenhouse.

Figure III. 12: Air Pump. [90]

Here are the specifications:

Table III. 9: Air pump data sheet. [90]

Parameter	Value
Name	RS-028A
Frequency	50 Hz
AC	220-240V
Puissance	6Watt
Q max	450 L/H
H max	0.9 m

III. 4.4.5 Relay:

Is an automatic switch that is commonly used in an automatic control circuit and to control a high-current using a low-current signal. The input voltage of the relay signal ranges from 0 to 5V. [91]

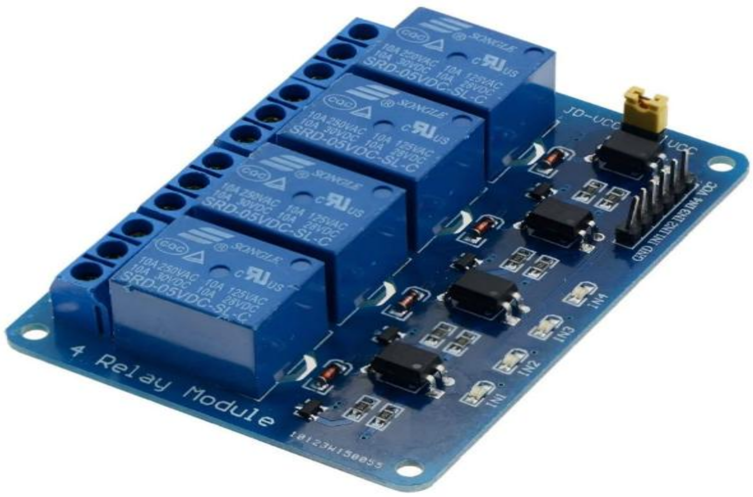


Figure III. 13: Relay. [92]

Here are the specifications**:**

Table III. 10: Relay data sheet. [91]

Parameter	Value
AC load current Max	10A at 250VAC or 125V AC
Coil Voltage (Relay)	5V
DC load current Max	10A at 30V DC or 28V DC
Relay Activation Current	15mA~20mA
Operating time	10msec
Dimensions	75x55x16.8 mm
Release time	5msec

III.4.4.6 Heating:

We use the heating to produce hot air, in order to control the temperature inside the greenhouse.

Figure III. 14: Heating. [93]

Here are the specifications:

Table III. 11: Heating data sheet. [93]

Parameter	Value
Operating voltage	12V DC
Power	150 W
Size	14x14x4cm
Item Weight	400g

III.4.4.7 Smart Float:

This device is used to control the level of water in a reservoir, to guarantee regular and continuous irrigation.

Figure III. 15: Float. [94]

III.4.4.8 LCD:

LCD (Liquid Crystal Display) screen is an electronic display module used in various devices and circuits. A 16×2 LCD can display 16 characters per line with the characters stretched between 2 rows (i.e. lines). In a 16×2 LCD, each character is displayed in a 5×7-pixel matrix. The 16×2 intelligent alphanumeric dot matrix display is capable of displaying 224 different characters and symbols. This LCD has two registers, namely, Command and Data. [95]

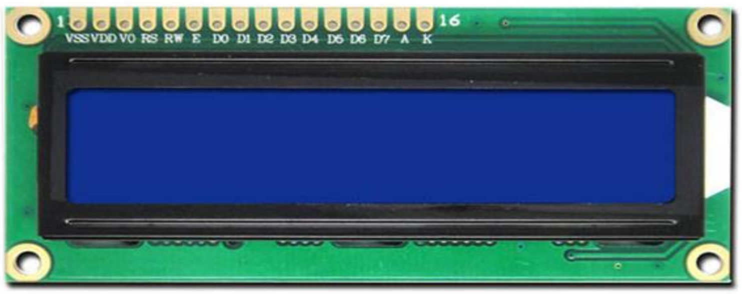


Figure III. 16: **LCD. [95]**

Here are the specifications:

Table III. 12: LCD data sheet. [95]

Parameter	Value
Display format	16 x 2 characters
Built-in controller	ST 7066 (or equivalent)
Duty cycle	1/16
Driver Led	pin 1, pin 2, pin 15, pin 16, or A and K
Operating Temperatures	-20-70°C
Storage Temperatures	-30-80°C
Power supply	3.3V or 5V
Viewing Angle	6 hours

III.4.4.9 Lighting:

We chose this full Light Spectrum LED Plant Growth Lam because it is suitable for our greenhouse. It has a low heat, no UV or IR light radiation, High intensity LED double chips, energy saving, Effective light spectrum brings proper wavelength that are beneficial to plants and perfect for green houses. [96]

Figure III. 17: Light. [96]

Here are the specifications:

Table III. 13: Light data sheet. [96]

Parameter	Value
Material	Iron & Acrylic
Dimensions	(12.2 x 8.27 x 2.36)/(31 x 21 x 6)cm (L x W x H)
Weight	74.08oz / 2100g
Luminous Flux	10063 LM
Light Color	Full Colors
Spectrum	380-730nm
Power	20Pcs x 10W=1200W
Rated Voltage	85-265 V
Life Span	50000 hour

III.4.4.10. ESP32 Camera:

The ESP32-CAM is a full-featured microcontroller that also has an integrated video camera and microSD card socket. It’s inexpensive and easy to use, and is perfect for IoT devices requiring a camera with advanced functions like image tracking and recognition. [97]

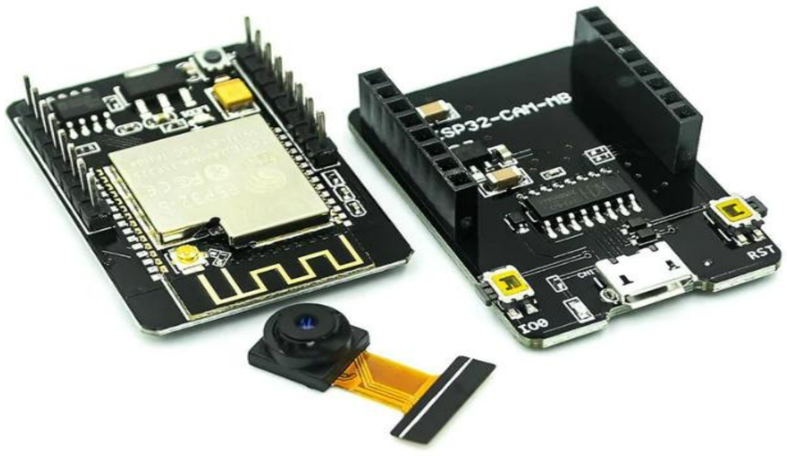


Figure III. 18: ESP32-CAM. [97]

Here are the specifications: [97]

1. **Wireless Module:** ESP32-S WI-Fi 802.11 b/g/n + Bluetooth 4.2 LE module with PCB antenna, u.FL connector, 32Mbit SPI flash, 4MBit PSRAM.
2. **External Storage:** micro SD card slotup to 4GB.
3. **Camera :**
   - FPC connector.
   - Support for OV2640 (sold with a board) or OV7670 cameras.
   - Image Format: JPEG (OV2640 support only), BMP, grayscale.
   - LED flashlight.
4. **Expansion:** 16x through-holes with UART, SPI, I2C, PWM.
5. **Misc:** Reset button.
6. **Power Supply:** 5V via pin header.
7. **Power Consumption :**
   - Flash LED off: 180mA 5V.
   - Flash LED on to maximum brightness: 310mA 5V.
   - Deep-sleep: 6mA @ 5V min.
   - Modem-sleep: 20mA @ 5V min.
   - Light-sleep: 6.7mA @ 5V min.

8. **Dimensions (ESP32):** 40 x 27 x 12 (LxWxH) mm.
9. **Temperature Range:** Operating: -20 ~ 85; storage: -40 ~ 90 @ <90%RH.

III.4.4.11 Inverter:

Developed for professional duty, the Phoenix range of inverters is suitable for the widest range of applications. The design criteria have been to produce a true sine wave inverter with optimized efficiency but without compromise in performance. Employing hybrid HF technology, the result is a top quality product with compact dimensions, light in weight and capable of supplying power, problem-free, to any load. [98]

Figure III. 19: Inverter. [72]

Here are the specifications:

Table III. 14: Inverter data sheet. [98]

Parameter	Value
Cont. AC power at 25°C (VA) (	180
Cont. power at 25°C / 40°C (W)	175/150
Peak power (W)	350
Output AC voltage / frequency	110 VAC or 230 VAC +/- 3% 50 Hz or 60 Hz +/- 0,1%
Input voltage range (V DC)	10,5 - 15,5 / 21,0 - 31,0 / 42,0 - 62,0
Low battery alarm (V DC)	11,0 / 22 / 44

Low battery shut down (V DC)	10,5 / 21 / 42
Low battery auto recovery (V DC)	12,5 / 25 / 50
Max. efficiency (%)	87 / 88
Zero load power (W)	2,6 / 3,8
Zero load power in search mode	n.a
Protection	a – e
Operating temperature range	-40 to +50°C (fan assisted cooling)
Humidity (non-condensing)	max 95%

III.4.4.12 Voltage Regulator:

The solar charge controller monitors the state of charge of the battery bank, controls the charging process, and controls the connection/disconnection of loads. This optimizes battery use and significantly extends its service life. A battery charging algorithm protects the battery from harmful states. Activation of the three deep discharge functions (LVW, LVD and LVR) is dependent upon the state of charge (SOC). The switching thresholds lie within the corresponding voltage window in accordance with the discharge or charging current. [99]

Figure III. 20: Regulator. [99]

Here are the specifications**:**

Table III. 15: Regulator data sheet. [99]

Parameter	Value
Terminal size (fine/single wire)	16/25 mm² = 6/4 AWG
Dimensions l x w x h	187 x 96 x 45 mm
Enclosure protection class	IP 32
System voltage	12 V / 24 V
Ambient temperature allowed	–25 °C ... +50 °C
Max. voltage of Solar collector	47 V DC
Temperature compensation	–4 mV/K/Z elle
Permissible battery voltage range	9 - 17 V
Deep discharge warning (SOC/LVW)	< 40 % / 11,7 V ~ 12,3 V
Deep discharge protection (SOC/LVD)	< 30 % / 11,2 V ~ 11,6 V
Reconnection set point (SOC/LVR)	> 50 % / 12,4 V ~ 12,7 V
End of charge voltage (float)	13,9 V
Boost charge voltage (boost)	14,4 V
Equalisation charge (equal)	14,7 V

III.4.4.13 Solar Panel:

In Today's there are different sources of energy to generate electricity such as solar energy. Solar energy is quite simply the energy produced directly by the sun and collected elsewhere, normally the Earth. The sun creates its energy through a thermonuclear process that converts about 650,000,000 tons of hydrogen to helium every second. The process creates heat and electromagnetic radiation. The heat remains in the sun and is instrumental in maintaining the thermonuclear reaction. The electromagnetic radiation (including visible light, infra-red light, and ultra-violet radiation) streams out into space in all directions [100]. In our project, we use solar panels to power the greenhouse and for different uses like: lighting lamps, powering machines…etc.

Figure III. 21: Solar Panel. [101]

III.4.4.14 Level shifter:

This device is an 8-bit non-inverting level translator that uses two separate configurable power-supply rails. The A port tracks the VCCA pin supply voltage. The VCCA pin accepts any supply voltage between 1.4 V and 3.6 V. The B port tracks the VCCB pin supply voltage. The VCCB pin accepts any supply voltage between 1.65 V and 5.5 V. Two input supply pins allows for low Voltage bidirectional translation between any of the 1.5 V, 1.8 V, 2.5 V, 3.3 V, and 5 V voltage nodes. [103]

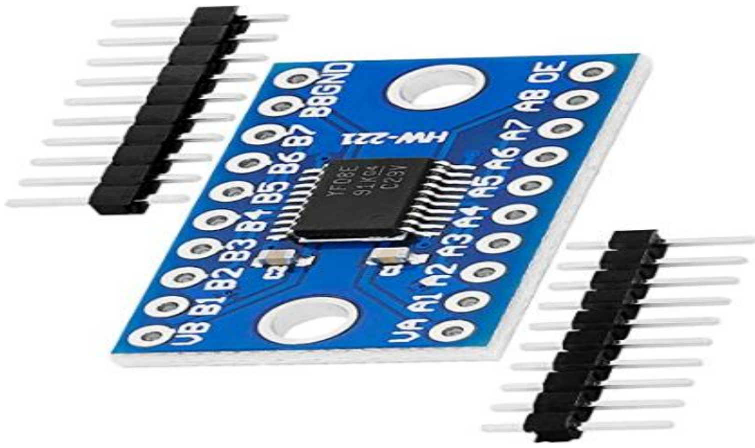


Figure III. 22: TXS0108E level-shifter. [103]

Here are the specifications:

Table III. 16: TXS0108E level-shifter data sheet. [103]

A Port Voltage Range	1.2 to 3.6 V

Maximum Data Rates	*110 Mbps (Push Pull) *1.2 Mbps (Open Drain)
B Port Voltage Range	1.65 to 5.5 V
Board Dimensions	25mm x 15mm (0.985" x 0.591") / Long x Wide
Weight	2.6g (0.092oz)

III.4.4.15 Fuses and Circuit Breakers:

A circuit protection device operates by opening and interrupting current to the circuit. The opening of a protection device shows that something is wrong in the circuit and should be corrected before the current is restored. When a problem exists and the protection device opens, the device should isolate the faulty circuit from the other unaffected circuits, and should respond in time to protect unaffected components in the faulty circuit. The protection device should not open during normal circuit operation. The two types of circuit protection devices are used in this project are fuses and circuit breaker to ensure the highest security. [104]

Figure III. 23: Fuses. [105]

Figure III. 24: Fuses. [106]

III.5. Software part:

III.5.1. Arduino IDE:

The Arduino software (IDE) is open-source software, The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them. [107]

Figure III. 25: Arduino logo. [107]

Libraries used:

1. IOXhop_FirebzseESP32.h
2. Wire.h
3. WiFi.h
4. OneWire.h
5. SimpleTimer.h
6. ArduinoJson.h
7. DHT.h
8. LiquidCrystal_I2C.h
9. Adafruit_GFX.h
10. Adafruit_SSD1306.h
11. Dallas Temperature.h

III.5.1.1 Interfacing ESP32 with Arduino IDE:

To program the ESP32 using the Arduino IDE and its programming language there’s an add-on for the Arduino IDE that allows.

To install the ESP32 board in an Arduino IDE, we have to execute the following instructions:

1. In the Arduino IDE, go to **File**> **Preferences**.
2. Enter the following into the “Additional Board Manager URLs” field:
3. https://dl.espressif.com/dl/package_esp32_index.json
4. Then, click the “OK” button.
5. Open the Boards Manager. Go to **Tools** > **Board** > **Boards Manager…**
6. Search for **ESP32** and press install button for the “**ESP32 by Espressif Systems** “version 2.0.9 **[107]**

III.5.2 Anaconda:

Anaconda is a Python distribution that is particularly popular for data analysis and scientific computing [108]

- Open source project developed by Continuum Analytics, Inc.
- Available for Windows, Mac OS X and Linux
- Includes many popular packages: NumPy, SciPy, Matplotlib, Pandas, IPython Cython.
- Includes Spyder, a Python development environment.
- Includes conda, a platform-independent package manager.

The figure is an interface graphic to launch Jupiter (to write python in notebook format), As shown in figure III.26)

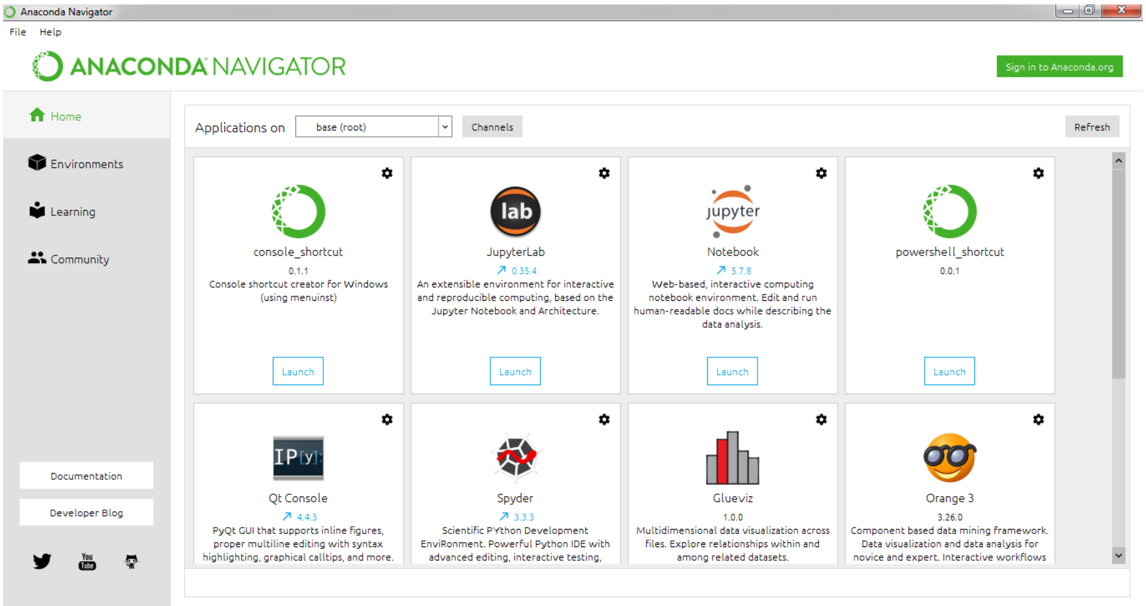


Figure III. 26: Anaconda Navigator interface.

After installing Anaconda, it is always useful to make sure that we have the latest versions of the packages that we will be using. For the purposes of Machine Learning, we generally need the following libraries:

1. Keras:

Keras is a deep learning API written in Python, running on top of the machine learning platform TensorFlow. It was developed with a focus on enabling fast experimentation. Being able to go from idea to result as fast as possible is key to doing good research.

2. TensorFlow:

TensorFlow is an open source framework developed by Google researchers to run machine learning, deep learning and other statistical and predictive analytics workloads. Like similar platforms, it's designed to streamline the process of developing and executing advanced analytics applications for users such as data scientists, statisticians and predictive modelers.

The TensorFlow software handles data sets that are arrayed as computational nodes in graph form. The edges that connect the nodes in a graph can represent multidimensional vectors or matrices, creating what are known as tensors. Because TensorFlow programs use a data flow architecture that works with generalized intermediate results of the computations, they are especially open to very large-scale parallel processing applications, with neural networks being a common example. [109]

3. Matplotlib:

Matplotlib is a comprehensive library for creating static, animated, and interactive visualizations in Python.

Matplotlib produces publication-quality figures in a variety of hardcopy formats and interactive environments across platforms. Matplotlib can be used in Python scripts, Python/ IPython shells, web application servers, and various graphical user interface toolkits. [110]

4. Ipython[111]:

IPython (Interactive Python) is a command shell for interactive computing in multiple programming languages, originally developed for the Python programming language, that offers introspection, rich media, shell syntax, tab completion, and history.

5. NumPy:

NumPy is the fundamental package for scientific computing in Python. It is a Python library that provides a multidimensional array object, various derived objects (such as masked arrays and matrices), and an assortment of routines for fast operations on arrays, including mathematical, logical, shape manipulation, sorting, selecting, I/O, discrete Fourier transforms, basic linear algebra, basic statistical operations, random simulation and much more. [112]

III.5.3 Jupyter Notebook:

Jupyter Notebook (formerly known as Python Notebook) is an open-source web application for running Python code in the terminal using the REPL model (Read-Eval-Print-Loop). The Python Kernel runs the computations and communicates with the Jupyter Notebook front-end interface. It also allows Jupyter Notebook to support multiple languages. Jupyter Notebooks extend Python through additional features, like storing your code and output and allowing you to keep markdown notes. [110]

Figure III. 27: Jupyter logo. [110]

III.5.4 Kaggle:

Kaggle is an online community platform for data scientists and machine learning enthusiasts. Kaggle allows users to collaborate with other users, find and publish datasets, use GPU integrated notebooks, and compete with other data scientists to solve data science challenges. The aim of this online platform (founded in 2010 by Anthony Gold bloom and Jeremy Howard and acquired by Google in 2017) is to help professionals and learners reach their goals in their data science journey with the powerful tools and resources it provides. As of today (2021), there are over 8 million registered users on Kaggle. [115]

Figure III. 28: Kaggle logo. [115]

III.5.6 React JS:

React JS is a JavaScript library for building user interfaces. It is used to create reusable UI components and single-page applications. React JS uses a component-based architecture, allowing developers to create modular components and combine them to build complex UIs. React JS works by creating a virtual DOM (Document Object Model), which is a lightweight copy of the real DOM. When a change is made to the UI, React JS updates the virtual DOM, compares it with the real DOM, and only updates the parts that have changed. This makes React JS very efficient, allowing for faster rendering times and an improved user experience. React JS is also highly customizable and can be integrated with other libraries and frameworks such as Redux, React Native, and Angular JS. It is widely used in web development and is a popular choice for building modern, dynamic, and responsive user interfaces.

III.5.6 Java Script:

JavaScript is a programming language that developers use to make interactive web pages. From refreshing social media feeds to displaying animations and interactive maps, JavaScript functions can improve a website's user experience. As a client-side scripting language, it is one of the core technologies of the World Wide Web. For example, when browsing the internet, anytime you see an image carousel, a click-to-show dropdown menu, or dynamically changing element colors on a webpage, you see the effects of JavaScript.

III.6 Conclusion:

In summary of this chapter, we present our smart greenhouse project components. All these components work together to create a sustainable and efficient growing environment that maximizes plant growth and minimizes resources such as water and electricity, as well as the hardware and software tools used for the design and implementation of the system of disease prediction. In the next chapter, we will delve into the implementation of the smart greenhouse project and detail each step of the process.

IV: Realization

IV.1 Introduction:

Our project aims to remotely control a hydroponic greenhouse by an android application based on ESP32 electronic card through a Wi-Fi connection by using the Internet of Things.

This project aims to build a monitoring system with integrated sensors, real-time measurements, able to provide information on water conditions, nutrients, and also provide warnings to farmers if conditions are not suitable. The device proposed in our project measures the 5 parameters of hydroponic farming media, such as; PH, TDS, water temperature, also air humidity and temperature trough an Android app on ESP32 electronic card through a Wi-Fi connection by using the Internet of Things that allows us to obtain data about the parameters. Our work aims to apply automation technology that utilizes microcontrollers and the IoT in an effort to improve the quality and quantity of hydroponic agricultural products. With this method, hydroponic farming that is still heading towards productivity is expected to quickly move up to the productive step.

In this last chapter, we are proposing overall function of the circuit of the IoT system and of each part temperature and humidity, PH, EC and luminosity through mobile application. As well as the application and without forgetting the result associated with the hydroponic system.

IV.2 Circuit Overview:

The hydroponic smart greenhouse has multiple wired sensing units. Real-time values of temperature, humidity, PH, EC, and light are recorded and sent to the ESP32 controller, and sent to firebase real time database afterwards.

An android application is also used to show real time readings to the manager or owner of greenhouse and can be accessed from anywhere in the world using internet. Ranges like Temperature range or value of EC can also be changed using the smart phone, a manual override is also possible.

The Diagram below explains clearly the whole functionality of "Smart Greenhouse".

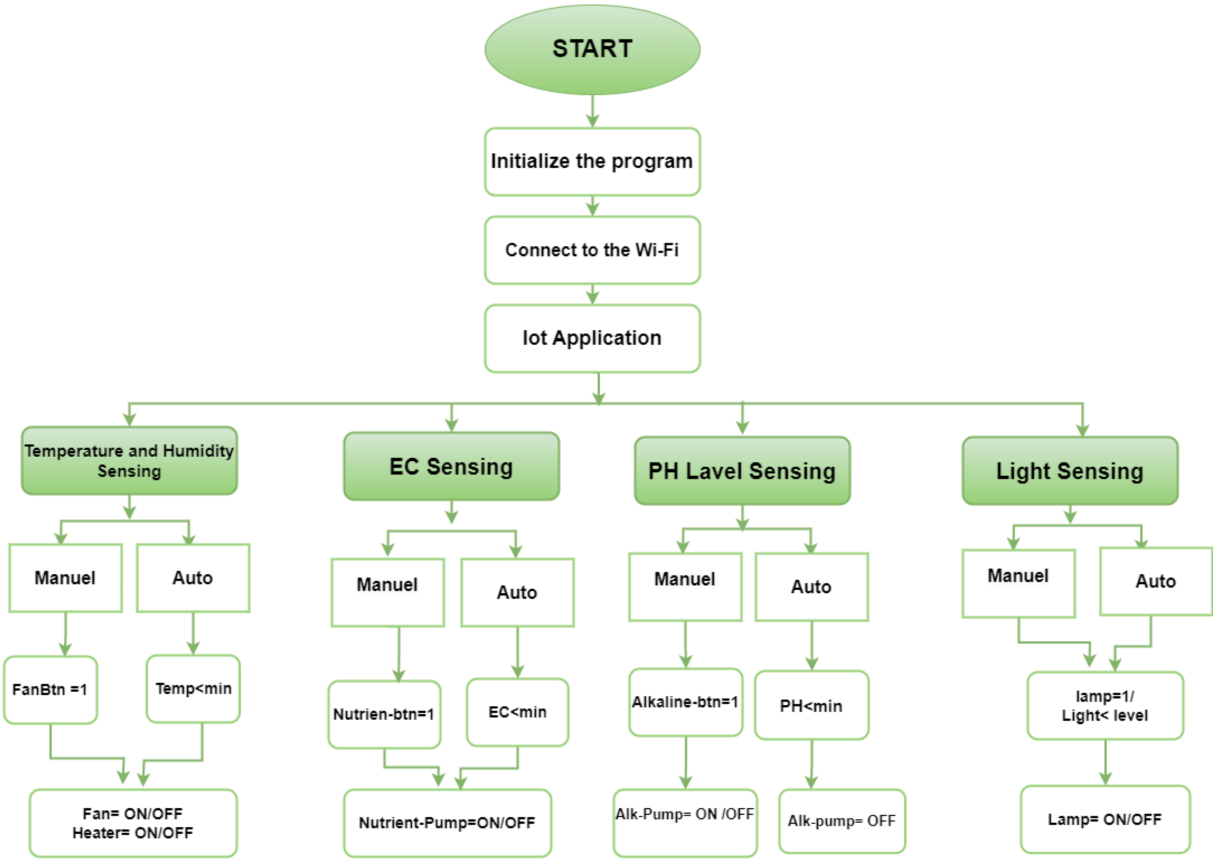


Figure IV. 1: Flowchart of the automatic hydroponic system.

IV.3 Tests of sensors with application:

To ensure the efficiency and proper functioning of electronic devices, we should to test them before using.

IV.3.1 Temperature sensor:

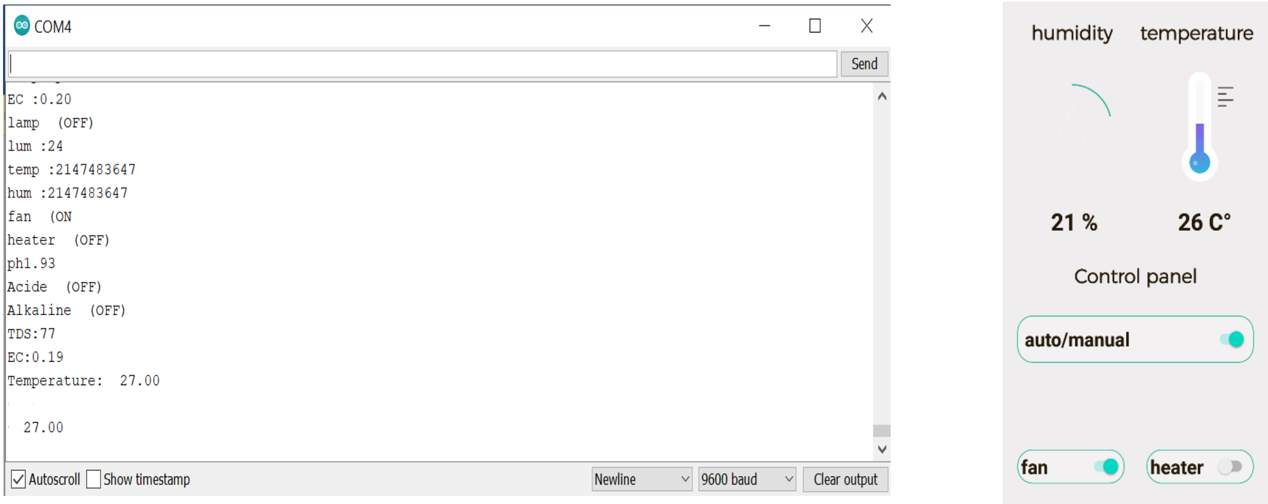


Figure IV. 2: Humidity and Temperature test.

As we see in the figure the DHT22 sensor is working properly.

IV.3.2 Light sensor:

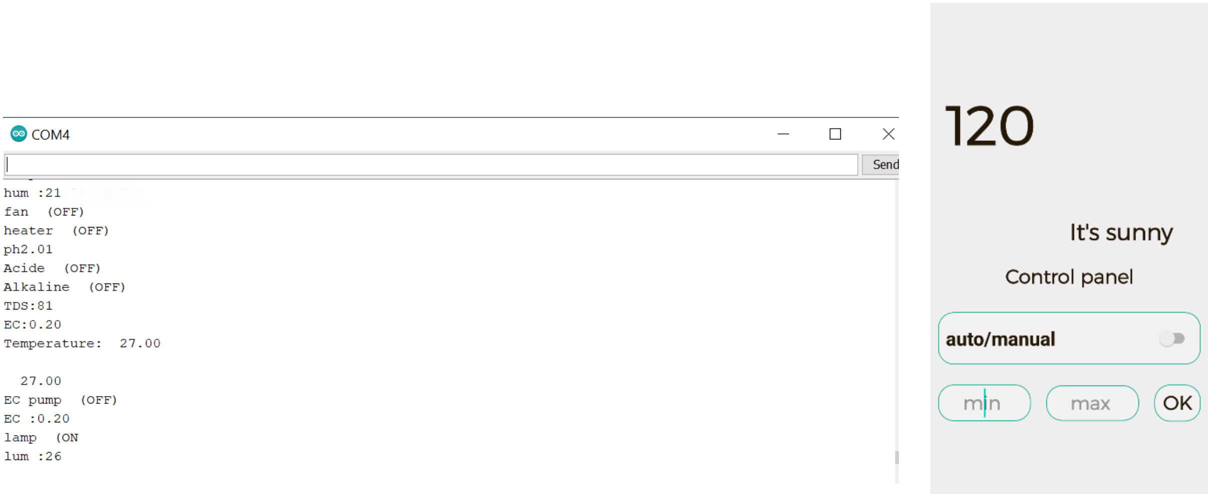


Figure IV. 3: Light test.

As you can see the light value, which led us to say that the sensor works well.

IV.3.3 EC sensor:

The figures IV.4 mention the EC sensor test:

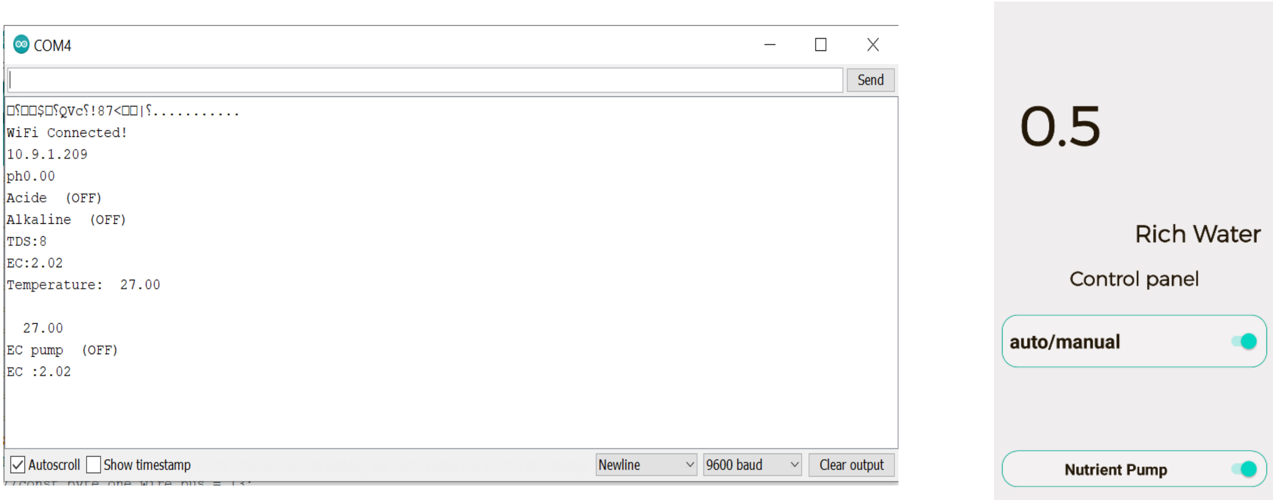


Figure IV. 4: EC test.

IV.4 Web Application:

In the following, we present our work by exposing the interface of the web application. We start first, with the web logo

Figure IV. 5: Lettuce Disease Classification logo.

IV.4.1. Web interfaces:

The graphical interface shows the services provided by the web, which is the classification of lettuce disease. The web interface can be accessed from any device with a web browser and an internet connection, making them highly accessible and widely used. We can view web app in the browser on:

Local: http://localhost:3000/

Network: http://172.26.144.1:3000/

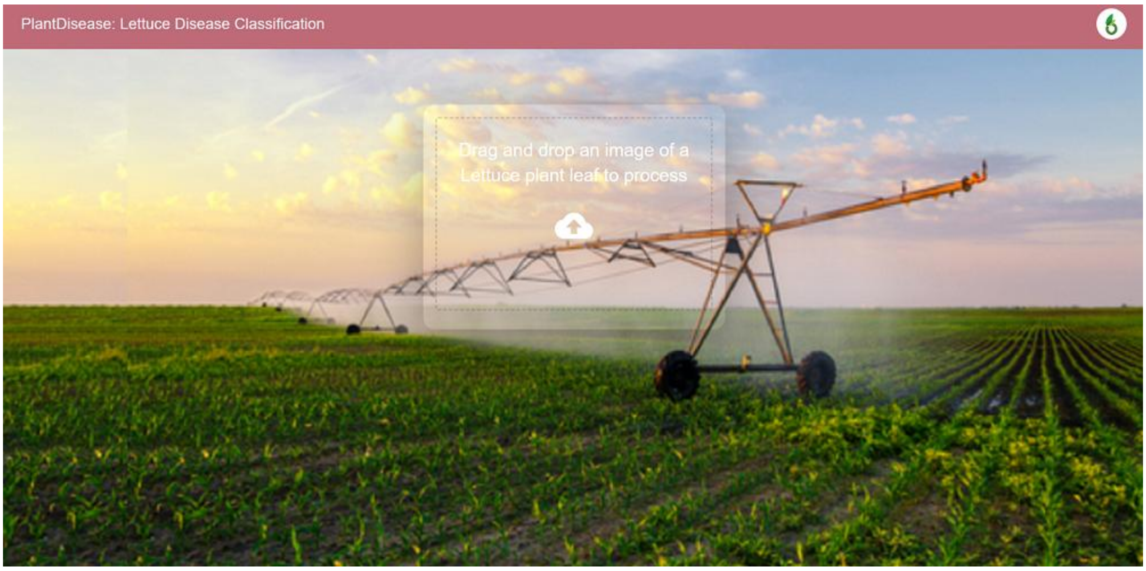


Figure IV. 6: Web Interface.

IV.5 Lettuce leaf disease detection and identification using CNN:

The main objective of this ambitious project is detecting the various diseases that affect the lettuce plant by capturing a snapshot of the diseases that assault lettuce, it’s vital to analyze the diseases that afflict this beloved plant in order to make sure it doesn't succumb to extinction or serious degradation. If you wanted to accurately detect a certain condition or illness, it may be worth considering utilizing a camera. With its advanced imaging technology and automated deep learning algorithms, this device has the potential to swiftly predict the severity of an ailment.

Identification which is done manually in agricultural fields, most of the time, happens at the final stage which could result in economic losses. The main objective of the project is to automatically detect and identify the banana plant disease, which plays a vital role in causing loss at agricultural fields. The plant disease is identified by image processing using the concept of CNN, which is used to zoom the image and identify the affected part with more accuracy. Later severity of the disease is identified by comparing the value with the trained dataset and displaying it. The proposed system will reduce the manual work and used to increase the yield by identifying the disease in earlier stage. Hence, the loss will be saved and helps in agricultural field efficiently.

IV.6 Proposed System Design:

IV.6.1 Equipment:

Lap-top has been used for the entire training and testing process of the plant disease detection model described in our project. Each iteration of training took several minutes on these specified machines, whose basic characteristics are presented in Lap-Top specification.

Table IV. 1 : Lap-Top specification.

	Device specification
Hardware & Software:	Lap-Top
RAM:	16 GB
Processor:	Intel(R) Core (TM) i5-6300U CPU @ 2.40GHz 2.50 GHz
System Type:	64-bit operating system, x64-based processor

For the programming part, we used Jupyter Notebook. The choice of this web application is related to the ease of use as well as it is convenient (For example when we need any library, we download it from anaconda).

IV.6.2 Description of the database:

The database used in the learning phase. This is an open repository that contains 4 classes in total (FN, -N, -P, -K).

Once this database is downloaded using the Kaggle account [Lettuce NPK dataset | Kaggle]. We organize it and structure it in a directory (called Plant Village). In this folder Plant Village, the four classes of the lettuce plant have been taken into consideration. In total, we used 208 images of 1024×1024 pixel in binary PNG format. Figure IV.7 shows examples of image classes.

Figure IV. 7: Classes of the different images.

Our dataset has been divided into two parts:

1.Training:

As long as we've worked on one database, we need to split it into three, 70% to do the training, 15% to evaluate its performance (Test) and 15% for validation. In our case, we used 145 images for training .31 images for testing and the same for validation (See Figure IV.8 for some samples of the base).

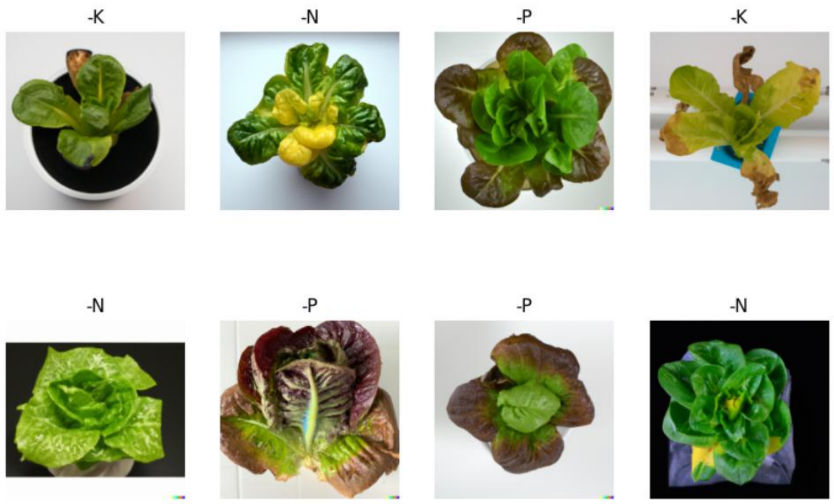


Figure IV. 8: Some Database samples (PlantVillage).

2.Prediction:

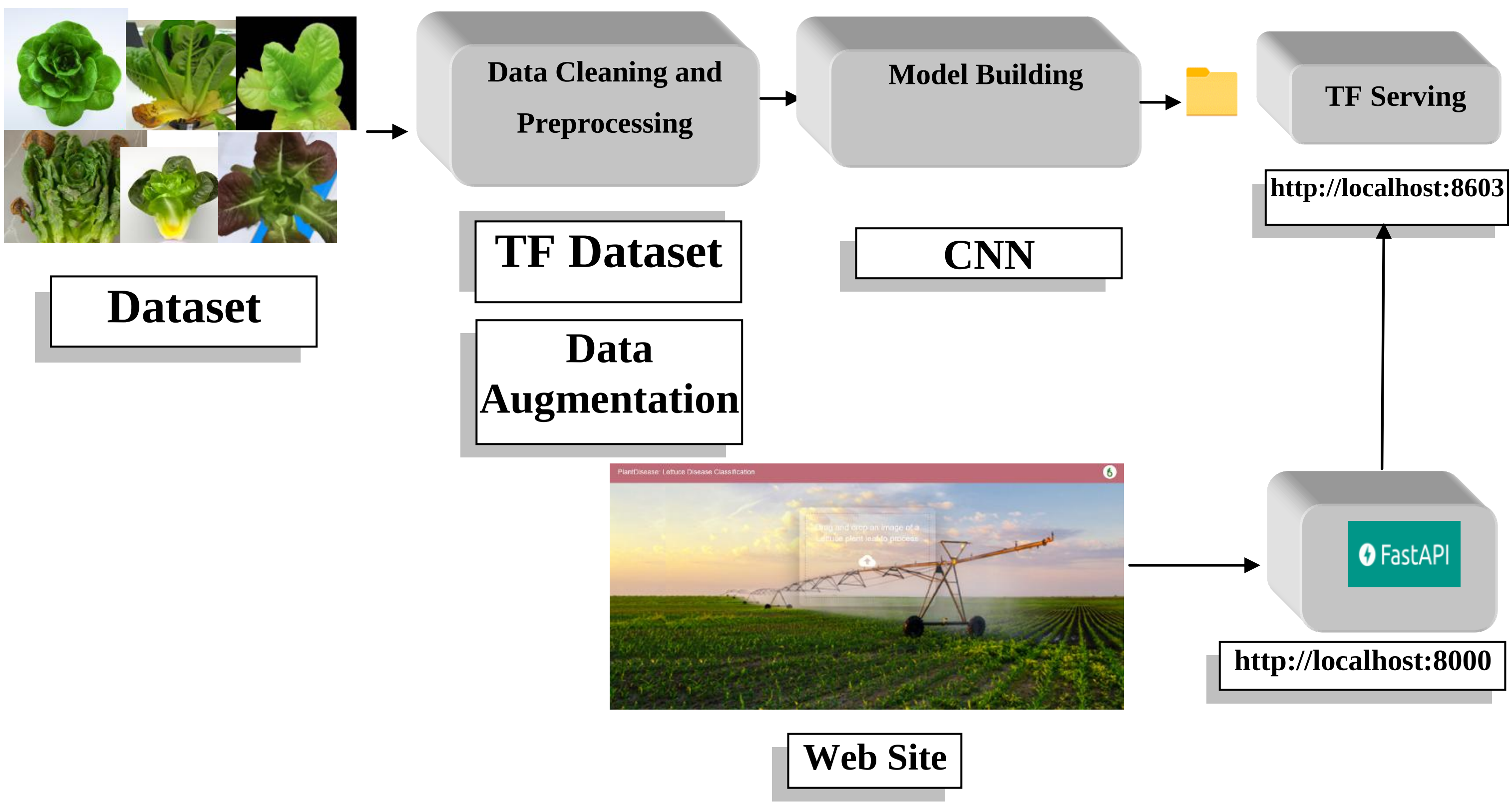


Figure IV. 9: Prediction Architecture model.

IV.6.3 Proposed CNN models:

We dedicate this part to the description of our various tests and experiments. As well as the results obtained by recognizing plant diseases. To achieve a rate of accuracy closest to 100%, we performed a number of important tests. Each time we changed the number of layers and the size of the filters as well as the number iterations. These experiments allowed us, on the one hand, to highlight once again the effects of these parameters on network efficiency, on the other hand to find the configuration optimal to achieve for a task with the best performance. Note that all experiments have been made on the same database with images of the same size 1024 *1024 pixels.

IV.6.4 Results obtained for the model:

The result presented in the figures is below. The execution step of this model as in the figure IV.10:

```
dataset = tf.keras.preprocessing.image_dataset_from_directory(
    "PlantVillage",
    seed=123,
    shuffle=True,
    image_size=(IMAGE_SIZE,IMAGE_SIZE),
    batch_size=BATCH_SIZE
)
```

```
Found 208 files belonging to 4 classes.
```

Figure IV. 10: Image files Considered for Training.

```
class_names = dataset.class_names
class_names
```

```
['-K', '-N', '-P', 'FN']
```

Figure IV. 11: Names of Classes Considered.

```
Model: "sequential_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 sequential (Sequential)     (32, 256, 256, 3)         0

 conv2d_6 (Conv2D)           (32, 254, 254, 32)        896

 max_pooling2d_6 (MaxPooling  (32, 127, 127, 32)       0
 2D)

 conv2d_7 (Conv2D)           (32, 125, 125, 64)        18496

 max_pooling2d_7 (MaxPooling  (32, 62, 62, 64)         0
 2D)

 conv2d_8 (Conv2D)           (32, 60, 60, 64)          36928

 max_pooling2d_8 (MaxPooling  (32, 30, 30, 64)         0
 2D)

 conv2d_9 (Conv2D)           (32, 28, 28, 64)          36928

 max_pooling2d_9 (MaxPooling  (32, 14, 14, 64)         0
 2D)

 conv2d_10 (Conv2D)          (32, 12, 12, 64)          36928

 max_pooling2d_10 (MaxPoolin  (32, 6, 6, 64)           0
 g2D)

 conv2d_11 (Conv2D)          (32, 4, 4, 64)            36928

 max_pooling2d_11 (MaxPoolin  (32, 2, 2, 64)           0
 g2D)

 flatten_1 (Flatten)         (32, 256)                 0

 dense_2 (Dense)             (32, 64)                  16448

 dense_3 (Dense)             (32, 4)                   260

=================================================================
Total params: 183,812
Trainable params: 183,812
Non-trainable params: 0
```

Figure IV. 12: Convolution Layer Coded Output.

```
Epoch 1/25
4/4 [==============================] - 28s 5s/step - loss: 1.3494 - accuracy: 0.2969 - val_loss: 1.4195 - val_accuracy: 0.1250
Epoch 2/25
4/4 [==============================] - 16s 4s/step - loss: 1.2823 - accuracy: 0.3281 - val_loss: 1.3687 - val_accuracy: 0.3750
Epoch 3/25
4/4 [==============================] - 16s 4s/step - loss: 1.2610 - accuracy: 0.3438 - val_loss: 1.3621 - val_accuracy: 0.3125
Epoch 4/25
4/4 [==============================] - 16s 4s/step - loss: 1.2203 - accuracy: 0.4922 - val_loss: 1.4529 - val_accuracy: 0.1875
Epoch 5/25
4/4 [==============================] - 16s 4s/step - loss: 1.1879 - accuracy: 0.3672 - val_loss: 1.1705 - val_accuracy: 0.6250
Epoch 6/25
4/4 [==============================] - 16s 4s/step - loss: 1.1044 - accuracy: 0.5078 - val_loss: 1.0446 - val_accuracy: 0.5625
Epoch 7/25
4/4 [==============================] - 16s 4s/step - loss: 1.0242 - accuracy: 0.5000 - val_loss: 1.3291 - val_accuracy: 0.4375
Epoch 8/25
4/4 [==============================] - 16s 4s/step - loss: 1.0212 - accuracy: 0.5234 - val_loss: 0.8271 - val_accuracy: 0.6875
Epoch 9/25
4/4 [==============================] - 16s 4s/step - loss: 0.9080 - accuracy: 0.6094 - val_loss: 0.7354 - val_accuracy: 0.7500
Epoch 10/25
4/4 [==============================] - 16s 4s/step - loss: 0.7084 - accuracy: 0.6797 - val_loss: 0.8445 - val_accuracy: 0.6875
Epoch 11/25
4/4 [==============================] - 16s 4s/step - loss: 0.6278 - accuracy: 0.6797 - val_loss: 0.6641 - val_accuracy: 0.6250
Epoch 12/25
4/4 [==============================] - 16s 4s/step - loss: 0.7047 - accuracy: 0.6094 - val_loss: 0.6431 - val_accuracy: 0.6875
Epoch 13/25
4/4 [==============================] - 16s 4s/step - loss: 0.6408 - accuracy: 0.6719 - val_loss: 0.5367 - val_accuracy: 0.7500
Epoch 14/25
4/4 [==============================] - 16s 4s/step - loss: 0.6546 - accuracy: 0.7344 - val_loss: 0.4398 - val_accuracy: 0.8125
Epoch 15/25
4/4 [==============================] - 16s 4s/step - loss: 0.5717 - accuracy: 0.6953 - val_loss: 0.7780 - val_accuracy: 0.6250
Epoch 16/25
4/4 [==============================] - 16s 4s/step - loss: 0.6491 - accuracy: 0.6641 - val_loss: 0.5319 - val_accuracy: 0.6875
Epoch 17/25
```

Figure IV. 13: Model Training.

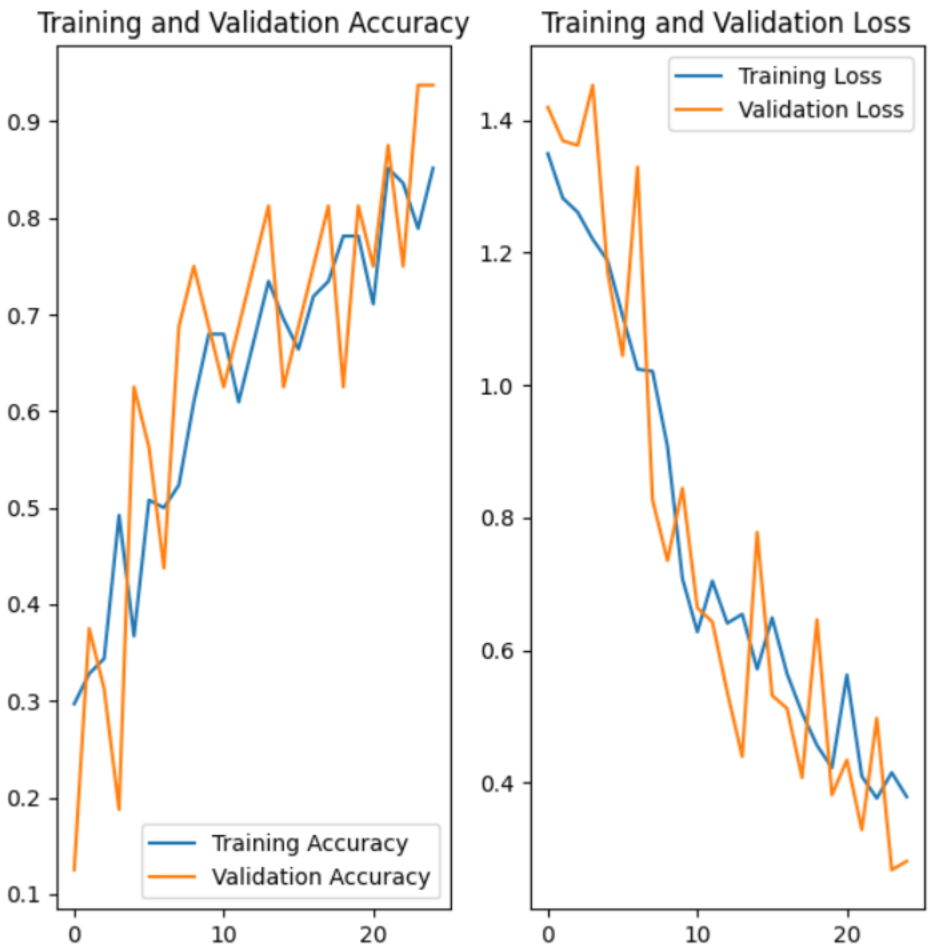


Figure IV. 14: Training and validation accuracy and loss.

From Figure IV.14 we noted that the accuracy of learning and testing with the number of times, this reflects that at each time the model learns more information. If the accuracy is decreased, then we will need more information to train our model, and therefore we must increase the number of epochs and conversely.

IV.6.5 Examples of tests:

After getting a good model, we moved on to the testing stage. Therefore, we tried our web application in two cases. In the first case (Figure Ⅳ.15) we tested photos that are already in the data folder of the prediction as well as photos taken from the internet (Figure Ⅳ.16).

In this part, we used only the web site to do the tests.

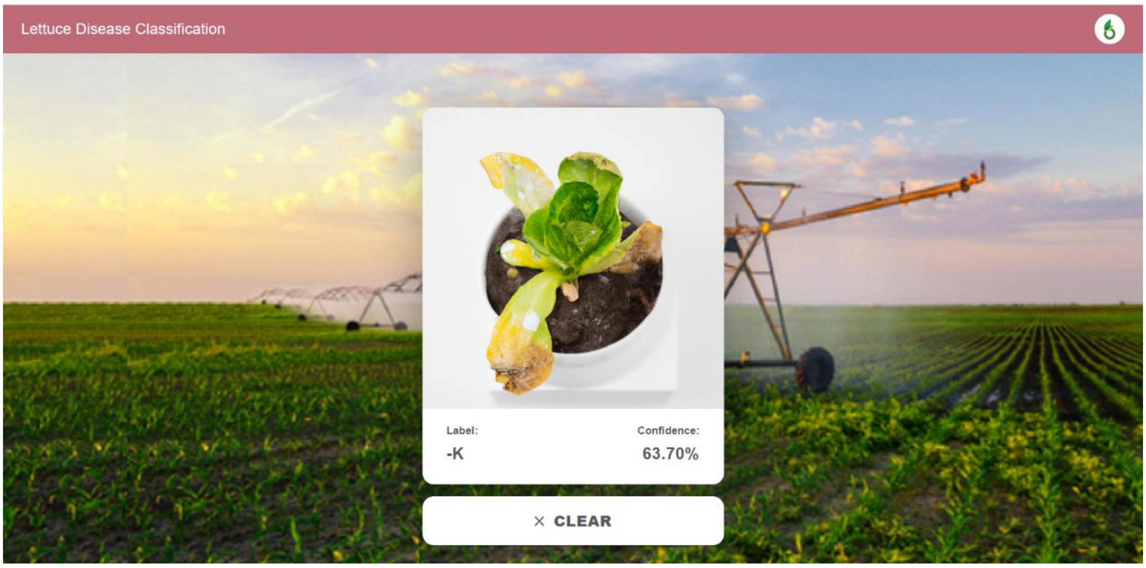


Figure IV. 15: Example photo from the Data.

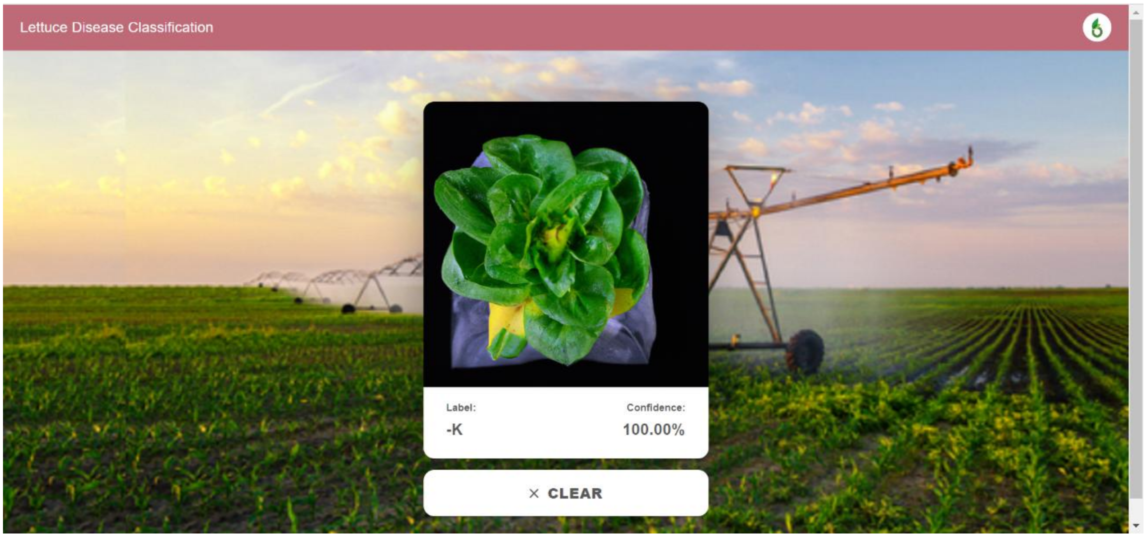


Figure IV. 16: Example photo taken from the internet.

IV.7 Conclusion:

Using a smart controlling system will help farmers treat hydroponic plants, because there is no need to check the plants any time. The smart controlling system will automatically help control the PH, EC, light and temperature, humidity in air, of plants so that the nutritional content and PH of the plant are within the desired normal condition so that plant growth can be optimal. The experiment result shows the smart controller produces significant growth in terms of leaf width and plants height.

In this chapter, we have presented a classification approach based on convolutional neural networks. The goal that we have set ourselves is to obtain the best performance in terms of accuracy and execution time. We have used several models with different architectures, and we have shown the different results obtained in terms of precision. The primary objective of the proposed project is to identify and detect several different factors by capturing the image can reveal the diseases that afflict the lettuce plant.

General Conclusion

General conclusion

In agriculture, rationalizing the use of water for irrigation and its intelligent management is one of the most important strategies for achieving long-term sustainability. This study deals with the application of the Internet of Things (IoT) technology in smart agriculture. In this study, the PH and the EC (Electric Conductivity) level, light, and surrounding environment temperature and humidity are monitored and used to make the right decisions and appropriate control actions. This project also uses ultraviolet lamps to enable photosynthesis to take place at night and during cloudy days to further accelerate the growth of plants. This thesis made several contributions, including its adoption of the dynamic factor in making the irrigation decision, meaning that the threshold value for taking the control decision is not fixed, but can be adjusted according to the type of plant and its requirements. The same is true for the appropriate number of controlling parameters, where the appropriate amount of PH and EC level is determined through the relationship among water temperature readings, air temperature, and humidity, and based on those values.

Through this project, we have developed a Web Application based on machine learning model to analyze images of lettuce plants and identify any signs of disease or pest infestation. Users can upload images of their plants and receive a diagnosis of any issues they may be facing.

Overall, this project has been a great learning experience for us, as it has allowed us to apply our theoretical knowledge and practical skills in a real-world application. We are proud of the results we have achieved in this project and believe that it has the potential to change the way we farm and produce food in the future and we look forward that future students to continue to explore ways to further develop and improve upon this technology, including:

- Optimization and improvement of the algorithm used for data analysis.
- Development of more Application using artificial intelligence algorithms.
- Reinforce the sensors security part using high technologies.
- Investigating the use of different growing hydroponic media such as Aquaponics, their impact on plant growth and health

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Annex

Figure A. 1 : Hydroponic Greenhouse Powered by a PV System.

Abstract:

Despite the world population continues to increase, and perception people may have regarding the agricultural process, the reality is that today’s agriculture industry is data-centered, precise, and smarter than ever. The rapid emergence of Technologies such as technologies based on the Internet of Things (IoT) and leaf disease detection are reshaping virtually every industry, including "smart hydroponic farming",

This project is aimed at providing a solution to optimize the hydroponic greenhouse system, reduce energy consumption by using PV panel, and improve the overall productivity and profitability of the hydroponic greenhouse via Android Application for monitoring and controlling in real-time data of environmental factors such as temperature and humidity, light, PH and EC sensors and actuators such as pumps, surveillance camera, and the control unit ESP32 card.

Detection of leaf disease requires a lot of work and knowledge in the field of plants and the domain of. The goal of this project is the design and implementation of an intelligent system that allows identification of classify lettuce diseases using CNN. The proposed system is implemented in a web application, test results show effectiveness of the proposed system.

Keywords: Hydroponic, Greenhouse, Internet of Things, Android Application, ESP32, AI, CNN.

الملخص:

على الرغم من استمرار زيادة عدد سكان العالم، وتصور الناس فيما يتعلق بالعملية الزراعية، فإن الحقيقة هي أن الصناعة الزراعية اليوم تتمحور حول البيانات الدقيقة والأكثر ذكاء من أي وقت مضى. إن الظهور السريع لتقنيات مثل التقنيات القائمة على إنترنت الأشياءIoT واكتشاف أمراض الأوراق يعيد تشكيل كل صناعة تقريبا، بما في ذلك "الزراعة المائية الذكية".

يهدف هذا المشروع إلى توفير حل لتحسين نظام الدفيئة المائية، وتقليل استهلاك الطاقة باستخدام الألواح الكهروضوئية وتحسين الإنتاجية والربحية الإجمالية للزراعة المائية عبر تطبيق أندرويد لرصد ومراقبة البيانات في وقت فعلي للعوامل البيئية مثل درجة الحرارة والرطوبة والضوء ومستشعرات الناقلية الكهربائية ECودرجة الحموضة PHوالمشغلات مثل المضخات وكاميرا المراقبة ووحدة التحكم عن بعد بطاقة ESP32.

كما ان الكشف عن امراض النباتات يتطلب الكثير من العمل والمعرفة في مجال النباتات والذكاء الاصطناعي الهدف من هذا المشروع هو تصميم وتنفيذ نظام ذكي يسمح بتحديد تصنيف أمراض الخس باستخدام الشبكات العصبونية الالتفافية CNN يتم تنفيذ النظام المقترح في تطبيق ويب، ونتائج الاختبار تظهر فعالية النظام المقترح.

الكلمات المفتاحية: الزراعة المائية، الدفيئة، أنترنت الأشياء، التحكم عن بعد، المراقبة، تطبيق أندرويد، ESP32، الذكاء الاصطناعي، الشبكات العصبونية الالتفافية

Résume :

Bien que la population mondiale continue d'augmenter et que la perception que les gens peuvent avoir du processus agricole, la réalité est que l'industrie agricole d'aujourd'hui est centrée sur les données, précise et plus intelligente que jamais. L'émergence rapide de technologies telles que les technologies basées sur l'Internet des objets (IoT) et la détection des maladies foliaires remodèlent pratiquement toutes les industries, y compris "l'agriculture hydroponique intelligente".

Ce projet vise à fournir une solution pour optimiser le système de serre hydroponique, réduire la consommation d'énergie en utilisant un panneau photovoltaïque et améliorer la productivité globale et la rentabilité de la serre hydroponique via une application Android pour surveiller et contrôler en temps réel les données des facteurs environnementaux tels que la température et l'humidité, la lumière, les capteurs et actionneurs de PH et d'EC tels que les pompes, la caméra de surveillance et la carte ESP32 de l'unité de contrôle.

La détection des maladies foliaires nécessite beaucoup de travail et de connaissances dans le domaine des plantes et du domaine de. L'objectif de ce projet est la conception et la mise en œuvre d'un système intelligent qui permet d'identifier les maladies de la laitue classées à l'aide de CNN. Le système proposé est implémenté dans une application web, les résultats des tests montrent l'efficacité du système proposé.

Mots-clés : Hydroponique, serre, Internet des objets, Application Android, ESP32, AI, CNN.